ANNEX 74

EBC
Energy in Building and Communities Programme

International Energy Agency

Competition and Living Lab Platform (Annex 74)
Solar Decathlon Competitions. Impacts and Performance.

Energy in Buildings and Communities Technology Collaboration Programme

June 2022

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Energy in Buildings and Communities Technology Collaboration Programme

June 2022

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Preface

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 30 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes. The mission of the IEA Energy in Buildings and Communities (IEA EBC) Technology Collaboration Programme is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission, and sustainable buildings and communities, through innovation and research. (Until March 2013, the IEA EBC Programme was known as the IEA Energy Conservation in Buildings and Community Systems Programme, ECBCS.)

The R&D strategies of the IEA EBC Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Buildings Forum Think Tank Workshops. These R&D strategies aim to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy efficient technologies. The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in five areas of focus for R&D activities:

- Integrated planning and building design
- Building energy systems
- Building envelope
- Community scale methods
- Real building energy use

The Executive Committee

Overall control of the IEA EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA EBC Executive Committee, with completed projects identified by (*) and joint projects with the IEA Solar Heating and Cooling Technology Collaboration Programme by (☼):

Annex 1: Load Energy Determination of Buildings (*)
Annex 2: Ekistics and Advanced Community Energy Systems (*)
Annex 3: Energy Conservation in Residential Buildings (*)
Annex 4: Glasgow Commercial Building Monitoring (*)
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities (*)
Annex 7: Local Government Energy Planning (*)
Annex 8: Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9: Minimum Ventilation Rates (*)
Annex 10: Building HVAC System Simulation (*)
Annex 11: Energy Auditing (*)
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Annex 38: ☼ Solar Sustainable Housing (*)
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Annex 52: ☼ Towards Net Zero Energy Solar Buildings (*)
Annex 53: Total Energy Use in Buildings: Analysis and Evaluation Methods (*)
Annex 54: Integration of Micro-Generation and Related Energy Technologies in Buildings (*)
Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost (RAP-RETRO) (*)
Annex 56: Cost Effective Energy and CO2 Emissions Optimisation in Building Renovation (*)
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Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group - Annex 36 Extension: The Energy Concept Adviser (*)
Working Group - HVAC Energy Calculation Methodologies for Non-residential Buildings

Working Group - Cities and Communities
Working Group - Building Energy Codes
Working Group - International Building Materials Database

Summary

The Annex 74 „Competition and Living Lab Platform“ ran between January 2018 und June 2021 within the Energy in Buildings and Communities Technology Collaboration Programme (EBC) of the International Energy Agency. Annex 74 was intended as a platform for mapping and linking the building competition and living lab experiences worldwide and working towards further improving both existing and developing new formats. Annex 74 should stimulate the technological knowledge, the scientific level and the architectural quality within future competitions and living labs based on the development of a systematic knowledge platform as well as the link to obtain expertise from previous and current IEA activities. A total of eleven experts from nine countries participated in this small annex with varying degrees of intensity.

This subtask acts as the “think tank” for the creation of innovative and useful competitions and living lab experiences. For this, the evolution of existing competition formats such as the Solar Decathlon and the creation, development and incorporation of the new competitions has been systematically analysed. The goal of subtask B is to learn from previous SD Competitions and existing living labs in order to take advantage of this knowledge, and learn how to improve and influence the direction and content of future editions as well as new competition formats and living labs initiatives around the world, but not to administrate/organize future competition.

Solar Decathlon is a competition that the U.S. Department of Energy began in 2002 (September) for American universities, which consisted of designing, building and operating a prototype of energy self-sufficient housing, powered by the sun, and equipped with all of the technologies that allow maximum energy efficiency. The final phase consisted of assembling the prototype on the National Mall in Washington D.C., where the so-called “Solar Village“ was located, and where all of the prototypes were exhibited and which then competed in 10 different Contests that make up the Competition (a decathlon). Its main objective was to educate the next generation of architects and engineers, making them and the public aware of the efficient use of energy, and promoting the development of integrated solar energy in houses. It has been 19 years since the first Solar Decathlon took place, since then five pararell competitions are being organized in Europe, China, Middle East, Latin America and Africa, overall 18 competions have been carried out around the world.

The contests have been progressively improved, adapting to time, to tecnology innovation and research and to local realities, forming one of the significant points of identity of the different Solar Decathlons around the world.

In some editions, events and activities around the Solar Decathlon Competitions has been organized to improve the educational and social awareness possibilities, and consequently improving the media impact and incentivising companies into sponsoring the event.

The main objective of educating the next generation of architects and engineers and making them aware of the need for more efficient and sustainable buildings is all well and good, but to what extent is this the case? To what extent is it effective in raising awareness among students, professionals and the general public on these issues? To what extent does it influence professionals? Innovation? And the development of Student skills?

This report aims to provide knowledge on the real impacts and performances of the successive Solar Decathlon competitions held around the world, as well as the organization of the events involved. These impacts and performances are to be measured in an objective and quantifiable way, allowing a qualitative

and quantitative analysis, as a basis for identifying key indicators, key drivers, lessons learned, etc. in order to improve them in the future and bring the actual performances closer to the desired ones.
The objectives of this report outlines:

- Gathering existing experiences on the competitions and living labs around the world as well as the events envolving them.
- Quantify and characterise the impacts and benefits in an objective way.
- Conduct a qualitative and quantitative analysis of SD performance, by means of surveys, indicators, and qualified interviews
- Identifying and analyse all the key drivers and lessons learned to assure an event that wrap up a successful competition.
- Engaging experts to be involved and work on the rules and regulations of the individual competitions within the Energy Endeavour.
- Defining new scenario developments that enrich existing competitions and living labs.
- The scope of EBC Annex 74 is on all Solar Decathlon editions and in the life after competition of the houses. One of the most significant challenges is how to improve the performance of these important investments with new possible scenarios.

The methodology followed was diversed, starting with the systematic collection of information on the various competitions held around the world to date, and documenting them in the Solar Decathlon Knowledge Platform: their houses, their strategies and technologies, their performances in the competition, as well as the objectives and strategies proposed by the organizing teams. Part of the information was organized in the Organizations'factsheets and Postcompetition Factsheets.
A systematic worldwide survey was developed to measure the impact and performance of every edition. Dozens of semi-structured interviews were conducted to complement the raw data of the surveys and to enrich the analysis. More than 70 interviews were conducted with students, professors and researchers, professionals, companies, and the different organizing teams and key people involved in the development of the competition since its origins. These interviews have helped to understand the relationship between objectives - strategies - achieved performance, key drivers, lessons learned, and suggestions for future improvement.

Beyond the achievements and successes, there have also been unsuccessful strategies and differentresults from one edition to another. If the Solar Decathlon is to be an effective vehicle to promote innovation and social awareness to improve energy efficiency and the sustainability of our buildings and cities, with a view to “zero carbon cities“, it is mandatory to document and critically analyse the development of the editions..

The intense experience accumulated in all editions is rich and varied, a systematic analysis has been carried out throughout this project to allow us to make a critical balance, to recognize the great potential of the competition, and to draw many lessons learned not only regarding the competition itself, but also on how to give continuity by taking advantage of previous experience and maximizing the outreach performance.

This is precisely the approach used to measure the performance achieved in these aspects. The following report documents the conclusions and lessons learned from these editions held so far, and provide a critical analysis with some recommendations on how to improve and enhance the potential of The Solar Decathlon. It has great potential to align and support with the priorities of the Sustainable Development Goals.

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Abbreviations

Abbreviations	Meaning
APDI	Association of Lighting Professionals
BACS	Building Automation and Control Systems
BEMS	Building Energy Management Systems
BIPV,	Building Integration Photovoltaics
BIM	Building Information Modelling
BUW	Bergische Universität Wuppertal
CAD	Computer Assited Drawing
CECODAS	European Social Housing Agency
CERMI	Comité Español de Representantes de Personas con Discapacidad
CISOL	Centre d'Investigació Solar
CODA	China Overseas Development Association
CSTB	Scientific and Technical Centre for Building
DEWA	Dubai Electricity and Water Authority
DOE	US Depatament of Energy
ECSO	European Construction Sector Observatory
EMI	Építésügyi Minőségellenőrző Innovációs Kht.
EEF	Energy Endeavour Foundation
GAIA	Les Grands Ateliers Innovation Architecture
GBCE	Green Building Council Spain, The European Social Housing Agency
GESLAB	Global Energy and Sustainable Laboratory in Building
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information and Communications Technology
IDAE	Instituto de diversificacion y ahoro de energía
IoT	Internet of Things
IRESEN	Moroccan Research Institute in Solar Energy and New Energies
KPIs	Key Performance Indicators
MOU	Memorandum of Understanding
MV/LV	Medium Voltage / Low Voltage
NEED	National Energy Education Development Project
NREL	National Renewable Energy Laboratory
ONCE	Organización Nacional de Ciegos Españoles
PCM	Phase Change Materials
RES	Renewable Energy Sources
RVI	Representative value index
SCC EIP	Smart Cities and Communities European Innovation Partnership
SD	Solar Decathlon
SDE	Solar Decathlon Europe

SDC	Solar Decathlon China
SDLC	Solar Decathlon Latinamerica and Caribe
SDME	Solar Decathlon Middle East
SDA	Solar Decathlon Africa
SDG	Sustainable Development Goals
SDKP	SD Knowledge Platform
SMEs	Small and Medium Enterprise
STEM	Science, technology, engineering, and mathematics
TES	Thermal Energy Storage (TES)
UPM	Technical University of Madrid
VET	Vocational and Educational Training.
ZEB	Zero Energy Buildings
ZEC	Zero energy clusters

Definitions

Assembly: Period between the arrival of trucks and the beginning of the contests in the SD Solar Village.
Communications Materials: All printed or electronic publications designed to convey information supporting the Competition goals.
Please refer to the Graph Chart & Brand Manual.
Competition: All aspects of the Solar Decathlon Europe 2019 in Hungary related to the 10 contests and the scoring of those contests, along with the project development of the Competition houses.
Competition Calendar: The timetable establishing the dates of the final phase of the Competition and the daily activities assigned.
Competition House: Complete assembly of physical components installed on SD Solar Village, in compliance with the SD Rules.
Contes: The Solar Decathlon Europe competition consists of 10 separately scored contests, each containing one or more sub- contests.
Contest week: Period of days on SDSolar Village when some or all contests are active.
Disassembly: Period between the conclusion of public tours and the completion of SD Solar Village clean-up.
Electric and Photovoltaic Chart – Interconnection Application: Form submitted by the Team's electrical engineer to the Site Operations Coordinator, which provides the technical details needed to determine the suitability of the Team's electrical and photovoltaic systems for interconnection to the village grid.
This form is part of the Electric and PV Chart and Checklists document.
Electric and PV Chart and Checklists: Document that includes the "Electric and Photovoltaic Chart", "Electric System Design Checklist", "Photovoltaic Checklist".
and "Electrical Storage System Checklist". It must be completed and submitted by Teams from Deliverable 3 onwards.
Event: Activities that take place on SD Solar Village including, but are not limited to, registration, assembly, inspections,
contests, special events, public exhibits, and disassembly.
Event Sponsor: An entity selected by the SD Organization to support the project and help to ensure its success.
Final phase of the SD Competition: The period of days including assembly, disassembly, and contest week periods.
Graphic Chart & Brand Manual: A document that describes, defines, and illustrates how the SD's visual identity elements, when used correctly, can help to create a consistent and memorable communications programmes and actions, thus building a distinct personality for the SD brand.

This document guides you in how to present the brand in various visual media such as print, internet and broadcast.
Grid-Tie Assembly: Period during assembly after the house has been connected to the village grid (interconnected).
Inspection: Each of the inspections realised in all the Competition Houses on SD Solar Village for verifying compliance with the SD Rules.
Inspections Card: Official card indicating the Teams' inspections' status.
Jury: Group of individuals selected by the Organizers to make evaluations on a specific aspect of each Team's project according to SD contests.
Penalty Referee: Individual, appointed by the Organization, to examine and assess the Team's faults, and propose to the Competition Manager all penalties in accordance with the Rules. They shall determine the severity of Rules infractions, classify them as minor or major and report them to the Competition Manager. Penalty Referee shall be independent of the SD Organization and shall have a nationality other than the nationality of the competing Teams.
Protest Resolution Committee: Group of individuals selected by the Organizers to resolve Team protests during the Competition. The Protest Resolution Committee consists of people who are familiar with the project, but not part of the organization or the Teams.
Public Exhibit: Areas of the Competition site open to the public during designated hours.
Rule: Principle or regulation governing conduct, action, procedure, arrangement, etc., for the duration of the project.
Scored Period: Any period during which a particular measured contest is in progress.
Scoring Server: Digital application that collects data from the central data logger server, includes forms for manually entering jury and task- based sub contest results, and calculates composite scores.
Solar Decathlon Europe Building Code: A set of design and construction standards set forth and enforced by the Solar Decathlon Europe Building Official for the protection of public health and safety during the event.
Speed Peer Review: A platform for exchange and knowledge to raise awareness and solve problems. Teams make short minute presentations of their solar house projects in front of their peers. They synthesise their concepts, learn from the other Teams projects and from each other.
Stand-Alone Assembly: Period during assembly before the house has been interconnected to the village grid.
Sub Contest: An individually scored element within a contest.
(Juried) Sub Contest: Sub Contest based on jurors' assessment.
(Measured) Sub Contest: Sub Contest based on task completion or measured performance.
Village Grid: Bi-directional, AC electrical network system installed on the Competition site which will constantly and individually measure the contribution and consumption of electrical energy of each house.
Communications Manager: This manager is the organizer responsible for the project´s public outreach, communications activities and special events.
Competition Direction: Competition Director is the organizer responsible for the management of the competition and responsible for mobilizing all the necessary resources for the achievement of its objectives, with decision-making authority in aspects related to the scope, planning, Rules and quality of the Competition.
Competition Manager: Enforcing the Rules and stating its content, conducting a fair and compelling competition, assigning penalties, and scoring.
Competition Strategies Management: Planning, coordinating, and controlling all the activities related to the Competition.
Competition Coordination: Organizing and supervising the Deliverable reviews, and planning, coordinating, and controlling the activities relate with the Competition.
Infrastructure Management: Planning, execution, development, and control of all the activities related to the assembly, functioning and disassembly of Solar Village.
Inspection: Carrying-out the house's inspection and filling out the corresponding Inspection Card, according to the SD Building Code.
Monitoring & Scoring Management: Monitoring & Scoring Manager is the organizer responsible for the instrumentation system, monitoring and scoring of the Competition.
Jury Manager: Organizer, liaison between the Solar Decathlon Organization and the jury, responsible for accompanying the jury during the house visits, the deliberation process, and the evaluation reporting. Competition area.
Observer: An organizer assigned by the Competition Manager to observe Team activities during the contest week. An Observer reports observed infractions of the Rules to the Rules Officials and records the results of specific contest tasks but does not provide interpretations of the Solar Decathlon Europe Rules. Competition Area.
Office Services Manager: Organizer responsible for planning, coordinating, and directing a broad range of services that allows the Organization to operate efficiently. Office Services Area.

Press & External Communications Coordinator:
Organizer responsible for communications issues between the internal and external parties of the Solar Decathlon, acting as proxy between the participating Teams and the media.
Project Manager: Organizer responsible for the management of the project and responsible for mobilizing all the necessary resources for the achievement of the objectives, with the final decision-making authority in all the aspects related to the scope, planning, costs, quality, resources, communications, risks, sponsorship, and acquisitions of the project.
Public Events Coordinator: Organizer responsible for planning, coordinating, implementing, and developing all the public activities and events related to the Competition and for the public outreach of the project. Communications Area.
Rules Official: Organizer authorised to interpret the Rules. The Competition Manager is the lead Rules Official. Competition Area.
Scorekeeper: Individual selected by the Organizers to operate and maintain the scoring server during the Competition. Competition Area.
Site Operations Coordinator: Organizer responsible for the evaluation of the Teams' Site Operations plans, consequently developing the Competition site operation plan and the coordination and supervision of the houses' assembly and disassembly works at Solar Village.
Universities Relations Coordinator: Organizer responsible for the communications with the participating Teams, helping them through the project development. Competition Area.

1. Introduction

Solar Decathlon is a competition that the U.S. Department of Energy launched at the end of the 20th century, the first edition of which was held in Washington DC in 2002.Seven other editions have been held since then in US. In 2007 the competition jumped to Europe thanks to the Universidad Politécnica de Madrid, who organized the first two competitions of Solar Decathlon Europe, and of which 4 editions have already been held. Subsequently China , Latin America, and Middle East organised two editions each, and Africa has hosted one so far. In total 18 editions have been held to date, with another 6 foreseen for the coming years.

Every competition consists of students designing, building and operating a prototype of high energy-efficient and sustainable houses, zero energy powered by the sun. The final phase consists of assembling the prototype to make up the so-called “Solar Village“, in which all of the prototypes are exhibited and compete in 10 different Contests that comprise the Competition (a decathlon). Its main objective is to educate the next generation of architects and engineers, making them and the public aware of the need for more efficient and sustainable buildings and cities.

The extent to which these objectives have been achieved is one of the raisons d’’être of this report, which attempts to collate the experience of the competitions and associated events as a whole, to evaluate it from both a qualitative and quantitative point of view, with its impacts and performances, to correlate the objectives with the strategies, and these with the results and performances achieved. The quantitative analyses developed with surveys and performance indicators, as well as the qualitative analyses developed with more than 70 interviews conducted with students, professors and researchers, professionals, companies, and the various organizing teams and key people involved in the development of the competition since its origins, have allowed us to understand these relationships and to identify, key drivers, lessons learned, and suggestions for future improvement.

This report summarises and systematizes all of the work performed by the Annex 74 team, describing the evolution of the competitions from their origins to the final use of the prototypes after the competition, the evolution of the Rules & Regulations, the evolution of the events and projects that have been developed around the different competitions, with their strategies, and the analysis of some of the most outstanding successes. It also describes and analyzes the strategies, objectives, and implementations developed by the different organizing teams with their performances and lessons learned.

The performances of competitions and associated events are assessed objectively through surveys and indicators, and a qualitative analysis is made in particular on the educational performances and professional skills development by the students, as well as the impact from the point of view of communications and social awareness. Finally, it identifies the main key drivers for successful competitions and their linked events, from their various points of view, finally extracting the main conclusions and lessons learned regarding the university competitions, the associated events, the experience of the organizing teams, and the performances and impacts of The Solar Decathlon.

1.1 Methodology

The focus of EBC Annex 74 is on all Solar Decathlon editions. Since the first competition in 2002, the Solar Decathlon has expanded internationally to include five additional worldwide competitions: Solar Decathlon Africa, Solar Decathlon China, Solar Decathlon Europe, Solar Decathlon Latin America and Caribbean, and Solar Decathlon Middle East. Since 2002 SD has pursued essentially similar objectives, but the introduction of wider and more topical challenges since then it has had an impact on the competition results and its evolution.

Solar-powered houses that participate in Solar Decathlon are used as case studies. The purpose of this competition is to facilitate understanding and raise the awareness of sustainable construction, and to shed the light on the importance of passive design strategies combined with active solar systems to put the world on a sustained pathway for decarbonised energy systems without compromising the high-standard of living for households.

This report aims to provide knowledge on the real impacts and performances of the successive Solar Decathlon competitions held around the world, as well as the organization of the events involved. These impacts and performances are to be measured in an objective and quantifiable way, allowing a qualitative and quantitative analysis as a basis for identifying key indicators, key drivers, lessons learned, etc., in order to improve them in the future and bring the actual performances closer to the desired ones.
In order to achieve these objectives of Annex 74 concerning the impacts and performance of Solar Decathlon competitions around the world, a methodology based on three main work phases has been defined (figure 1):

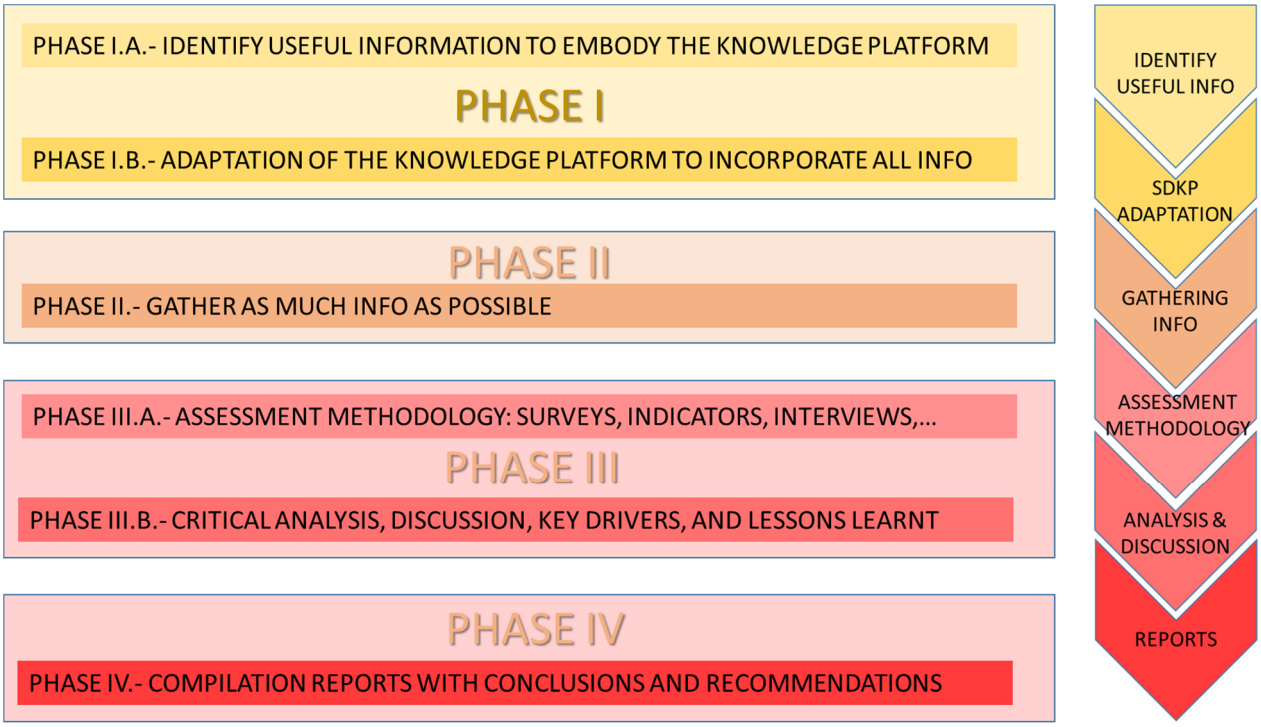

Figure 1: Research methodology

Work Phase I: Consisted of identifying what information would be important to gather in order to be able to analyse the competitions held and the associated events both qualitatively and quantitatively, thinking about how this information could - should - be analysed, and how to incorporate it into the SD Knowledge Platform (SDKP), which should be adapted accordingly. The work was articulated in two successive sub-phases:

PHASE I.A.: Identify useful information to embody the knowledge platform
PHASE I.B: Adaptation of the knowledge platform to incorporate all this information.

Work Phase II:Consisted of gathering information from every competition, both, from participating teams, their houses and its performance, and from the organization teams. This information has been uploaded to the Knowledge Platform.

Work Phase III: Real focus of our work and where added value is given to the information gathered. A systematic methodology has been developed to carry out both the qualitative and quantitative analysis. The application of this methodology has been articulated in two successive phases:
Work Phase III.A.: Assessment Methodology to objectify the impacts and performance of the different editions. The methodology consists of five main areas of work:

- Study of the documentation gathered and in-depth knowledge of the evolution of the rules and regulations, contests, strategies of the various organizing teams, and results obtained both from the point of view of the competition, as well as the events and activities directly or indirectly associated with Solar Decathlon competitions.
- Preparation of organization factsheets by the organizing teams compiling the main objective data of each edition, from the defined objectives, strategies, budget, planning, risk management, solar village, competition, events, outreach, and main conclusions and lessons learned.
- Conducting a comprehensive global survey in which, from a previous selection of qualifying questions, respondents were oriented to the different roles analyzed in the survey, such as students, faculties and professors, professionals and industry, general public and visitors, and organizers.
- The identification of variables, indicators and key performance indicators that, based on information from the Knowledge platform, Organizations factsheets, Postcompetition Factsheets, and survey results, were defined and calculated to facilitate the quantitative and qualitative analysis.
- Semi-structured interviews (70) were conducted with different stakeholders from different competitions. Distributed among decathletes from the SDE 2019 edition, faculties and professors (from SDE 2019 and others), professionals and companies (mostly from SDE 2012), and, the most important for the purposes of this report, with the relevant people who created the Solar Decathlon Competition in the United States, those responsible for bringing the Competition to Europe, Africa, China, or Miidle East, and those responsible for most of the organizing teams of the different competitions held around the world.

Work Phase III.B: Critical analysis of all data, surveys, indicators, and information gathered about competitions and linked events, discussion of results to perform qualitative assessments (about education, professional skills, peoples' awareness, etc.) and quantitative evaluation to analise the real performance and impacts and identify the key drivers for successful SD competitions and its events. From this global assessment some lessons learned have arisen.
Work Phase IV.- Compilation reports with conclusions and recommendations which are deliverable is this Solar Decathlon Competitions Report. Impacts and performance

2. Solar Decathlon Competitions. Evolution and linked initiatives

2.1 Origin. The concept. Initial Objectives

The origin of the Solar Decathlon competition is to be found in the student solar car racing competitions (Solar Race) organized by the Department of Energy (DOE) at the end of the 20th century, which was the inspiration for the brilliant idea of Mr. Richard King (DOE) to promote solar energy in homes through university competitions, with the technical support of Ms. Cecile Warner (NREL), who had participated in the organization of the university Solar Race competitions. Both were in charge of the organization of the first four Solar Decathlon competitions, and Mr. King continued in the organization first, and in the technical support even after his retirement, in practically all the 18 editions held around the world (figure 2: 9 in the USA, 5 in Europe, 3 in China and 2 in Latin America, 2 in Middle East and 1 in Africa).

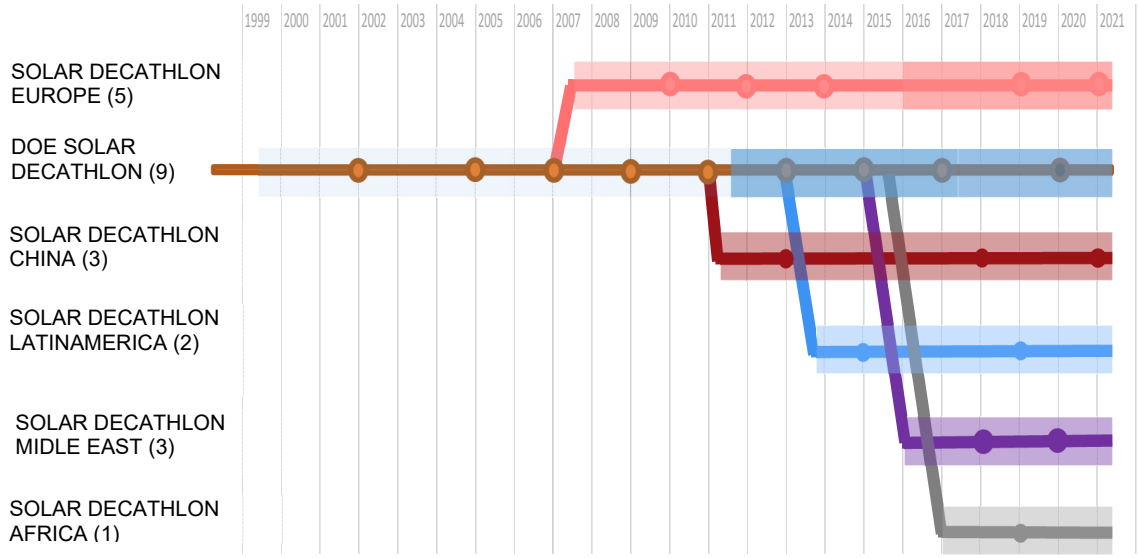

Figure 2: Solar Decathlon evolution.

The goals of the Solar Decathlon US 2002 were quite ambitious and all of them are still pertinent 19 years later in most of the territories, even so, the scope of Solar Decathlon has evolved as can be observed in the following analysis of its goals evolution. The Objectives of the first Solar Decathlon competition were to effectively integrate architecture and technology to create attractive houses that are comfortable to occupy, provide the amenities for, and energy to power, typical household and home office activities and produce enough additional power to maintain the charge of an electric vehicle. The engineering design challenge to accomplish these objectives was integrated into all parts of the design, construction, and operation phases.

Currently, the specific Solar Decathlon's goals are to:

- Provide participating students with **unique training that prepares them for the clean energy workforce.**
- **Educate students and the public** about the latest technologies and materials in energy-efficient design, **clean energy technologies**, **smart home solutions, electric vehicles, and high-performance buildings.**

- **Demonstrate to the public the comfort and savings of homes** that combine energy-efficient construction, home systems, appliances, and innovative design with onsite renewable energy production.

Compared with the initial goals there has been an evolution, the evolution of these goals has had a direct impact on the Contests, in the houses designed and in the competition itself.
As Solar Decathlon has expanded internationally, **the goals** of the Solar Decathlon **have been adapted to local idiosyncrasies**. The Solar Decathlon essence has been maintained, but in these six worldwide competitions: Solar Decathlon Africa (SDA), Solar Decathlon China (SDC), Solar Decathlon Europe (SDE), Solar Decathlon Latin America and Caribbean (SDLAC), and Solar Decathlon Middle East (SDME) interesting new approaches have been integrated which have influenced in the competition results.

2.1.1 Solar Decathlon goals.

The SDE 2010 goal was to contribute to the knowledge and dissemination of industrialised, solar and sustainable housing, and therefore has the following basic objectives:

- To **raise awareness of the students participating** in the competition on the benefits and opportunities offered by using **renewable energies and sustainable construction**, challenging them to think creatively and develop innovative solutions that contribute to energy savings and how it affects our everyday lives.
- To **encourage the construction professionals** to select materials and systems that reduce the environmental impact of a building over its entire lifetime, optimizing its economic viability and providing comfort and the safety of occupants.
- To **educate the public** about responsible **energy use, renewable energy, energy efficiency**, and the technologies available to help them reduce their energy consumption.
- To emphasise the **correct order of intervention: first reducing the building's energy consumption and increasing its energy efficiency; and afterwards, integrating solar active systems and/or other renewable technologies**. Moreover, the building systems must be selected and dimensioned using environmental and cost-effective criteria.
- To **encourage the use of solar technologies and other renewable energy sources**.
- To **promote architecturally attractive solar system integration**, working on using the solar technologies to replace conventional construction materials in the building envelope such as the roof, skylights or facades.
- To clearly **demonstrate that high performance solar homes can be comfortable, attractive and affordable.**

The purpose of the Solar Decathlon China 2013 competition was to closely combine solar energy, energy conservation and architectural design into a new integrated way with the help of the technology and creativity of the world''s top R & D, and design teams, so as to design, build and operate a solar residential space with perfect functions, comfort, livability and sustainability, And through the competition to accelerate the international integration and exchange of knowledge within the solar energy industry, promote the innovation, development and commercialisation of related technologies.

Solar Decathlon China 2018 aimed to explore ways of promoting green development through competition, to promote green technology and industrial innovation, and advocate the popularisation of a green lifestyle.
The goal of the SDME 2018 Organization was to contribute to the knowledge and dissemination of industrialised, solar and sustainable housing, and therefore had the following basic objectives:

- To **raise awareness of the students participating** in the competition of the benefits and opportunities offered by the use of renewable energy technologies, energy management and

sustainable construction, **challenging them to think creatively** and develop innovative solutions that contribute to energy savings.

- To **encourage professionals** from different industries to select materials and systems that reduce the environmental impact of their buildings, optimizing its economic viability and providing comfort and the safety of occupants.
- To **educate the general public** about responsible energy use, renewable energy, energy efficiency, and the technologies available to help them to reduce/optimise their energy consumption.
- To **encourage the use of solar technologies.**
- To promote **architecturally attractive solar system integration**, working on using solar technologies to replace conventional construction materials in the building envelope such as the roof, skylights or facades.
- To clearly **demonstrate that high-performance solar homes can be comfortable and attractive.**
- To increase public awareness about energy for residential use. The competition demonstrates that a **beautifully and well-designed house can generate enough** electricity to meet the needs of a household.

The goal of the SDA 2019 Organization was to contribute to the knowledge and dissemination of solar and sustainable housing, with the following basic objectives:

- **Raise awareness of participating students** of the benefits and opportunities of renewable energies and sustainable construction and challenging them to think creatively to develop innovative solutions that contribute to energy savings.
- **Educate the public** regarding responsible energy use, renewable energy, energy efficiency and available technologies to help reduce energy consumption.
- **Promote the use of solar technologies**, including architecturally attractive solar system integration, and enhancing the use of solar technologies to replace conventional construction materials in the building envelope such as the roof, skylights, or facades.
- **Demonstrate that high performance solar homes can be comfortable, attractive, and affordable.**

Solar Decathlon has pursued essentially similar objectives since 2002 but the introduction of wider and more up-to-date ambitions has had an impact on both the “Rules and Regulations” and in the competition results.

2.2 Timeline of Solar Decathlon Competitions. The evolution.

Since the first competition in 2002, the Solar Decathlon has expanded internationally to include five additional worldwide editions: Solar Decathlon Africa, Solar Decathlon China, Solar Decathlon Europe, Solar Decathlon Latin America and Caribbean, and Solar Decathlon Middle East.

2.2.1 The first SD US Competitions: SD 2002, SD 2005, SD 2007, SD 2009, and SD 2011.

In the fall of 2002, 14 teams of college and university students from across the United States, including Puerto Rico, competed in the first-ever Solar Decathlon on the National Mall in Washington, D.C. The Solar Decathlon’’s 10 contests challenged the teams to design and build energy-efficient, completely solar-powered houses. The competition, which was open to the public for more than a week, gave both the students and visitors to the Mall an opportunity to experience homes that feature environmentally sound, cost-effective technologies that meet the energy demands we face today.

The Challenge: “On the domestic front, our industry’s goal is to meet 10% of U.S. peak generation capacity by 2030…” – Solar Electric Power, the U.S. Photovoltaic Industry Roadmap - One Approach to the Challenge: Install significantly more building-integrated PV systems in residential and commercial buildings, growing to 1.7 GWp/aby 2020.

In 2020, the U.S. installed 19.2 gigawatts (GWdc) of solar PV capacity and by 2030, the current estimate is that 13.4% of U.S. homes will have a solar PV system. Residential deployment reached a record 3.1 GW in 2020, exceeding the goal to meet 10% of U.S. peak generation by 2030.

In the fall of 2005, 18 teams from colleges and universities across the United States, including Puerto Rico, and from Canada and Spain, assembled in Washington, D.C., for the second Solar Decathlon. The United States Department of Energy (DOE), its National Renewable Energy Laboratory (NREL), the National Association of Home Builders (NAHB), the American Institute of Architects (AIA), and private-sector partners BP, Sprint Nextel, and DIY Network sponsored the Competition. The 2005 event took place from October 6–16, 2005, on the National Mall in Washington, D.C. The Mall was again selected for this event because it is a national stage, but it necessitated the transport of each solar home from its campus to and from Washington, D.C., at considerable expense. Regulations that were designed to protect the National Mall limited building size and height, mandated handicapped accessibility, prohibited excavation, and limited the entire event (arrival, assembly, competition, disassembly, and departure) to 21 days.

The main innovations with respect to the prior competition in 2005 was to restructure the rules to focus on earning points vs. penalties that detracted from a perfect score. In this edition, the organizers also implemented a building code, with a greater emphasis on safety which was to become a key element of all future Solar Decathlon competitions globally. Without a safe event, the important messages of the Solar Decathlon could not be received. In this edition, all of the teams received $5,000 from the Department of Energy to compete.

For 2007, the competition continued to evolve. The main objects were categorised in three areas: Education, Competition, and Research & Development. For students, the competition provided hands-on learning to enhance classroom instruction. For the general public, the solutions inspired action in their own homes. For professional builders and architects, the competition influenced their future projects and careers. With regard to the competition, the objectives were to provide student motivation, generate public interest, and challenge perceptions: demonstrating actual working homes that look good. The final objective, R&D, the project showcased side-by-side comparisons of building technologies and provided an opportunity for industry and researchers to test within an iterative design process.

In 2009 (see figure 3), the competition refined what was done in the prior event. The main objectives surrounded competition and education. Additional funds were provided to each competing team - $100,000 per team, and competition criteria were refined. In 2009, the competition generated more than 300,000 house visits and 2.3 million Web site page views. In 2011, the competition pursued much the same structure as 2009, though the location was shifted from the main section of the National Mall to West Potomac Park. The competition allowed for slightly larger homes and increased its focus on affordability in response to the economic recession. Alongside the 2011 edition activities, the Solar Decathlon began to expand internationally, with the first international event occurring in Europe in 2010.

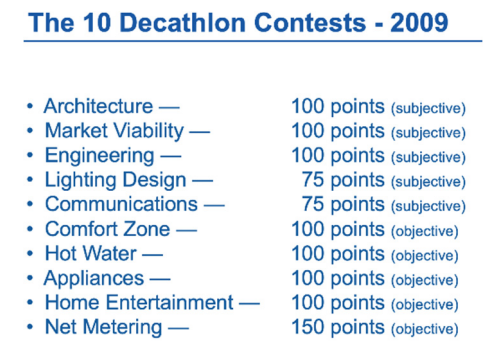

Figure 3: SD US 2005 contests and scores.

2.2.2 Solar Decathlon Europe Competitions: SDE 2010, 10 Action Project, SDE 2012, SDE 2014.

The *Universidad Politécnica de Madrid* (UPM) participated in three editions of the American Competition: in 2005 (first non-American university to participate in the Competition); in 2007 and in 2009. During the 2007 Competition, a Memorandum of Understanding (MOU) was signed between the Spanish and the American Governments, by virtue of which Spain would organize two editions of the Competition in Madrid, for European Universities, giving rise to the international Solar Decathlon Europe Competition.
The Spanish Government commissioned UPM to organize the first two editions of the Competition in Europe, with the aim of adapting it to European sensibilities, and taking advantage of the SDE to raise awareness and educate not only European university students, but also professionals and citizens, promoting energy efficiency, renewable energy, and the sustainability of buildings and cities.
The organizing team articulated two additional major objectives to be developed:

- **To promote the Innovation and Generation of Knowledge** in systems to improve the energy efficiency of buildings, the integration of renewable energies, and the enhancement of sustainability in cities and buildings, transferring all this knowledge to the industry and professionals, in order to generate a critical mass of technical experts who integrate it into their daily thinking, and can apply it in their designs and technical activities.
- **To take advantage of the social interest and the media attraction** that the Competition aroused in the media in order **to sensitize society**, from children and young people to the general public, to the responsible use of energy, the need to improve the energy efficiency of our buildings, to integrate renewable energies, and to help develop a more sustainable society.

In order to meet the challenge and the proposed objectives, **many changes and innovations were incorporated into the Competition in Europe**. Various strategies were developed, many of them shared with the participating teams, some favoured by the European Commission, and many of which were extended and improved on in the successive European Competitions. This developed an SD Competition with a clear European character and different from the other editions held over the years in the United States, China, Latin America, the Middle East, and Africa.

Four editions of Solar Decathlon Europe have taken place to date: SDE 2010 & SDE 2012 in Madrid with the commitment of the Spanish Government, SDE 2014 in Versailles with the commitment of the French Government and SDE 2019 in Szentendre.

The Energy Endeavour Foundation (EEF) is a Netherlands-based non-profit business entity endorsed by the U.S.Department of Energy (DOE) to steward the SDE in 2016. Custodian of the SDE Rules and SDE brand, the EEF nowadays produces the European-wide SDE Call for Cities and its corresponding international SDE Call for Teams. The Energy Endeavour Foundation provides the structure and framework for the future of the SDE.

SDE 2019 in Szentendre was organized under the Energy Endeavour Foundation designation and the commitment of the Hungarian Government. The next edition of SDE 2021 will be held in 2022 (postponed as a result of COVID19) in the German city of Wuppertal, under the Energy Endeavour Foundation designation and the commitment of the German Government.The Second Phases SD US Competitions: SD 2013, SD 2015, SD 2017

For the period of 2013 – 2017, the competition left Washington, D.C. and was hosted by local municipalities, first in California and then in Colorado. The U.S. edition of Solar Decathlon was in 2013 and 2015 held at the Orange County Great Park in Irvine, California. Teams competed to design, build, and obtian cost-effective operation, energy-efficient, and attractive solar-powered house. The teams spent

almost two years designing and building energy-efficient houses powered by the sun. In the final competition, the teams and their houses went head to head in 10 contests to determine an overall winner. The winning team produced a house that:

- Was affordable, attractive, and easy to live in
- Maintained comfortable and healthy indoor environmental conditions
- Supplied energy for cooking, cleaning, entertainment, and commuting
- Provided adequate hot water
- Produced as much or more energy than it consumed.

For this edition, the program benefitted from a highly publicised event with high-quality designs and a successful collaboration with industry. The team adapted to changes in the site and local municipal governmental control. Some challenges, such as how to get started with recruiting amidst a government shutdown due to lack of funding, the challenge of dealing with a non north-south site, challenging wind conditions, but productive engagement in educating students, enthusing the public, and involving industry.

For the 2017 edition, the party responsible for carrying out of the competition changed from the National Renewable Energy Laboratory to a private industry partner, Energetics, Inc. The Solar Decathlon 2017 competition was held in October 5–9 and 12–15, 2017, in Denver, Colorado, at the 61st & Peña Station on the University of Colorado A line commuter rail connecting Denver International Airport to downtown Union Station. Eleven teams competed to design, build, and operate cost-efficient, energy-efficient, and attractive solar-powered house. The Swiss Team won the overall competition with their entry,

NeighborHub. It was the first entry for this combined team of École Polytechnique Fédérale de Lausanne, School of Engineering and Architecture Fribourg, Geneva University of Art and Design, and the University of Fribourg. For more information about the 2017 event, read the visitors guide. (https://www.solardecathlon.gov/2017/)

The 2017 competition was enhanced with new contests to emphasise:

- Innovation
- Water use and re-use strategies
- Smart energy use
- Market potential.

In addition, Solar Decathlon 2017 emphasised:

- Cost-effective architectural and engineering design
- Energy-efficient heating and cooling systems, appliances, and electronics
- Occupant health and comfort
- Communications.

For the first time in the event''s history, teams were eligible for cash prizes vs. pre-determined contracts for financial support. Each team that successfully built a solar house at the competition site would receive at least $100,000 for rising to the challenge, and top finishers would receive significantly more. With DOE funding limited to $2,000,000 in total, the return on investment was incredibly high with over 2,000 students educated (less than $1,000 per student) and over 40,000 visitors (50 per student) if each were counted individually. Overall, though, it was a challenging structure to work with a for-profit entity in a new city on a tighter timeline.

2.2.3 The Chinese SD Competitions: SDC 2013 and SD h2018.

In January 2011 SD China signed an MOU between China & the US, in April 2011 the first SD China was launched. In September 2011 Datong was chosen as the SD China 2013 host City, in Shanxi Province. The next milestones are highlighted:

- 2012.05 SDC 2013 final teams released.
- 2012.10 SD China 2013 competition housing concepts and models released.
- 2012.12 SD China 2013 official mascot “YangYang“ and slogan “,“Shine in the Future, Great Harmony in the World “ Released.
- 2013.08 SD China 2013 Finals opened, exhibited, awarded and closed.
- 2016.04 SD China 2017 host city Dezhou City, Shandong Province.
- 2016.07 SD China 2017 final teams appeared.
- The second SD China competition was launched in April 2016, as SD China 2017 hosted in the city of Dezhou City, Shandong Province, and in July 2017 the final teams were selected.
- 2016.07 SD China 2017 final teams appeared.

January 2017. Housing concept and model released and the final dates were postponed to 2018. The SD China 2018 final opened in August 2018, exhibited, held a series of activities, presented awards and concluded

2.2.4 The Latin-American Competitions: SDLAC 2015 and SDLAC 2019

Solar Decathlon Latin America and Caribbean was conceived in March 2014, through a memorandum of understanding between the U.S. Department of Energy and the government of Colombia. This competition has a great difference in relation to others because it was the first edition in this region of the planet and the projects must be adapted to the needs of a tropical climate and respond to the need for social housing, prioritizing solutions with a positive impact on the community.

The first competition was held in Columbia, where fifteen universities participated in December 2015. Universities from Uruguay, Peru, Mexico, Chile, Panama, United Kingdom, United States, Spain and parts of Colombia presented their prototypes to the public at the Solar Villa located on campus of the Universidad del Valle in Santiago de Cali, Colombia.

The organization Solar Decathlon Latin America and the Caribbean decided to focus on four components which were: Social Housing, Density, Rational use of Environmental Recourses and Regional Relevance. In addition to all the basics of the Solar Decathlon objectives, the teams had to focus on housing solutions specifically for the Latin America and Caribbean region, that prototypes are affordable, that meet the needs of occupants with reduced mobility, that are suitable for dense urban areas and obviously make efficient use of natural resources.

The contests of this competition were: Architecture, Engineering and Construction, Energy Efficiency, Electrical Energy Balance, Comfort Conditions, House Functioning, Urban Design & Affordability, Innovation, Sustainability and Communication, Marketing and Social Awareness. Each of them had a maximum score of 100 points, totaling 1,000.

Among the fifteen participating houses, the one with the highest score and first place was the team from the Universidad ORT from Uruguay with the prototype called “La Casa Uruguaya“ (see figure 4) and a total score of 779.15. Completing the podium, “Calicivita“, representing the Pontificia Javeriana de Cali and ICESI universities took second place with 777.55 points. Third place went to the house “HísCali“ representing the universities of Santiago de Cali and Sevilla with a total score of 764.38.

Figure 4: SDLAC 2015 Winner: La Casa Uruguaya (Universidad ORT Uruguay)

Totaling 689 participating people and 72,200 visitors, the competition was considered a success and on November 21, 2016, representatives from the U.S. Department of Energy; the National Planning Department (DNP) and the Ministry of Mining and Energy (MME) of the Republic of Colombia; and the State of Valle del Cauca, Colombia signed a memorandum of understanding to collaborate on the development of the second Solar Decathlon Latin America and Caribbean that was held in December 2019 (figure 5).

The second competition was also held with the same objectives and in the same location as the first. In this second edition, universities from seven different countries participated: Brazil, Italy, England, Peru, Germany, Spain and different regions of Colombia.

Figure 5: SDLAC 2019 Solar Vila. (Carlos Rodriguez)

With the same contests as those held in the first edition, fifteen teams exhibited their prototypes at The Solar Villa. The winning house of this edition was “Minga“, represented by the universities Pontificia Javeriana de Cali (see figure 6) and Universidad Federal Santa Catarina/Instituto Federal Santa Catarina (Brazil and Colombia). Second place went to “PEI“ (Pontificia Universidad Javeriana) and third to “TUHOUSE“ (Universidad de San Buenaventura/ Universidad Autónoma de Occidente).

Figure 6: SDLAC 2019 Winner: Minga House (Universidad Javeriana de Cali)

2.2.5 The Middle East Competitions: SDME 2018 and SDME 2020

In 2018, the first competition was held in the Middle East. It was headquartered in the city of Dubai (see figure 7), in the United Arab Emirates and organized by DEWA. Solar Decathlon Middle East 2018 aimed to develop and promote ideas, capabilities and technologies that can be implemented for the benefit of the inhabitants of the Middle East region.

The prototypes had to follow standards with respect to the cultural, climatic and social contexts of the region, as well as a high-performance prototype that had to function successfully for the duration of the competition. The proposals had to be aimed at solving the problems and needs of a sustainable life in this region, where high temperatures, high humidity and dust affect the daily lives of the population for most of the year.

Universities from the United States, Oman, Pakistan, Qatar, France, Jordan, Serbia, Netherlands, Italy, Romania, Palestine, Saudi Arabia, Malaysia, Taiwan, Australia and from various parts of the UAE participated for 14 days in total, in November 2018, in the first Middle East competition, located in Mohammed bin Rashid Al Maktoum Solar Park in Dubai.

Figure 7: SDME 2018 Solar Vila. (SDME)

The main objectives of this competition were:

- Make the participating students aware of the benefits and opportunities offered by the use of renewable energy technologies, energy management and sustainable buildings.

- Encourage professionals from different market segments to select materials and systems that reduce the environmental impact of buildings, optimizing their economic viability and providing comfort and safety to occupants.
- Educate the public about responsible energy use, renewable energy, energy efficiency and available technologies to help you reduce your energy consumption.
- Encourage the use of solar technologies.
- Promote architecturally attractive solar systems and the integration of solar technologies such as roofs, skylights, or facades, and demonstrate that high-performance solar homes can be comfortable, attractive, and affordable.

The competition that had 1,000 points to be distributed in the following contests: Architecture (max 100p), Engineering and Construction (max 100p), Energy Management (max 140p), Energy Efficiency (max 80p), Comfort Conditions (max 120p), House Functioning (max 120p), Sustainable Transportation (max 80p), Sustainability (max 80p), Communication (max 80p) and Innovation (max 80p).

The winning house was from the United States, Team Virginia Tech (see figure 8) with a total score of 937.83. In second place was Team UOW, from Australia and UAE with a score of 905.56 and in third place, Baitykool Team with 895.97 points.

Figure 8: SDME 2018 Winner: Virginia Tech Team. (SDME)

The competition returned to the Middle East in October 2021 for new universities to bring what is most modern and technological to the region.

2.2.6 The Solar Decathlon Africa: SDA 2019

In November 15, 2016 in Marrakesh, the Moroccan Ministry of Energy, Mines and Sustainable Development; The U.S. Department of Energy; And the Moroccan Research Institute in Solar Energy and New Energies (IRESEN); signed a MOU to collaborate in the development of the first African edition of Solar Decathlon (see figure 9).

For the first time being held on the African continent, the event brought together more than 1,200 students from 54 different universities with the aim of designing and building smart homes that run exclusively on solar energy.

In order to emphasise the significance of Solar Decathlon Africa, the contestants had to integrate regional sustainable raw materials while working on the components of the building. The competition''s main

objectives were to generate knowledge on net zero energy buildings within the emerging continent, highlighting the perks of decentralised solar energy in bringing about an increasingly electrified continent, speeding up actions in achieving sustainable energy for all Africans, and taking advantage of local African materials and knowhow in the building sector.

The first Solar Decathlon Africa was held in September 2019 where eighteen teams presented their prototypes at the Solar Village, which was located in the Green & Smart Building Park R&D platform in the city of Benguerir, Morocco. The houses were then evaluated by a jury of professionals throughout the ten contests to determine the winners. The exhibited houses were intended to adapt perfectly to the African climate and specifications. The African edition was characterised by the integration of local sustainable materials in the components of the competition prototype houses. The teams used low energy embodied materials and their projects should make a small environmental footprint.

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Figure 9: SDA 2019 Solar village. (SDA)

With a total score of 846 points, the house “INTERHOUSE“ (United States and Morocco) was the winner of the competition (see figure 10). In second place, the house “Bayt-Akhdar“ (Senegal and Morocco) had the final score of 814 points. With a difference of just two points in relation to second place, home “Solar-Ution“ (Morocco) took third place.

Figure 10: SDA 2019 Winner: Interhouse. (SDA)

Solar Decathlon Africa was one of the continent’’s most ambitious and inspiring events in the area. As the final balance of the competition, more than 300 companies supported the teams and organizers; the program taught the visiting and participating public about energy efficiency and renewable energies; so far, many innovative technologies have been developed by local companies; Business and job creation; many start-ups and small and medium-sized companies benefited from the event’’s advantages and emerged with a growing potential for success.

2.2.7 The new Solar Decathlon Europe Competitions coordinated by The Energy Endeavour Foundation (EEF): SDE 2019 and SDE 2021/22

After five years without having any competition on the European continent, the fourth edition was held in Szentendre, Hungary, in July 2019. Universities from Spain, Netherlands, Thailand, Algeria, Romania, Belgium, France and Hungary, totaling ten teams, presented their home prototypes at The Solar Villa, located in the ÉMI Szentendre Industrial Park.

SDE 2019 is the first competition in Solar Decathlon history focused on the renovation of existing buildings (see figure 11). This was made incorporating the contest “Neighbourhood Integration and Impact”. Teams had different aproaches to retroffit the built environment. Most students chose an existing building, analising the building and the context proposing solutions to upgrade both. This contrasts with the construction of new, energy-efficient residential buildings editions of the Solar Decathlon competition. This positioning adopted affordable and viable building renovation schemes combining modern, environmentally-friendly and innovative solutions. It is a fact that these are among the most relevant current challenges faced by the construction industry, triggered by social demand in Europe and beyond.

Figure 11 SDE 2019 Solar Vila.

The contests that year were: Architecture; Engineering & Construction; Energy Efficiency; Communication & Social Awareness; Neighborhood Integration & Impact; Innovation & Viability; Circularity & Sustainability; Comfort Conditions; House Functioning; Energy Balance. Contests were worth 100 points each.

With a total of 853.48 points, the home of the French team “Habiter 2030“ won the competition (see figure 12). Second place went to the representative house of “Team MOR“ (Netherlands) who had a total of 851.79 points. Third place was “Team OVER4“ (Romania) with 802.50 points.

Figure 12: SDE 2019 Winner: Habiter 2030 House.

That year, the prototypes could be visited for longer than normal: an extended 2-month exhibition took place after the end of the competition. In other editions of the Solar Decathlon Europe Competitions, the disassembly of prototypes usually starts immediately after the final awards ceremony and takes place

within a few days. SDE 2019 organizers decided to change this tradition to host an extended exhibition beyond the 2-week public competition phase. The expanded exhibition was at the end of September 2019, and allowed the prototypes to be visited by a very wide audience.
In October of that year, the call for the next SDE competition was opened, which will take place in 2022, in Wuppertal, Germany.

2.2.8 The new US approach Race to Zero Design Challenge.

Following the Solar Decathlon 2017, the U.S. Department of Energy expanded the ways in which teams could compete by incorporating the historical Race to Zero student design competition, which first began in 2014. With this change, the Solar Decathlon expanded to include both a Design Challenge – where teams design a zero-energy-ready building over 1 or 2 semesters and a Build Challenge – where teams design and build a home. For the 2020 edition, the Solar Decathlon originally expected to exhibit some homes on the National Mall as part of the Smithsonian Folklife Festival while others were built permanently in their own community, however, due to the COVID-19 pandemic, the program was delayed and all homes were built permanently in their own communities. By adding the Design Challenge, the U.S. Solar Decathlon grew from about 20 teams per year to over 100 teams.

The annual Design Challenge allows for more schools, more building types, and a greater emphasis on education at a lower cost-per-participant. Teams competing in the Solar Decathlon Design Challenge work for one or two academic semesters. Participants prepare creative solutions for real-world issues in the building industry. Qualifying teams complete a design project and attend the Solar Decathlon Design Challenge Weekend, where they present their designs to a panel of industry expert jurors.

For the Local Build activities, not requiring the teams to transport their houses to a central competition site, more schools were able to compete with lower budgets and lower environmental impacts. Collegiate institutions that are recognized as leaders in cultivating career-ready, young professionals with cutting-edge skills. Industry partners who collaborate with teams gain national and local recognition and have the opportunity to interact with knowledgeable future design and construction professionals. To learn more about the two-challenge structure, visit https://www.solardecathlon.gov/event/challenges.html and to see the houses from the 2020 edition, visit the Solar Decathlon Virtual Village at https://www.solardecathlon.gov/virtual_village/ .

2.2.9 Other Initiatives and proposals

Construye Solar – Chile

The government of Chile has made a commitment to reduce the country''s energy consumption by 20% by 2025, and that 20% of the energy generated corresponds to non-conventional renewable sources. They carried out a series of actions related to the energy and environmental agenda, which respond to this commitment and within them *Construye Solar Chile* was created.

Organized in 2015 by the Ministry of Housing and Urbanism of Chile, the Chile Green Building Council and *La Ruta Solar*, the competition that has already had three editions (2015, 2017 and 2019) invites universities in Chile (and other places in the world) to design and build prototypes of sustainable social housing, in order to contribute to improving the quality of this type of building and change the community''s perception of social housing in Chile. The prototypes are built to the real scale and are exhibited for ten days in the event called "*Villa Solar*" (see figures 13,14,15), which is located in *Parque O''Higgins* in Santiago. The main objectives of the competition are:

- Develop sustainable housing solutions that contribute to improving the quality of social housing in Chile.
- Align the work of different sectors: The State, the private sector, the academic world and the citizens, so that together they contribute to improving the quality of social housing in the country.
- Convene Chilean and foreign universities to develop innovative prototypes that offer feasible solutions to replicate as social housing in the country.
- Promote the development of social housing prototypes that respond to particular problems, through sustainable strategies.
- Disseminate among citizens the concepts of sustainability in construction through the exhibition of proposals for sustainable social housing. *Construye Solar* participating teams compete through ten individual contests. Like the Solar Decathlon competitions, the sustainable social housing proposal that obtains the highest overall score is the winner. The houses were evaluated through three modalities that are: jury contests (Architecture, Engineering and Construction, Communication and Social Awareness, Urban Design and Accessibility, Innovation, Sustainability), Measured contests (Well-being and Comfort, Housing Operation) and Mixed contests (Water Use, Energy Efficiency).

During the ten days of the Villa Solar, different activities were developed for families, public and professionals interested in issues of energy efficiency and sustainability, such as workshops, sustainable theater, eco-cinema, etc.

Figure 13: Winning Team 2015. Casa Parrón S-27

Figure 14: Winning Team 2017. Casa Parrón S3

Figure 15: Winning Team 2019. Casa Tecno.

Oman Eco House Design Competition

The EcoHouse Design Competition (EHDC) is a program based on the rules and concept of Solar Decathlon where university teams are challenged to design, build, and operate energy efficient houses. In 2011, the concept of the competition was presented so that something similar could be carried out in Oman. The Research Council of Oman (TRC) led the effort to organize the commitment that began to be prepared the following year.

In November 2014, five teams participated in the competition which consisted of eight contests (see figure 16), which had a score of 100 points each, totaling a maximum of 800 points. As in SD competitions, the winner is the team that accumulates the highest overall score in the competition. The eight contests were: Conceptual Design & Design Development, Architecture, Engineering, Sustainability, Communications, Comfort Zone, Appliances/Lighting/Electronics and Energy Balance. The winning team was the one that best combined consumer appeal and design excellence with optimal energy production and maximum efficiency.

Unlike the SD competition, the Oman Eco House Design Competition did not have a central location where all the houses were gathered to be judged and visited. It was decided that the prototypes would be built close to each respective campus, it being a decentralised competition.

Figure 16: Oman Eco House Design Competition. Right winning team house: HCT Team (City of Muscat), left 2nd place house: GUtech team (City of Muscat).

In 2015, the development of a second edition of the EHDC began, which unfortunately, due to the consequence of the collapse of oil prices in Oman, activities were suspended indefinitely.

Global energy & sustainable building Challenge (GESBC)

The Global energy & sustainable building Challenge is a proposal developed by The UPM for The United Nations in 2013, to create a global research network based on active demonstrators / buildings developed by universities worldwide in order to obtain measurable results within a continuous evaluation process.

The topic was to challenge universities worldwide to improve energy efficiency and sustainability in buildings and cities dealing with both existing buildings to be retrofitted and new zero energy buildings. The competition was designed with a wide margin of flexibility both in terms of the conditions of the houses and the conditions of the competition, which were ultimately fully adapted to the local cultural and economic environment. The competition measured the progressive improvement in sustainability and energy efficiency conditions over time, so that the creativity and energy of university students was invested in

innovating technologies and house performance, sharing knowledge in a worldwide network of GESBC researchers and professors who shared knowledge and exploited synergies, transferring technologies and strategies to resource-limited countries, with participation funded by the World Development Bank.

This challenge covers all technical and non-technical universities, from different countries with different types of building processes adaptable to economic, social conditions, etc.

The main social objective is to provide a global collaborative network of GESBC researchers and universities by:

- **Promoting Research and Innovation:** Developing new strategies, technologies and materials. Enhancing interdisciplinary collaboration with R&D Institutions.
- **Disseminating Communication:** Creating awareness among local administrations. Transferring knowledge to the university environment & professionals. Requesting the reformation of national and local regulations.
- **Sharing Knowledge:** Exchange Program of Students & Researchers. Optional Technical Support from U.N. Program (NGO, GBC, etc.). Workshops and Conferences (Annual Global + Yearly Local). Publications (Newsletters, papers, etc.). Web site (virtual lecture room and real time results).

The competition was to be held in dozens of universities around the world in developed, developing and third world countries. It was articulated in five years of growth in accordance with the following scheme, in which, as you can see in figure 17, could directly access all the Solar Decathlon houses of the various competitions in the world, that entered directly in the year of the competition. Every University competed from their campuses with all kinds of houses, buildings to be retrofitted, pavillions, with all kinds of local Technologies, constructive solutions.

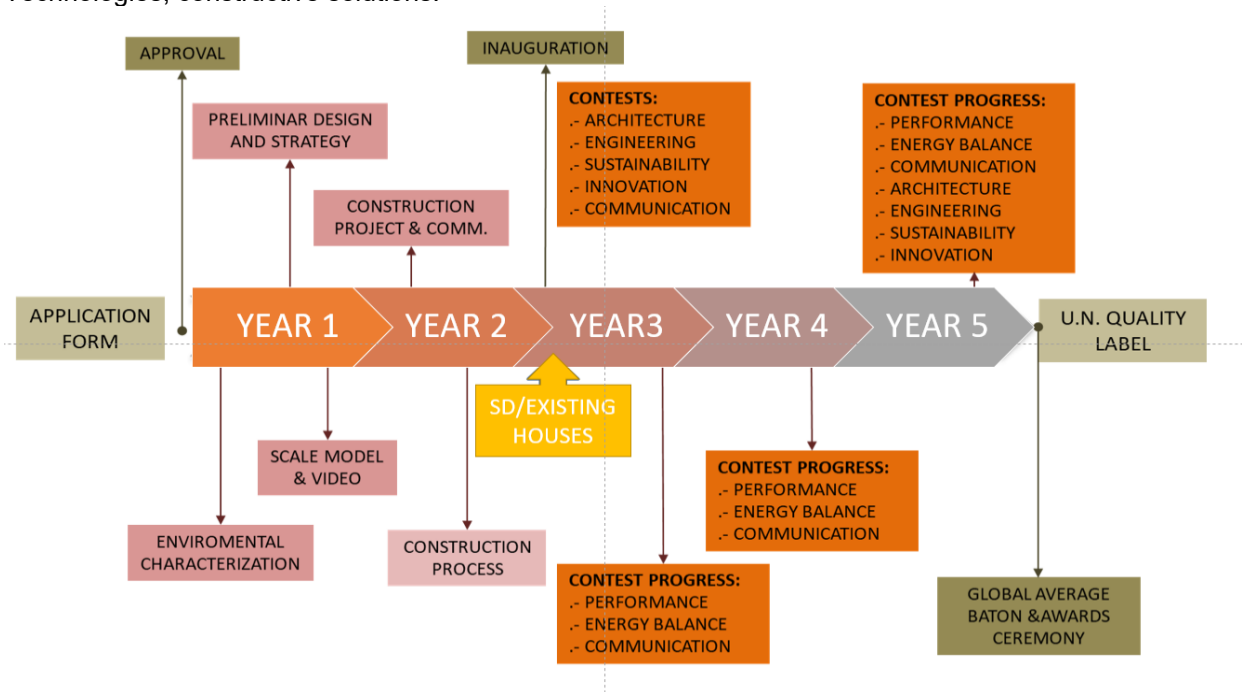


Figure 17: Schedule of Global energy & sustainable building Challenge

The proposal, which was never implemented, foresaw a system of recognition with UN quality labels that would allow the international progress of universities in their commitment to sustainable development.

3. Competition Rules & Regulations

3.1 Rules and Regulations Document. General Approach and Structure

By entering a Solar Decathlon Project, the team (faculty advisor, and the members of the team as individuals) agree to comply with the document setting out Rules & Regulations.The Competition Regulations exist to promote a fair and interesting competition. Failure to comply with the Competition Regulations may result in official warnings, point penalties, or disqualification from the Competition.
From Solar Decathlon 2002 to 2019 the document has maintained the structure and essence: it is divided into three Sections:

Section I: Definitions
In this chapter the specific terminology of the Solar Decathlon is compiled:
Decathlete, Observer, Contest, Contest Officials, Assembly and Disassembly, Faculty Advisor, Headquarters, Inspectors, Jury, Official Scores, Organizers, etc. After each new edition of Solar Decathlon, the Solar Decathlon Community grows and this terminology, full of meaning, travels around the world along with the experience of new decathletes, faculty advisors and organizers.

Section II: General Rules
The Rules primarily exist to promote a fair and interesting competition. In this section information and rules about the Authority, the Solar Decathlon Goals, the Organization, the Administration, the participation, the site Operations and the houses design is compiled.

Section III: Contest criteria
Following the structure of the Olympic decathlon, the Solar Decathlon was conceived to have ten different contests. These contests are designed to gauge how well the houses perform, how livable they are, and how sustainable they are. The contests cover all the aspects of the sustainably built environment including the integration of renewables and the communication and social awareness efforts of the solar decathletes. That explains why the Solar Decathlon competition is known as the “Olympics of the Sustainable Built Environment.”

There are three types of contest:

- From the first Solar Decathlon, depending on the evaluation method the contests are classified on Juried, Monitored and Task Completion. The Juried Contests are evaluated by experts in their field. The jury assessment is based on the documentation submitted by the teams, the information shared by the teams during the project guided visit, and the on-site corroboration of the features of the project.
- The monitored contests are related to the projects’’ success in providing comfortable indoor conditions and their energy performance. The organizers install a monitoring system in each of the projects that record their performance in real-time.
- The task completion contests are assessed based on the success of the teams in completing the tasks required in the competition rules. The organizers designate people to supervise and record the results of the teams when they carry out the tasks. These people are known as Observers.

The Competition Rules and Regulations have a direct impact in the design of the houses. The construction process, in every kind of construction, usually has limitations. The usual conditionings are budget, space,

weather, time, etc. Nevertheless, limitations in the Solar Decathlon house construction process are more and different than usual:

- They are designed, built and operated by students.
- They use Solar energy exclusively.
- They must comply with a specific solar envelope, footprint and measurable area.
- They must be assembled and disassembled in a specific available time and space.
- They will be visited by a significant amount of public, so the orientation and the organization of the lots are important to make them accessible and safe.
- The houses performance and the students work will be evaluated in 10 contests.

3.2 Timeline of Rules & Regulations Evolution

Solar Decathlon has been in a continuous evolution, changes have been made from one competition to the next one, nevertheless there are some **major changes**, which can be considered innovative and strategic, making differences and being maintained in the following editions.

3.2.1 Main changes associated with main SD periods.

The main changes associated with the certain homogeneous periods of the competition are listed below. The grouping of editions is determined by very significant changes, however, in addition to these changes, other minor adaptations occur in all editions.
In the first editions there were significant adjustments (see figure 18), the main ones **from SD US 2002 to SD US 2011** being**:**

- From 2002 to 2005 the main contest changes were made, most of the main contest will remain in future editions as a sub contest. In 2002, the Architecture contest was called “Design and Liveability”.
- Evolution from autonomous houses to smart villages, from 2002 to 2007 houses were autonomous, energy was stored in batteries in each house, in SD US 2009, the houses became part of the Solar Village grid.
- In SD US 2009 the contest “getting around” was eliminated.

Some relevant changes were incorporated into the second period of SD US (SD US 2011 to SD US 2017) :

- For the first time in the event’’s history, teams were eligible for cash prizes. Each team that successfully built a solar house at the competition site would receive at least $100,000 for rising to the challenge, and top finishers would receive significantly more.
- In SD US 2015 the contest “Commuting” and the contest “Water” were incorporated.
- In SD US 2017 the contest “Commuting” was eliminated.

An adaptation of the Competition to European reality resulted in the incorporation of the largest number of changes between competitions (Main changes from SD US 2009 to SDE 2010):

- Evolution from a Solar Houses Competition to Sustainable Houses Competition.
- Shift the focus from high energy production to low consumption (low energy demand) and a wise use of the energy, seeking alignment with the energy efficiency policies of the European Union.
- Increasing the emphasis on the integration of the solar systems (BIPV) and the nearly Zero Energy Buildings (NZEB).
- For first time in the SD the ten contests were divided into five categories: Architecture, Solar, Comfort, Social-Economic and Strategic.
- Changes on 9 of the 10 contests, 2 totally new contests and 7 reinvented ones.

- SDE 2010 evaluates all the items in the SD US 2009 (except the Home Theatre) and add new contests and sub-contests.
- For first time in the SD transversal (cross-cutting) evaluation was used. That is the case in Innovation and Sustainability.
- New evaluation areas: Construction, Solar Systems, Energy Efficiency, Social Awareness, and Industrialised Construction.

SD US 2002		SD US 2005	
Contests	Subcontests	Contests	Subcontests
Design & Livability **200 points**	Firmness	Architecture 200 points	Firmness
	Commodity		Commodity
	Delight		Delight
Presentation & Simulation **100 points**	Construction Documents 50 points	Dwelling 100 points	Livability
	Building Energy Analysis 50 points		Buildability
Home Business 100 points	J Office space comfort and integration 30 points	Documentation 100 points	As-Built Drawings and Submittals 40 points
	M Electrical energy consumed by home business equipment 20 points		Schematic Energy Analysis Report 40 points
	Completion of contest diaries 25 points		Final Project Summary 10 points
	Operation TV/video 25 points		Pre-Event Project Deliverables 10 points
Graphics & Communication 100 points	Web Site 40	Communications 100 points	Web Site 50 points
	House Tours 30		House Tours 40 points
	Newsletters 30		Branding Effectiveness 10 points
Comfort Zone 100 points	J Innovation of systems 15 points	Comfort Zone 100 points	Temperature Control 40 points
	J Consumer appeal/ integration of system 15 points		Humidity Control 20 points
	M 24 h :T,HR 20 points		Comprehensive Assessment of Thermal Comfort 20 points
	M Week-long T,HR 20 points		Comprehensive Assessment of Indoor Air Quality 20 points
Refrigeration 100 points	**J Innovation of systems 15 points**	Appliances 100 points	Refrigeration Temperature Control 20 points
	J Consumer appeal/ integration of system 15 points		Freezer Temperature Control 20 points
	M Performance Index 35 points		Clothes Washing Tasks 15 points
	M Electrical energy consumed to provide refrigeration 35 points		Clothes Drying Tasks 15 points
Hot Water 100 points	**J** Innovation of systems 15 points		Dishwashing Tasks 10 points
	J Consumer appeal/ integration of system 15 points		Cooking Tasks 10 points
	M Performance Index 35 points	Hot Water 100 points	Shower Tests 75 points
	M Electrical energy consumed to provide refrigeration 35 points		Comprehensive Assessment of Hot Water System 25 points
Energy Balance	Balancing electrical supply and demand 100 points	Energy Balance	Energy Balance Measurement 100 points
Getting Around	Mileage Credit	Getting Around	Mileage Credit
Lighting 100 points	**M** Hand-held light meter 60 points	Lighting 100 points	Electric Lighting Quantity 20 points
	M Office work space 10 points		Standard Usage Patterns 15 points
	M Kitchen work space 10 points		Exterior Lighting 5 points
	M Performance Index 35 points		Integration of Electric and Natural Lighting 5 points
	J Innovation of systems 10 points		Electric Lighting Quality 40 points
			Daylighting Quality 15 points

Figure 18: Main changes from SD US 2002 to SD US 2005

The sustainable building objectives of the European Union have led to the continuous evolution of the competition in Europe. The main changes from SDE 2010 to SDE 2012 are:

- The solar envelope height was increased in order to expand the scope of the contest, addressing the use of roofs in collective buildings and the analysis of two-story housing.
- The valuation of the energy efficiency analyzing houses in passive operation.
- A more exhaustive monitoring of the progress of the teams was carried out by organizing two workshops.
- The limitation of PV power is increased to promote the use of innovative systems.
- A smart grid and smart grid centre are assembled in the Solar Village.

The intention of a continuous improvement of the competition has resulted in changes and adaptations in all European competitions. The main changes from SDE 2012 to SDE 2014:

- The limitation of PV power was further increased to promote the use of innovative systems.
- The scope of the competition was expanded by incorporating the Urban contest, urban density and building renovation.
- Building Sustainability was included through the requirement of a lifecycle analysis.
- Urban design/Transport/Affordability Contest
- Adaptive thermal comfort, comfort range adjusted every day.
- Indoor environmental quality evaluation: Air quality new easements, Daylight factor, Operative temperature, Reverberation.
- In 2018 the creation of Energy Endeavour Foundation to ensure the continuity and quality of the competition.

The “Sustainable transportation” contest was incorporated in Solar Decathlon Middle East. The main change in the Solar Decathlon China was the reflection of interests from hosting cities. One of the enhanced concepts was solar energy during the first SD China competition. All of the houses reached net-zero performance during the competition. Diversified solar systems were also employed by the teams. A new concept of permanence was introduced during the second competition, which resulted in more two-storey houses with larger finished areas. This actually created challenges for the teams in terms of costs and difficulties in construction. The third SD China competition introduced a new concept of interactive experiences through including the evaluation of the media, on-site and online audiences.

3.2.2 New and enhanced concepts associated with main SD periods.

In the transition to Europe (from SD US 2009 to SDE 2010) there were some new and enhanced concepts integrated into SD:

- Sustainability and Innovation contest were included as transvesal contests.
- Research and the scientific utilisation of the results was fostered to promote the collaboration of the organization with prestigious scientific journals.
- Industrialised construction and modularity were included as a specificic subcontest to foster building construction technology transfer to the market.
- Communication to foster Students and people awareness
- Energy efficiency with passive and active performances

In SDE 2014, the organization in France decided to focus on the following items:

- Density, mobility, sobriety, innovation, affordability.
- Project in its environment vs. Prototype in the competition.
- Additional area of operation was included to facilitate assembly work.
- Density and community development were fostered.

From SDE 2014 to SDE 2019, continuing with the idea of the SDE 2014 of “Project in its environment vs. Prototype in the competition” and focus on renovation. The scope of the contest was a value-added renovation of an existing building. Teams could choose between:

- Renovation of the traditional rectangular ground floor building model with a brick wall either with concrete flooring or without a heavy flooring solution.
- A roof-top apartment built on the site with other indications of the context (augmented / virtual reality, etc.).
- Renovation project to solve typical problems in the country or region of the Team.
- Any other proposal to solve specific local challenges that could enrich the SDE community.
- Teams can design their installations considering the heating and cooling network. However, the houses will not be connected to the Low temperature district heating and cooling networks during the contest period.
- The houses will remain for two more months after the final award ceremony.

It is planned to lease approximately 10 of the houses to stay in the Solar Village for one or two years (long-term monitoring and public visits).

In Africa (from SD US to SDA) new and enhanced concepts focus on education; Africa is rich in resources, has very young population, and undergoes a substantial increase in its energy infrastructure to connect a population in need of energy. However, it should invest in its human capital by training and educating its collegiate students, researchers, and providing a qualified workforce. This critical mass has the knowledge and the know-how to best serve its communities by developing advanced decentralised electricity systems to assist the emerging continent. Innovation and applied research are the key factors in bringing energy to

Africa and making the best use of its resources. In that, the continent is becoming a test bed of renewable technologies that will be able to provide a fundamental contribution to the future of the industry.
In this topic, the Solar Decathlon Africa, with its perks to Africa, has enhanced the north-south cooperation and contributed to training its collegiate students, and form a strong workforce of tomorrow able to sustain the growth of Africa. The SDA enhances the outcomes of R&D in boosting innovative solutions to better serve a community in need.

3.2.3 Other changes

Some other improtant changes affecting the principles of the design of the houses and the Solar Village's infrastructure were introduced in Europe (from SD US 2009 to SDE 2010):

- The lot size and proportions were changed. The new square proportion permits an easy accommodation on any site.
- Increase the height of the Solar Envelope and permit the participation of two-storiey houses.
- First time in the SD that the projects were able to send electricity to the grid.
- PV limited for first time in the SD. The sum of the nominal power of inverters was limited to 15 kW.
- First time in the SD that batteries were permitted on grid connected projects. Battery banks limited to 5000 VA.
- The design approval document required the signature and stamp of an electrical engineer, in addition to the structural one.
- The deliverables include architectural models of the projects. The first SD models' exhibitions were held.
- The scoring and the monitoring data were show in real-time on the SDE 2010 website.
- Health and Saefty rules and deliverables structure were changed.
- Water on site, no cistern trucks were needed to deliver the water to the projects.
- Custom made web-based communications tool for participating teams and the organization, the SDE WAT.

From SDE 2012 to SDE 2014 the continuous improvement of SDE gave rise to the following changes:

- No generators were permitted on site.
- Use of colour code and grading the teams' deliverables.
- Provide training on the Sima Pro software and template for the houses' lifecycle analysis.
- The Instrumentation and monitoring group was separated from the competition group.
- The Chairman/woman of the jury was selected by the organizers.

The African edition has focused on the integration of local sustainable materials while working on the components of the competition prototype houses. The collegiate decathletes have used low embodied energy materials and their projects should be resource responsible. The sustainable houses are adapted to the local climate. SDA edition gave rise to the following changes:

- Two-day Heath & Safety training provided to the participating teams
- Construction period was 23 days
- Installed PV capacity was limited to 10 kW and storage capacity to 5 kWh.

3.2.4 Evolution of the "solar village", solar envelope and house size.

Location of the Solar Villages:

- SD US 2002-2009: National Mall, Washington D.C.US
- SD US 2011: New Solar Village location: National Mallwest Potomac Parkwashington, D.C.US
- SD US 2013,2015: Orange County Great Park, Irvine, California.US

- SD US 2017: Denver, Colorado
- SDE 2010: Both Banks River Manzanares, Madrid. Spain.
- SDE 2012: Casa de Campo, Madrid. Spain.
- SDE 2014: Versalles, France.
- SDE 2019: Szentendre. Hungary.
- SDC 2013: Shanxi Datong, China.
- SDC 2018: Shandong Dezhou, China
- SDLAC 2015: Universidad del Valle in Cali, Colombia
- SDLAC 2019: Universidad del Valle in Cali, Colombia
- SDME 2018: Mohammed bin Rashid Al Maktoum Solar Park, Dubai, EAU
- SDA 2019: Benguerir.Morocco.

The evolution of the solar envelope and the house size (table 1) has provided more design possibilities and solutions, mainly from the point of view of the urban problematic approach.
The main changes are:

- From one- to two-storiey houses.
- Bigger space for assembly and disassembly.

	Lot dimensions		Architectural footprint	Conditioned area
SD US 2002, 2005, 2007, 2009	82 ft 25.0 m)	67 ft (20.4 m)	800 ft^2	450 ft^2
SD US 2011, 2017	78 ft (23.8 m)	60 ft (18.3 m)	1000 ft^2 (92.9 m^2) - 600 ft^2 (55.7 m^2)	600 ft^2 (55.7 m^2)
SDE 2010	25.0 m (82 ft)	20.0 m (65.6 ft)	74.0 m^2 (797 ft^2).	42.0 m^2 (452 ft^2)
SDE 2012, 2014,2019 and SDME 2018	20.0 m (65.6 ft)	20.0 m (65.6 ft)	150.0 m^2.	45.0 m^2 70.0 m^2 for one-storey houses and 110,00 m^2 for multi-storey housing units.
SDA 2019	20.0 m (65.6 ft)	20.0 m (65.6 ft)	200 m^2 (2150 ft^2)	55 m^2 (600 ft^2) to 90m^2 (970 ft^2) for single floor housing unit and 110.00 m^2 (1200 ft^2) for multi-storey housing units

Table 1. Lots, footprint, and conditioned area dimensions.

3.2.5 Evolution from autonomous houses to Smart grids:

One of the goals of the first Solar Decathlon Competition in 2002 in Washington was to demonstrate that the sun can supply the energy necessary for all of the daily energy demands of a small autonomous house.

The houses should reduce consumption to a minimum and produce electricity in quantities equal to or greater than their consumption.

In SD US 2009 the Solar Village upgraded from a group of autonomous houses (2002,2005 and 2007) to the first Solar Decathlon Grid.

In the SDE 2010, the first microgrid in Spain was designed and implemented to support the competition, connecting houses that worked with different types of electrical power.

In the SDE 2012 competition an intelligent distribution network was created operating in a way that was both comprehensible and visible: the visitors to the Solar Decathlon could understand how energy is managed in a smart environment.

3.2.6 Evolution of Competition schedule

The participating universities have less than two years to design and build a complex house with specific limitations. From 2002 the competition consisted of an Assembly phase, a Competition and Public Visit phase ending with the Awards Ceremony and the disassembly phase.

Figure 19 gathers the available information of the Competitions schedule, compiling the 2-year period before the competition event and the main milestones that the Teams have to comply with. Time management is a key factor in the Team's Organization.

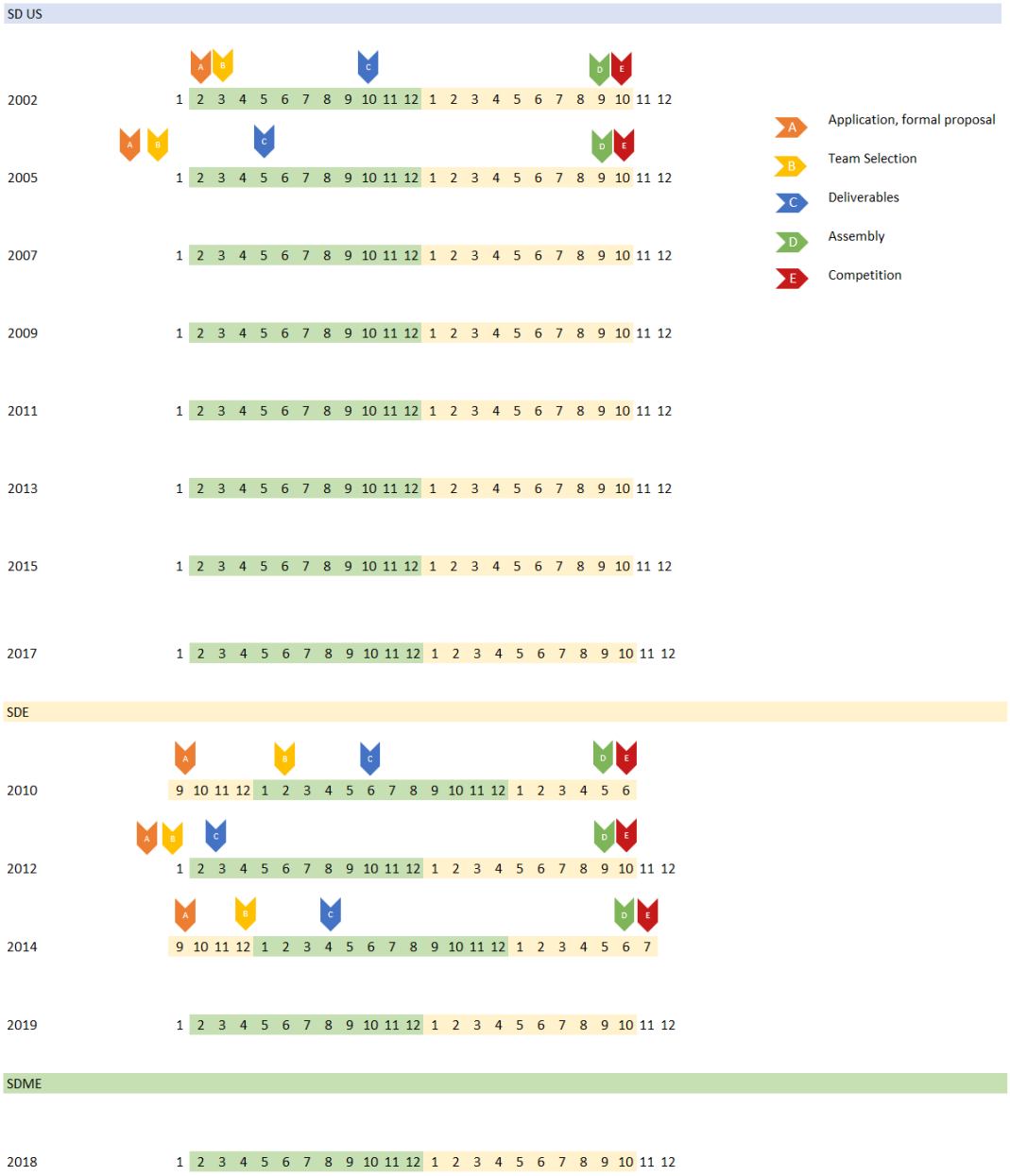


Figure 19: Period before the competition event

The event schedule, as can be observed in figure 20, has gradually expanded, which provides more “assembly and disassembly” time, “competition” time and “public visits” time.

In SDE 2019 a 2-month extended exhibition was proposed, that made it possible for the wider public to view the showcase houses and which also facilitated the monitoring of the technical performance of the houses for a longer period than usual.

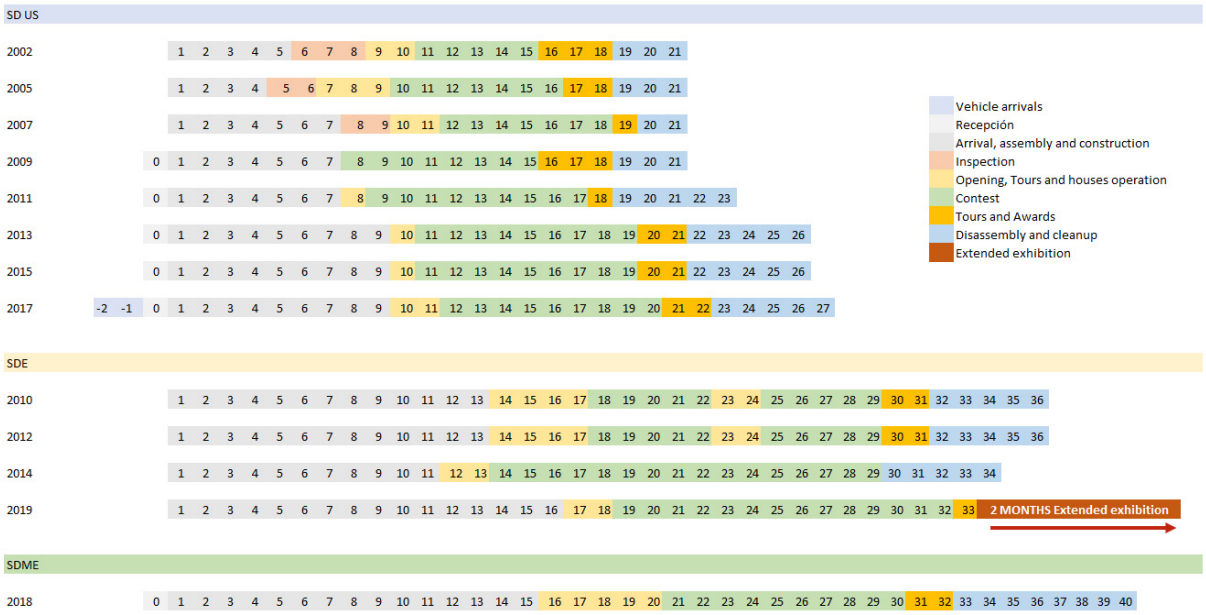


Figure 20: Events schedule.

3.3 Timeline of contests evolution

The Solar Decathlon has always had 10 contests which have changed and have incorporated complexity throughout the years.

The ten contests of the Decathlon are divided into major categories, which may also vary from one edition to another. There are three different ways of assigning scores: Jury Scoring, task Completion Scoring and “in situ” measurement Scoring.

Table 2 compiles the contest and subcontests of each competition, colors indicate its evolution from 2002 to nowadays:

SD US	SD US	SD US	SD US	SDE	SD US	SDE	SD US	SD C	SDE	SD US	SD LATC	SD US	SD ME	SDE	SD A	SD LATC
2002	2005	2007	2009	2010	2011	2012	2013	2013	2014	2015	2015	2017	2018	2019	2019	2019
Design & Livability 200	Architecture 200	Architecture 200	Architecture 200	Architecture 120	Architecture 100	Architecture 120	Architecture 100	Architecture 100	Architecture 120	Architecture 100	cost-effective design 100	Architecture 100	Architecture 100	Architecture 100	Architecture 100	cost-effective design 100
Presentation & Simulation 100	Dwelling 100	Engineering 150	Engineering 100	Engineering 80	Engineering 100	Engineering 80	Engineering 100	Engineering 100	Engineering 80	Engineering 100		Engineering 100	Engineering 100	Engineering and construction 100	Engineering 100	
Home Business 100	Documentation 100	Market Visibility 150	Market Visibility 100	Industrialization and Market Visibility 80	Market Appeal 100	Industrialization and Market Visibility 80	Market Appeal 100	Industrialization and Market Appeal 80	Urban design, transportation and affordability 120	Market Appeal 100	Market Potential 100	Market Potential 100		Neighbourhood Integration & Impact 100	Market Appeal 100	Market Potential 100
					Affordability 100		Affordability 100			Affordability 100						
Graphics & Communication 100	Communications 100	Communications 100	Communications 75	Communication and Social Awareness 80	Communications 100	Communication and Social Awareness 80	Communications 100	Communications 100	Communication and Social Awareness 80	Communications 100	Communications strategies 100	Communications 100	Communications 80	Communication and Social Awareness 100	Communications 100	Communications strategies 100
Comfort Zone 100	Comfort Zone 100	Comfort Zone 100	Comfort Zone 100	Comfort Conditions 120	Comfort Zone 100	Comfort Conditions 120	Comfort Zone 100	Comfort Zone 100	Comfort Conditions 120	Comfort Zone 100		Health and Comfort 100	Comfort Conditions 120	Comfort Conditions 100	Health and comfort 100	
Refrigeration 100	Appliances 100	Appliances 100	Appliances 100	Appliances and Functionality 120	Appliances 100	House Functioning 120	Appliances 100	Appliances 100	House Functioning 120	Appliances 100		Appliances 100	House Functioning 120	House Functioning 100	Appliances 100	
Hot Water 100	Hot Water 100	Hot Water 100	Hot Water 100		Hot Water 100		Hot Water 100			Hot Water 100						
Energy Balance 100	Energy Balance 100	Energy Balance 100	Net Metering 150	Electrical Energy Balance 120	Energy Balance 100	Electrical Energy Balance 100	Energy Balance 100	Energy 100	Electrical Energy Balance 120	Energy Balance 100	energy production, time-of-use 100	Energy 100	Energy Management 140	Electrical Energy Balance 100	Electrical energy balance 100	energy production, time-of-use 100
Getting Around 100	Getting Around 100	Getting Around 100						Commuting 100		Commuting 100			Sustainable Transportation 80			
Lighting 100	Lighting 100	Lighting 100	Lighting 100													
			Home Entert. 100		Home Entert. 100		Home Entert. 100	Home Life 100		Home Entert. 100		Home Life 100			Home Life and entertainment 100	
											Water 100	Water 100				Water 100
				Innovation 80		Innovation 80		Innovation 100	Innovation 80		Innovation 100	Innovation 100	Innovation 80	Innovation and viability 100	Innovation 100	Innovation 100
				Sustainability 120		Sustainability 100			Sustainability 80				Sustainability 100	Circularity & Sustainability 100	Sustainability 100	
				Solar systems and Hot water 80												
						Energy Efficiency 100			Energy Efficiency 80		Energy Efficiency 100		Energy Efficiency 80	Energy Efficiency 100		Energy Efficiency 100

Table 2. Evolution matrix of the contests.

Contests
Constant from the begining (2002 or 2005)
Sucessfully incorporated into Europe with continuity in ME and LatinAmerica
Great variation
In last editions in Europe they are not
In USA, China and Africa
Recently incorporated
Converted to subcontests

Significant changes in contests and subcontets were made from the SD US 2009 to SDE 2010 (see figure 21). As mentioned, there are ten contests in the Solar Decathlon but it can be observed in the matrix how the evaluation gains complexity over time by increasing the number of sub-contests and evaluation criteria, from 31 in 2002 to 63 in 2019, promoting the design of houses that address a more comprehensive problem.

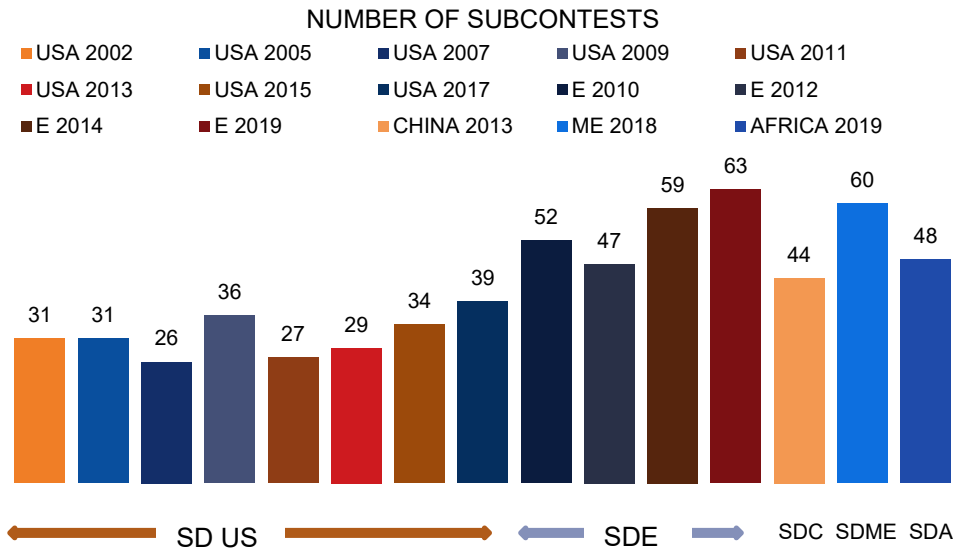


Figure 21: Number of subcontests

The main changes in the rules are analysed considering the competition results. The European organization considered some mayor changes in the rules and regulations to favor the attainment of the objective of **promoting innovation**.

The categories which were clearly defined in the objectives of the SDE 2010 competition were: architecture; engineering and construction; solar systems; electrical energy balance; comfort conditions; appliances and their functionality; communication and **social awareness**; **industrialisation and market viability**; **innovation; and sustainability**, the last four being new and very different from the categories included in the American version of the competition (see table 3). The contests for the **SDE 2012** competition were Architecture, Engineering and Construction; Energy Efficiency; Electrical Energy Balance; Comfort Conditions; House Functionality; Communication and Social Awareness; Industrialisation and Market Feasibility; Innovation; and Sustainability. Among many other changes, it is worth mentioning the introduction of the positive assessment of the affordability concept in the section on market viability and the multifamily houses in the industrialisation contest. In SDE 2014, in Versailles, the Organization goal was to contribute to the **knowledge and dissemination of industrialised, solar and sustainable housing**. It is intended to provide habitats that meet the triple challenge: **energy, environment and society** that we all are facing.

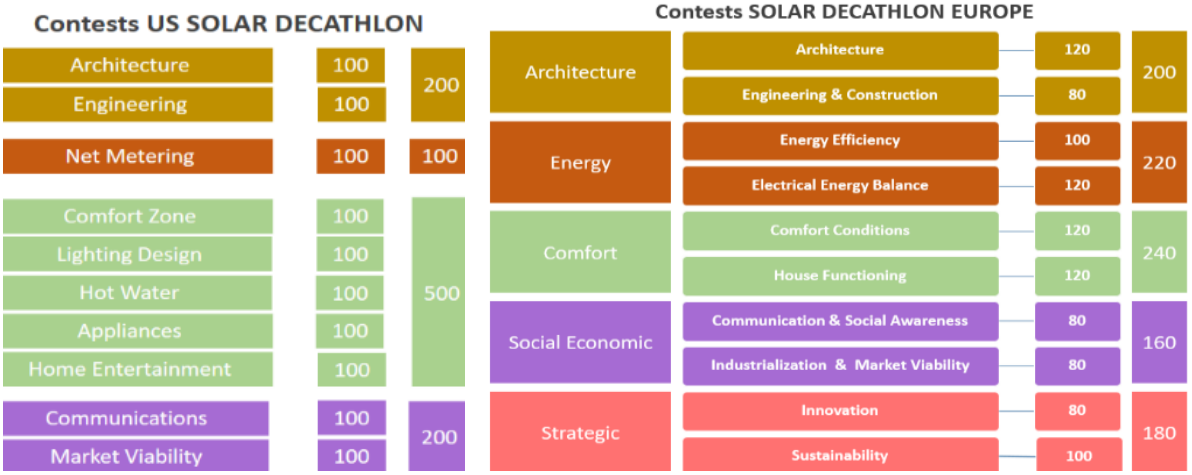


Table 3: The evolution of Solar Decathlon Contests from SD US 2009 to SDE 2010.

In SDE 2019 in Szentendre, Hungary, similar objectives were pursued (see table 4): "to contribute to the **knowledge and dissemination of industrialised, solar and sustainable housing**." A subtle nuance: "it is intended for habitats that meet the triple challenge that our societies are all facing **energy, environment and equitable living."** [1]

	Architecture	Engineering		Communication and Social Awareness	Comfort Conditions	House Functioning	Electrical Energy Balance	Innovation	Sustainability		
2010	120	80	Industrialization and Market Viability 80	80	120	120	120	80	120	Solar systems and Hot water 80	
2012	120	80	Industrialization and Market Viability 80	80	120	120	100	80	100		Energy Efficiency 100
2014	120	80	Urban design, transportation and affordability 120	80	120	120	120	80	80		Energy Efficiency 80
2019	100	Engineering and construction 100	Neighbourhood Integration & Impact 100	100	100	100	100	Innovation and viability 100	100		Energy Efficiency 100

Table 4: The evolution of Solar Decathlon Contests from SDE 2010 to SDE 2019**.**

Since 2010, the Solar Decathlon Europe has undergone a continuous self-improvement, changes in the SDE contest since then can be observed in Table 2. "**Urban design and transportation"** became a contest for the first time in SDE 2014, and the **"Neighbourhood integration and impact"** contest in SDE 2019.

The main features that differentiate SDE from the previous American editions, and the main strategies followed, were:

There was a readjustment of the Competition Rules to promote innovation, energy efficiency, sustainability, industrialisation, social awareness and communication. This resulted in changes in the Competition Contests, renewing around 50% of the Competition scoring with respect to the American original. The 1,000 points of the Competition were distributed in the SD US in ten Contests with 100 points each. In the SDE they were distributed according to the importance attributed to each Contest, with 120, 100 or 80 points. 400 of the points came from four Contests related to the functioning of the houses, which in the SDE were reduced to 120 points in one Contest, freeing up points to weight other Contests and new sub-contests to explicitly promote other values.

These contests have been **progressively improved in the successive European editions**, forming one of the significant points of identity of the European editions. Some of these contests have been incorporated into successive editions in the United States, China, Latin-American, Middle East, and African, editions. An example of the international influence and the transfer of experiences and, in this case, evidence of this can be seen with some of the competitions such as in SDLAC 2019, Latin America and Caribbean held in Cali, with the following contests: cost-effective design; innovation balanced with market potential; water and energy efficiency; energy production and time-of-use energy; and communications strategies.

The evolution of the proposals implemented over the years in The Solar Decathlon is remarkable, not only due to the evolution of the technology itself but also because from the organizations, some changes in the Competition Rules and evaluation criteria have been made. Behind these changes there is a philosophy of focusing on the students' creativity, interest and effort towards the materialisation of new ideas and resolution of different problems. Students are required to consider the reality of taking their designs to market at this early prototype stage, but innovation is also a key focus of the competition.

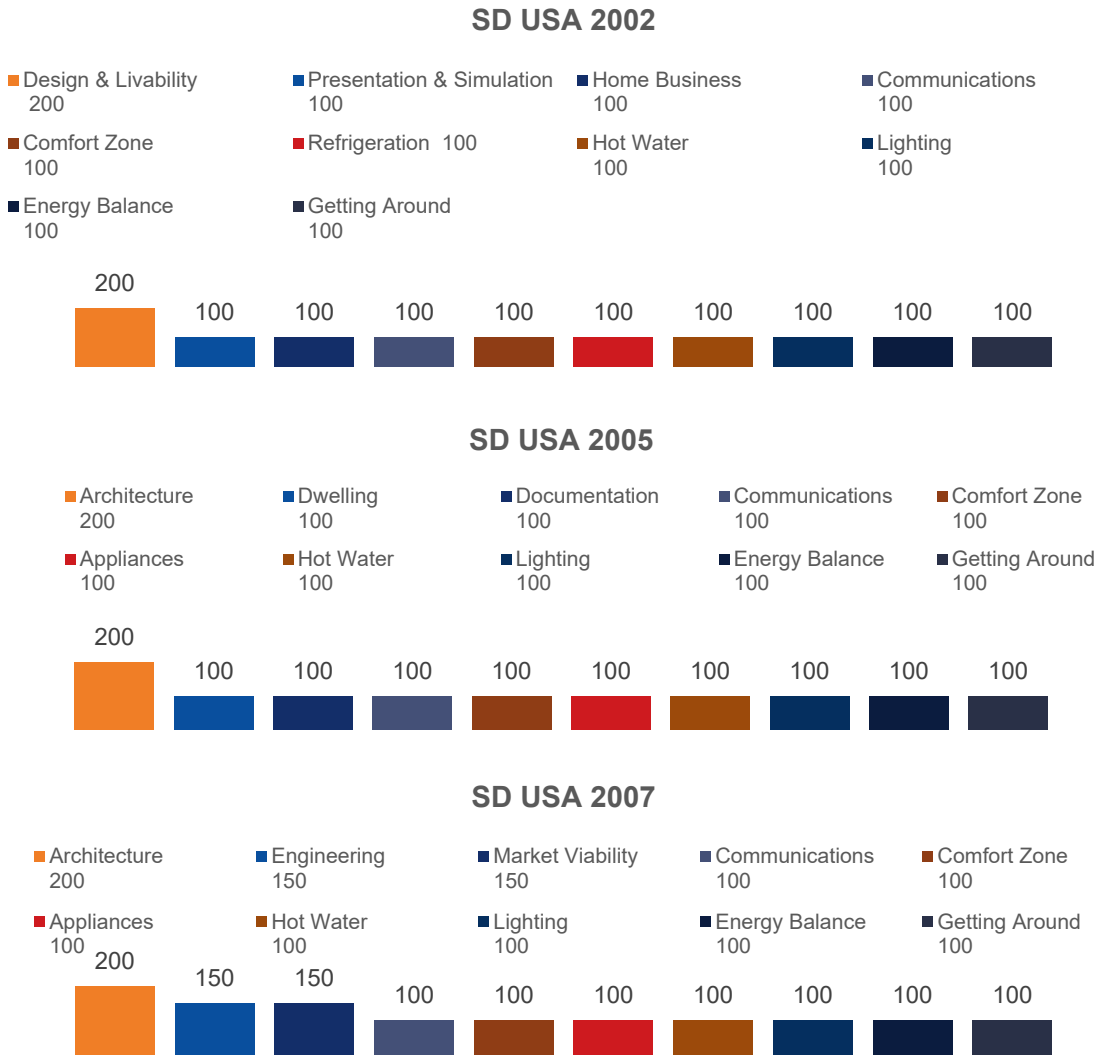
[1] Solar Decathlon 2019 Rules and Regulation Document. https://solardecathlon.eu/category/information/sde-downloads/

3.4 Scoring

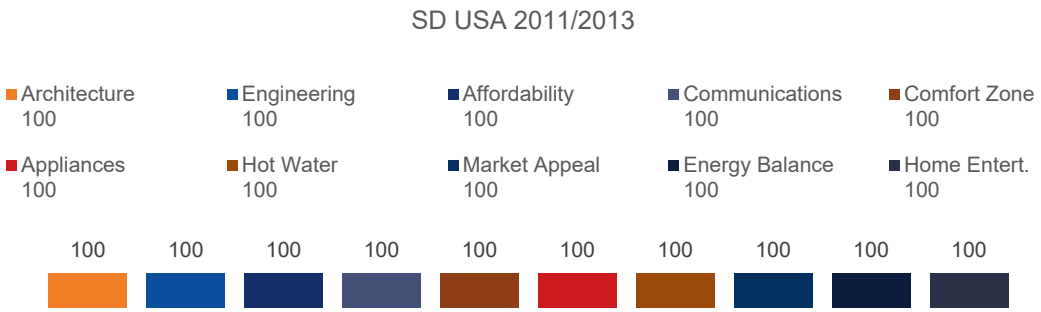
3.4.1 Monitoring contests

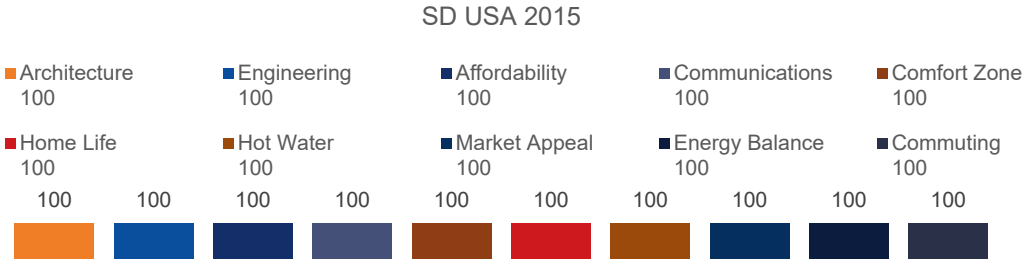
Quantitave scoring is obtained through Task Completion Scoring. The teams obtain points for successfully completing the requested tasks. The carrying out of each task are controlled by an observer, and by “in situ” measurement scoring, during the competition week, the houses are continuously monitored and specific measurements are also taken. The scores are made known at the end of the measurement period corresponding to every contest. The scoring is based on the approach to the goal predetermined in the contests.

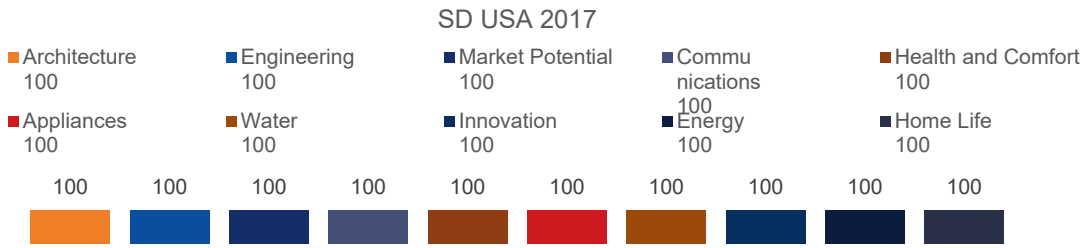
The weight of each contest in the overall scoring is a way to support the competition goals. In SD US 2002 to 2007 not all of the contests had 100 points, from 2011 in all competitions all contests had 100 points. The tendency is similar in Europe, before 2019 each contest had different weight in the overall scoring, in SDE 2019, in SDC and in SDA all of the contests had 100 points. In SDME different contests had different scoring (see figure 22).

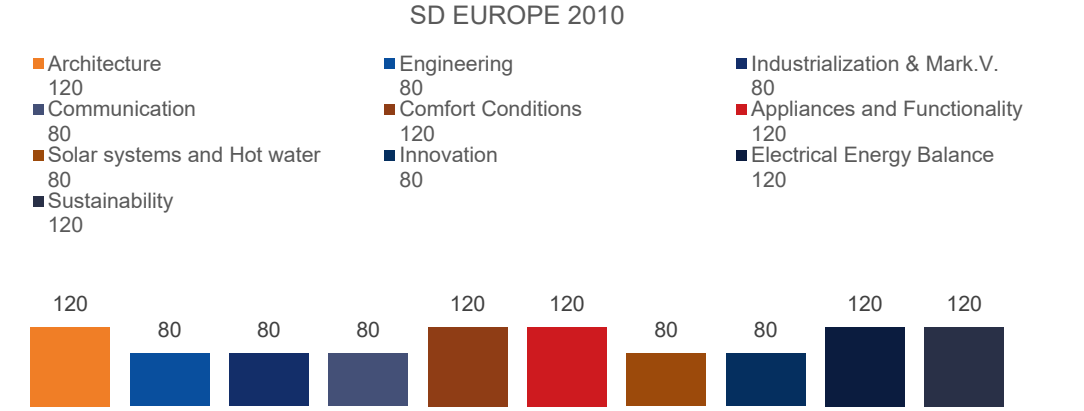


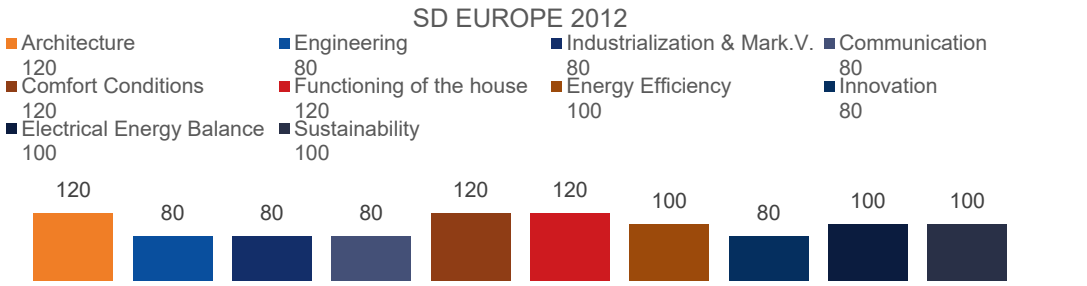
SD USA 2011: All contest score 100 points











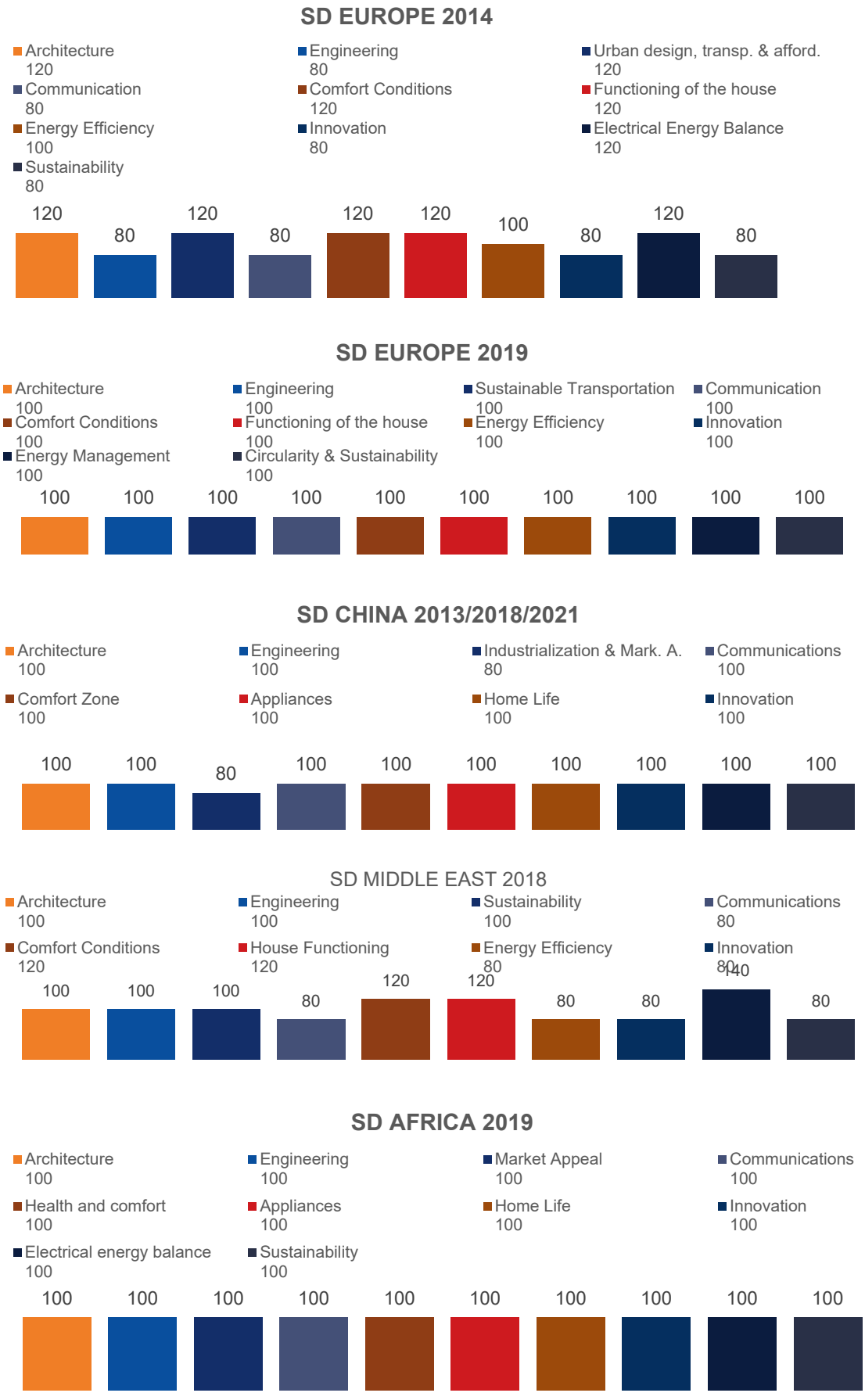


Figure 22: Solar Decathlon Contests weight of each contest in the overall scoring.

3.4.2 Regarding Jury Evaluation

A multidisciplinary jury, made up of by experts in the different fields, and internationally renowned, use their experience and knowledge for the evaluation of the houses. The scorings weremade following the evaluation criteria and guidelines developed by the SD organization for these contests.
The Juries are selected by the SD organization. Due to the complexities of some of the contests, there will be different juries selected for their academic and professional expertise related to the contests evaluated.
The evaluation process of the juries is organized in three main phases:

- Deliverables review (graphic and written documentation)
- Visits to each of the houses in the Villa Solar
- Deliberation

First phase: Deliverables review**.** The deliverables review gives the juries the opportunity to study the projects, to familiarise themselves with them, and to explore the specific technical details of each of them.
The second phase: Visits to the houses. The visits take place during the Competition Week in the Villa Solar, giving the juries the opportunity to visually verify the information previously delivered and raising any question or clarification that they consider appropriate directly to the decathletes.
The third phase: Deliberation. The deliberation is the process in which the different members of the same jury bring ideas together, sharing their opinions regarding the previous phases.

3.5 Feedback and transfer of learning from one edition to another

With each edition of the Solar Decathlon, both in the U.S. and globally, a community of organizers grows. Clear communication, the sharing of lessons-learned, and willingness to improve are key to the continued success of the program. Following each edition in the U.S., teams are asked to provide feedback to the Organizers, via both questionnaires and a final report. This, combined with conversations will impact decisions around the contests, rules, structure, and timeline. While each international edition has its own set of constraints and goals, the structure for measured contests, incorporation of innovation, and ensuring a competition that is fair to all student teams is consistent. By maintaining positive working relationships with all of the international partners, each program can tailor its efforts to local constraints while benefitting from the efforts of others.

For a comprehensive list of resources and lessons learned, the web portal developed as part of Annex 74 has extensive historical information and advice for future organizers.

In SDE after the competition a lessons-learned report is completed by the organizers of the different areas and an overall analysis is carried out to consider these lessons learned in the following editions.

In the first edition of the SDE communication with SD US and transfer of knowledge from SD US Organizers was essential for the success of the first European competitions. 20 people from the 2010 SDE team shadowed the 2009 SD organizing team to learn the organizational ins and outs of the American competition, concluding their participation with a critical analysis report and lessons learned that were the basis for the organizational success of the European edition. Some of the changes carried out in this edition like the monitoring visualisation, the energy efficiency contest, the innovation contest, the PV limitation, two-storey houses where afterwards integrated into the SD US competition, as well as in the following worldwide editions.

The first SD China competition was well received by the teams, the host city and the audiences. One of the feedback points was that the temporary construction could be a waste of money and energy. Therefore, the second SD China competition explored the possibility of permanent building. However, it created new challenges for both organizers and teams mainly in workload and level of difficulties in construction.

4. Events and Projects around Solar Decathlon Competitions

4.1 Objectives for Events linked to the Solar Decathlon Competition

To have an effective potential in social awareness, it is important to understand that the Solar Decathlon Competition is not just the Competition. **It must be the competition plus the events associated with a strategy to make the visits of the public attractive in order to raise awareness among children, young people, professionals, etc., with activities designed for each target audience**. Moreover, without a suitable **communications strategy** and an accessible and centred venue, the effectiveness of the event is small and, as we have had the opportunity to see, a competition without an audience is meaningless, it discourages universities, reduces the support of the Administrations, minimises the possibility of sponsorship, and in the end, would mean the disappearance of the Competition.

4.2 Event Strategies.

The intensity required for a good organization of the Competition and associated events, has meant that communication actions are limited to the host location of the competition, and to a lesser extent, the organizing country. The consequence is that the impact is limited to the universities that participate, with no impact on the media, professionals, and citizens.

In Europe only in the second edition SDE 2012 was a certain European impact achieved by mobilizing the European universities participating in SDE 2010 and 2012 by extending social awareness to their respective environments, cities and citizens, helped by the leverage gained through the EU''10 Action'' project funded by the European Commission within its Intelligent Energy Programme. Many dozens of activities took place in 12 European countries, in addition to activities such as conferences, workshops, and educational exhibitions for the general public, family visits, guided tours, with material and messages of social awareness for each target group. In this sense, **the synergy of the 10Action project was a key driver for the success of the first two editions, and its absence was noticeable in the last two editions**.

A lesson learned from the first editions is that the commitment and direct and active participation of the Government of the organizing country, and the European Commission (in the first edition there was a visit by the Ministers of Housing of the European Union to the Villa Solar, and the financing for the 10 Action project was approved), resulted in the direct participation in activities of about 600,000 European citizens. The lack of commitment by the European Union after the funding of 10 Action project has led to a drastic reduction in the impact outside the location in which the competition is organized.

10 Action project has been developed by seven partners working together towards raising awareness of energy issues, trying to influence the peoples' attitudes, obtaining a reduction in energy consumption. 5 target groups in 12 different countries have been addressed. As all of the partners were involved in almost all of the activities, a strong interaction between the partners was needed. The experience of organizing the activity in one country was transferred to other partners, as were the peculiarities of each of the problems that arose which needed to be solved. Materials have been developed by the leaders and later have been translated and adapted to be used in other countries.
One of the key drivers for a successful awareness event such as Solar Decathlon Europe Competitions is to benefit from all opportunities that arise, with clear objectives and strategies to reach every target group.

4.3 Activities linked to Solar Decathlon Events

The global balance only for SDE 2010 and 2012+10Action in terms of communication is overwhelming: Public and private institutions taking part from 34 collaborating countries, 48 Universities participating out of university applicants (among 800 universities contacted), 400 researchers and PhD Students collaborating with the teams, 3,500 volunteers, more than 25,000 children and teenagers taking part in activities, 7,000 university students taking part in workshops and courses, 25,000 professionals from 12 EU member countries, significant scientific output (books, papers, journals, patents, doctoral theses), over 680,000 people participating, over 700 Million individuals reached through activities and media. Because of this, Solar Decathlon Europe has been awarded many times throughout these years (see figure 23), with multiple prizes, especially important being the **EU Prize of Sustainable Energy Award in Communication** during the Sustainable Energy Week 2011, and the **European Solar Prize 2018** in the One World Cooperation category, in Eurosolar.[2]

Figure 23: EU Prize of Sustainable Energy Award Solar Decathlon Team and members of the Spanish Ministry.

4.4 A Successful Case Study: The EU 10 Action Project and SDE 2012

10 Action Projects was a supplementary extension of the communication activities developed in Solar Decathlon Europe 2012 funded by Intelligent Energy Europe. This initiative also included the active support of more than 12 additional European countries that collaborated to organize specific activities. This project looked for ways to encourage behavioural changes in European citizens, promoting education, social awareness and the dissemination of the **responsible use of energy, increasing energy efficiency, developing renewable energy integration, and improving the conditions of sustainability in our buildings and cities.**

The synergy reached among Solar Decathlon Europe and 10 Action project, and the shared strategy with participating teams and sponsors generated more than a hundred activities for children (se figure 24), adolescents, university students, professionals, and general public, which fulfilled the proposed objectives of these initiatives. The overall communications strategy comprises two general dimensions: Although the core of the communications plan is the message to be transmitted, the creative expression is the key to making it appealing to every target.

The Internet has been the key strategy chosen although other conventional media channels: promotional events, press, radio, etc. have been considered.

Figure 24. "Create your own Solar Village" Workshop results with children.

[2] https://www.eurosolar.de/en/index.php/text-and-media/press-releases-eurosolar/850-renewable-energies-european-solar-prize-2018-awarded-to-eight-winners

4.4.1 Activities and potential for children

Children represent the future of Europe; the objective of the programme was to provide educational material to teachers, so they can give the children adapted information and to develop games to make them aware of the small gestures in their day-to-day habits to save energy and reduce CO_2 emissions. Many different activities were carried out such as the “How to Save Energy in Our Life Game”; Workshop - Reduce CO_2 Production Webgame + Energy Worksheets; International childrens’ drawing competition.

In Austria 31 **handicraft workshops** were organized in interested schools in co-operation with the Austrian Climate Protection Alliance. For instance, more than 3,000 children participated in workshops organized during Solar Decathlon Europe 2012. **A Webgame called “My Energy Smart Home”** was produced in English, German, Greek, Spanish and Portuguese. The webgame was used on the Internet more than 8,000 times, and as complement to other activities in many events. In 10 easy understandable steps children can build and furnish their homes and assess the eco-friendliness of their built houses. As a meaningful complement, **15 graphically appealing work sheets** have been produced, which teachers can use supplementary to their lessons.

An **international childrens’ drawing competition** was launched in 2012, in SDE 2012 the best drawings were exhibited (see figure 25).

Figure 25: Pictures from 10Action "Drawing Contest"

This has been successful because the activities have been developed **using already existing institutional settings and channels of communication such as eco-schools** to create synergy effects and to avoid costly efforts with no adequate results. An analysis of the **special needs of the target group** was made before beginning to design activities. Activities for children need **special communication channels** such as childrens’ magazines and especially a language suitable for them. The activities were designed to be fruitful for children with learning disabilities and not only for the highly skilled.

It was very important that from the beginning two organizations were involved: one experienced in the work with children and another one specialised in energy matters.

It was important to **look for alliances**, when addressing children and teachers, because it was not possible for every country to have direct access to schools. It was not important to have a huge marketing budget, but it was important to **select the appropriate channels of communication.** They are very specific ones for teachers and children.

4.4.2 Activities and potential for teenagers

As regards adolescents, the objective of the programme was to contribute to raising awareness through personal motivation and implication. 1,550,000 teenagers were reached through the communications programme. It was based on providing educational material, directing teachers and providing adapted information, so adolescents get involved in games and debates to consolidate their civic conscience, favouring more sustainable habits and models to share with their families. Many different activities were carried out for teenagers as a Debate “How we want our own solar village”, a Solar Design Competition “Ideas for the Future”, a Solar Photo Competition “Energy in Focus” (see figure 26).

By means of a **planning game,** students can assume and put themselves into the positions of different participants and actors in urban planning. In addition to the debates, a set of lessons and educational material were developed to help the teacher. The material for the debate “Energy + Architecture“ was developed in English, Spanish, Greek and German.

Figure 26: 1st Prices, Solar Design Competition “Ideas for the future” and Photo Competition “Energy in Focus” (children and teenager’s activities)

The activities of the **Solar Design Competition** were implemented in Greece, Austria and Germany reaching 752 adolescents designed 194 solar devices. Competition leaflets, posters and rules were prepared in English, Spanish, Greek and German. Participating students were asked to develop ideas for “**The Town of the Future**“ (Age group 10-14 years) or “**The Building of the Future**“(15-19 years). Problems and challenges were to be discovered and explored.

The activities of the **Solar Photo Competition** (see figure 27) were implemented in Greece, Portugal, Spain, Austria and Germany reaching 1,303 adolescents (1,582 photos). The means of a playful introduction to the subject of renewable energy through the creative medium of photography provoked a direct examination and reflection of the participants’ own behaviour. Thus, the student competition was aimed at awakening interest in energy and sustainability matters and the consciousness of one’s personal contribution already at an early age; one small step on the way to achieving long-term behavioural changes, concerning the use of energy and the source of CO2-emissions.

Figure 27: On the left, Ciclab Solar; on the right, Science workshop.

Motivation of teachers makes a difference for teenagers. Most of the teachers are extremely busy, struggling to implement their normal required curriculum and feel unable to acquire new additional knowledge.

The collaboration with the Ministries of Education is necessary to get the topics of renewable energies and finite resources included in the mandatory grade school curriculum. A lot of time and effort was necessary to achieve collaboration with the Ministries of Education, especially in countries where education is subject of individual federal states. Unfortunately, most of them did not agree to transfer information to their school contacts.

In some countries, a lot of well-respected competitions already exist (Jugend Forscht, NaturPur Award, etc.), which are primarily on the teachers´ radar and of interest. The assistance of experts from the field of media management and communications seems necessary to make the competitions more attractive for the teenagers. A lot of effort was necessary to implement the competitions internationally.

Synergy effects from the joint preparation of materials such as leaflets and competition rules helped to accelerate the implementation of the competitions.

4.4.3 Activities and potential for university students & the Scientific Community

Reaching this target group has doubled the interest: first, seeking to consolidate the generation of awareness and training, and second, accessing the most effective knowledge creator and knowledge disseminator in Europe: The Universities.

These activities aimed at encouraging the university student's commitment and imagination, not only decathletes but students from other European universities, to contribute to modifying habits with ideas in order to reduce CO_2 emissions, improve energy efficiency in buildings and bring about a more sustainable world.

The active participation of the Scientific and University Community ensured the dissemination of knowledge and helped to generate the new concepts necessary for achieving the European objectives. Many different activities were carried out such as as the "MORE about LESS [emissions]" Debate, Ideas Competition "MORE with LESS [emissions]"(figure 28), Technical Workshops, etc.The **debates on how we want our own Solar Village "MORE about LESS [emissions]"** were implemented in Madrid (2012) as well as by the online Moodle system reaching 1,180 students.

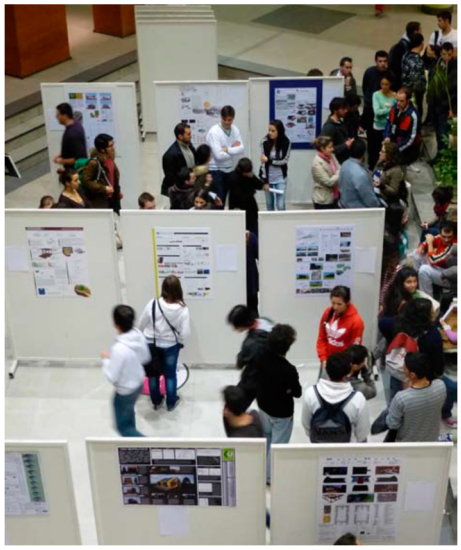


Figure 28: Exhibition, MORE with LESS [emissions]

Participants in 15 debates organized during SDE 2012 and the online system came from 46 different universities or schools and 15 countries: Spain, Germany, UK, Finland, Greece, France, Austria, Romania, Egypt, Brazil, China, Japan, Bulgaria, Portugal and Italy. The aim of the debates was to provide the students with the knowledge to be able to think for themselves how an ideal city should be from an energy point of view, without forgetting the basics of an urban development. In addition to the debates a set of lectures were developed in pdf and Powerpoint format, in English and Spanish, related to the main topics to consider throughout the debates: consumption and production of energy, bioclimatic urban planning, materials and constructive systems, sustainable industrialisation and environmental control both passive and active systems.

"Ideas Competition on impossible ideas for a possible world "MORE with LESS [emissions]". The competition reached 43 submittals and 221 participants from 30 different universities or schools. The main

aim of the competition was to obtain new conceptual ideas on how to deal with the energy issues that are affecting our world, both in construction and urbanisation projects.

Numerous Technical Workshops were carried out in Portugal, Spain, Germany, France, Spain, Finland, Greece, England and Austria reaching 747 participants from 25 universities. The goal of the technical workshops was to raise awareness about the responsible use of energy and energy efficiency in buildings among graduate and undergraduate university students. Organized with the help of different universities, the workshops were oriented towards awareness, with objective data, of the use we make of natural resources and the low energy efficiency of many everyday processes, followed by showing the technologies available on the market for the use of renewable energy and improve the efficiency of our activities and everyday customs.

Thousands of university students and professors visited the solar houses in every edition of the competition, both, during the assembly and disassembley processes, and during the competitions. Later, back in their Universities the re-assembled solar houses have been used as living labs, demonstrators, and research facilities, reaching again thousand of university students and professors for education and research.

58 universities from around the world have participated in the four Solar Decathlon Europe Competitions held to date. Over 400 researchers and PhD students have participated in research projects associated with the SDE both directly or indirectly.

It was hard to reach the target group through the universities. We learned that the best way to reach the students was through their professors. When we came across a motivated and interested professor, we had access to his students, and he or she would take care of implementing our activities. One of the most successful activities was the organization of workshops because it was where we could really confirm the gain in knowledge on behalf of the students. To achieve a greater outcome of these results, it could be very interesting to video record all of the workshops in order to make them accessible to all students or to use online streaming.

4.4.4 Activities and Potential for Profesionals

Professionals from the building sector must be involved for the achievement of the European Union's objectives. The objective was based on providing all the available information and transfer of innovative technology to the market, using existing mature technology to build "zero emission" buildings, looking to generate change in the technical and productive model. Many different activities were carried out as an active participation in the most important International European Trade Fairs - Organization of International and National conferences, Workshops. The total attendance to these fairs was of 486,885 people in 2011 and 2012.
In order to reach the biggest target audience as possible and to pass our messages on to key market players and professionals, workshops and conferences were organized[3] within the International Trade Fairs framework with exhibitions in some of which scale models of houses participating in SDE 2010 and SDE 2012 competitions were shown.

Conferences were organized within the most important energy, architecture and environment international trade fairs in Europe. To have a big audience means that a huge dissemination effort is needed before any

[3] BAU Trade Fair (Munich 2011). Urba Verde Fair on Sustainable Cities (Estoril 2011). Workshop on "Eco-Urbanism and Eco-Architecture". GENERA'11, International Energy & Environment Trade Fair (Madrid 2011). Construmat'11, International Construction Exhibition & Trade Fair, (Barcelona 2011) Conference on "Nearly zero-energy buildings, from research to real construction". DEUBAU Trade Fair, (Essen 2012), Conference on Aesthetics of Sustainability in architecture and communication. GENERA'12, International Energy & Environment Trade Fair, (Madrid 2012), Conference-Debate on "Nearly zero-energy buildings: new construction and refurbishment". Workshop on the "URSOS Programme: Software for the development of sustainable urbanism", Madrid at Solar Decathlon Europe 2012 Exhibition.

promotional activity. It must be considered that to get a successful response from dissemination campaigns is to obtain 2% to 5% of positive answers or participation. For this reason, on two occasions we have done direct e-mail shots to more than 22,000 people. This was a key point for gathering the audience we have got in our conferences/workshops.

It was important to use innovative formats for the conferences and new means of communication. Professionals are already bored with conventional presentations, therefore to organize a debate, such as the one held in GENERA 2012 (figure 29) about “Nearly zero-energy buildings” was very successful, but even better was to broadcast the event online, this not only guaranteed a very high participation, but also the implication of all the Conference speakers.

Figure 29: Conference-Debate on "Nearly zero-energy buildings ", GENERA 2012, Madrid, Spain.

All participant Professional Associations were very active before and after the event, they have placed publicity and articles on their web pages. By broadcasting the conference, the debate increased interest and the implication of the professional associations at the conference. The professional associations saw this event as an opportunity to advertise themselves among their clients and within the GENERA trade fair.

4.4.5 Activities and potential for the general public

The general public (see figure 30) was identified as the most efficient, in the short term, in raising awareness on how small behavioural changes may save a great amount of CO_2 annual emissions, ensuring a more sustainable world. The objective was based on maximizing the media impact and dissemination to enhance European Union objectives, especially those related to energy saving**s .**

Figure 30: SDE 2012. Image of "Solar Village" (Villa Solar).

Many different activities were carried out by European SDE universities, to develop activities and exhibitions in their houses, both before and after the competition, as well as the Organization of SD Europe House exhibitions. The organisation of SD Europe scale model exhibitions, and the competitions themselves were key drivers, with dozens of activities and exhibitions aimed at the social awareness of visitors in every Solar Decathlon Europe Edition.

The **scale models of the SDE house prototypes** have been used for travelling exhibitions so that the general public were able to visit the scale models of SDE 2010, SDE 2012, and SDE 2014 (figures 31,32). Along with the scale models, audio-visuals were integrated in the exhibitions, explaining the different technologies to the public and showing the importance of making responsible and effective use of energy. There were many scale model exhibitions implemented in energy fairs in Spain, Germany and Portugal, generating a substantial impact. Furthermore, there has been a connection with other activities and fairs addressed at children (mainly in the exhibitions that took place in Madrid).

The main idea of the **house exhibitions during the SDE editions**, was to provide comprehensive guided tours for the general public (figure 33). This activity would familiarise them with new energy efficient technologies.

During the house exhibitions, thousands of people visited every single house. They enjoyed the houses and had the opportunity to meet the enthusiastic explanations of the students about the active and passive strategies they had implemented to make their homes more sustainable.

The feedback received from the visitors to the solar houses, both at every Competition, and at their own university location, was excellent. According to a 10Action Survey, 81% of the visitors believed that the exhibition of energy efficient houses was meaningful since it provided useful information on innovative technologies in the general public. Another interesting fact is that the 70% of the visitors would be interested in buying the exhibited house they visited.

Figure 31:SD Europe model exhibition in Madrid Science Week

Some of the houses have been exhibited in their corresponding university campus after competition, or in the case of University Rossenheim, Aalto University and Universidad de Sevilla, at a trade fair. They have received a total number of 94,000 visitors. The scale model exhibition of the Solar houses of SDE 2010 and SDE 2012 took place in nine different trade fairs with a total amount of 51,252 visitors.

The exhibitions of energy efficient houses are an impressive method of informing the general public about new innovative technologies in a practical manner. From the feedback received, the exhibitions proved to be a significant tool for raising the energy awareness of the European society.

The collaboration between the Universities and the local schools in order to establish continuous school visits to the exhibitions works positively for the students. It is an interesting environmental tour that increases the students' knowledge of energy matters. This is clear from the feedback received from exhibitions at which most visitors were children and youths.

Figure 32: Scale models of the SDE house prototypes exhibition.

Figure 33: Public visits to CANOPEA House. SDE 2012.

Universities were more focused on the research concept (taking measurements in their houses, etc.) than informing the public on new innovative and energy saving technologies. Since most of the Universities rebuild their houses after the SDE competitions, it is important to utilise the houses as much as possible, not only for research purposes but also for guided tours in order to raise the energy awareness of the European citizens. The visitors can see with their own eyes the technologies that are integrated in the house and receive crucial information from the scientific professionals of the Universities.
In SDE 2019, in Hungary, for the first time it was possible for the wider public to visit the prototypes in the form of a 2-month extended exhibition.

5. About the Organization and Project Management of University Competitions

As will be seen below, from the analysis of the surveys, indicators, and multiple semi-structured interviews with students, professors, companies, and above all, organizers, one of the key drivers to achieving successful editions of competitions and the events associated with them has to do, in the end, with good organizational management.

Aspects such as the organizing team, budget and fundraising, good planning, reliable identification and risk management, etc. become fundamental for a successful competition. This section reflects on some of the important aspects to take into account when organizing a university competition, and specifically, one of the ambitions and impact of Solar Decathlon.

As regards documenting the organizational experience of the competitions and the linked events, the decision was to make some organization factsheets that would collate the summary of the data of this experience, accompanying it after those specific files that each organization wants to share with the international community, and that would document the experience.

The intention of the Organization Factsheets (Annex 1) is to be a very graphic and descriptive document that gives an overview of the different aspects of the organization of the competition and the linked events, as well as compiling a summary of all the data that will be analyzed later to determine the indicators and KPIs to assess the overall impact of the Solar Decathlon competitions worldwide.

We are aware of the difficulties in collecting many of the data that we want to document from past competitions, so the approach is very flexible. The idea is that each of the organizing teams from every competition will complement the Organization Factsheets, in the best possible way. The most important part is the Variables and Indicators (Annex 2), because they will serve for the evaluation of the global impact.

The ORGANIZATION FACTSHEETS consist of 8 Excel sheets that cover the different organizational aspects (see figure 34). They include:

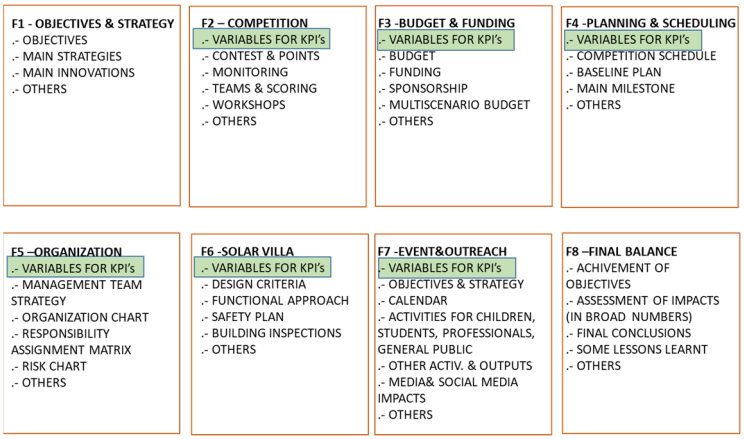


Figure 34: Organizational aspects

In most of the sheets there is first a section of VARIABLES AND INDICATORS in which the Organizers have to fill in as many data as possible, because they will be data that will be used later for the assessment of the impact of the competitions. An example can be observed in figure 35:

Applicant Teams:	33	**Initial Participating Teams:**	20 + 3	**Final Compiting Teams:**	19
Universities involved (partip):	30	**Countries involved (partip):**	15	**Continents involved:**	4

Figure 35: Example of Data in an ORGANIZATION FACTSHEETS

The rest of the headings are open, this means that there is freedom to choose the content of what the organizers want to say, and the format they want to use. To make it easier, and for people to understand it better, it was proposed to use pictures, graphics, charts, screen shots of power point presentations, whichever is easiest. The idea is to give an overview of the experience of organizing the competition in all of its aspects: budget, planning, team organization, infrastructure and solar village, linked events and impacts on society.

Annex 1 of this report contains the collation of the Organization Factsheets of all the organizing teams from the various competitions around the world (figure 36), with exception of SDME and SDLAC, which have failed to submit the requested information.

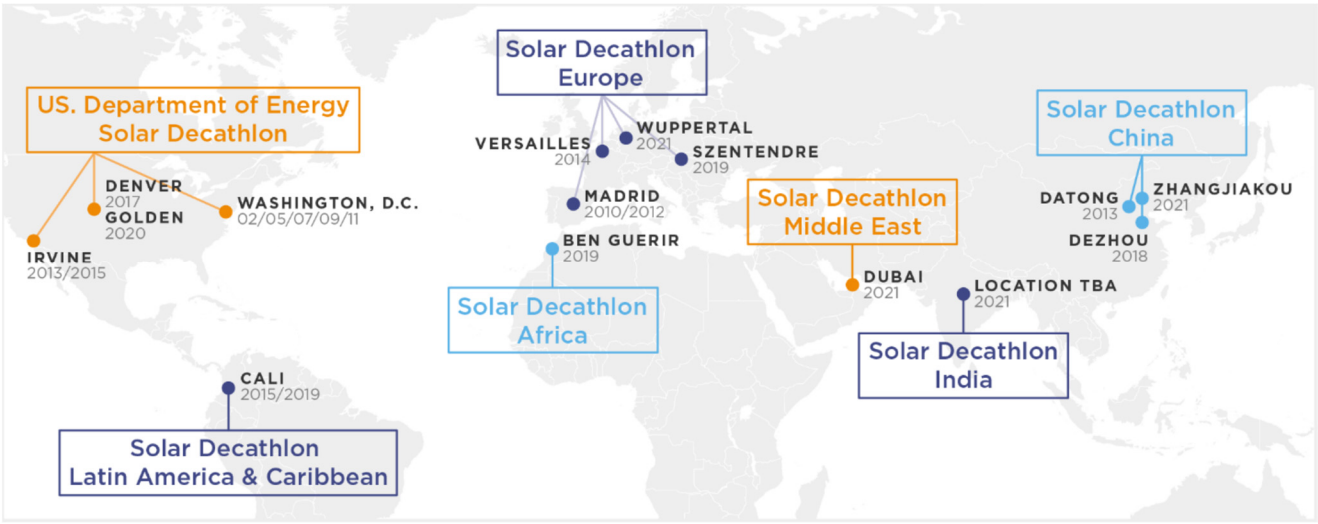


Figure 36: Map of competitions around the world

The following is a partial, non-systematic description of the main organizational aspects and their importance for the success of the competitions and associated events.

5.1 As regards the Objectives and the Strategies to Achieve them

As always when you want to organize and plan the development of a project, the first thing to make clear is the scope and objectives proposed for it. In this case, the competition itself has been the invariant in the scope of all the organizing teams worldwide, but the scope of the associated event surrounding the competition has varied from one edition to another, ranging from minimal and secondary approaches, to cases in which it takes on as much or even more prominence than the competition itself.

5.1.1 US Solar Decathlon Competitions.

In the fall of 2002, 14 teams of college and university students from across the United States, competed in the first-ever Solar Decathlon on the National Mall in Washington, D.C. The Solar Decathlon''s 10 contests challenged the teams to design and build energy-efficient, completely solar-powered houses.

The competition, which was open to the public for more than a week, gave both the students and visitors to the Mall an opportunity to experience homes that feature environmentally sound, cost-effective technologies that meet the energy demands we face today.

The Challenge: "On the domestic front, our industry's goal is to meet 10% of U.S. peak generation capacity by 2030…" – Solar Electric Power, the U.S. Photovoltaic Industry Roadmap. One Approach to the Challenge: Install significantly more building-integrated PV systems on residential and commercial buildings, growing to 1.7 GWp/yr by 2020.

The strategies fixed in SD 2002 were:

- Achieve market penetration for BIPV; The Steps: Simplify the architectural integration of PV into buildings, demonstrate aesthetic and functional applications, Expand the availability of design choices in BIPV products
- Achieve widespread acceptance of BIPV-equipped buildings; The Steps: Coordinate among all design and construction team participants (architects, engineers, and building trades) early in the building, design and construction process and throughout each phase of it.
- The general objectives of the organizers of the following American editions were based on three main objectives:
  - The education of both Decathletes and university students and professionals (Builders and architects), as well as the general public.
  - With the competition itself, provide student motivation, generate public interest and change perception by demonstrating homes looking good.
  - Research and development with the largest housing experiment ever held and the opportunity of side-by-side comparision of building technologies and testing and redesign iterative process to drive improvement.

These objetives were in later editions similar, although Research and Development was reduced in the ambition.

The strategies to reach these objectives was based in the competition itself, with strong teams, outreach, and engagement.

5.1.2 Solar Decathlon Europe Competitions

Further to the general objectives defined for the SD Competitions, two more objectives were defined for SDE 2010, the competition held in Madrid:

- To generate knowledge on the industrialisation and sustainability of the houses, as well as the dissemination of the knowledge, and transfer to professionals and industry.
- To take adventage of social interest and high media impact to make students, professionals, and the general public aware of environmental and sustainability issues, especially in the responsible use of energy and natural resources, promoting the use of the renewable energies, improving energy efficiency, etc.

For SDE 2012 competition in Madrid, a new objective was added:

- To promote the best legacy of Solar Decathlon Europe developing activities to take advantage of this body of knowledge for the near future: Books with a description of the experience, technologies, learned lessons, Virtual Lecture Room, 40 research prototypes, exhibitions of the scale models, awareness games, research network, etc. and transfer of these experience for Solar Decathlon Community, Solar Decathlon France 2014, etc.

The main strategies to reach these objetives in SDE 2010 were:

- EU 10 Action project to leverage activities all around Europe linked to Solar Decathlon Europe
- Shared objectives and commitmment with European teams to promote their active participation with a communication shared strategy.
- To develop as many activities as possible to attract people. Organized around 5 target groups: children, teenagers, university students, professionals, general public
- To promote news for media and social media
- Shadow team close to US SD 2009 Organizing Team. Very close learning and critical analysis with a report on lessons learned
- Innovations in monitoring systems

For SDE 2012 two more strategies were implemented:

- Change of competition dates to september, in order to have active schools and universities and to maximise the participation of children, teenagers, and university students in activities organized in the solar village
- Innovations in monitoring systems, smart grid, electric mobility etc.

Similar objectives were shared in the SDE 2014 competition held in Versailles, but emphasizing new challenges of social innovation and sustainable mobility on an urban scale.

Solar Decathlon Europe 2019 held in Szentendre was focused on the value-added renovation of existing buildings. SDE 2019 was the first competition in the history of the Solar Decathlon, which was aimed at placing a specific emphasis on resource responsibility, Net Zero Energy Balance (NZEB) focused the renovation of existing buildings.

This contrasted the construction of new, energy-efficient residential buildings that had usually been encouraged by former Solar Decathlon editions. This topic centred on the identification of affordable and viable building renovation schemes combining modern, environmentally-friendly and innovative solutions. It is a fact that these are among the most current challenges faced by the construction industry, and social demand in Europe and beyond.

The strategy implemented to reach this objective was to extend the exhibition following the 2-week long public competition phase. The extended exhibition, which lasted until the end of September, allowed the prototypes to be seen by 15,000+ visitors at the SDE 2019 Solar Village.

The organizers invited a wider audience of professionals and residents to view the messages of the Teams and their prototypes which indeed called for a sustainable lifestyle with practical solutions.

5.1.3 Solar Decathlon China

The Chinese organization defined the close combination of solar energy, energy conservation and architectural design in a new integrated way with the help of the technology and creativity of participating teams, so as to design, build and operate a solar residential space with perfect functions, comfort, livability and sustainability as the purpose of the Solar Decathlon China 2013.

Furthermore, through the competition, to accelerate the international integration and exchange with the solar energy industry, promote the innovation, development and commercialisation of related technologies, with a new lifestyle.

For SDC 2018 the competition aimed to explore ways to promote green development through competition, promote green technology and industrial innovation, and advocate the popularisation of a green lifestyle

The main strategies were through:

- Training students to become future leaders of industry; Educate the public to promote the concept of green energy conservation;
- Stimulate ideas and promote the merging of scientific research ideas; Boost industry and accelerate the in-depth innovation in the field;
- Create a platform to promote multi-party interaction and cooperation; Promoting regional transformation and development.

5.1.4 Solar Decathlon Africa 2019

The Solar Decathlon Africa 2019 was held in Benguerir and conceived SD as an international competition where more than 1,200 students from 54 universities competed to win the challenge. They conceived, constructed and tested zero-energy sustainable houses. These houses were equipped with technologies allowing very high efficiency. The proposed houses are suited perfectly to the african climate and specifications.

This competition is aligned with the Moroccan objectives: To conceptualise low-energy consuming buildings that achieve the objective of net zero energy buildings. In order to emphasise the significance of Solar Decathlon AFRICA, the contestants had to integrate regional sustainable raw materials while working on the components of the building.

The competition’s main objectives were to generate knowledge of net zero-energy buildings within the emerging continent, highlighting the perks of decentralised solar energy in bringing forward an increasingly electrified continent, speeding up actions on reaching sustainable energy for all Africans, and valorizing the African local materials and knowhow in the building sector.

5.1.5 Solar Decathlon Middle East and Latinamerica

There is no specific information available regarding the competitions held in the Middle East, and Latinamerica.

5.2 As regards the Organizing Teams. Strategies and Organization Charts

Solar Decathlon competitions have become very inspiring events for students, professionals and the general public, with a wide international scope and with very notable possibilities for social and media impact.

The magnitude of the Solar Decathlon competitions in the world, the number of participating teams and universities, the high technical and scientific level of the teams, the logistical needs associated with the Solar Village in terms of infrastructure, the coordination and management of hundreds of large transport trucks and heavy cranes operating together in a small space with the pressure of limited available time, the tens of thousands of people, in some cases hundreds of thousands of visitors, the large number of activities for all ages and profiles that are developed, the media coverage, etc. The magnitude of the project means that the organization of the event cannot be left to people without organizational experience.

One of the keys to success will be to select a project manager who preferably has theoretical training and applied experience in project management, who is sensitive and committed to the world of sustainability and energy efficiency, and who has leadership skills.

Then the Project Manager must recruit a good team, be well endowed financially to have all the means necessary, balanced between young, dynamic, creative and highly motivated and committed people, with people with a more senior profile and professionals who, with their expertise, guarantee the viability of the key areas in a solvent way. Given that the team is large and from different backgrounds, it will be necessary to apply “team building“ strategies, a training and coaching plan that complements the shortcomings of the team, and a good organization of the whole team, distinguishing between the organization of the competition, and the organization of the event around it.

Throughout the various editions, different organizing teams from different backgrounds have managed the organization of Solar Decathlon competitions. The most frequent models have been public energy agencies (NREL, IRESEN), public construction agencies (CSTB, EMI), public universities (UPM, BUW), or companies, associations, public or private foundations (EEF, DEWA, CODA) or a consortium of public agencies and ministries in the case of the SDLAC. Experience shows that it is not so much a question of the organizing institution, but of the project manager and the organizing team.

Several of the interviewees who have organized the competition with university teams have emphasised the added value of having university students, young, dynamic, creative, and very committed to society and the project, becoming one of the great assets of the project. It is very likely that after the selection of the team it will be necessary to provide the members with the necessary training complements in order to have a work methodology and organization shared by all.

An aspect that should also be highlighted is the convenience of having in the organizing team former organizers, faculties of previous editions participating teams, or former decathletes, because they have the vital experience of the competition and its values incorporated in their DNA, facilitating the continuity of the spirit of the competition.

The teams must be well sized so that they really have adequate control and coverage capacity. The average teams have been between 50 and 75 people in general, plus hundreds of volunteers who have complemented the logistical needs of the teams.

Let’s see how the teams in charge of different competitions have been organized.

5.2.1 US Solar Decathlon Competitions

To show the complexity of organizing an event of this magnitude, the organization chart of US SD 2007 (see figure 37) held in Washington has been selected.

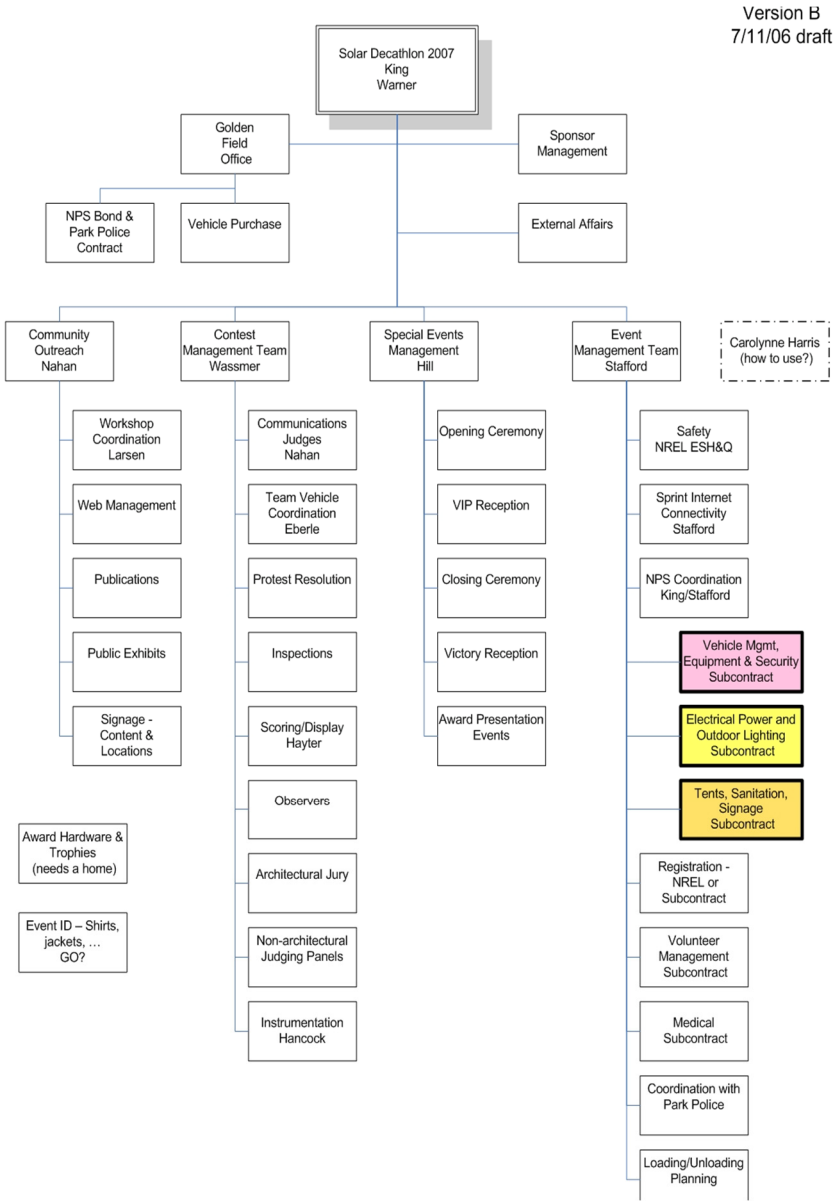


Figure 37: Organization chart of US SD 2007

The team is complemented by a large pool of volunteers who collaborate for specific tasks such as welcoming the public, observers during the competition, organizing guided tours, and following the assembly and disassembly processes of the houses in the Villa Solar.

According to the US Department of Energy document – Solar Decathlon. International Solar Decathlon Best Practices (July 2020), successfully delivering a safe, fair, and exciting Solar Decathlon Build Challenge event requires a wide variety of skills, including oversight for project management, event production, site operations, competition management, and communications outreach. Each of these areas of responsibility (see figure 38) will likely have additional support staff and development activities

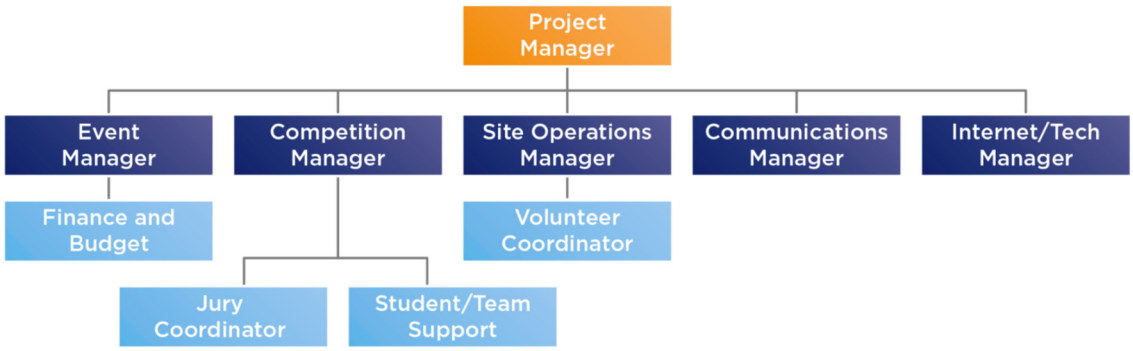


Figure 38: Areas of responsibility

Director Responsibilities

- Programmatic guidance of the competition, including the determination of goals, brand, and staffing
- Oversight of governmental funding and the Organizer team in implementing the competition
- Adjudication of any disagreement between the Organizer team and the competing collegiate teams for a fair and safe evaluation of winners
- Recognition and support of financial and in-kind partners of the program through the comprehensive stewardship of the program brand
- Coordination with DOE to ensure delivery of the activities outlined in the MOU.

Project Management Responsibilities

- Specific responsibility to deliver the project at a given budget under the direction of the Director Responsible for the oversight of the organizing staff, finance and budget, project direction, brand, strategies, timelines, and reporting.

Event Management Responsibilities

- Management of organizer staff, budget, and schedule coordination; event visitor management; coordination of volunteers; special events; event infrastructure; sponsor relations; registration and team workshop coordination; and visitor safety
- Support services for event infrastructure, signage, and visitor management.

Competition Management Responsibilities

- Rules and building code development and enforcement, collegiate team liaison, the inspection of rules, safety inspections, construction documentation coordination, subjective Contest coordination, objective Contest monitoring, and leading the on-site inspection of rules
- Support services for instrumentation, cost estimation, and code inspections.

Site Operations Management Responsibilities

- Competition site microgrid, power, and lights; vehicle management; assembly/disassembly coordination; house water supply/removal; public safety inspections; construction and student safety, including work plans, lift plans, fall protection, and work conditions
- Support services for event utilities.

Communications Management Responsibilities

- Messaging; branding; publications; signage design; exhibits; awards; and content writing and editing for outreach materials, blogs, press releases, speeches, and other media materials; management of website and social media, online tool development, and media inquiries and relations.

Internet/Tech Management Responsibilities

- Development of scoring database engine for the competition, infrastructure for website hosting, on-site infrastructure management for Ethernet LAN, WAN internet connection, and mobile communications.

5.2.2 Solar Decathlon Europe Competitions

The organization of the first competitions in Europe was organized in a similar way to the US SD. In SDE 2010 two main responsible people were defined under the direction of the Project Manager.

One is the Competition Manager, and the other is the Event Manager. The strategic decision to organize the Competition with the Universidad Politécnica de Madrid, meant creating a large team in which approximately 5% were professors, 5% were professionals, 50% were researchers and PhD and Master students, and 40% were recently graduated students.

For the organization of the SDE 2012 team, the organizing team was divided into the following areas and teams (see figure 39):

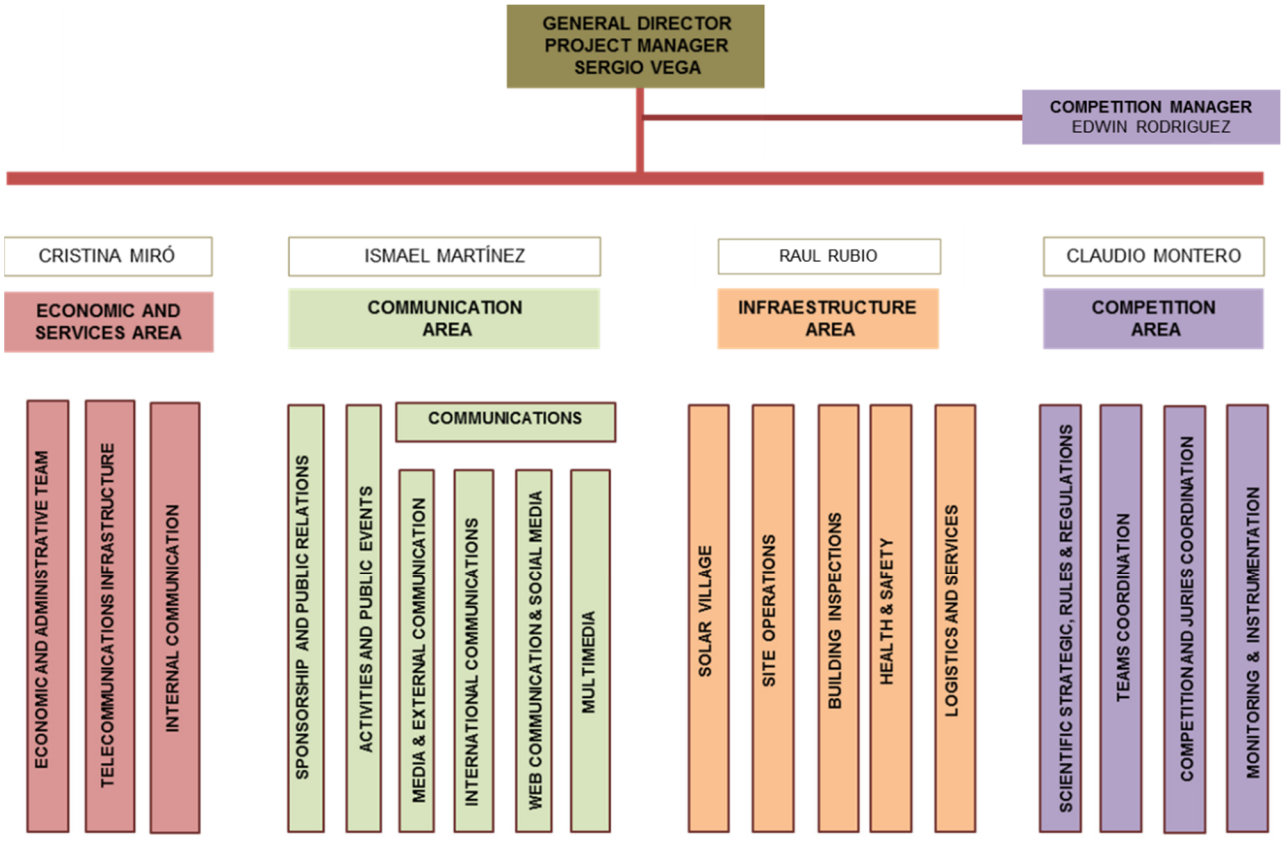


Figure 39: SDE2012 organizing areas and team.

During work planning, a complete definition of the responsibilities of each of the work areas and teams was made, as well as a responsibility assignment matrix (organization areas and teams in figure 40), which can be seen in the organization factsheets.

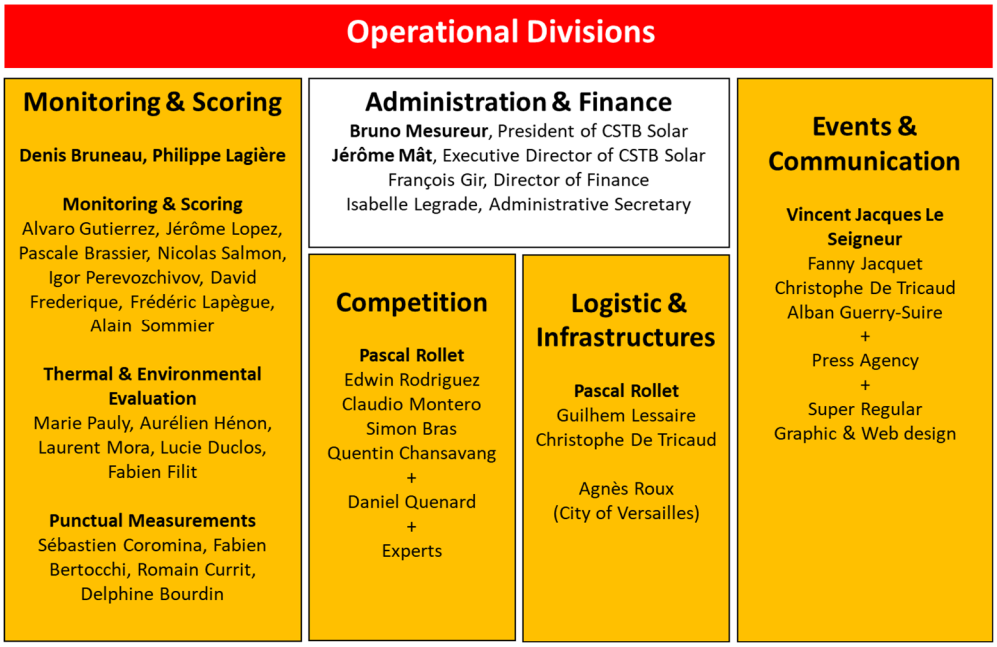


Figure 40: SDE 2012 organizing areas and team.

The operational organization chart (see figure 41) for SDE 2014 was:

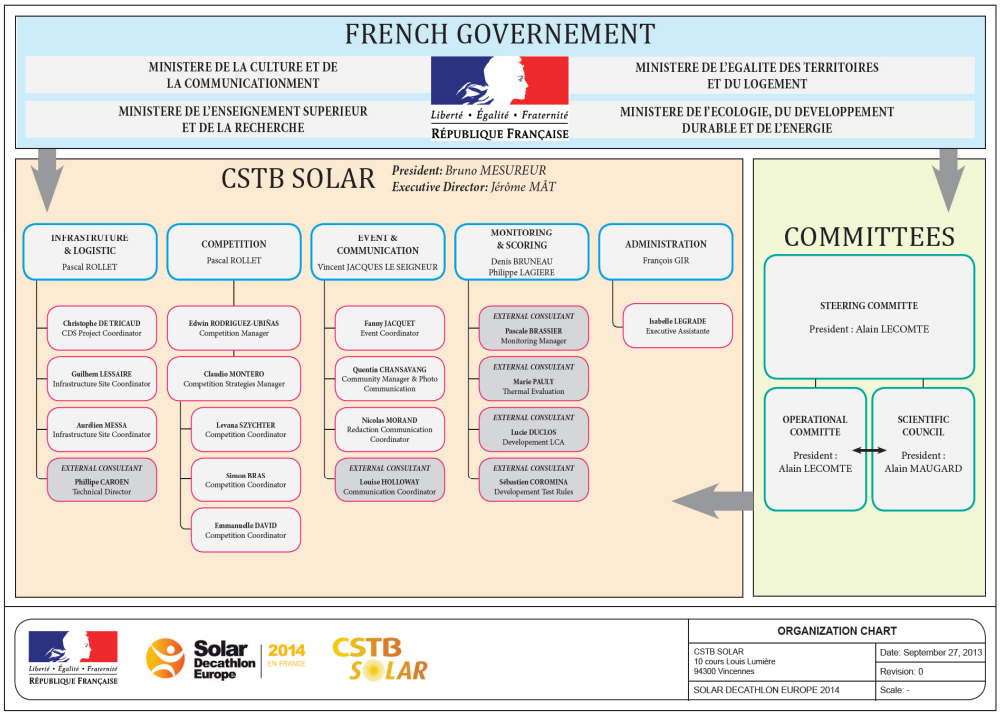


Figure 41: SDE 2014 organization chart.

The organization chart (see figure 42) of SDE2019 held in Szentendre was:

Figure 42: SDE 2019 organization chart.

5.2.3 Solar Decathlon China

The organization of SDC 2018 was with an organizing committee that had set up six working groups, including comprehensive coordination, construction and environmental improvement, industrial cooperation promotion, investment promotion and field service, publicity and promotion, and safety assurance

5.2.4 Solar Decathlon Africa

The first African Solar Decathlon was held on September 13th- 27th, 2019 in Benguerir, Morocco and organized by the Moroccan Research Institute in Solar Energy and New Energies (IRESEN) and Mohammed VI POLYTECHNIC UNIVERSITY (UM6P).
The different tasks and areas arising from the organisation of the whole three-week competition and its related side events were under the supervision of the SDA project Manager and with the support of more than 20 collaborators from IRESEN/UM6P, who have undertaken the subtasks of the competition. Also, there has been a massive recruitment of more than 60 PhD and Master students as volunteers, to support the organizing team.
For the organization of the SDA team (see figure 43), the organizing team was structured as following structure:

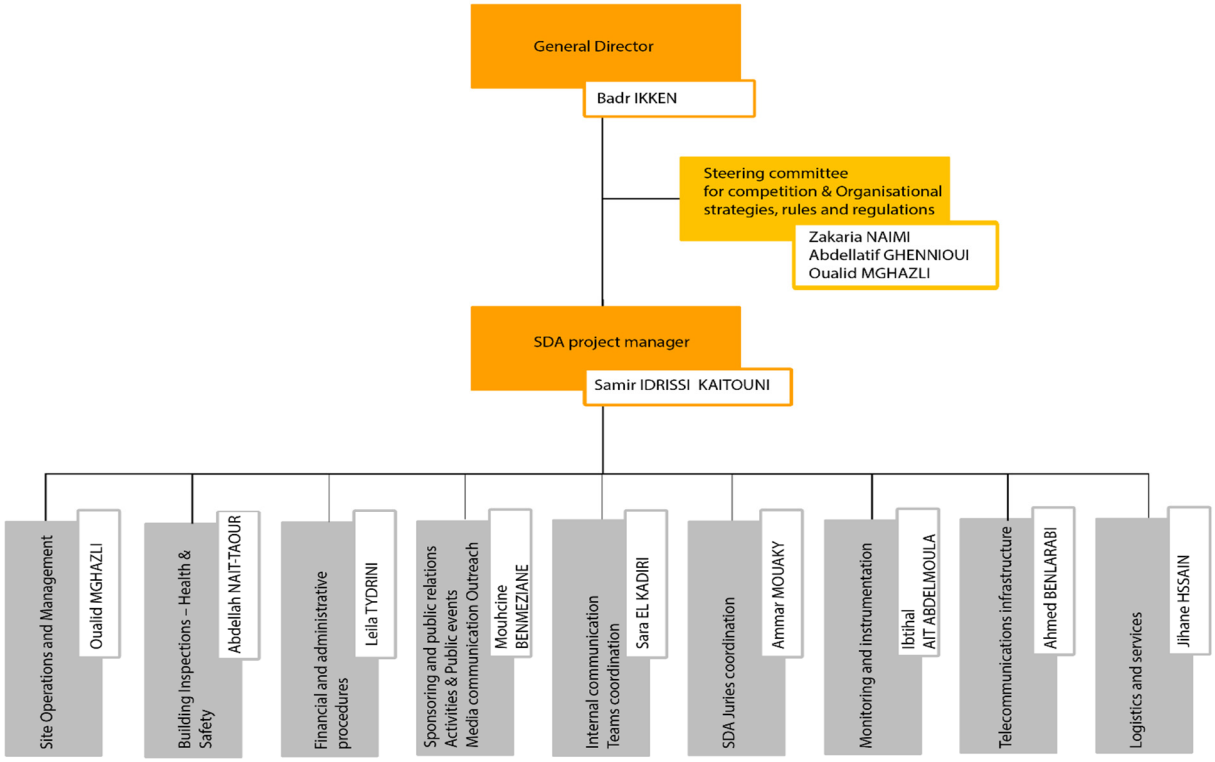


Figure 43: SDA 2019 organization chart.

One of the main platforms being conceived by IRESEN is a Green Energy Park, the first of its kind in Africa. It enables, on the one hand, to pool the efforts and resources of participating research institutions and form a critical mass so to come up with innovative and efficient solutions in active solar technologies, adapted to our local climate, and on the other hand, to diffuse the knowledge and the know-how on renewables to the partner universities through research studies, training and workshops, and to enhance the dissemination of adapted solar technologies to Moroccan industries.

5.3 About the Competition and Location. Solar Village Design

A good location is one of the most important factors for the success of the competition, especially from the point of view of public visits. From this perspective of the need to attract the public in order to have visibility, media attraction, and real possibilities of public funding and private sponsorship, the location of the Solar Village is undoubtedly critical. The ideal conditions would be locations in central areas of large cities, where they are easily accessible by public transport, and that are compatible with the logistical needs associated with the transit of large trucks, large cranes, heavy weights, etc., that allow an extensive area of solar exposure that guarantees equal sunlight for all equipment, and that in turn have large shaded areas for public activities. The more centrally located and better communicated it is, the better.

The first editions of SD US held on the National Mall in Washington DC had an average of 100,000 visitors per edition, as the solar village was located in the most touristic area of the city. When the competition moved to Europe or China, the Solar Villages were also located in areas accessible by public transport in large cities, which also attracted hundreds of thousands of people. When the Solar Villages have been located outside the cities, in less accessible areas, the number of visitors has been drastically reduced, diminishing the potential of the competition. It occurred in the move from the National Mall to the SD 2011 location in which the number of visitors was significantly reduced, and was accentuated when it moved to Irvine (Orange County) in California in SD 2013, and SD 2015 (around 25,000 visits), and later to Denver in SD 2017 (around 40,000 visits).

It also happened in Europe. The first two editions in Madrid were not located in a central or crowded place, but in both locations, there was a good public transport connection and media campaigns were carried out to make people aware of the locations and visit them. The result was 190,000 visitors in 2010 and 220,000 visitors in 2012. In the SDE 2014 edition, the location in Versailles is very touristic but with direct excursions from Paris. The location of the Villa Solar was neithervisible nor advertised in the media. Still there were 82,000 visitors. The SDE 2019 edition was held in Szentendre, a nice village about 40 km from Budapest. The location of the Solar Village on EMI premises, and the absence of public transport and advertising, meant that the number of visitors did not exceed 15,000.

In China the location in urban and accessible locations facilitated a high turnout, reaching 230,000 visitors at SDC 2013 and 500,000 visitors at SDC 2018.

The location of SDA in the Moroccan town of Benguerir, about 40 km from Marrakech, was neither touristy nor particularly well connected. Even so, more than 40,000 visitors visited the solar village thanks to the organization of activities and the communications strategy followed.

The location of the Solar Village of the SD Middle East 2018 competition in the desert, about 40km from Dubai, the poor publicity of the competition, and the very limited organization of activities, probably led to it being the least visited competition of all those held so far, with a low number of visitors.

Regarding the design of the solar village, it is very conditioned by the requirements of the plot size, which has been mostly in lots of 20*20 m, with full solar exposure, as well as by the North-South orientation, and

the logistical needs of trucks and cranes. In addition to the participating houses arranged in plots, there are also reception areas for the public, a large collective space to organize meetings, awards ceremonies, etc. VIP area, electrical infrastructure, water, exhibition areas and activities for the public, etc.

5.3.1 Us Solar Decathlon Competitions

In the first editions held at the National Mall in Washington, the Solar village was organized along a main East-West circulation axis that allowed the plots to be organized on both sides of it, with some houses facing South, with the main entrance facing the Walkway, and another row of houses with the entrance on the North façade (see figure 44) .

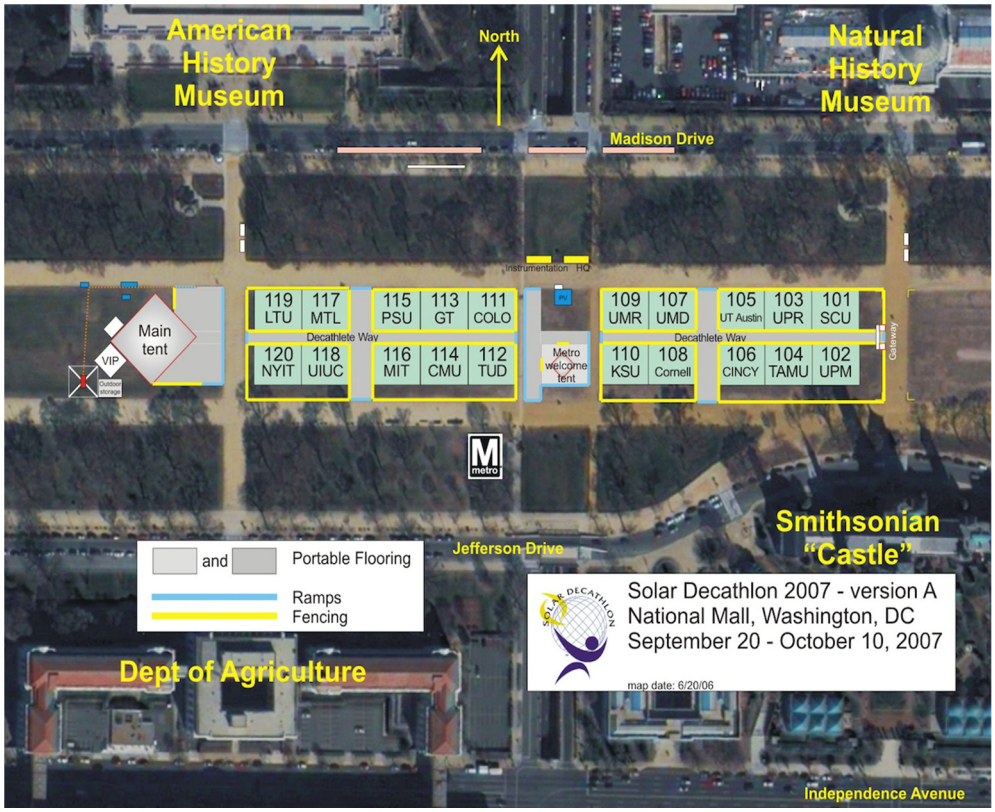


Figure 44: SD 2007 Solar Village. National Mall in Washington (United States).

The location of the Solar Village at the SD 2013 and SD 2015 editions in Irvine (Orange County) was located at the intersection of the runways of a former base area, on the tarmac. The Solar Village was organized with two parallel main streets with North-South orientation leaving 5 and 4 plots of 20*20m on each side of them.

At the SD 2017 competition held in Denver the requirements requested for the location of the solar village were:

Location/Venue

Each proposed site should be:

- Located in the lower 48 states dueto the logistical challenges of transporting the houses.
- A minimum size of six acres, preferably 11-12 acres, with a rectangular configuration and east-west orientation.
- Available at least 23-30 continuous days with an end dat e no later than November 15 of the Solar Decathlon year (2017 or 2019). DOE has historically held the event between mid- September to mid-October, which is typica'lly after the start of the college fall semester, and when the outdoor temperat ure is tolerable for visit ors as well as for heavy.

- Construction work by the students. i.e., below 90 degrees F and above SO degrees F. Although DOE held the events in autumn, many schools would prefer a summerevent that doesn ot interfere with classes. Applicants must identify the dates for which the site will be available and the proposed event dates.
- Accessfüle 24/7, allowing stu dent teams and staff to work around-the-clock if necessary.
- Free of restrictions on construction noise, or at least lim, ited restrictions.
- Clear of overhead power or communicatio n lines of any kind.
- Conduciveto securing structures (houses, tents, etc.) to the ground with stakes, weights, or other means.
- Accessfüle to·COnstruction vehides, in cluding semi- and flat-bed trucks of up to 16' wide, 110' long, 16' tall, and 120,000 lbs.
- Accessible to a hardscape or paved surface. lf a grassy area is proposed, applicants must provide a plan showing how heavy equipment could be moved onto and off of the sit e without difficulty or turf damag.e.
- Accessible to five to ten cranes rated up to 160 tons, with sufücient workni g space for them.
- Accessible to utility electric power (minimum 500 lkW - 3-phase) or should allow for the use of geNerators (or sorne other means) that can supply that amount of power.
- Serviced by sanltation facilities to support up to the projectednumber of daily attendees.
- Secured 24/7, with a plan detailing how the grounds and structures will be monitored.
- Access to venues for special events, such as receptionsand award ceremonies.

With the following operational requirements:

Operations

Each proposed site must provide:

- Internetaccess, preferably with wireless capability, with sufficient band width to accommodate competition and public needs.
- Public transit and/or have public parking to support the projected number of attendees for this type of event.
- Potable water to support up to the projected number of daily attendees. Media access to all major networks.
- Location inanarea with aesthetic surroumdings.
- Food and amenities inclose proximity to support the projected number of attendees per day.
- Emergency services support and on-site medical assistance.
- Lodging near support the projected number of attendees per day.

In the first three competitions the competition's solar powered houses were stand-alone with battery storage. Since 2009, the houses have been grid-connected. For 2017 and future competitions, DOE is considering allowing battery storage again, most likely in a hybrid design. The local electric utility company must confirm that sufficient grid capacity is available to receive expected production from interconnected solar generation. Note that for past Solar Decathlons, an event micro-grid connection has been provided either using one or more on-site generators or through interconnection to the local power grid. Any reliable and safe option will be considered for providing power to the event site and competition homes.
These requirements for the venue are based on DOE's experience with Solar Decathlon competitions since 2002. DOE welcomes new ideas and or alternatives that may produce a better or more impactful event.

The solar village was located on a plot of land owned by the University of Colorado halfway between Denver and the International Airport, well connected by highway and train (see figure 45). The organization was again with an East-West axis and the 13 competing team plots organized north and south of the central drive.

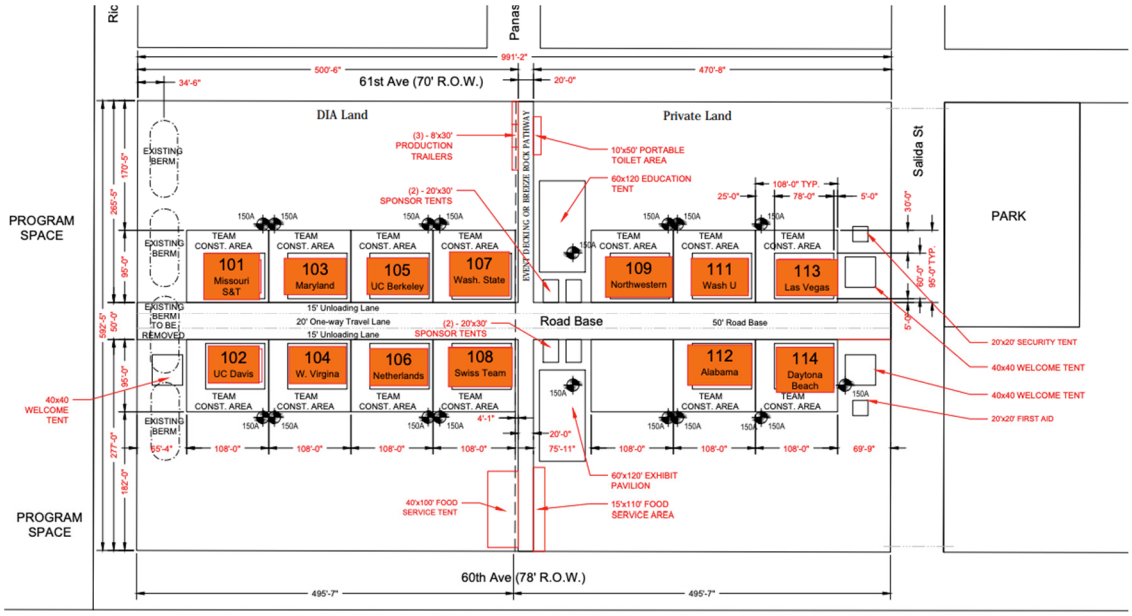


Figure 45: SD 2017 Solar Village. Denver (Colorado, United States).

5.3.2 Solar Decathlon Europe Competitions.

In the SDE 2010 competition held in Madrid the solar village was located next to the Manzanares River (see figure 46) occupying both banks, with the northern half for common areas, activities, ... and the southern bank with the plots with a promenade along the river with an orientation ostensibly East-West and all the houses with access from the south.

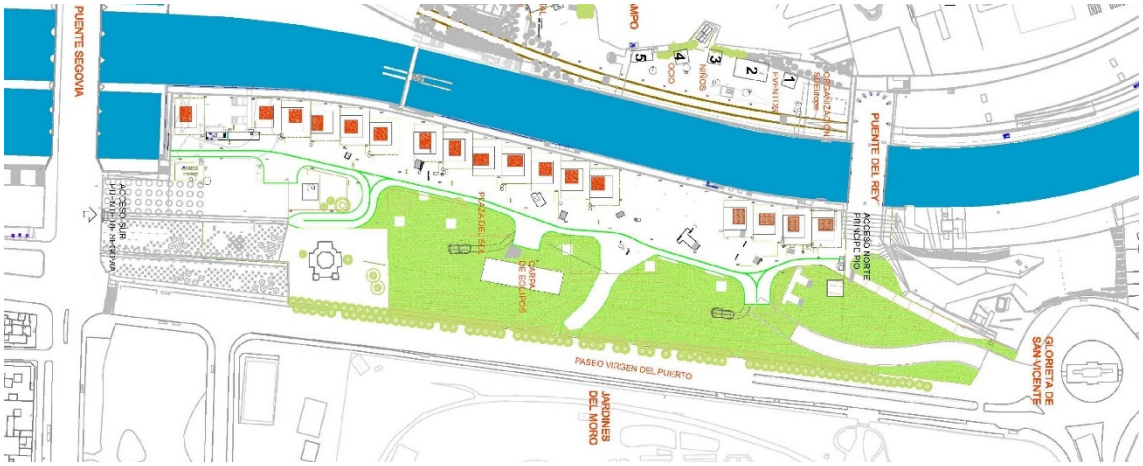


Figure 46: SDE 2010 Solar Village. Madrid (Spain)

It is important to point out the important technical difficulties derived from the location, as the solar village was located on both banks over a swarm of overlapping tunnels corresponding to one of the connection nodes between the M-30 ring road (with up to 5 lanes in each direction in that area) and the N-V highway with three lanes in each direction (see figure 47).

The location of the solar village at SDE 2012 was less central, in a quieter and more suggestive place where people had to go specifically to visit the solar village, with some logistical limitations due to the protected

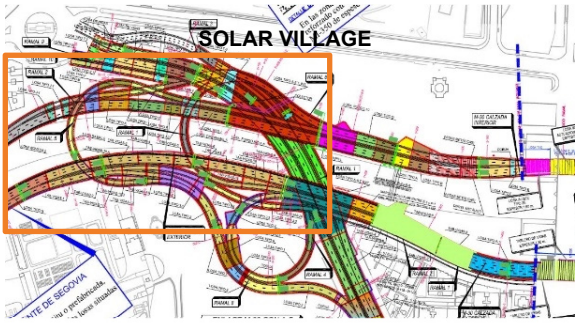


Figure 47: Tunnels under SDE 2010 Solar Village.

wooded areas that had to be crossed by the trucks. The organization of the solar village in the triangular site was solved with two east-west avenues and a perimeter circulation walkway, arranging around it all the facilities for the organization of activities, congresses, press center, smart city, headquarters, etc. Figure 48 shows the pedestrian access (red) and vehicle access to the Solar Village (blue).

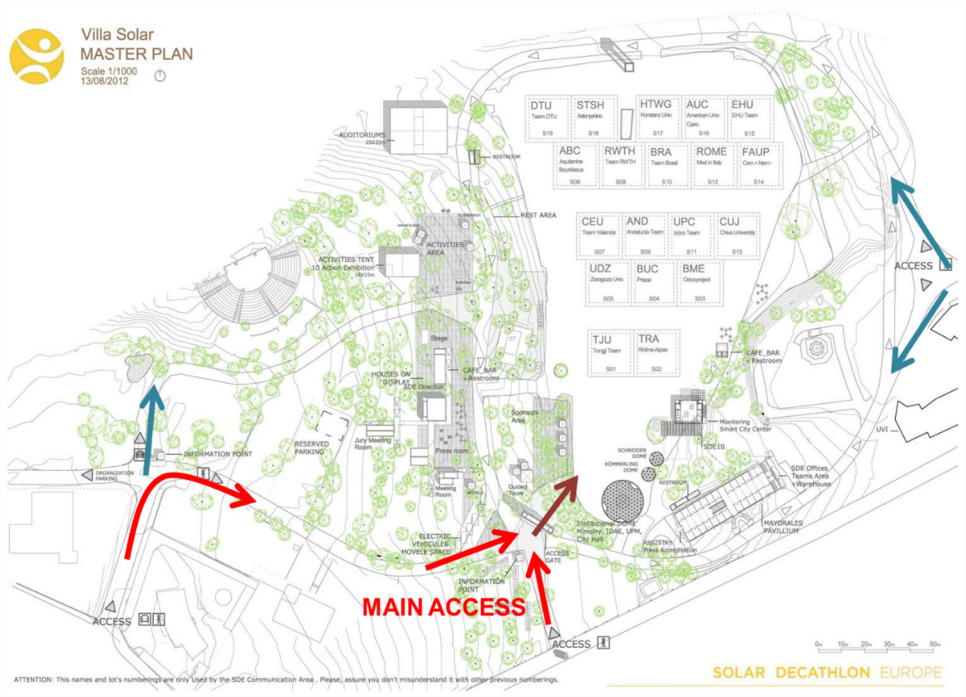


Figure 48: SDE 2012 Solar Village. Madrid (Spain)

The solar village layout in SDE 2014 (see figure 49) was organized with two east-west oriented longitudinal avenues and north-south transverse avenues between groups of four plots - or two plots.

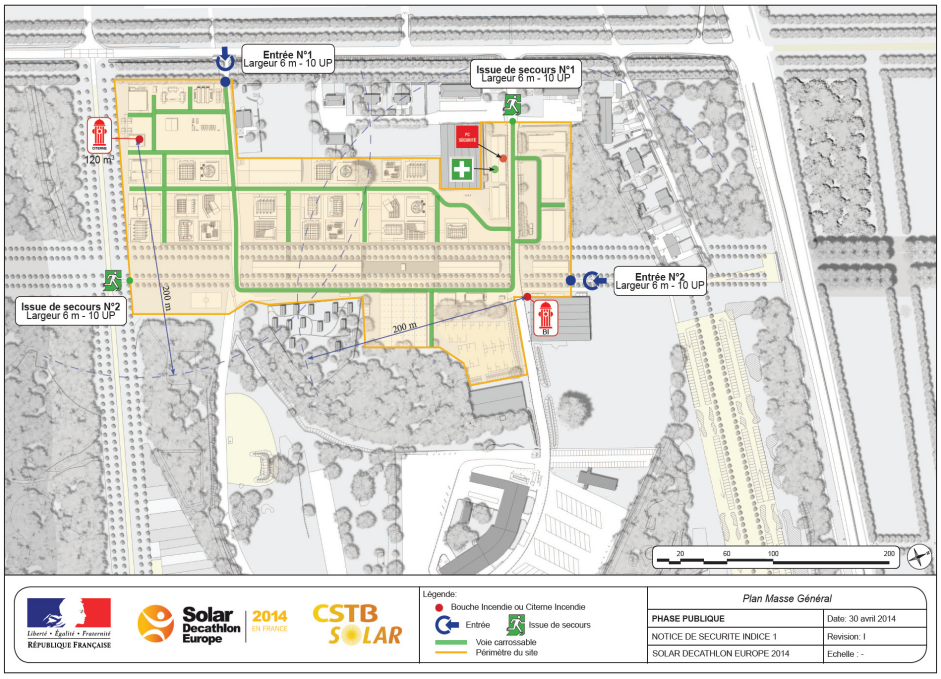


Figure 49: SDE 2014 Solar Village.Versailles (France)

5.3.3 Solar Decathlon China

The competition venue of SDC 2013 (see figure 50) included competition square and service facilities. The competition square covers an area of 132,000 square meters, which is used to display the work of the teams to meet the needs of competition and public visit. The surrounding environment is good and the transportation is convenient. The Sun Palace, close to the competition square, has a total construction area of 205,000 square meters, including accommodation, catering, conference, media center, business, exhibition and other functions, providing comprehensive services for the participating teams and organizing committee during the competition.

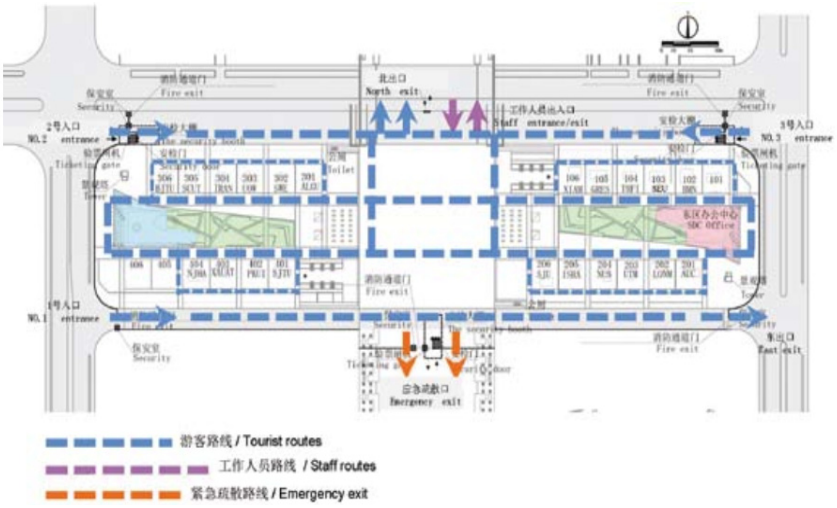


Figure 50: SDLAC 2013 Solar Village.Datong (China)

The SDC 2013 Solar Villa has big East-West avenues with lots oriented to north and south with a common area of public facilities.

The competition venue in SDC 2018 (see figure 51) was divided into three functional areas: competition area, coporate exhibition area and service supporting area. The competition area which was authorised by the competition organizing committee to display top technologies, products and applications, covered an area of 16 Ha. The entire competition area was considered a smart park which consisted of 22 solar green buildings with different styles, central functional service area and electric car runway.

The supporting Area included Wisdom Valley and Hotel. Wisdom Valley covered an area of 50 thousand square meters. It is made up of an international standard theatre, professional meeting place, large international exhibition place, food and beverage, shopping centre and so on. It has the international standard exhibition, thus creating nine themed activities a week across the field. It attracted professionals and visitors from different industries to participate in high-end professional Summit Forum, enterprise conferences and theatrical performances, customised VIP business activities, high-end personage dialogues, media interviews and so on.

Corporate Exhibition Area covered a variety of service functions including enterprise brand display, featured bar, five-star hotel etc. It covered an area of 26,66 Ha with 30 enterprises exhibition halls, the Sun Wing, Guangming Pavilion, Supporting AB Area, Five Star Expert Apartments and other halls.

Figure 51: SDC2018 Solar Village.Dezhou (China)

5.3.4 Solar Decathlon Latin America and The Caribbean

The second edition of Solar Decathlon Latin America and Caribbean was held in Cali, Colombia in 2019.

In addition to the basic principles of the Solar Decathlon, potential teams were asked to focus on housing solutions specifically for the LAC region that are affordable, meet the needs of occupants with reduced mobility, are suitable for dense urban areas and make efficient use of natural resources.

The SDLAC 2019 solar village (figure 52) is organized in four quadrants with North-South and East-West axes as set out in the attached layout.

Figure 52: SDLAC 2019 solar village, Cali (Colombia)

5.3.5 Solar Decathlon Middle East 2018

This competition was organized by DEWA in Dubai at the Mohammed bin Rashid Al Maktoum Solar Park (see figure 53), in the desert, about 40 km from Dubai. SDME consists of 10 competitions similar to previous editions of the competition, customised to challenge student teams to adapt their designs to the heat, dust and high humidity of the Middle East.

The distance to the city, the lack of publicity of the competition, and the very limited organization of activities were the main reasons of the very low number of visitors, around 5.000 people.

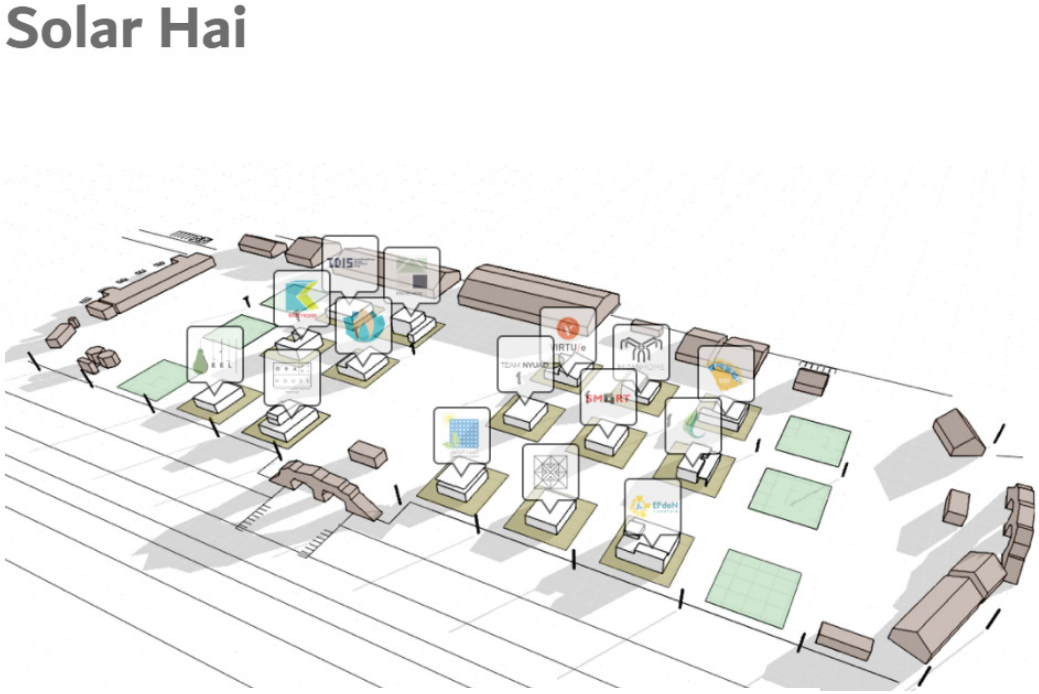


Figure 53: SDME 2018 solar village, Dewa (Dubai)

5.3.6 Solar Decathlon Africa 2019

For the SDA 2019 competition, the solar village was located at the Moroccan Research Institute in the Solar Energy and New Energies (IRESEN) complex in Benguerir, with the Solar Village forming part of a complex that includes research center workshops, laboratories, offices, a Smart campus, several existing demonstrators, and the Solar Village itself, is set out in the general layout observed in figure 54.

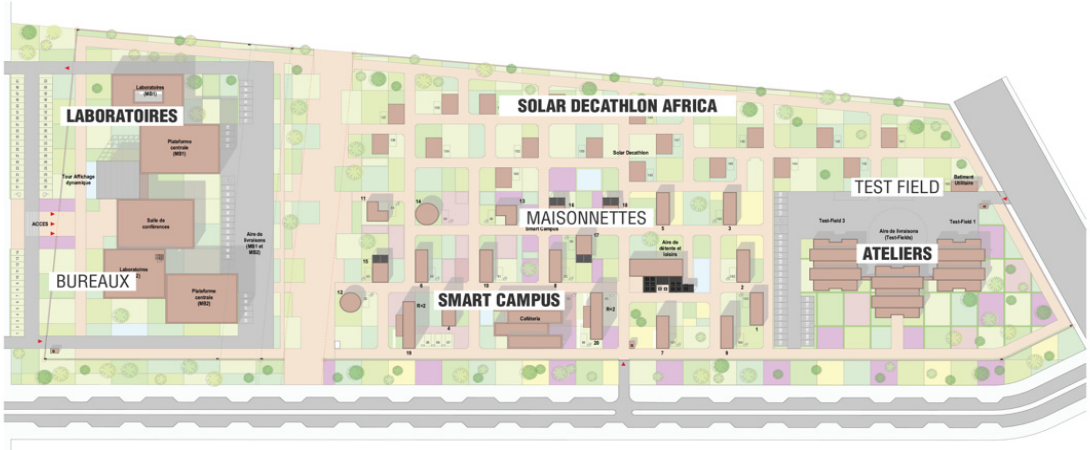


Figure 54: SDA 2019 Solar Village. Ben Guerir (Morocco)

Assambly of houses in SDA 2019 and Solar Village (figure 55).

Figure 55: Images of SDA 2019 Solar Village. Ben Guerir (Morocco)

5.4 Budget and Funding. Project Finance. Sponsorship

Budget and project finance is one of the major challenges facing the organizing teams. The financing of Solar Decathlon competitions is usually mixed, with money coming from the central, regional or local government, with support from other departments, ministries or institutions, and with money from private sponsorships that complement “In cash“ or “in kind“ the official budgets.

Official budgets require lengthy procedures, money takes time to be committed, and even longer to arrive on time as agreed. Sponsorship money is even more volatile, because companies take time to decide and approve the money to sponsor, and then it takes even longer to arrive. The consequence is that this means that a large part of the competition depends on money that is neither consolidated nor arrives on time, often affecting the very scope of the competition and the associated events and their activities.

The budget necessary to organize the competition and the subsidy traditionally given to the teams must be assured from the very beginning, as well as a defined payment schedule with certain guarantees. Based on the experience of many of the competitions, a lot of the activities planned for the organization of the event, the communications issue, activities designed for all audiences, even the scope of the Villa Solar, may be unconsolidated, depending on the income obtained from sponsorships.

This, which unfortunately has affected the organization of many editions of Solar Decathlon competitions, has conditioned the final result due to the high volatility of sponsorships, the difficulty of specifying with the sponsors the contributions “in cash“ and “in kind“, and above all, the extreme delay of the companies, and sometimes public funding too, in providing the money in cash, with the associated uncertainties, until the last moment.

Therefore, there are three challenges to be met by the organizing teams in terms of budget:

- On the one hand, the total starting budget, which must be adjusted to the conservative expectations of income that can be foreseen, both from governments and from private sponsorships “in cash“ and “in kind“.

- The second challenge is to match the revenue schedule with the payment schedule (project finance), which means having mechanisms to make the project''s progress more flexible in order to match the flow of revenue.
- Finally, the great challenge associated with the risk of significant revenue reductions that will force budget cuts that must be planned, as well as contingency plans that anticipate scenarios of revenue delays or unforeseen cuts.

5.4.1 US Solar Decathlon Competitions

In the United States, for the 2007, 2009, 2011, and 2013 competitions, DOE funded NREL as the program administrator, with an average range of $6–$8 million per event, inclusive of $2 million in prize funding awarded to participating teams. With this $2 million, each participating team received about $100,000–$150,000 in seed funding for the design and construction of their houses. In recent years, DOE's investment has been limited to approximately $3 million per event, with approximately $1 million in prize funding distributed across about a dozen teams.

In addition to this amount, each event benefited from sponsorship contributions and in-kind donations totaling from several hundred thousand dollars to up to approximately $2 million per event. Additional DOE-staff time and resources for the overall event vision, sponsorship development, and media relations has also been provided for the overall program support.
The first edition for which we have express reference to the budget used is SD 2007, which is estimated at US$ 6.5 million, almost entirely contributed by public bodies, of which US$ 1,700,000 went to finance the teams (US$ 100,000 per team).

The impact of this budget per team was US$ 325,000 per team, and the impact for each of the estimated 25,000 visitors was US$ 260. The main commercial sponsors of this edition were EDS/WorldCom/Nextel mentioned as sponsor but the amount has not been tracked. For SD 2002, in addition to NREL and DOE, sponsors included BP, AIA, EDS and Home Depot.

The SD 2009 budget amounted to US$ 8.4 million, almost entirely provided by public bodies, of which US$ 1,700,000 went to finance the teams (US$ 100,000 per team). The impact of this budget per team was US$ 420,000 per team. The main commercial sponsors of this edition were Applied Materials, BP, Pepco, Schneider Electric and Schneider Electric.

The budget for SD 2011 was the highest of the American editions, amounting to 9 Million US$, almost entirely provided by NREL, to which should be added an estimated 2.5 M US$ of contributions from "in Kind" sponsors. Of the US$ 9 M, some US$ 2.4 M went to finance the teams. The impact of this budget per team was US$ 473,000 per team, and the impact for each of the estimated 25,000 visitors was US$ 360.

With the relocation of the competition to California and Colorado, the budget dropped slightly, with a budget of $6 MUS in SD 2013 (DOE), $5.5 MUS in SD 2015 (DOE), and $7.4 MUS in SD 2017 (including $3,000,000 (DOE) + $4,200,000 (cash and in-kind cost share/sponsorship)), with a budget per team impact of 315,000; 790,000; 343,000;750,000; and 672,000, 220,000; and 185,000 US$ per competing team respectively, and an impact per visitor of 240, 220, and185 US$.

The main commercial sponsors of the California editions were Bosch, Cisco, Edison International, Schneider Electric, Wells Fargo, and those of the edition held in Denver in 2017 were Wells Fargo, City and County of Denver, Denver International Airport.

5.4.2 Solar Decathlon Europe Competitions

The SDE 2010 edition held in Madrid, had a budget financed by the Spanish government of €7,446,639 (Euros) plus some €650,000 of sponsorships in cash, and another €672,833 in kind. The subsidy for the teams was €100,000 per participating team. The impact of this budget per team was €515,851 per team, and the impact for each of the estimated 192,000 visitors was €45.67 per visitor.

The Madrid edition of SDE 2012 had a final budget funded by the Spanish government of €5,300,000 plus some €676,500 in cash sponsorships, and another €505,676 in kind. The subsidy for the teams was €50,000 per participating team. The impact of this budget per team was €341,167.16 per team, and the impact for each of the estimated 220,000 visitors was €28.46 per visitor.

With the support of the Spanish government and with the approval of the parliament, the declaration of an event of special public interest was approved, which together with a careful strategy of sponsorship with and without tax incentives, made it possible to achieve a certain amount of sponsorship despite the fact that the two editions coincided with a deep world economic crisis (2008) which led to a major economic downturn that had a serious impact on the availability of “communications“ funds for companies, and a severe budget cuts in the contributions planned from the government.

The main sponsors of the two competitions held in Madrid were the Ministry of Housing and Development, UPM, Madrid City Council, IDAE, European Union - Project 10Action, and the companies Schneider, Kömmerling, Saint Gobain, Rockwool, etc.

Both in SDE 2010, and especially in SDE 2012, in which, due to a change in the Spanish government and the economic crisis, the competition was suspended for 6 months, and finally more than two million euros were cut in 2012, the biggest organizational challenge was precisely the absolute uncertainty of the budget available for each edition. The objective was to organize the maximum number of associated social awareness activities without generating any deficit that would have had to be assumed by the UPM as organizer.
This challenge, and all the risks associated with the economic uncertainty of how much money would finally be available and when, was managed with a complex multi-scenario planning in which the activities of the competition and, especially, the awareness activities associated with the event were all planned, but only activated at the latest possible date and when the budget availabilities were guaranteed with a high probability.

The strict cost control system, the continuous monitoring of the economic-financial scenario, and the risk management developed allowed a large number of activities to be carried out, resulting in one of the Solar Decathlon editions with the greatest social and media impact in the world.

There has been no confirmation of the exact budget for SDE 2014, It was about €8 million but the organizing team also suffered severe budget cuts that generated limitations in the communications budgets, with lower investement in media and publicity. The impact of this budget per team was around €363,000 per team, and the impact for each of the estimated 85,000 visitors was €94.11 per visitor.

The main sponsors Diamant were Scheneider Electric and Total, and sponsors Gold were Monoprix y Bouigues, and ADENE as partner expert. In figure 56 is define the 14 institutional partners for SDE 2014.

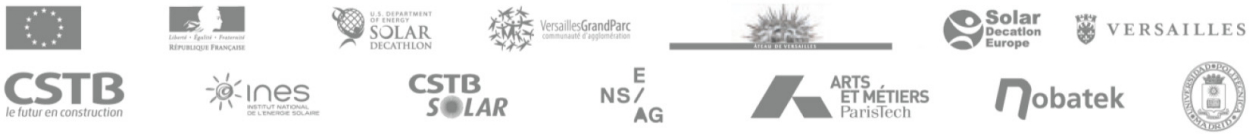


Figure 56: Institutional partners for SDE 2014.

The SDE 2019 edition held in Szentendre, had a budget financed by the Hungarian state of €6,000,000 plus about €206,000 of sponsorships in cash, and a little more in kind. The impact of this budget per team was €620,600 per team, and the impact for each of the estimated 15,000 visitors was €413.73 per visitor. The main sponsors were

- Tungsram Group: Development of public lighting of the competition area, development of indoor and outdoor navigation application
- STILL Ltd.: Providing 10 electric forklifts to teams during the construction period
- Layher Ltd.: Providing scaffolding for teams, providing a mobile grandstand (viewpoint) and a drink bar for the organizers
- Makita Ltd.: Providing cordless power tools for teams

5.4.3 Solar Decathlon Africa 2019

The budget of the SDA 2019 held in Benguerir had a final budget financed by Green Energy Park (IRESEN & UM6P) of US$4,482,774 (Table 5). The subsidy allocated to the teams was US$55,000 per participating team. The impact of this budget per team was US$ 249,043 per team, and the impact for each of the estimated 40,000 visitors was US$112.07.

The main sponsors of this edition were the Ministry of Energy, Mines & Sustainable Development; US Department of Energy; IRESEN; GEP; OCP; GIZ; ALMADEN; SADV, MENARA PRÉFA; OFPPT; Jet Energy; JESA; AMEE; and IT RADIO.

SECTION	AMOUNT MAD
Organizational costs (1)(2)	18 302 258,74
Seed funding for participating teams	11 892 201,12
The development of the SDA village "Electricity network & Drinking water and sewage network included"	4 000 000
Winning Awards	4 000 000
Monitoring & Scoring System	1 673 741,4
Concrete Slabs for the 18 prototype houses	1 821 600
Total MAD	**41 689 801,26** Total $ **4 482 774,33**
MAD: MOROCCAN DIRHAM	Exchange Rate $ to MAD = 9,3

Table 5: SDA 2019 Budget chart.

5.4.4 Solar Decathlon China, Middle East and Latinamerica

There is no available specific information regarding competitions in China, Middle East and Latinamerica.

5.5 About competition and events planning & scheduling

Another essential factor for the successful organization of a competition and event of the size, scope and impact of the Solar Decathlon is the planning of the development of the work over the average two years of each competition.

There is also a good unanimity on the need to have a good strategic planning for the development of the projects, so that from the beginning the whole team is committed to the timing of the project, and all the universities have the time frame set out in the Rules and Regulations. The strategic planning must also consider how to monitor and control the time, cost, quality, risks, etc.

Each of the organizing teams have planned the development of their competition in the way they have considered most effective, and all of them have been so to the extent that all the editions have been held on time and with satisfactory results, more or less fulfilling the objectives proposed by each team. In some cases, this planning has been more informal, less systematic, undocumented, but ultimately effective, while in other cases the planning has been more professional and systematic, being better documented.

Within the planning that must be carried out for an event of these characteristics, it is necessary to distinguish between different approaches and scopes of planning, grouping them into three main categories:

- The time planning and deadlines of the project, important in defining the framework of both the organization and the teams. This planning has been exclusively developed by all the organizing teams.
- The planning of the activities during the weeks of assembly-competition-disassembly of the Villa Solar, which in turn would consist of three major areas of sub-planning: the planning of the assembly and disassembly of the Villa Solar, the planning - calendar of the competition, and the planning-calendar of each of the activities associated with the event that involves the competition. These calendars and schedules have also been systematically developed by all the organizing teams.
- The third, and most important from the point of view of project management, and which encompasses all of the above, has to do with Strategic Planning, which, depending on each of the organizing teams, has been more or less systematic. This strategic planning encompasses from the initial project management plan of the Project Manager, to the development of the different aspects that should be included, such as:
  - The planning of all the activities to be developed over time with the Schedule Management Plan, and the strategies for the control of the schedule such as the project progress curve (“S Curve“), control milestones, control of the team workload, etc.
  - Detailed definition of the Cost Management Plan with the project budget and its activities, defining the fundrising, sponsorship strategy, expected cash flow, Gap financing strategy, control indicators to be used, etc.
  - Plan of Quality Management defining the quality management strategy to be followed in the development of the project, the procedures to be followed, the quality control to be implemented (technical quality of the projects, of the implementation and assembly of the houses, health and safety, quality of the services provided, quality of the subcontracted services, indicators, etc.), the strategy of continuous improvement of the project, with special relevance to the final phase of critical analysis of each issue and lessons learned.
  - Plan of team management, especially focused on team building activites, map of capabilities and training plan necessary to complement the required capabilities, organization chart, responsability matrix, etc.
  - Plan of Stakeholders Management with the identification of all stakeholders, both internal and external to the project, with the possible threats and opportunities associated with each one, and with the communications and management strategy associated with each one.

- communications plan, both internal, aimed at the organizing team and its collaborators and volunteers, and external to the project, which in turn includes at least three levels of approach: the communications strategy with the teams, juries, etc.; the communications strategy with all project stakeholders, sponsors, authorities, ambassadors, etc.; and the communications strategy with society: website, media (written press, radio, television, digital media, etc.), and Social Media. It should also include the planning of the corporate image, advertising, brochures, leaflets, signage, merchandising, etc.
- Plan of Risk Management one of the key drivers for the successful development of the competition and the events and activities linked to it. It must include the strategy for identifying the threats and opportunities of the project, the qualitative and quantitative analysis techniques for each of the identified risks, with their indicators, risk matrix, hierarchy criteria, etc. and the Risk Responses Plan with its contingency guideline, contingency plans and reserve analysis. The strategy for monitoring and follow-up of risks and their continuous readjustment must also be defined and articulated.
- Finally, the Plan of Procurement Management is also important, identifying all the tasks and services that need to be developed and that cannot be developed by the team, defining for each of them the contracting strategy, the Service Level Agreements, the indicators and Key performance indicators to document and control the quality of the service, the Request for proposals RFP, RFQ, RFT, etc.

5.5.1 US Solar Decathlon Competitions

There has been no significant information on the planning of the first editions (figure 57), other than knowing that since the first edition of SD 2002, the competition has had about 7 days of assembly of the Solar Village, about 10 days of competition always from Friday to Sunday of the following week, and about 7 days of complete disassembly of the Solar Village. In the organizations factsheets you can find the schedules of the different competitions.

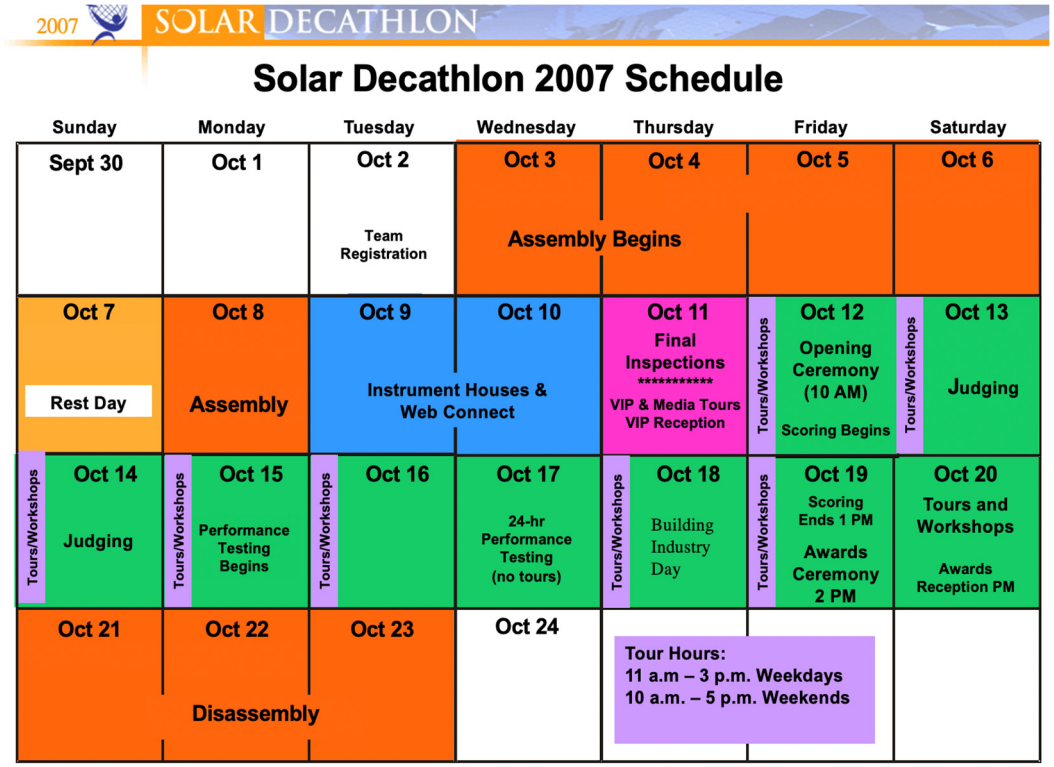


Figure 57: SD 2007 Schedule

The schedule used in the following editions can be summarised in the one used in SD 2017 held in Denver.(Figure 58)

A-1. Overview Event Calendar

This calendar provides an overview of daily activities. Refer to the Detailed Event Schedule (Appendix A-3) for a complete list and schedule of daily activities.

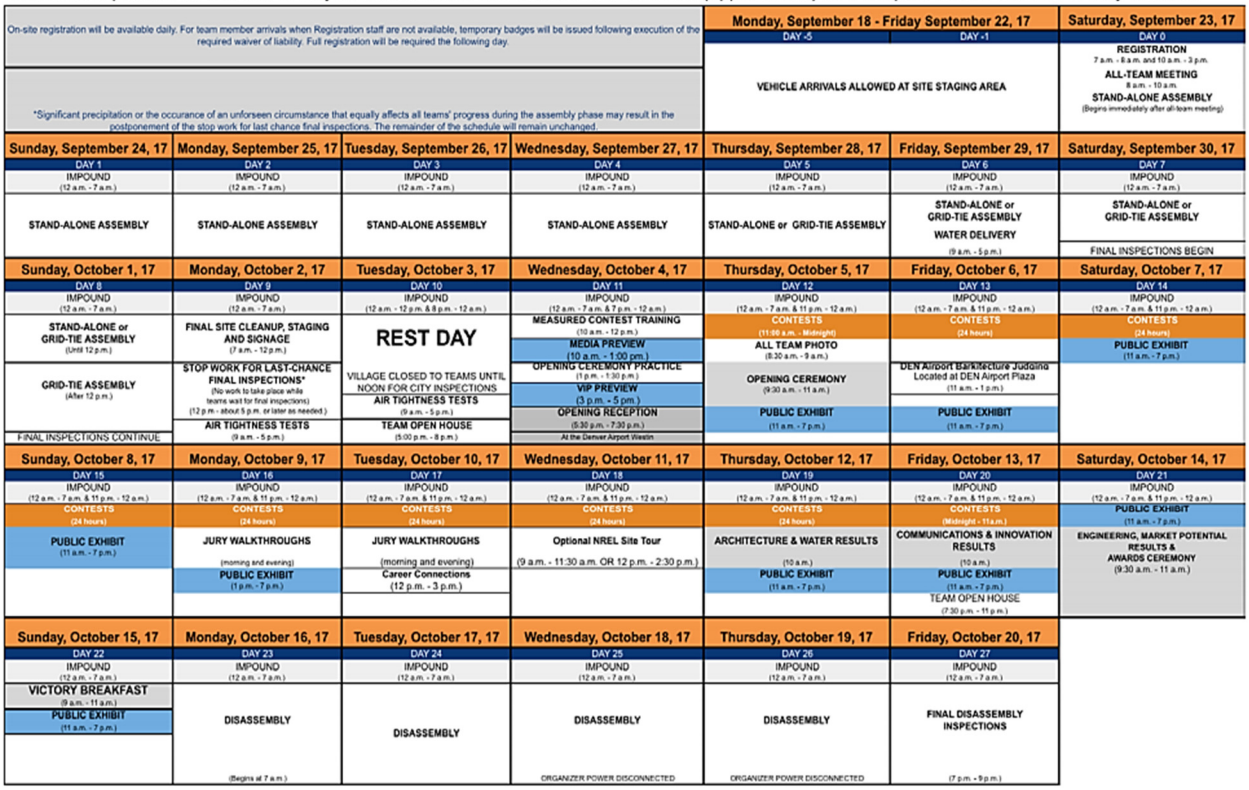


Figure 58: SD 2017 Overview Event Calendar

The timeframe of reference of the American competitions (table 6), and of all the editions in the world, has always been defined in the Rules and Regulations and always referred to the deliverables to be submitted by the teams. As an example, the deliverables in the SD 2017 were:

Deliverable Name	Maximum Penalty Points if Received on Due Date	Due Date
D1: Team Short Description & Project Management Plan	0	March 31, 2016
D2: Schematic Design Summary	0	April 29, 2016
D3: Team Overview	1	September 15, 2016
D4: Design Development Documentation Submission	2	November 17, 2016
D5: Digital Project Representation	1	December 16, 2016
D6: Final Construction Documentation Submission	3	February 23, 2017
D7: Project Summary & Public Exhibit Materials	1	April 27, 2017
D8: Jury Deliverables	2	August 10, 2017
D9: Final Report	0	November 16, 2017

Table 6: SD 2017 Deliverables.

5.5.2 Solar Decathlon Europe Competitions

The consequence of budgets cuts and the uncertainty associated with sponsorships, with many different possible scenarios to be managed with multi-scenario strategic planning, with milestones and deadlines defined for each of the identified scenarios, and in which, if a sponsorship has not been signed or the money has not been received, certain planned and developed activities ready to be implemented will no longer be active. The consequence of this dependence on project fundraising and sponsorship has resulted in budget cuts that have usually been concentrated in the budgets of communication and activities organized for the public, children, university students, professionals, etc. resulting in a much lower social and media impact, tarnishing the competition.

Probably due to these conditions derived from the world economic crisis of 2008, in the context of which the SDE 2010 and SDE 2012 editions were held, with all their associated risks, the need for a stricter and necessarily more documented multi-scenario planning was fostered.

Each of the plans were based on the time frame of the different phases and deliverables of the competition, which can be consulted in the Organization's Factsheets in the Annex 1. As an example, the SDE 2012 timeframe is gathered in figure 59:

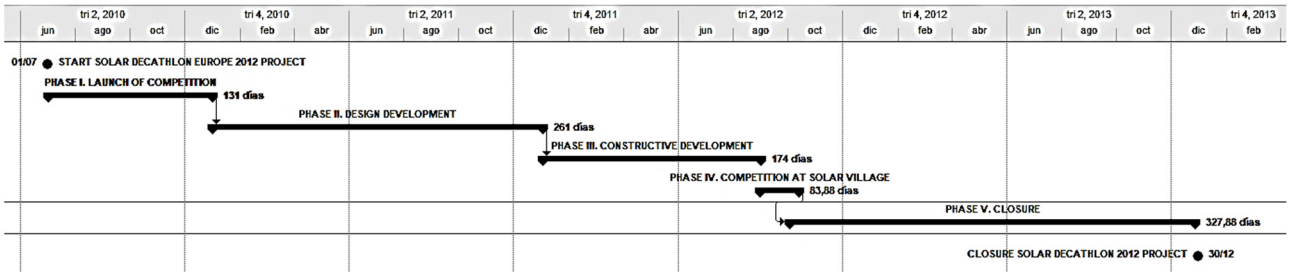


Figure 59: SDE 2012 timeframe.

Based on this, the multi-scenario planning was developed with a nested planning technique for each of the four major organizational areas (Competition Area, Infrastructure, Communications, and general activities) and in turn, within them, for each of the teams (see figure 60). This nested planning strategy allowed the planning, control and management of each of the teams independently, or aggregated by each of the areas, or the general management of the Project. Despite the apparent complication, the strategy proved to be very efficient, and vital for the successful completion of the project and control of the entire process. Project progress curves, control milestones, the monitoring of some indicators, etc., were used for control.

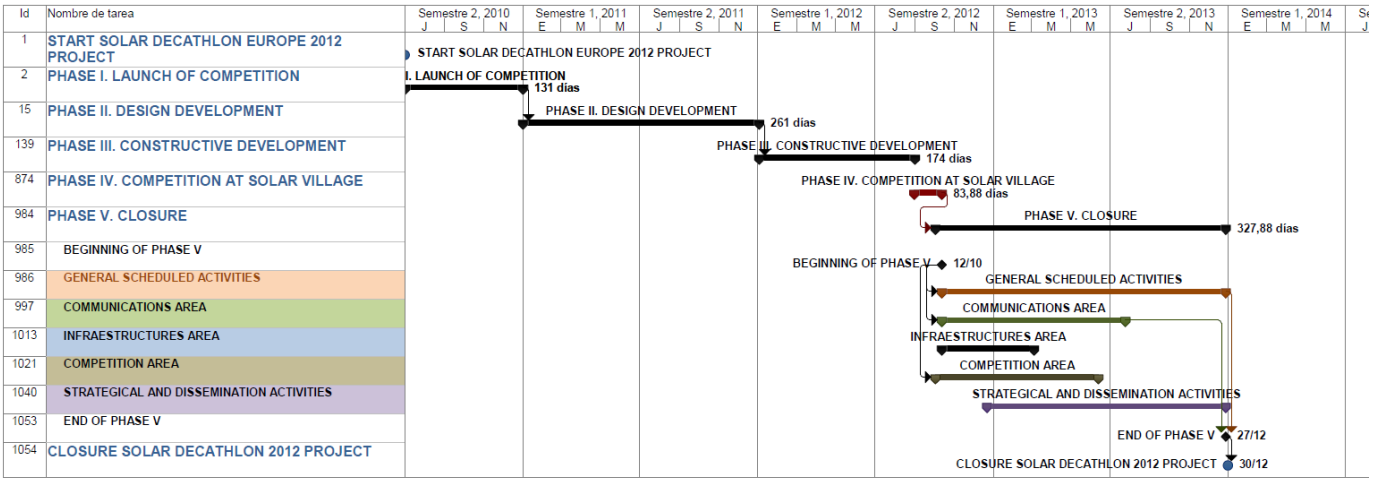


Figure 60: Project Management chart SDE 2012.

The third level of planning corresponded to the calendar of the competition and the various associated events and activities, noting that for the first time in SDE 2012 (see figure 61), the competition was extended from the 10 days of all previous editions to 18 days, in order to have a greater social impact.

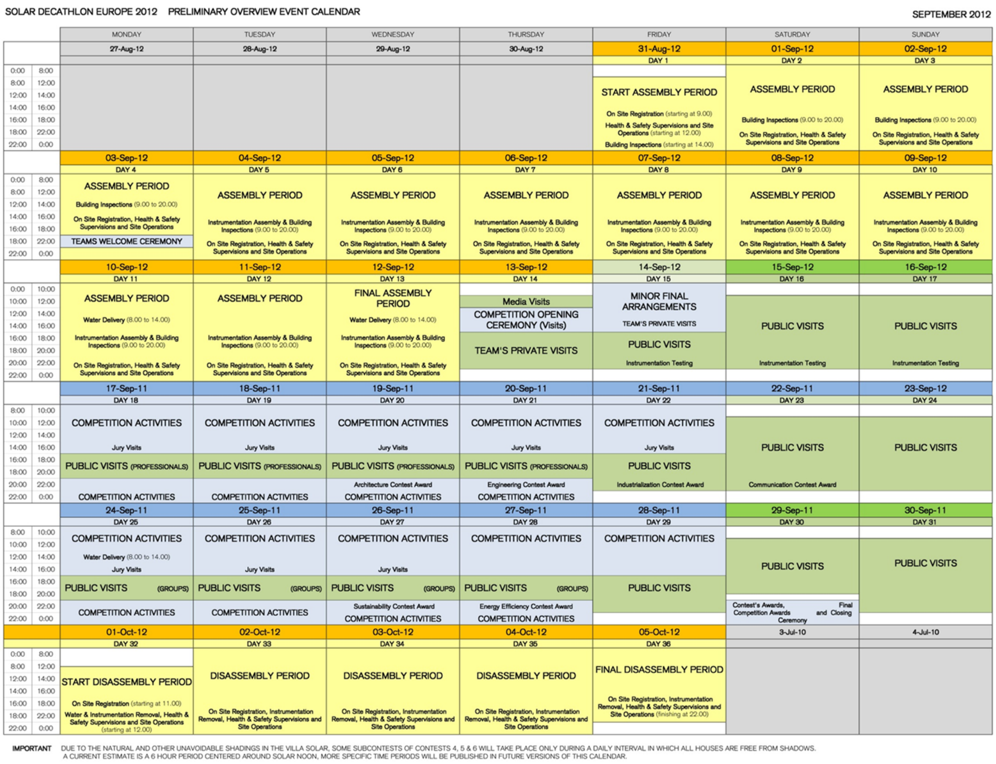


Figure 61: SDE 2012 Event Calendar.

The organizing team of the SDE 2014 competition held in Versailles followed a similar planning strategy (figure 62):

Figure 62: SDE 2014 Event Calendar.

5.5.3 Solar Decathlon China

There has been no specific information on the planning strategy in the editions of Solar Decathlon held in China, referring to the description of the phases for SDC 2013 and SDC 2018 collected in the Organization Factsheets. As an example, the phases scheduled in the SDC 2013 competition were:

- On April 28, 2011, the SDC 2013 competition was launched at Peking University
- On September 6, 2011, China International Solar Decathlon call for city bid evaluation meeting was successfully held.
- On September 21, 2011, the city selection activity of SDC 2013 competition was held, which decided the competition will be held in Datong City, Shanxi Province.
- On May 26, 2012, the 22 finalists were officially announced.
- On May 27, 2012, “training meeting for design scheme review of participating teams“ was held in Datong
- On October 28, 2012, the “design scheme deepening training meeting“ was held in the Datong holiday hotel.
- From October 26 to 28, 2012, the participating housing models were put on public display for the first time.
- On December 28, 2012, the official mascots and slogans were announced.
- On April 21, 2013, the 100-day countdown of the competition was held in Datong City.
- From July 12 to 16, 2013, the teams successively arrived in Datong
- From July 18 to August 1, 2013, the teams built their houses
- On August 2, 2013, the opening ceremony of the competition was held
- From August 3 to 13, 2013, the competition was open to the public with a total of 230,000 visitors
- On August 9, 2013, the three individual awards ceremony was held.
- On August 11, 2013, the closing ceremony and award ceremony of the competition were held, and all of the awards were announced
- On November 1, 2013, the summary meeting of 2013 SDC competition was held

5.5.4 Solar Decathlon Africa 2019

The time-frame of the SDA 2019 competition (figure 63) was articulated according to the following milestones:

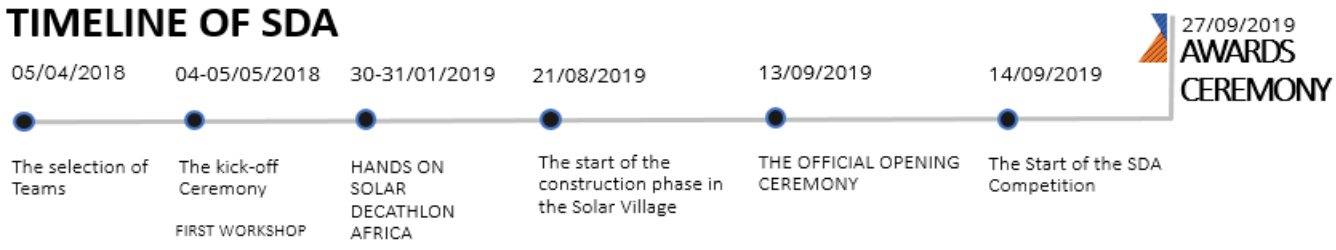


Figure 63: Time-frame of the SDA 2019

The planning of the competition was similar to those held in Europe, with a duration of 14 days between the opening and award ceremonies, with two additional days of public exhibition before the final closing of the event, with the subsequent Living Lab period (figure 64).

COMPETITION SCHEDULE

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
		DAY 1 - AUGUST 21	DAY 2 - AUGUST 22	DAY 3 - AUGUST 23	DAY 4 - AUGUST 24	DAY 5 - AUGUST 25
		00:00 - 7:00 IMPOUND	00:00 - 7:00 IMPOUND	00:00 - 7:00 IMPOUND	00:00 - 7:00 IMPOUND	00:00 - 7:00 IMPOUND
		7:00 - 00: 00 STAND-ALONE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY
JOUR 6 - LE 26 AOUT	JOUR 7 - LE 27 AOUT	JOUR 8 - LE 28 AOUT	JOUR 9 - LE 29 AOUT	JOUR 10 - LE 30 AOUT	JOUR 11 - LE 31 AOUT	JOUR 12 - LE 1er SEPTEMBRE
0:00 - 7:00 METTRE EN FOURRIÈRE	0:00 - 7:00 METTRE EN FOURRIÈRE	0:00 - 7:00 METTRE EN FOURRIÈRE	0:00 - 7:00 METTRE EN FOURRIÈRE	0:00 - 7:00 METTRE EN FOURRIÈRE	0:00 - 7:00 METTRE EN FOURRIÈRE	0:00 - 7:00 METTRE EN FOURRIÈRE
7:00 - 00: 00 STAND-ALONE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY
DAY 13 - SEPTEMBER 2	DAY 14 - SEPTEMBER 3	DAY 15 - SEPTEMBER 4	DAY 16 - SEPTEMBER 5	DAY 17 - SEPTEMBER 6	DAY 18 - SEPTEMBER 7	DAY 19 - SEPTEMBER 8
0:00 - 7:00 IMPOUND	0:00 - 7:00 IMPOUND	0:00 - 7:00 IMPOUND	0:00 - 7:00 IMPOUND	0:00 - 7:00 IMPOUND	0:00 - 7:00 IMPOUND	0:00 - 7:00 IMPOUND
7:00 - 00: 00 STAND-ALONE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY or GRID-TIE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY or GRID-TIE ASSEMBLY	7:00 - 24: 00 STAND-ALONE ASSEMBLY or GRID-TIE ASSEMBLY	7:00 - 00: 00 STAND-ALONE ASSEMBLY or GRID-TIE ASSEMBLY
JOUR 20 - LE 9 SEPTEMBRE	JOUR 21 - LE 10 SEPTEMBRE	JOUR 22 - LE 11 SEPTEMBRE	JOUR 23 - LE 12 SEPTEMBRE	JOUR 24 - LE 13 SEPTEMBRE	JOUR 25 - LE 14 SEPTEMBRE	JOUR 26 - LE 15 SEPTEMBRE
					(24 hours) Evaluation de mesure	(24 hours) Evaluation de mesure
0:00 - 7:00 METTRE EN FOURRIÈRE	0:00 - 7:00 METTRE EN FOURRIÈRE	0:00 - 7:00 METTRE EN FOURRIÈRE	0:00 - 7:00 METTRE EN FOURRIÈRE	0:00 - 7:00 METTRE EN FOURRIÈRE	0:00 - 7:00 METTRE EN FOURRIÈRE	0:00 - 7:00 METTRE EN FOURRIÈRE
7:00 - 00: 00 GRID-TIE ASSEMBLY & FINAL SITE CLEANUP	7:00 - 00: 00 GRID-TIE ASSEMBLY & FINAL SITE CLEANUP	7:00 - 00: 00 FINAL SITE CLEANUP & SIGNAGE	7:00 - 00: 00 TESTINGS & REHEARSALS	**10:00-18:00 CÉRÉMONIE D'OUVERTURE OFFICIELLE**	11:30 - 19:00 EXPOSITION PUBLIQUE	11:30 - 19:01 EXPOSITION PUBLIQUE
		18:00 - 20: 00 AVANT LE SOLAR DECATHLON - PERFORMANCE DE LA CHORALE DANS LE VILLAGE SOLAIRE				
JOUR 27 - LE 16 SEPTEMBRE	JOUR 28 - LE 17 SEPTEMBRE	JOUR 29 - LE 18 SEPTEMBRE	JOUR 30 - LE 19 SEPTEMBRE	JOUR 31 - LE 20 SEPTEMBRE	JOUR 32 - LE 21 SEPTEMBRE	JOUR 33 - LE 22 SEPTEMBRE
(24 hours) Evaluation de mesure	(24 hours) Evaluation de mesure	(24 hours) Evaluation de mesure	(24 hours) Evaluation de mesure	(24 hours) Evaluation de mesure	(24 hours) Evaluation de mesure	(24 hours) Evaluation de mesure
0:00 - 8:00 METTRE EN FOURRIÈRE	0:00 - 8:00 METTRE EN FOURRIÈRE	0:00 - 8:00 METTRE EN FOURRIÈRE	0:00 - 8:00 METTRE EN FOURRIÈRE	0:00 - 8:00 METTRE EN FOURRIÈRE	0:00 - 8:00 METTRE EN FOURRIÈRE	0:00 - 8:00 METTRE EN FOURRIÈRE
JOUR DE REPOS pour les équipes	EXPOSITION PUBLIQUE	EXPOSITION PUBLIQUE	EXPOSITION PUBLIQUE	EXPOSITION PUBLIQUE	EXPOSITION PUBLIQUE	EXPOSITION PUBLIQUE
	10:00 - 17:00 **EVALUATION DU JURY INGENIERIE ET CONSTRUCTION - INNOVATION**		10:00 - 17:00 **EVALUATION DU JURY ARCHITECTURE-POTENTIEL SUR LE MARCHE**			
			16:00 - 18:00 ANNONCE DES RESULTATS INGENIERIE ET CONSTRUCTION - INNOVATION		**16:00 - 18:00 ANNONCE DES RESULTATS ARCHITECTURE-POTENTIEL SUR LE MARCHE**	
JOUR 34 - LE 23 SEPTEMBRE	JOUR 35 - LE 24 SEPTEMBRE	JOUR 36 - LE 25 SEPTEMBRE	JOUR 37 - LE 26 SEPTEMBRE	JOUR 38 - LE 27 SEPTEMBRE	JOUR 39 - LE 28 SEPTEMBRE	JOUR 40 - LE 29 SEPTEMBRE
(24 hours) Measured Contests	(24 hours) Measured Contests			**ANNONCE DES RESULTATS SUSTAINABILITY - COMMUNICATION & SOCIAL AWARENESS**		
0:00 - 8:00 METTRE EN FOURRIÈRE	0:00 - 8:00 METTRE EN FOURRIÈRE	0:00 - 8:00 METTRE EN FOURRIÈRE	0:00 - 8:00 METTRE EN FOURRIÈRE		0:00 - 8:00 METTRE EN FOURRIÈRE	0:00 - 8:00 METTRE EN FOURRIÈRE
JOUR DE REPOS pour les équipes	EXPOSITION PUBLIQUE	EXPOSITION PUBLIQUE	EXPOSITION PUBLIQUE		EXPOSITION PUBLIQUE	EXPOSITION PUBLIQUE
	10:00 - 18:00 **EVALUATION DU JURY COMMUNICATION & SENSIBILISATION SOCIALE - DURABILITE ET SOUTENABILITE**			**CÉRÉMONIE DE REMISE DES PRIX**		
		ANNONCE DES RESULTATS BALANCE ELECTRIQUE-CONDITIONS DE CONFORT - APPAREILS ELECTROMENAGERS - DIVERTISSEMENT A DOMICILE ET LOISIRS				

Figure 64: SDA2019 Event Calendar

A calendar of organized activities for professionals was also available (figure 65).

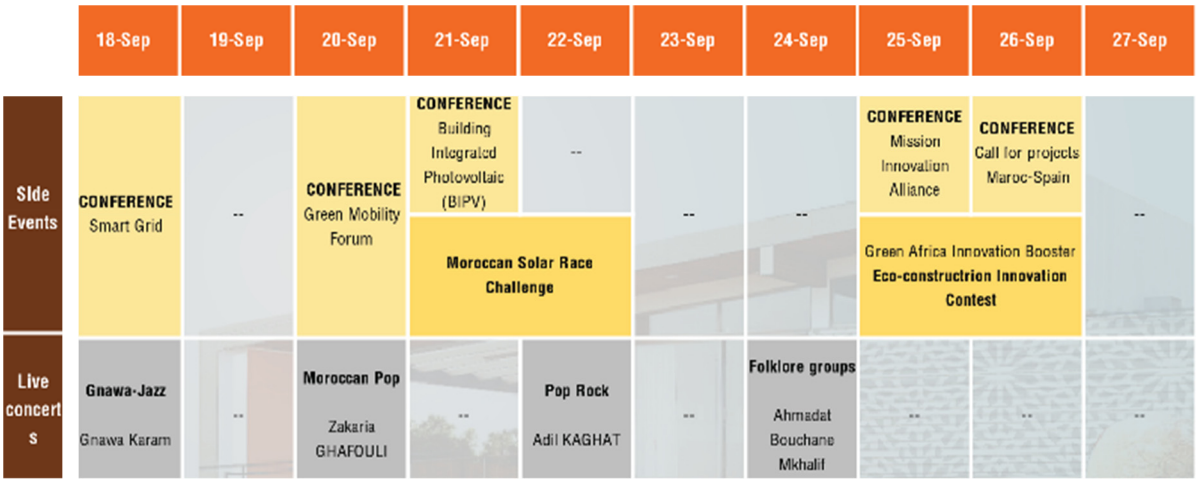


Figure 65: SDA 2019 Activities for professionals Calendar

There is no available specific information regarding competitions in the Middle East and Latinamerica.

5.6 About Internal and External Communications.

Except for a few editions in which a good communications strategy to attract the public to the solar village and have a high media impact has been deliberately avoided, most of the competitions have tried to maximise the media impact and attract as many visitors as possible, being aware that the media impact and the visiting public is the best guarantee to awaken and maintain the interest of public institutions and private companies in the successful editions of Solar Decathlon competitions and to support them economically. However, the strategies and their effectiveness have been very uneven throughout the different editions.

5.6.1 US Solar Decathlon Competitions

After the success of the first competition, a more defined communications strategy was developed for the SD 2005 edition, both at the web site and media level. The official Solar Decathlon Web site received about 73,000 unique visits between October 6 and October 16, 2005. The average time per visit was more than eight minutes.
In the SD 2007 competition the media outreach was better (table 7), and some of the strategies to maximise outreach of SD competitions and linked Events were to develop outreach activities before, during and after the event included:

- Developing comprehensive media lists for national outreach to trade, newspapers, magazines, radio, TV and Web outlets.
- Issuing media advisories to reporters, producers, and PR Newswire via e-mail to announce and promote the competition and energy-efficiency.
- Targeted outreach to the hometowns of participating teams.
- Sending customised press packets and e-mails to key editors and reports specific to the genres of energy/solar, architecture/home, environmental/green, building, business, science/ technology and general consumer interest.
- Following up by telephone to recipients of the e-mailed media advisories during and after the event.

2007 Media Outreach Results – Summary

Media Type	Hits/Airings	Impressions
Television	425	37,777,007
Print/Magazine	269	201,540,904
Radio	47	133,057,907
Online	311	277,568,922
Documentaries	5	TBD
Total	1053	649,781,240

Table 7: SD 2007 Schedule

- Securing media coverage on the Mall.
- Securing calendar and day-book listings.
- Generating interest from national and local media.
- Managing media and requests throughout the event.
- Directing photo inquiries to the Solar Decathlon photo site, flickr.com, and Manage Solar Decathlon photo site.
- Coordinating interviews with Solar Decathlon officials and decathletes.

The media impact has been decreasing in recent editions, no concrete information has been available.

5.6.2 Solar Decathlon Europe Competitions

When the competition moved to Europe in 2010, some new objectives were defined to raise social awareness among citizens, for which the communications strategy, both internal and external, was decisive.
The internal communications of the European editions was organized around two fundamental tools: the website (figure 66,67) and the SD WAT (figure 68).
The SD WAT - WORKPLACE AREA FOR TEAMS was designed as a collaborative workspace for the entire SDE 2010 organization, both internally and in its relationship with all the teams and main sponsors and stakeholders:

Figure 66: SDE 2010 Website. (www.sdeurope.org)

This collaborative tool was complemented with the website that was designed to serve as a showcase for society, for monitoring the competition and all the events organized, and also for the coordination of stakeholders, sponsors, press, etc., access to the SD WAT, virtual tours, consultation of the scores of each team, competition scoreboard, technical information for each house, activities planned for children, professionals, public, etc., every day, media, publications, leaflets, ...

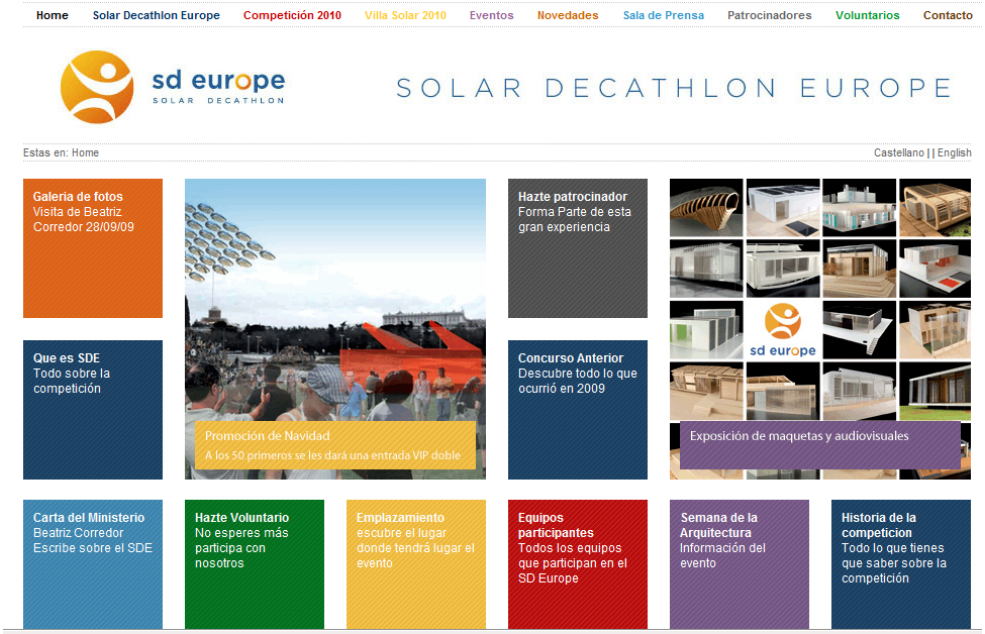


Figure 67: SDE2012 Website (www.sdeurope.org)

For the successive editions of the competition in Europe, the SD WAT has been maintained, incorporating improvements in its functionality, proving to be a very effective tool for collaboration with teams, management of deliverables, FAQs, planning, etc.

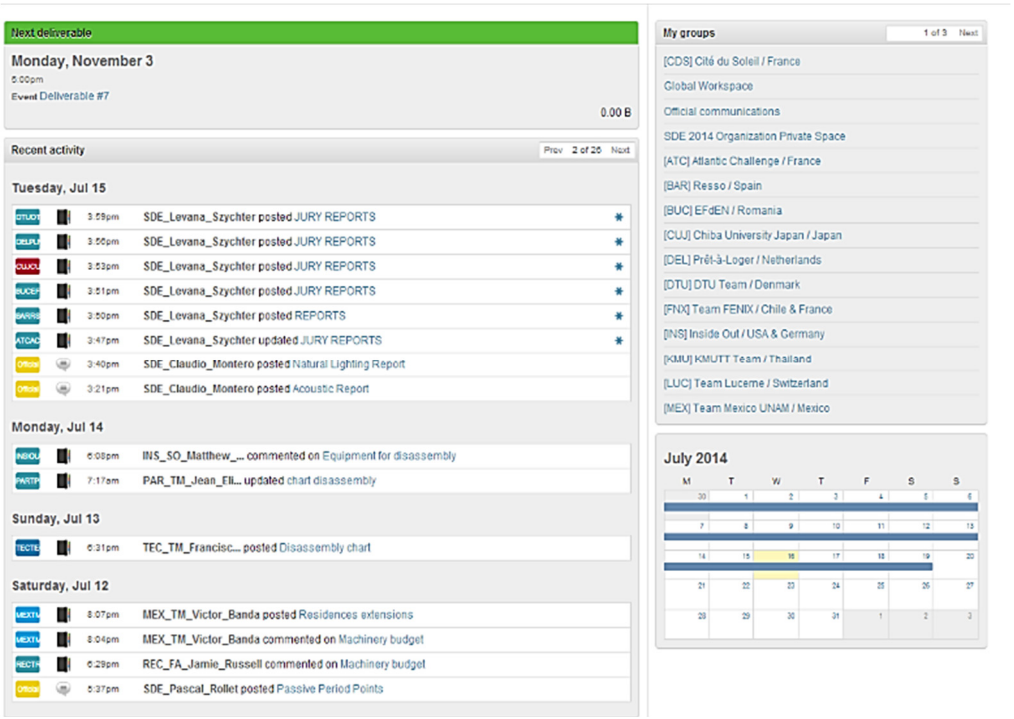


Figure 68: SDE 2014 WAT.

For SDE 2019, the wat@solardecathlon.eu email address under one.com webmail service was created by the EEF in the beginning of January 2018, right after the selection of the teams. Since then, official communication with the teams had been carried out through this channel. Both ÉMI and EEF dedicated staff had unlimited access to this email account for the duration of the project. During the two-year period, from January 2018 to January 2020, there were approximately 4,000 correspondence messages altogether.

Tthe Facebook Workplace solution was selected as collaborative tool, which had a free-to-use mobile application. The system was introduced after testing on 01/07/2019. The collaboration solution provided tremendous help in direct communication with teams during the assembly and competition period and had over 100 active users in the system during the one-month long period.
New webpages were developed by organizers for the three first competitons in Europe (figure 69,70).

Figure 69: SDE2012 (www.sdeurope.org) and SDE2014 websites (www.solardecathlon2014.fr)

For the new era of SDE competitions under the EEF (Energy Endeavour Foundation) stewardship, a common and coordinated design has been defined. For instance; the SDE 2019 and SDE 2021 websites.

Figure 70: Energy Endeavour Foundation website. (www. solardecathlon.eu)

To promote the media impact, a capillary strategy was deployed in the first editions, contacting the media progressively and summoning them to activities, presentations, press conferences, etc. in order to awaken the interest of the media. They were regularly provided with material produced for the press with the excuse of organizing conferences, professional fairs, summer courses, etc. During the competition phase, in order to attract the media, all the Ministers of Housing of the European Union were invited and attended, the King of Spain attended, several Ministers, presidents of autonomous communities, Ambassadors of

participating countries (USA; UK, France, China, Germany, Hungary, Romania, Japan, etc.), mayors, regional councilors, ... Each of these appearances attracted the media...
The results of the strategy were satisfactory. In SDE 2010, the number of appearances exceeded 2,000 with an audience of more than 172 million citizens, with an economic value of more than €4,350,000 (table 8).

SDE 2010 IMPACTS SUMMARY 2009-2010

	NO. OF APPEARANCES	AUDIENCE	ECONOMIC VALUE (€)
RADIO	61	6.779.101	488.216,55
PRESS	379	125.507.733	1.948.750,3
TV	80	39.539.500	1.917.658,6
ON LINE	1.489	N/A*	N/A*
TOTAL	1.886	97.615.250	4.016.731 €

Table 8: Results of the communication strategy.

In the SDE 2012 the number of appearances was 1,886, with an audience of over 97,615,000 million citizens, with an economic value of over €4,016,731 (table 9).

SDE 2012 IMPACTS SUMMARY 2011-2012

	NO. OF APPEARANCES	AUDIENCE	ECONOMIC VALUE (€)
RADIO	70	4.985.250	350.419
PRESS	265	64.578.000	1.458.518
TV	53	28.052.000	2.207.794
ON LINE	1.498	N/A*	N/A*
TOTAL	1.886	97.615.250	4.016.731 €

Table 9: SDE 2011-2012 media impact.

There is no available specific information regarding to media impacts in competitions SDE 2014 and SDE 2019.
It is also worth mentioning the planning and development of a strong presence in social media (see figure 71), with regular information requests echoing a constant trickle of activities and news throughout the period of development of each edition, and of course, during the competition showing the results in real time, videos, news, links, invitations to activities of all kinds and for all audiences, etc. The impact of social media was very high in the first two editions, especially in SDE 2012, as can be seen in the following figures:

- 220,000 visitors to the Solar Village during the Competition
- 5,000 children and adolescents who participated in our activities
- 2,000 University students who made study visits
- 6,000 Professionals who participated in the workshops and conferences organized during the Competition

- 124,000 people who consulted the progress of the Competition on Facebook
- 120,000 people who consulted the progress of the Competition on twitter
- 148,213 Visits to the SDE 2012 website during the Competition
- 5,700 Visits to the SDE 2012 Blog during the Competition
- 5,740 kWh generated, 2,977kWh consumed, 2,763kWh injected into the grid
- 2.380.000 Hits or entries in Google
- 7,810 Videos on the Web
- 156,000 SDE 2012 images available on the Web
- 59,700 results in Blogs
- 2,810 results in Debate Forums
- 200 Videos on Vimeo
- 291 Videos in YouTube

Figure 71: Presence in social media sde 2012

5.6.3 Solar Decathlon China

The social and media impact of the Chinese competitions was very important and significant, and resulted in a high number of visitors in both editions. They were the two editions that received the most visitors of all the competitions held.

According to Organization factsheets (see attached annexes), in the SDC 2013 competition held in Shanxi Datong, 230.000 visits were reported. The competition has been widely covered by the media. Through a large number of vivid and intuitive media reports and propaganda, SD China has rapidly formed a hot whirlwind, covering the whole of China and spreading to the world through the participating international teams. In Datong, the host city, even in the streets, everyone was talking about the grand occasion of SD.

From the popularity of basic solar energy knowledge to the popularity of competition rules, from urban transformation and development to the discussion of a new field of energy in the future, the media publicity of SD China competition excellently completed the influence of communications of its first show in China. According to incomplete statistics, there are more than 1,200 Internet media reports, more than 600 paper media reports, nearly 100 TV and radio reports, and more than 7,200 Sina Weibo fans. The number of visits in the Website during Competition was 148,799 visits.

For the SDC 2018 competition held in Shandong Dezhou, the number of estimated visits was around 500.000, the most visits to a solar villa ever. Industry, university, research cooperation is one of the highlights of this competition. A total of 370 enterprises supported the teams in different ways, covering building materials, new energy, smart home, electrical equipment, Internet of Things, promotion and communication, automobile and other industries. This shows that the impact of SDC competition in related industries cannot be ignored, and has gradually become a major driving force to promote industry university research cooperation and innovation. Total documented “On Line” media impacts were 3,300,000 visits. Documented national media impacts was estimated by organizers to as 60 millon people reached.

5.6.4 Solar Decathlon Africa 2019

At SDA 2019, 40,000 visitors were estimated during the competition, with about 5,000 children and teenagers who participated in activities organized specifically for them, about 10,000 university students who visited the Villa Solar, and about 6,000 professionals who participated in some of the activities organized specifically for them. More than 600 national and about 150 international media impacts were measured, with more than 100,000 visits to the web during the days of the competition (figure 72).

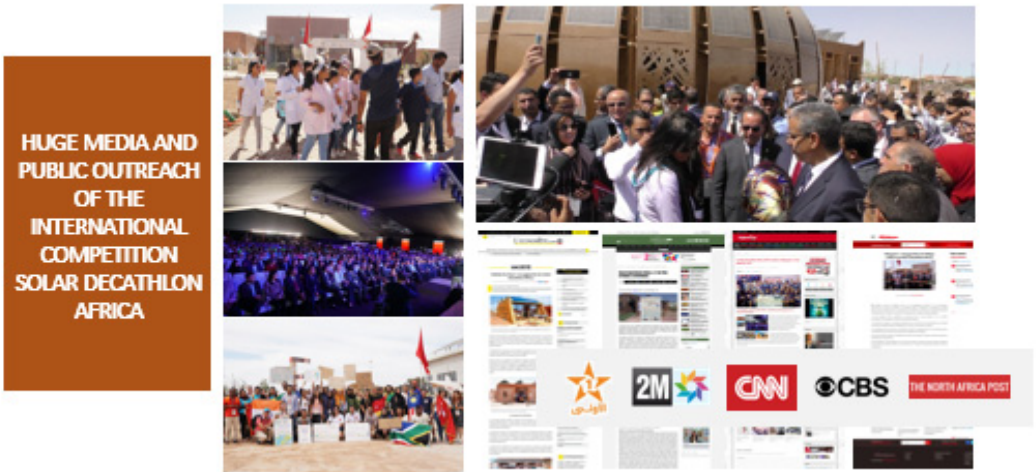


Figure 72: SDA 2019 Media outreach.

The media impact was very significant, with more than 150 appearances on radio and television media in Morocco and more than 100 media in the United States and other European and African countries. The impact in the written press was more than 500 media and more than 100 in the international press.
The organizers have counted more than 250,000 generated pictures and images, and 50,000 videos produced (figure 73).

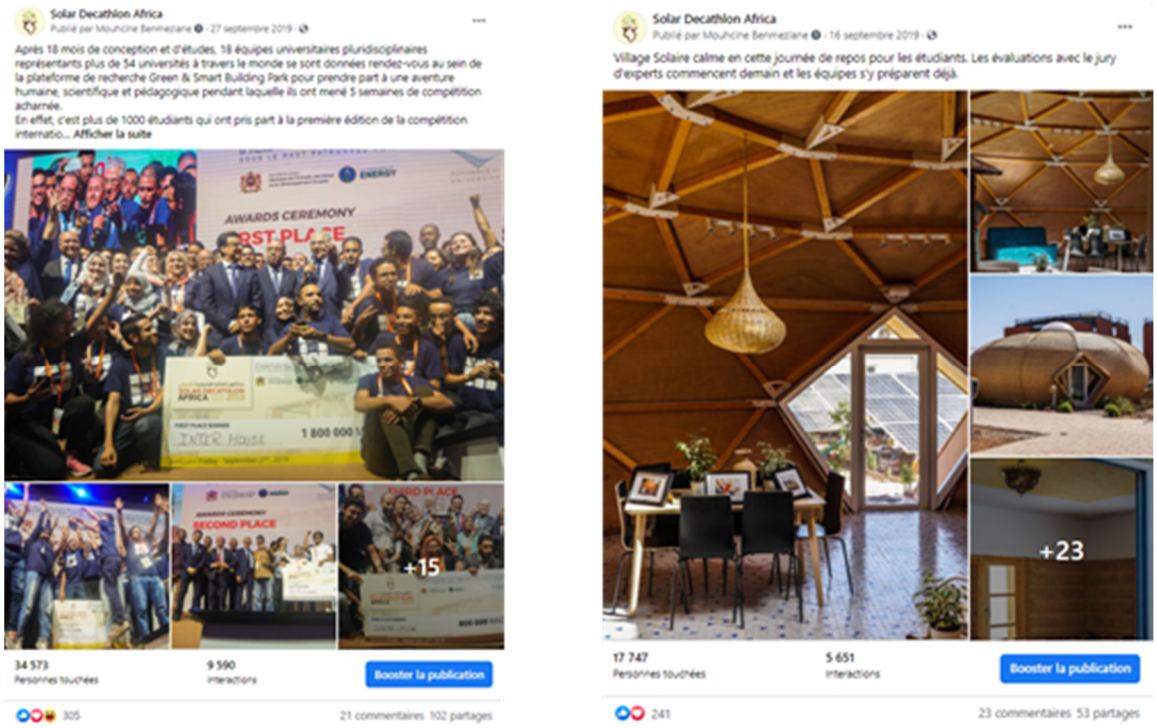


Figure 73: SDA2019 Social media publications

From a technical and scientific dissemination point of view, 3 books focused on SDA 2019 have been published, and more than 7 papers published in high impact scientific journals. The organizers also report at least 5 PhD theses in progress, based on SDA 2019 house experimentation.

There is no available specific information regarding competitions in Middle East and Latinamerica.

5.7 About linked events, activities, and solar decathlon outreach

In any event, the ability to attract public to the Villa Solar with the associated media potential, public and private sponsorship, visibility, social awareness, etc., does not only lie in a good location of the Villa Solar, in an area accessible to the public by public transport, or in a good communications strategy during the years that each edition lasts.

It is important to note that higher visitor numbers do not necessarily mean greater impact or a better experience on the part of learners, participants, or visitors. Excessively long queues and the inability to interact with students significantly limit the awareness-raising potential of the competition, one of the important objectives of the competition, especially for public decision-makers.

As the objective is to educate and make people aware of energy efficiency and sustainable ways of life, it is essential to have a specific strategy to organize activities for each of the target audiences that are defined, that are attractive, and that convey the clear message that is intended, so as to attract families, children,

young people, professionals, citizens, etc. What strategies have the different organizing teams followed in this regard?

5.7.1 US Solar Decathlon Competitions

In the first editions of the American competitions, no distinction was made between the competition and the associated event. They simply organized the competition, and tried to take care of communications with all the visiting public, but no specific activities were organized for children, professionals, or the general public, beyond the guided tours.

In SD 2007 some activities oriented to the social awareness of the visitors started to be organized, with the collaboration of some sponsoring companies. Based on the findings of this year''s 2007 Solar Decathlon media analysis, FD Dittus (a consulting firm that studied the communications strategy to be followed by the DOE) had the following recommendations for future Solar Decathlon outreach:

- Consider a more promotional outreach, partnerships with environmental and green nonprofit organizations; lunch-ins for reporters; distribute marketing materials and brochures to a wider audience.
- Organize additional private media tour hours and times when the homes are open only to the media.
- Seek partnerships with environmental and green nonprofit organizations founded, chaired and endorsed by celebrities.
- Consider recruiting high-profile judges for the competition. This could constitute another way of generating media coverage.
- Collaborate with sponsors early on to further develop media and marketing opportunities.
- Cultivate relationships with magazines and cable shows three to five months before the event to ensure knowledge of the event and coverage.
- Maintain relationships with media in off years of the event, and work with them to generate coverage on the Solar Decathlon that does not revolve solely around the event.
- Develop a press packet about the winners and work to place stories in annual “green” issues, and around Earth Day.
- Determine the best day to announce the winner. We lost out on an exclusive with a morning program because of the time the awards were announced. Can we announce the winner live on Good Morning America in 2009?
- Consider “winner media” satellite tour the day after the announcement is made — this should not be a weekend.
- Consider more radio tours for DOE officials.
- The Decathlon is first a competition and then an educational tool. Due to this year’s immense amount of corporate and consumer interest, extending the public viewing and tours will generate more interest and action. However, decisions need to be made regarding public hours, days or amount of people in homes to make sure that there is an efficient use of time allotted for public tours.
- Efforts to generate media interest six months prior to the event are necessary in order to lay the ground work and cultivate contacts for coverage closer to the event.
- Soar above and beyond — due to the excellence of the 2007 Solar Decathlon, renewable energy options were effectively brought to the attention of millions both nationally and internationally. Millions more need to know, can be reached, educated and influenced by the 2009 Solar Decathlon.

In the SD 2009 Competition there was a greater control of the number of visitors to the competition website (figure 74,75), as well as to the Solar Village itself and to each of the houses. An average of more than 30,000 visits per day were counted in the 10 days that the houses of the solar village were open to the public (on 14 October they were closed to the public due to the needs of the competition).

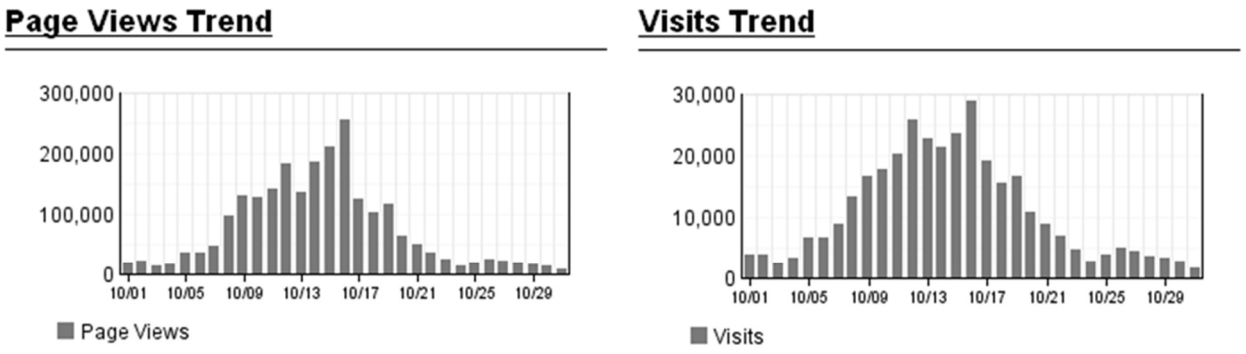


Figure 74: SD 2009 number of visitors.

House	10/8/09	10/9/09	10/10/09	10/11/09	10/12/09	10/13/09	10/14/09	10/15/09	10/16/09	10/17/09	10/18/09	Total
101 - Wisconsin	0	105	1,403	2,366	1,214	1,428	C	1,235	1,833	2,617	2,937	**15,138**
102 - Louisiana	828	247	2,325	2,684	1,267	1,675	C	1,544	2,259	2,226	2,348	**17,403**
103 - Missouri	1,263	512	2,709	2,822	1,570	1,550	C	2,185	1,839	2,964	3,988	**21,402**
104 - Arizona	906	566	1,268	1,755	1,014	850	C	975	1,840	2,650	3,782	**15,606**
105 - Rice	833	1,089	2,120	2,485	1,054	1,812	C	1,121	1,326	1,525	2,027	**15,392**
106 - Alberta	867	839	1,457	1,474	411	1,033	C	1,301	1,208	1,498	1,923	**12,011**
107 - Ontario/BC	870	2,094	3,003	2,750	738	1,700	C	1,268	1,753	1,216	2,548	**17,940**
108 - Iowa State	64	703	1,901	2,259	599	1,839	C	1,610	1,277	2,122	3,015	**15,389**
109 - Penn State	33	643	1,635	1,271	1,035	1,059	C	704	780	1,679	2,406	**11,245**
110 - Spain	1,100	508	1,403	3,235	1,800	2,238	C	1,473	2,438	3,118	4,000	**21,313**
111 - Kentucky	445	1,056	1,221	6,121	783	1,961	C	1,652	1,087	1,311	2,171	**17,808**
112 - Ohio State	998	1,459	1,210	2,109	1,261	1,532	C	1,489	1,359	2,468	2,639	**16,524**
113 - Boston	0	908	836	1,753	576	1,131	C	1,904	1,949	3,030	2,853	**14,940**
114 - Germany	1,328	928	746	1,567	803	1,175	C	1,076	1,325	1,761	2,143	**12,852**
115 - Virginia Tech	774	775	1,960	2,362	1,166	1,081	C	1,082	1,503	1,211	1,470	**13,384**
116 - Cornell	993	604	1,347	2,426	887	413	C	554	417	922	1,664	**10,227**
117 - Puerto Rico	534	2,140	1,449	1,792	964	1,286	C	1,123	1,148	2,123	2,446	**15,005**
118 - Minnesota	965	681	2,190	2,713	1,524	1,107	C	1,364	1,236	1,792	2,354	**15,926**
119 - California	481	783	2,510	3,371	1,491	1,459	C	1,195	1,120	2,083	2,448	**16,941**
120 - Illinois	559	262	1,427	1,465	1,285	924	C	954	840	1,550	1,790	**11,056**
GRAND TOTAL	**13,841**	**16,902**	**34,120**	**48,780**	**21,442**	**27,253**	**0**	**25,809**	**28,537**	**39,866**	**50,952**	**307,502**

Figure 75: SD 2009 Visitors tracker.

In general, the focus of the Solar Decathlon competitions in the United States has been more on getting the public, children and professionals to visit the houses than in organizing specific activities for them.
The strategies to maximise the outreach of the SD competitions and linked Events are to foster public interest in a free and public event. About basic knowledge for energy efficiency and renewable energy. Topics on public awareness are basic solar and energy efficiency strategies and connections to the science of building.

Opportunities for consumer workshops. There are no scheduled activities for the general public further than house visits and student presentations. There have been some scheduled activities for children and teenagers such as some scavenger hunt activities, mostly focused around tours of houses. For professional and university students, scheduled activities are limited to some partnerships with professional organizations for tours and hosted activities.

5.7.2 Solar Decathlon Europe Competitions

When the competition moved to Europe in 2010, some new objectives were defined, which had a great influence on the communications strategy. The two main objectives were:

- Take advantage of social interest and high media impact to make students, professionals, and the general public aware of environmental and sustainability issues, especially in the responsible use of energy and natural resources, promoting the use of the renewable energies, improving energy efficiency, etc.

- Attract the maximum number of people to visit the Villa Solar during the competition to raise awareness of sustainability issues in our buildings and cities, the need to make the consumption of our resources more responsible, improve energy efficiency in our daily use, and raise awareness of the availability of renewable energy, sustainable mobility, recycling, etc.

The strategies to maximise the outreach of SDE competitions and linked events were:

- Give even more importance to the event around the Competition to attract as many people as possible and maximise the impact of the competition
- Media and Social Media strategy.
- Objectives and strategies shared with public bodies, sponsors, and compiting teams.
- According to the guidelines of the 10 Action project, 5 priority target groups were defined: children, teenagers, university students, professionals and the general public. The organization of activities for each of the target groups is planned in order to attract as many people as possible to the Solar Village and to promote their education, social and professional awareness, play, etc.

From the very beginning, one of the main objectives was to develop activities associated with Solar Decathlon to educate and raise awareness among university students, professionals, children and young people, and the general public on the need for more efficient and sustainable buildings and cities.

Throughout the two editions held in Madrid, hundreds of activities were planned with messages and approaches appropriate to each target group, and with the leverage provided by the 10 Action project and the commitment of the SDE 2010 teams, many of these activities were carried out in 12 European countries, making the Madrid editions the ones with the greatest international outreach.

The SDE 2010 and SDE 2012 Organization Factsheets graphically describe some of the activities and products generated within the scope of the two projects, which led hundreds of thousands of visitors to play, think, reflect and enjoy with the decathletes and organizers.

In big numbers, SDE 2010 had an estimated 192,000 visitors during the competition, with about 4,000 children and teenagers playing with us, about 1,000 university students reflecting with us, about 20,000 professionals, and more than 75 educational and awareness-raising activities developed in Madrid for all audiences. Some 2,000 national and 5,000 international media impacts were measured, with more than 100,000 visits to the website during the days of the competition.

In big numbers in SDE 2012 220,000 visitors were estimated during the competition, with about 5,000 children and teenagers who played with us, about 2,000 university students who reflected with us, about 6,000 professionals (+25,000 10Action), and more than 45 educational activities that were repeated daily (more than 200 activities in total) and other 42 activities organized in other countries by 10Action. Some 1,886 national media impacts and a large number of unmeasured international impacts were measured, with almost 150,000 visits to the website during the days of the competition.

In addition to moving the competition to the second week of September in order to organize activities with schools (figure 76,77,78), institutes and universities, the strategy was adjusted to make the competition activities compatible with visits for the public, according to the general criteria:

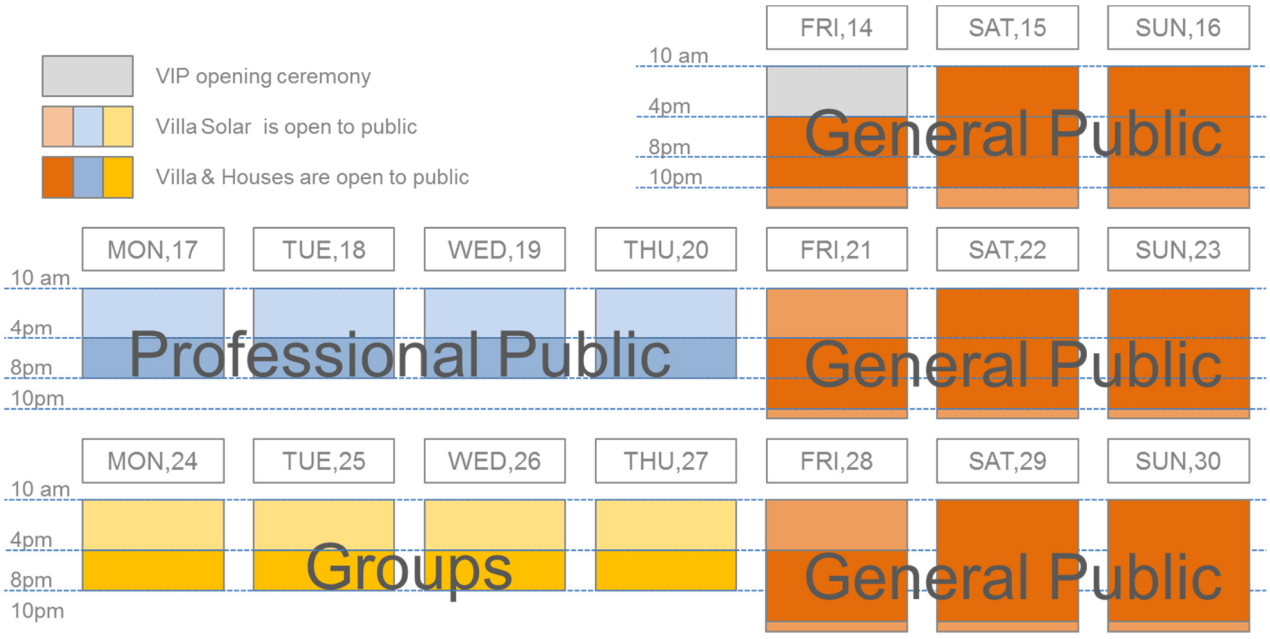


Figure 76: SD2012 visitors calendar.

GENERAL SCHEDULES OF THE VILLA SOLAR

Everyday from 10:00 to 22:00 hrs*

*The Villa Solar will open its doors to the public as from 16:00 hrs on 14 September.
*The Villa Solar closes at 19:00 hrs on Saturday 29th.

OPENING SCHEDULES OF SDE 2012 HOUSES:

- **Mondays to Thursdays:** from 16:00 to 20:00 hrs (by reservation from 17th to 20th for professionals and from 24th to 27th for groups)
- **Fridays:** from 16:00 hrs to 22:00 hrs
- **Saturdays and Sundays:** from 10:00 hrs to 22:00 hrs

The decathletes who built the SDE 2012 Competition houses will explain their projects and technologies to the public in 15-minute visits around the inside of the houses. These visits should be booked in advance on week days, while from Fridays to Sundays, they can be visited by queuing. A system of booking visits to the houses will be activated on this website as from 3rd September. You can consult the houses taking part in this edition Here.

ROUND TABLE DISCUSSIONS WITH MEMBERS OF THE INTERNATIONAL JURY + CONTEST AWARD CEREMONIES

- Architecture Contest Awards (19th/Sep)
- Engineering Contest Awards (20th/Sep)
- Industrialization Contest Awards (21st/Sep)
- Communication Contest Awards (22nd/Sep)
- Sustainability Contest Awards (26th/Sep)
- Energy Efficiency Contest Awards (27th/Sep)
- Electrical Energy Balance, Comfort Conditions and House Functioning Contests Awards (29th/Sep)
- Innovation Contest Award (29th/Sep)
- Final Competition Awards (29th/Sep)

Out of Contest Awards

- Solar System Integration Awards (20th/Sep)
- Interior Design Awards (21st/Sep)
- Social Housing meets Solar Decathlon Europe-For a fair Energy Transition in the EU (22nd/Sep)
- General Public Awards (29th/Sep)• Eficiencia Energética (27/sept a las 19:00 h)

GENERAL PROGRAMME
ACTIVITIES

GO1 GUIDED TOURS OF THE VILLA

These are visits of a general nature, explaining the SDE competition and the Villa Solar, while strolling around the houses on the outside.
Duration approximately 60 min.
TIMETABLE: Fri 16:00-22:00 hrs and Sat-Sun 10:00-22:00 hrs.

GO2 VISITS TO THE HOUSES OF SDE COLLABORATORS (OUTSIDE THE COMPETITION)

The public will receive explanations of the most outstanding technologies or building systems in houses not taking part in the competition: ecHor house (of IECA), FabriQ21, MODULAB, Saint Gobain Wanner and House of SDE 2010 UPM (Smart City Center).
TIMETABLE: Mon-Thur 10:00-20:00 hrs, Fri-Sun 10:00-22:00 hrs.

GO3 SOLAR KITCHENS

Installation of 2 kitchens and a solar oven with demonstrations, ranging from making coffee and boiling water for infusions to making cakes and paellas.
TIMETABLE: 17:00-20:00 hrs. and Sat -Sun 11:00-14:00 hrs. and 17:00-20:00 hrs.

GO4 VILLA SOLAR PHOTOGRAPHY MARATHON

Photo competition for everyone on scenes from the Villa Solar. The photos will be uploaded onto Facebook. There will be daily prizes and a grand prize at the end of Solar Decathlon Europe
TIMETABLE: Mon-Thur 10:00-20:00 hrs and Fri-Sun 10:00-22:00 hrs and 17:00-20:00 hrs.

GO5 MICRO-SORT FILM CONTEST

Which everyday object do you hate because you think it's unnecessary and harmful to our planet? Which do you admire for the common sense and honesty of its design? Upload your short film into the network and win: a new 32GB iPad, 20 T-shirts exclusively designed by Loreak Mendian, 40 film tickets and above all..... Your short film will become part of the collective film "I like/I don't like", based on everyday objects.
TIMETABLE: Mon-Sun 10:00-22:00 hrs.

GO6 10ACTION EXHIBITIONS -IEE

Exhibition of activities organized by the 10ACTION project for 180,000 people in 10 European countries. These include work by children, young people and students who have taken part in 10 ACTION activities. The winners and best national and international entries from the "Draw the sun's energy" contest, the "Focus on Energy" photographic competition, the "Ideas for the Future" drawing competition and the "More with less" architecture and urban planning contest.
TIMETABLE: Mon-Thur 10:00-20:00 hrs and Fri-Sun 10:00-22:00 hrs.

GO7 CASA PASIVA (SLOW ENERGY)

Aimed at young people and adults, where an "unfolding" house is used to show how our existing houses can be transformed so that they hardly lose any energy, through passive means (Passivhaus applied).
TIMETABLE: 17:00-20:00 hrs. and Sat -Sun 11:00-14:00 hrs. and 17:00-20:00 hrs.

Figure 77: SD2012 Activities Programme.

Figure 78: SD2012 / 10 Action project Activities.

The 10 Action project contributed significantly to the organization of activities during the Solar Decathlon 2012, (figure 79) and in the preceding years in 12 European countries with the collaboration of the SDE 2010 teams. The bottom line could not be more positive in every way:

- 9,350 European children who have actively participated in the 10Action activities and games organized for them
- 6,967 European teenagers who have participated in the debates and competitions 10Actions organized for them in various countries

- 2,086 university students from 12 European countries who have participated in the workshops, conferences, debates and competitions organized by 10Action
- 43,854 professionals from the construction sector who have participated in the exhibitions and conferences organized throughout Europe
- 142,803 European citizens who have participated in the model exhibitions, visits and demonstrations held in the various European countries involved.
- In total, 180,514 European citizens of all ages who have actively participated in 10Action activities, and have had the opportunity to reflect and learn about the responsible use of energy and how to contribute to making cities and buildings more sustainable, with a total estimated impact of 4 million European citizens who have heard about these activities organized in 12 European countries by 10Action.

ACTIONS FOR CHILDREN:

- "How to Save Energy in our Life" HANDICRAFT + DRAWING COMPETITION. [4.350 DRAWINGS]
- "MY ENERGY SMARTHOME" WEB GAME.. [5.000 PLAYED GAMES]

ACTIONS FOR TEENAGERS:

- DEBATE: "ENERGY + ARCHITECTURE". [4.912 PARTICIPATED]
- Design COMPETITION: "IDEAS FOR THE FUTURE". [752 PARTICIPATED]
- Photos COMPETITION: "ENERGY IN FOCUS". [1.303 PARTICIPATED]

ACTIONS FOR UNIVERSITY STUDENTS AND THE SCIENTIFIC COMMUNITY:

- "THINK URBAN: MORE about LESS [emissions]" DEBATE. [1.180 REACHED DIRECTLY]
- "THINK: MORE with LESS [emissions]" IDEAS COMPETITION. [159 STUDENTS]
- Technical Workshops for Dissemination -Universities & Scientific Community. [747 STUDENTS]

ACTIONS FOR PROFESSIONALS OF THE BUILDING SECTOR AND CITY COUNCILS:

- Active attendance at trade fairs and events about energy efficiency and sustainability in buildings . [15.750 VISITORS]
- Technical conferences about innovative sustainable building techniques. [1.488 VISITORS]

ACTIONS FOR THE GENERAL PUBLIC:

- Exhibitions of real Solar Houses at SDEurope. [93.621 VISITORS]
- Travelling exhibition of architectural scale models of solar houses. [51.252 VISITORS]

PARTNERS:

- **SPAIN, Universidad Politécnica de Madrid.**
- **SPAIN, Instituto para la Diversificación y Ahorro de la Energia.**
- **GERMANY, Technische Universität Darmstadt.**
- **GREECE, Center for Renewable Energy Sources and Saving.**
- **PORTUGAL, Agência a Energia.**
- **AUSTRIA, Austrian Energy Agency.**
- **SPAIN, Helago Marketing Team.**

CHILDREN

ACTION PLAN	PLACE	RESULTS
- Handicraft + Drawing Competition.	SPAIN, GREECE, AUSTRIA, PORTUGAL.	**In total 4.350 drawings have been submitted.**
- WebGame "My Energy Smart Home".	INTERNATIONAL	**The online version of the game has been played more than 5.000 times.**

GENERAL PUBLIC

ACTION PLAN	PLACE	RESULTS (visitors)
- Organization of the SDEurope house exhibitions.	Total of 12 SDEurope Houses (from FRANCE, UK, FINLAND, SPAIN, GERMANY).	**93.621**
- Organization of the SDEurope scale model exhibitions.	-BAU 2011. Munich, Germany. -Urbaverde 2011. Estoril, Portugal. -Construmat 2011. Barcelona, Spain. -Science Week 2011. Madrid, Spain. -Dabadum 2011. Madrid, Spain. -Deubau 2012. Essen, Germany. -Construtec 2012. Madrid, Spain. -Genera 2012. Madrid, Spain.	**49.182**

ADOLESCENT

ACTION PLAN	PLACE	RESULTS
- Debate on how we want our own Solar Village "Energy + Architecture".	SPAIN, GREECE, GERMANY.	**In total 4.912 adolescents and teachers has participated.**
- Solar Design Competition "Ideas for the Future".	GREECE, AUSTRIA, GERMANY.	**In total 752 adolescents has participated.**
- Solar Photo Competition "Energy in Focus"	PORTUGAL, SPAIN, GREECE, AUSTRIA, GERMANY.	**In total 1.303 adolescents has participated.**

BUILDING PROFESSIONAL SECTOR

ACTION PLAN	PLACE	RESULTS (visitors)
- Active attendance at trade fairs & events.	-BAU 2011. Munich, Germany. -Urbaverde 2011. Estoril, Portugal. -Genera 2011. Madrid, Spain. -Construmat 2011. Barcelona, Spain. -Deubau 2012. Essen, Germany. -Genera 2012. Madrid, Spain.	**15.750**
- Technical conferences on off-the-shelf technologies.	Estoril, PORTUGAL. Barcelona, SPAIN. Barcelona, SPAIN. Essen, GERMANY. Madrid, SPAIN. Madrid, SPAIN.	**1.488**

UNIVERSITY STUDENTS

ACTION PLAN	PLACE	RESULTS
- Debate on how we want our own Solar Village "MORE about LEES emissions".	SPAIN, Madrid.	**In total 1.180 people reached directly, from 46 different universities or schools.**
- Ideas Competition on impossible ideas for a possible world "MORE with LESS emissions"	SPAIN, Madrid.	**In total 159 students have taken part in this competition. Overall around 30 universities or schools have been reached by the competition.**
- Technical Workshops	SPAIN, GERMANY, FINLAND, FRANCE, AUSTRIA, UK, GREECE.	**In total 747 students participated in the workshops organized by 10ACTION.**

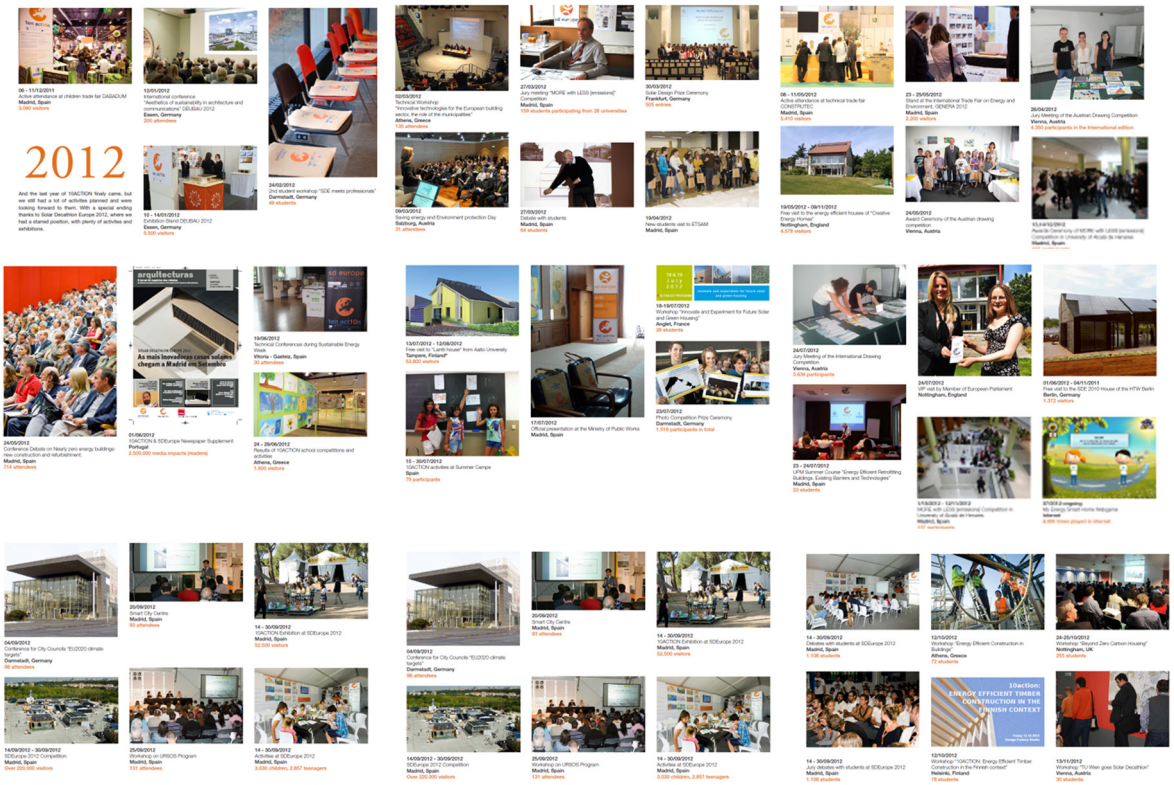


Figure 79: 10Action Project Impact.

The balance of the editions held in Madrid is completed with the publication of two books bringing together all of the experience of SDE 2010 and SDE 2012, a special issue of Energy & Buildings, and multiple scientific articles published in high impact scientific journals (figure 80), 4 PhD theses (figure 81) with at least partial focus on Solar Decathlon houses, multiple visits of ambassadors, politicians, ministers, housing ministers of the European Union, etc., and an award from the European Union in the Sustainable Energy Week in 2011, in the category of communications.

Figure 80: SDE2010 and SDE2012 books.

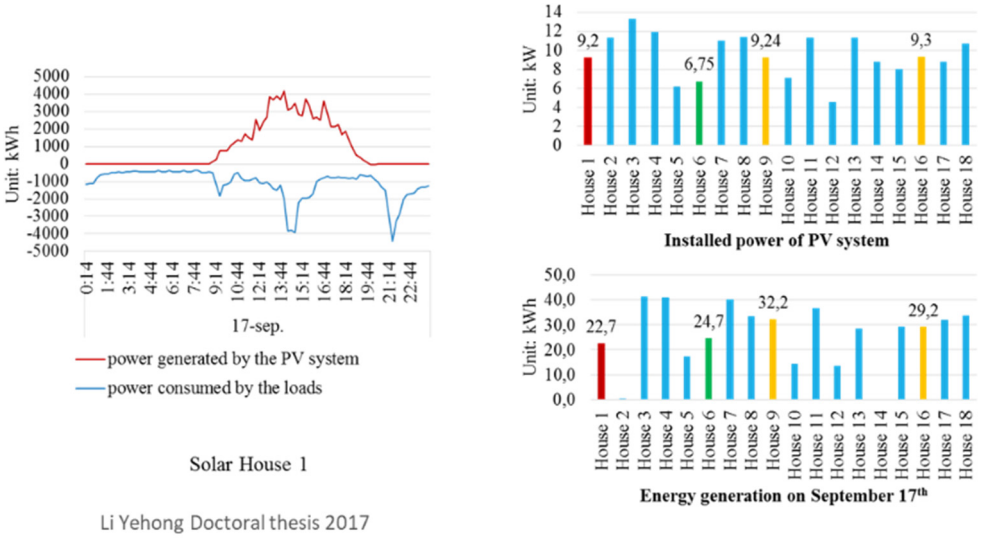


Figure 81: PhD Thesis.

There is no available specific information regarding to the event and outreach in competitions SDE 2014 and SDE 2019.

5.7.3 Solar Decathlon China

It has not been possible to gather information on the activities that took place at the SDC 2013 competition held at Shanxi Datong. A summary of figures has been sent regarding the SDC 2018 competition held in Shandong Dezhou which ended up being by far the most visited competition in the world with an estimated 500,000 visitors.

This edition did develop a strategy of holding activities both in the host city and in other Chinese cities, supported by the 370 sponsors who actively supported both the organization and the different teams in different ways, covering building materials, new energy, smart home, electrical equipment, Internet of things, promotion and communications, automobile and other industries. This shows that the impact of the SDC competition in related industries cannot be ignored, and has gradually become a major driving force to promote industry university research cooperation and innovation.

A total of 27 different activities were organized in the host city, and some 42 other activities were organized in other cities in China. There were 27 activities for university students and professionals and 12 activities for the general public, which were held during the 16 days of the competition. At least 1,097 university students visited the Solar Village (in addition to the Decathletes) as well as some 523 professional visitors. In addition to the significant media impact and number of visitors, it is worth mentioning the production of popular books and scientific articles, with more than 50 publications identified by the organizers of SD China, of which 35 were scientific papers in journals of scientific impact.

5.7.4 Solar Decathlon Africa 2019

As mentioned formerly, SDA 2019 had an estimated 40,000 visitors during the competition, many of whom participated in some of the activities organized for them.

According to the information provided by the organizers, multiple activities were developed, many of which were repeated every day of the competition. Ten activities were organized for university students, which generated the visit of some 10,000 students. More than 5 specific activities were organized for Moroccan professionals, which resulted in the visit of some 6,000 professionals.

Three awareness activities for Children&Teenagers were organized for many days, with a total number of around 5.000 children and teenagers visiting and playing in Solar Village. More than 14 activities were organized for the general public in the Solar Village with more than 40,000 visits as a whole. Another 10 more activites were developd in other Moroccan cities.

There is no available specific information regarding competitions in Middle East and Latinamerica.

5.8 About Risk Management

A lesson learned by all of the organizing teams is that no matter how well planned the project may be, they have always had to deal with unforeseen events of all kinds, often jeopardizing the continuity of the competition itself. It is important to highlight the importance for a good competition to develop a good strategic planning of risk management to ensure the fulfillment of the proposed objectives. It is essential to identify all the possible uncertainties facing the project, both threats and opportunities, analyze them qualitatively and quantitatively, plan the response to neutralise or mitigate the threats, and enhance the opportunities, incorporating the appropriate reserve analysis into the strategic planning.

It is also necessary to plan how to monitor and follow up the main risks identified with the necessary early warning notices and the organization and procedure of the responses to be given in each case. One of the risks to which special attention has always been paid by the organizing teams has been the safety of the decathletes both during construction and during the competition phase, and of the visiting public, planning specific strategies of, for example, intense control and surveillance of safety aspects, such as technical quality control of structural safety, access, fire, electrical installation, etc.

Other risks identified and managed in one way or another, have had to do with government budget cuts, delays in payments producing severe tensions in the cash flow of the projects, or not reaching the expected funding through sponsorships, or arriving late. Other risks are of a political nature, risks of terrorist attacks, problems associated with the Villa Solar, construction delays, risks associated with the simultaneous operation of 20 teams working under pressure with cranes and machinery that involve risks, inclement weather of all kinds, with floods during assembly, temperatures of 44ºC, snow, etc., the removal of equipment in the final stretch leaving plots of land unbuilt. Programs for monitoring management that are not on time or are not sufficiently reliable, the need for teams to work at night with the associated risks, etc. In short, proper planning and risk management is critical to cope with the possible contingencies of the competition, with some guarantee of success despite the most unexpected problems.

Some specific risks suffered, or analyzed in the SDE 2010 had to do with teams leaving the competition along the way. The need to withdraw a team from Israel selected for contravening a political decision of the European Union. The technical risk associated with placing the Villa Solar over some tunnels of the M-30 (freeway of the ring road of Madrid) and the need to lighten at the last moment the existing fillings combined with torrential rain that caused flooding in the Villa Solar, security risks before the visit of the King , ministers, ambassadors, etc. in a world showcase.

Some risks suffered or analyzed in SDE 2012 were the change of the color of the governing party in Spain, who cancelled the competition halfway through. For more than 6 months the competition was unofficially cancelled, and after intense negotiations, it was completed with severe budget cuts from the Government of Spain. Dozens of activities were not implemented due to lack of sufficient sponsorship, etc. Figure 82 is part of the sheets of the matrix of risks identified and analyzed for the SDE 2012 competition, one of the few documents that have been collected from all the editions held.

RISKS CHART

code	risks			eval.			response			
	identify	description	cause	P	I	RI	triggers	action	responsable	cost
PHASES: ALL										
R-01	ELECTIONS FOR THE NEW PRESIDENT OF SPAIN.	The election for the new President of Spain will be in the 2011-2012 winter, just 10 months before the competition	GENERAL ELECTIONS	5	5	25		Summoning the new General Director of Housing of the Ministry of Civil Works to a meeting, in order to present the SDE project, in case of changes.	PROJECT MANAGER	0,00 €
R-02	RELATIONS WITH MINISTRY OF CIVIL WORKS.	Crisis in the relations between the SDE Organizers and the Ministry for Public Works.	SDE - MINISTRY	2	4	8	Continuing quarrels	Summiming the Technical Representative of the Ministry for Public Works, in case of problems.	PROJECT MANAGER	0,00 €
R-03	ESTIMATED MINIMUM BUDGET FOR 2012, NOT FINALLY APPROVED.	The general budget of Spain for 2012 is not already approved, so the SDE project, does not have yet the particular budget approved.	MINISTRY	5	4	20		Strict control of the costs of the project by the Administrations and the Economic Department	PROJECT MANAGER	0,00 €
R-04	ELECTIONS FOR THE NEW UPM VICE-CHANCELLOR.	Our political (President) and technical (Inernational Relations Vice-Chancellor) UPM representatives can change due to the elections.	UPM	5	4	20		Summoning the new President and International Relations Vice-chancellor to a meeting, in order to present the SDE project, in case of changes.	PROJECT MANAGER	0,00 €
R-05	RELATIONS WITH UPM, ETSAM AND DCTA.	Crisis in the relations between the SDE Organizers with UPM, ETSAM and DCTA.	SDE - UPM - ETSAM - DCTA	2	3	6	Continuing quarrels	Summoning all the necessaries meetings in order to solve all kind of items, in case of changes.	PROJECT MANAGER	0,00 €
R-06	PROBLEMS BETWEEN SDE ORGANIZERS.	Inadequate running in the daily work of the SDE Organization between human resources.	SDE	2	3	6	Continuing quarrels	Plan several team building activities.	PROJECT MANAGER	0,00 €
R-07	ELECTIONS FOR THE NEW MAYOR OF MADRID.	The election for the new Mayor of Madrid City Council will be held in the 2011 spring.	MADRID CITY COUNCIL	5	3	15		Summoning the new Technical Representative of Madrid City Council to a meeting, in order to present the SDE project, in case of changes.	PROJECT MANAGER	0,00 €
R-08	RELATIONS WITH MADRID CITY COUNCIL.	Crisis in the relations between the SDE Organizers and Madrid City Council.	SDE - MADRID CITY COUNCIL	2	4	8	Continuing quarrels	Summiming the Technical Representative of the Ministry for Public Works, in case of problems.	PROJECT MANAGER	0,00 €
R-09	RELATIONS WITH MADRID ESPACIOS Y CONGRESOS	Crisis in the relations between the SDE Organizers and Madrid City Council, who manage the site where the Villa Solar is going to be located.	SDE - MADRID ESPACIOS Y CONGRESOS	2	3	6	Continuing quarrels	Summiming the Infraestructures Department of Madrid Espacios y Congresos, in case of problems.	INFRASTRUCTURES MANAGER	0,00 €
R-10	BAD RELATIONS IN THE INFRAESTRUCTURES TEAM	Existing bad relations between team members of Infraestructures Area.	INFRAESTRUCTURES TEAM	2	1	2	Continuing quarrels	Recognize those bad relations between members of the Infraestructures Team and try to solve the problemas as soon as possible.	INFRASTRUCTURES MANAGER	0,00 €
PHASE I: ARRANQUE										
R/I-01	NO RISKS IN INFRASTRUCTURES AREA					0				
PHASE II: DESIGN DEVELOPMENT										
R/II-01	DELAYS ON THE DESIGN PROJECT OF THE VILLA SOLAR.	Breach of planning of the Area, in terms of the Design project of the Villa Solar.	VILLA SOLAR TEAM	3	4	12	Breach of planning deadlines	Strict control of the planning of the Infraestructures Area.	INFRASTRUCTURES MANAGER	0,00 €
R/II-02	CHANGES IN THE VILLA SOLAR PROGRAM.	Important changes in the program of the Master Plan of the Villa Solar, which involve significant consequences in the development of the project.	ALL	3	3	9	Continuing changes in the program.	Continuing meetings with all the stakeholders of the project, who have interests in the Master Plan.	VILLA SOLAR TEAM	0,00 €
R/II-03	DELAYS ON THE ENVIRONMENTAL PERMISSION OF THE VILLA SOLAR	The problems caused by the delay of the authorization from Department of Green Heritage, Madrid City Council for the development of the Master Plan of the Villa Solar	MADRID CITY COUNCIL	2	5	10	Breach of planning deadlines	Summoning a previous meeting with the Department of Green Heritage in order to know the highest scope of our proposal, trying to get the approval as soon as possible.	VILLA SOLAR TEAM	0,00 €
R/II-04	PROBLEMS WITH SHADOWS IN THE SORRUONDINGS OF THE VILLA SOLAR	The competition can be affected by the projecting shadows of the trees located in the sorruondings of the Villa Solar.	ENVIRONMENT OF THE SITE	4	5	20	Analysis of the study of the Villa Solar shadows.	Plan an activitie in order to prune the trees in spring and summer.	VILLA SOLAR TEAM	0,00 €
PHASE III: CONSTRUCTIVE DEVELOPMENT										
R/III-01	DELAYS IN MANAGEMENT OF THE PROCUREMENTS	The economic problems of the funding of the Project can affect the launch of the procurements.	MINISTRY FOR PUBLIC WORKS	2	4	8	Breach of planning deadlines	To make sure that the 2012 funding promised by the Ministry for Public Works will arrive on time, in order to start the process of the procurements, as soon as possible.	PROJECT MANAGER	0,00 €
R/III-02	DELAYS ON THE CONSTRUCTION PERMISSIONS OF THE VILLA SOLAR	The problems caused by the delay of the authorization from Department of Urbanism, Madrid City Council for the development of the Master Plan of the Villa Solar.	MADRID CITY COUNCIL	2	4	8	Breach of planning deadlines	Plan the meetings necesaries with the Department of Urbanism in order to solve all the problemas appeared.	INFRASTRUCTURES MANAGER	0,00 €
R/III-03	DELAYS ON THE CONSTRUCTION OF THE VILLA SOLAR	The problems caused to the event if the Villa Solar is not already prepared on September, 3rd, when the assembly period of the competition starts.	INFRAESTRUCTURES TEAM	3	4	12	Breach of planning deadlines	Strict control of all the works.	INFRASTRUCTURES MANAGER	0,00 €
R/III-04	PROTEST OF THE ASSOCIATION "FRIENDS OF CASA DE CAMPO"	We are waiting for the pobable protest of the association of "Friends of Casa de Campo" basically because of the prune needed in order to make a succesfull competition.	ASSOCIATION "FRIENDS OF CASA DE CAMPO"	3	5	15	Protests	Summoning necessaries in order to negotiate with them all the items, in case of problems.	MADRID CITY COUNCIL	10.000,00 €
R/III-05	OVERUNS ON THE COST OF THE CONSTRUCTION OF THE VILLA SOLAR	The indecisiveness in all the activities related to the own event and the competition can affect on the cost because of the changes in the Master plan.	INFRAESTRUCTURES TEAM	3	4	12	Breach of budget approved	Continuing meetings with all the stakeholders of the project, who have interests in the Master Plan.	MADRID CITY COUNCIL	5.000,00 €
R/III-06	ROAD (MACHINERY) AND INDUSTRIAL (PERSONNEL) ACCIDENTS	Any road accident (machinery: cranes, trucks, forklifts…) and any industrial (personnel) accidents occured during the construction of the Villa Solar.	NOT DEFINED	2	5	10	Breach of Health and Safety plans.	Strict control of the works in terms of Health and Safety, security private company, mecial care, and insurances.	HEALTH AND SAFETY TEAM	0,00 €

Figure 82: SDE2012. Risks identified and analyzed.

There is no available specific information regarding competitions in USA, SDE2014, SDE2019, Middle East, China, Africa, or Latinamerica.

5.9 Lessons Learned from every Competition

An important lesson learned is to have a feedback system for previous experiences. The most significant advances have occurred when processes of critical analysis and lessons learned have resulted in important qualitative leaps that have enriched the competitions, as in the case of the leap from the US competition to Europe, and the leap from SDE 2010 to SDE 2012. The UPM produced an elaborate report on lessons learned from SD 2009, SDE 2010 and SDE 2012 that substantiated the changes introduced in the first European editions with respect to the American ones, in order to adapt them to European sensibilities and priorities.

Regarding the Postcompetition and living labs, they have never been regulated by the Rules and Regulations, so that after the competitions, each team has done with its house what it has considered appropriate. In some cases, they have been thrown away and have not even returned to their country. In other cases, they have been sold, and in most cases, the houses have returned to their universities of origin and have been used as living labs, as educational centers for university students, as research objects, as offices, social centers, demonstrators for companies, etc. Among the organizers interviewed, there is a certain consensus that the houses are underutilised, and that the organization of the competitions can promote the planning of a second life for the SD solar houses in order to take advantage of them from an educational, research, social, professional, children''s, etc. point of view.

The trend of the last editions of Solar Decathlon held as SDME 2018, SDE 2019, or SDA 2019 point to leaving the competition with the Solar Village and all the houses, or a substantial part of them assembled and in operation, forming a large Living Lab that can extend both research and educational activities with awareness visits of professionals, schools, and the general public for several more months. In this sense, the SDE 2021 edition to be held in 2022 as a result of COVID 19, promises to be a milestone, having

already planned from the beginning to leave 8 houses set up in the Solar Village for social and scientific use.

The evolution and continuous improvement processes from one edition to another reflect the vitality of the Competition and its organizing teams. Each one, in a more informal or systematic way, has tried after each edition of the competition to critically analyze how each edition has developed and whether the objectives and expectations generated with it have been met. This exercise of General Assessment of impacts, final conclusions of the Competition and linked Events performance, and main lessons learned, which has been compiled in the organization factsheets in Annex 1, is illustrative of why the evolution of the competition has been like this and not otherwise.
Some of the conclusions and lessons learned from one edition to the next are collated below to illustrate this process:

5.9.1 US Solar Decathlon Competitions

The scoring of the SD 2002 competition was based on team rankings. The teams were ranked first through fourteenth (14 teams), and scores were assigned based on rank. Team scores went up and down during the competition, because rankings in individual contests were dynamic. As the rankings changed, so did the scores. In the SD 2005 competition, the ranking system was discarded, and points were cumulatively awarded for achievement. Generally, team scores were always increasing from the beginning of the contests.

The 2005 Solar Decathlon houses raised the bar in performance relative to the inaugural event. And the team homes have proven once again that there are multiple aesthetic and functional solutions to the challenge of creating homes powered entirely by the sun. The students and faculty who participated in the 2005 Solar Decathlon demonstrated a vision to everyone for a bright energy future that runs efficiently and dependably on renewable energy.

One of the lessons learned in SD 2005 was that the wireless network set up by Sprint for the purpose of disseminating the scoring spreadsheet to the teams every 15 minutes was unsatisfactory. The network went down for one reason or the other several times a day, and many teams simply tired of attempting access the network to download the spreadsheet. It is in everyone's interest that the scoring spreadsheet be reliably accessible by all the teams and by people outside of Washington. The organizers proposed that an existing, proven wireless network such as Verizon Broadband be used in SD 2007. This way each team could set up their computer ahead of time and be sure that it worked. We would have a site set up on the internet that would allow us to send the spreadsheet every 15 minutes and allow teams to download it when they pleased. A small program could even be written to automatically download the spreadsheet to each of the team's computer at regular intervals. This would encourage team members to watch their data and scores as well as those of other teams.

Some of the lessons learned in SD 2009 Communications are detailed in next sections.

5.9.2 General Communications

Use NREL staff, not outside contractors, for all communications work. We do not get the quality, technical knowledge, or responsiveness we can provide from outside sources.
The need for a master task list. Know all expected deliverables upfront.
Create an online style guide that can be easily accessed by all parties and updated regularly to encourage consistency among products. The external Web presences were inconsistent (and often had typos).
Create budget systems immediately at the end of the 2009 event to accurately track expenses throughout the work.

Determine overall leader of communications efforts. Just one person in charge of everything and who reviews all of it.
Clearly define roles and responsibilities well in advance of the event. TAO wreaked havoc on timelines, budgets, and work because of last-minute requests, no funding, responsibility, confusion, etc.
Involve TAO in organizer team/planning at some level? They do not “get it” because they only see a sliver of the overall work. If they were more involved, they would at least understand the big picture.
Establish hard deadlines for new projects. If we do not have funding/content/etc. by X date, we simply cannot carry out the requested work. We suffered some disappointments and functional issues because we created products under unreasonable schedules and circumstances.

Awards

Discuss most equitable system to award teams. Give physical awards (acrylics) and not just paper diplomas for first, second, and third place in each contest?
Honorable mentions (teams that don’t place in any contest) get only certificates at the Victory Reception.

Branding and Design

Create a visual style guide, branding, and design elements in January before the event. Doing it early allows reviews to be made and the ability to share them with contractors and others. Include sample signage, print, etc. products in the guide for others to refer to.
Assign an NREL art director to establish branding and design templates by March 2010. Ensure that this person will oversee all design work going forward through the 2011 event.
Distribute Style Guide to teams and sponsors no later than January 2011.

Media Kits

The Media Team should be responsible for developing and producing media kits based on established NREL messaging. (NREL only reviews for appropriate style and visuals.)
All of this could be set up and tested ahead of time, rather than simply trusting that everything will work when we get there.

The SD 2009 edition has probably been the most studied in history, given that in addition to the critical analysis of the organizing team itself, the UPM team, the organizer of the SDE 2010 competition, also carried out a critical analysis. In order to know the ins and outs of the competition in detail, a team of more than 15 people were direct witnesses of the organization as “shadows“ of each of the key organizing profiles. On their return, an exhaustive description of the work developed by the SD 2009 organizing team was made, and a critical analysis with lessons learned for its application in SDE 2010.
The balance of the SD 2013 and SD 2015 editions held in California was equally positive despite the difficulties in the change of location and limited public funds, with a productive event, with high-quality designs and successful collaboration with industry. Adapted to changes in site and local municipal government. Tight budget, challenging to get started with recruiting admidst a government shutdown due to lack of funding, challenging to deal with a non north-south site, challenging wind conditions, but productive engagement educating students, exciting the public, and involving industry. The main lessons learned was to secure local support and total funding for the project and not dependent on funding.

The SD 2017 in Denver had a positive outcome, described by the organizers as a successful event, with tens of thousands of visitors, competitors presented to juries and homes measured, and no notable injuries. Thousands of students and public educated. With DOE funding limited to $2,000,000 in total, the return on investment was incredibly high with over 2,000 students educated (less than $1,000 per student) and over 40,000 visitors (50 per student) if each was counted individually. Challenging structure to work with a for-profit entity in a new city on a tighter timeline. Limited ability to recruit participants and participants did not know where the event would be when they signed up. This led to weaker initial teams. The main lesson learned was do not do a tiered prize structure, it causes issues for all involved with little benefit.

5.9.3 Solar Decathlon Europe Competitions

In the Organization factsheet of SDE 2010, we took stock of the fulfillment of most of the objectives defined by the organization together with the UPM and the Government of Spain. In conclusion, despite the fact that many of the activities initially planned were not carried out due to known budgetary limitations, and despite the fact that many of the activities and events developed are perfectible, the final balance is very positive in terms of the project: The Competition was organized within the scope and with many of the planned activities, all the objectives were covered satisfactorily, it was a success with the public, it had a great media impact, Both the participating teams, as the Ministry itself, Madrid City Council, IDAE, UPM, and the SOLAR DECATHLON Organization in the USA (DOE), and the many sponsors and technical suppliers, expressed their high degree of satisfaction with the results obtained.

The Competition attracted many authorities and politicians as the King of Spain, Housing Ministers of all EU countries, Ambassadors, etc. Solar Decathlon Europe was awarded with the prestigious EU Prize for Sustainable Energy Award in Communications during the Sustainable Energy Week 2011

Related to the lessons learned from DS??2010 organization, that 15 people from the Spanish organizing team participatated as “shadows“ of the American organizing team of the US-SD 2009 Competition held in Washington D.C. Critical Analysis and Lessons Learned from this “Shadow“ experience were implemented for the European Competition and many Rules and Contests were changed to adapt to European sensitivity, and to answer to the lessons learned concluded.

For the 2012 edition of the SOLAR DECATHLON competition in Madrid, most of the almost 100 lessons learned, and suggestions for improvement, derived from the final critical analysis process and lessons learned from the 2010 SOLAR DECATHLON EUROPE were recommended in a specific Critical Analysis and Lessons Learned Report. The result in this 2012 edition was clearly better than the 2010 competition in many respects, despite the budget cuts.

The continuous improvement of the competition requires, after each of the editions, an effort to make a critical analysis of the balance, and to extract the lessons learned that should be transferred to the next organizing team. The transfer of the experience of the organization and management of previous competitions is critical to ensure continuity in the learning of the competitions and the use of the lessons learned and continuous improvement.

It is worth noting the crucial importance of active support from governments in the development of this type of competition. It is the main stakeholder that must be planned and taken care of in the development of the project. Political ups and downs and changes in government have a decisive effect on the development of the competition, so a special planning of the communications strategy, risk management and the management of this critical stakeholder are essential.

“One lesson learned is that the success of the competition must be measured, in addition to the results of the competition, by the volume of people who visit it and the impact it has on the media. The large budget required for both the organization and the teams would not make sense if it were not for the social and media impact it achieves, which translates into high social awareness for children, university students, professionals, and the general public. This social impact awakens political interest, and allows the existence of companies that sponsor both the event and the teams. The very survival of the competition lies in this social and media impact.

To maximise this impact, it is critical to share these objectives with all of the stakeholders:politicians (local, regional, country, and the European Union), as sponsors, teams, universities, etc.

Another lesson learned is the amazing performance of the university team selected for the organization of the Competition, supported only by professionals, in very specific technical and communications aspects. The unconditional and professional support of the University, the leadership of the team, and the enthusiasm, creativity, unlimited dedication, resilience and tenacity of the young team members, together with their ability to tune in to the participating teams and the vision shared with them, have been the most important assets in achieving the success of the competition

Another important aspect to be promoted, in order to better justify the large amounts of effort and money invested by the universities and sponsoring companies for the competition, is to encourage the continuity of the educational, research and professional and social awareness potential of the houses. The use of the houses after the competition to generate living labs and educational, research and technological innovation demonstrators should be encouraged by the competition organizers themselves. The organization should also promote the exploitation of the educational potential that Solar Decathlon competitions represent for universities, given that not all universities exploit the possibilities of promoting cross-disciplinary collaboration between both disciplines and schools, or of promoting the development of multiple transversal skills to which SD lends itself, so necessary for the education and training of the next generation of architects and engineers committed to the sustainability of our planet.

The final balance of the SDE 2010 and 2012, together with the activities developed by 10Action Project, is more than 600,000 European citizens who have visited or actively participated in activities organized by both projects (see figure 83):

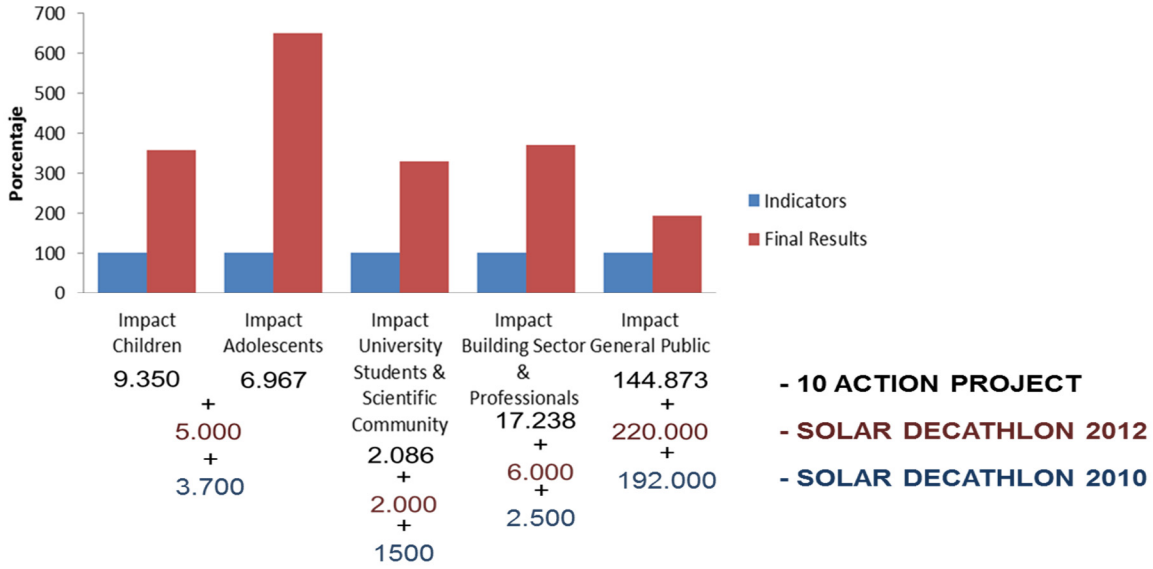


Figure 83: European citizens who visited or actively participated in activities.

In conclusion, despite the fact that many of the activities initially planned were no carried out due to known budgetary limitations, and despite the fact that many of the activities and events developed were perfectible, the final balance is very positive in terms of the project: The Competition has been organized with the scope and with many of the planned activities, all the objectives have been covered satisfactorily, it has been a success with the public, it has had a great media impact. All of the stakeholders have expressed their high degree of satisfaction with the results obtained.

All the activities foreseen in the signed Agreements have been covered, including all the activities for the closing of the project and the liquidation of the relations with the teams; the SDE 2010 and SDE 2012 Books (https://building-competition.org/publication) has been published and, courses, conferences, and multiple presentations have been given worldwide. We have tried to take advantage of the legacy of the SDE by laying the foundations for the scientific use of the material generated at the GESLAB Platform in

Montegancedo, with a special issue of the renowned scientific publication Energy & Buildings (www.sciencedirect.com/journal/energy-and-buildings/vol/83/suppl/C), or by collaborating in the organization of the SDE 2014 in France, or by encouraging the launch of new future competitions in Europe and the world.

In this sense the balance of the 10Action project (funded by EC through the Intelligent Energy Program) has been outstanding, and in it, the active collaboration of the Solar Decathlon 2010 and 2012 teams, the collaboration of the European Energy Agencies, and the European Commission itself have been essential.

The just over 2 million euros financed by the 10Action project has leveraged activities for children, teenagers, university students, professionals, and the general public in 12 European countries, giving much more impact to the Solar Decathlon Europe Competition. For the next editions, it would be important to have projects and initiatives similar to the 10Action to leverage the impact in Europe. However, these are projects that take 1 year to prepare and 3 years to develop, so it is difficult for the organizers of a single competition to promote them."

For the SDE 2019 competition, the organizers carried out significant infrastructure investments for the competition with landscaping, demolition works, utility development, road repairs and the construction of roads and sidewalks, building renovation, as well as the creation of a surface suitable for high-traffic freight traffic. We had to adapt to the Solar Decathlon system, so they provided the teams with a financial contribution tied to meeting uniform professional criteria. The implementation of the event and communications processes took place in accordance with the legal regulations, in accordance with the procurement procedure of the National Communications Office, with the participation of an external company, whose work was assisted by continuous coordination. In addition to the continuous professional contact and guidance with the teams, covering all disciplines, the SDE 2019 event was organized, which consisted of several sub-events and events.

The SDE 2019 organizers are convinced that the competing young talents have gained lifetime experience of professional and community skills, and the prototypes they built have given energy-efficient architectural solutions for thousands of people providing inspiration for environmentally conscious construction and renovation. They also believe that Solar Decathlon Europe 2019 has also enabled us to strengthen their country''s international reputation.

One of the lessons learned was that ÉMI started the preparation work after October 2014. After a long and massive preparation time the Ministry of Innovation and Technology recognized the need, the scope and the importance of this project and they acted rapidly, quickly and provided adequate funding and resources to ÉMI for the project, which allowed ÉMI for effective preparation for, and implementation of the competition. ÉMI had a very effective and dynamic core team suplemented by Hungarian and international expert teams who had solar decathlon experience.

5.9.4 Solar Decathlon China

The organizing teams of the competitions held in China in 2013 and 2018 make a very positive assessment of the successful editions organized.

Thus, the SDC 2013 competition reports an almost complete fulfillment of the proposed objectives:

- Train students and train future industry leaders: The SD competition has always attached importance to student participation. It took two years for the teams to prepare for the final. Each team set up an organizational structure according to the requirements of the competition and completed the phased tasks of the project, including fund-raising, scheme design, housing construction, etc.,

all of which were completed by the student-centered team. During the preparatory period, the organizing committee helped the teams to better understand the competition and the relates issues in China by holding training meetings, teleconferences, email exchanges and Yahoo groups. This competition gives college students a special opportunity to practice. By directly participating in world-class competitions and learning, they can understand the most cutting-edge application of new energy and energy-saving technology, and lay a foundation for becoming a global talent and industry leader in the future.

- Stimulate ideas and promote the merging of scientific research ideas: In this competition, all of the teams integrated the active and passive energy-saving design and technology, and adopted the latest energy-saving products. Many of them have reached the world''s leading level. With revolutionary technology and forward-looking creativity, they have demonstrated the modern residential example of paying equal attention to both the “visual effect“ and the “application effect“, which has triggered the construction, new energy, and energy conservation, not to mention the ‘thought spark’ of scientific research in related fields such as the reuse of resources.
- Boost the industry and accelerate the in-depth innovation in the field: During the competition, the solar energy houses of the teams successfully achieved self-sufficiency in energy and ran smoothly with zero failure connected to the external network. They made a lot of exploration into the integration of solar energy application technology and building technology, which has important practical significance for promoting the integration of solar energy and building and accelerating profound innovation in the field of solar energy application. The 19 participating dwellings not only fully met the needs of self-sufficiency, but they also met the requirements of the national grid after testing. It is the first example of zero energy consumption in a solar micro community in China, which is of great significance for the promotion and development of distributed energy.
- “Create a platform to promote multi-party interaction and cooperation”: The competition takes the event operation as the platform to promote the communications and cooperation among the governments, universities, business and non-profit organizations. According to preliminary statistics, there are more than 400 organizations supporting and subsidizing the team, including nearly 20 government departments and industrial organizations; more than 400 businesses sponsor, many of which are global top 500 busniesses.
- During the training and the final meetings, in order to better promote the exchange and interaction between all parties involved in the competition, the Organizing Committee organized several professional forums, exhibitions and other activities to discuss the current industry hot key issues, which were well received by all parties.“
- Promoting regional transformation and development: Datong, the host city, has carried out various kinds of exchange and cooperation activities with the help of the competition, which has expanded Datong''s international reputation and demonstrated to the world its good advantages and firm determination in developing the solar energy industry. It plays an important role in accelerating the transformation from a traditional coal-fired energy base to solar energy and other new energy bases, developing a complete solar energy industrial chain and building a new energy city. Through direct invitation and chamber of Commerce organizations, more than 100 businesses have come to negotiate with them on projects. During the period, 11 letters of intent for investment have been signed, with a total amount of RMB 11 billion. After the competition, 15 of the 20 participating houses stayed in Datong after negotiation between Datong City and the competition team. It is planned to build a green energy saving and solar energy application demonstration base integrating education and public display.

Educate the public and promote the concept of green energy conservation: Through the demonstration of solar energy residential real life, the competition improves people''s understanding of solar energy technology and energy-saving products, promotes the concept of green consumption, environmental protection and energy conservation, and promotes the development of regional strategic emerging industries. The smart Exhibition Center grid built jointly by the three sponsors of the competition has vividly displayed the real-time monitoring data of housing energy consumption to the public by means of large screen display and explanation.

Some of the lessons learned by organizers from SDC 2013 were:

- **Optimise the top design of the competition**: Since the SD competition has achieved great success around the world, it is the first time the original design has been held in China. However, there are many problems to think about as, for example, how to balance the competition time and the demand for opening and attracting visitors. As a project aimed at training future leaders and promoting industrial development, we need to optimise competition design gradually on the premise of ensuring the fairness and openness of the competition platform, to carry out the role of competition in education, industry, society and policy better.
- **Improve the professional level of organization**: The competition lasted two years from its inauguration. For the organizing committee team, the specific implementation work is a new challenge. Therefore, there is still a lot of room for improvement, especially in coordinating the relationship between various partners, improving the project plan and various subsequent plans, strengthening the interaction with the industry and institutions, and improving the effectiveness of publicity.
- **Strengthening urban interaction and cooperation**: The SD competition came to China and carried out its sponsorship in a new way of authorisation, cooperation between the organizer and the host city, which created a new operating mode of the competition. During the finals, Datong Municipal government departments and student volunteers were the main force of organizing the team, and their efforts are one of the keys to the success of the competition. In the future competition, the organizing committee should strengthen the interaction and cooperation with the city and play the host city''s position and role better.
- **Enhance the lasting influence of the competition**: Compared with the U.S. and European competitions held in the park, it is of great significance to retain the participating houses in the host city for the impact of the competition on the region. It can also inspire some thoughts on how to make SD China a truly influential global solar event from the perspective of organizational design and follow-up promotion.

Related to the SDC 2018 organizer's experience there was a successful achivement of the objectives. Through the successful holding of the competition, we can inject new formats into the urban development, provide high-quality cases for the development of related industries, provide practical opportunities for college students'' innovation and entrepreneurship, and provide a platform for science education for the public.

During the SDC 2018 competition, the park received a total of nearly 500,000 public visits. In addition to visiting the team''s houses and getting to know the latest housing products, technologies and designs, the public also had a good experience through various activities such as the academic forum, innovative dialogue, cultural exchange, popular science education, interesting interaction and so on.

In conclusion, this competition has brought together elites from more than 20 countries around the world to create a different style and distinctive solar houses which provide a model of high quality and low-carbon green life, so that every participant can feel the great power of innovation and technological progress, and experience the beautiful green life in the future.

This competition has come to an end, but our pursuit of a green life and green development will not stop there. In order to continue to promote the mission of building a green future entrusted to us by this era, we must unite and work together to pursue further new technologies, new ideas and new methods, strive to improve the sustainable development of human settlements, and promote the harmonious coexistence of humanity, science and technology and nature. For "advocating green life and promoting green development", we should cultivate the best talents and future leaders, promote the development and transformation of the most cutting-edge industries, cultivate the best public understanding environment, and jointly create a future that we all believe in; a more sustainable future.

5.9.5 Solar Decathlon Africa 2019

Most of the objectives proposed at the beginning of the competition following the signing of the MOU with the DOE have been achieved:

- Public funding was around 60% of total cost
- 4 to 1 leveraging by university teams: The teams received $55K from GEP and raised an average of $150K;
- Sponsors supported Solar Decathlon AFRICA because it had a significant influence, role, and impact on the marketplace.
- 300+ companies in SDA competition supported the teams and the organizers;
- The programme helped to develop a strong workforce;
- The programme taught the public about energy efficiency and renewable energy;
- The programme was an innovation and fresh avenue to job growth and future technologies implementation and deployment. So far, many innovative technologies have been developed by local companies.
- Success Stories – Business and Job Creation. Through this program, many start-ups and Small & Medium companies have benefited from the Solar Decathlon Africa and emerged with a looming potential for success: ECODOME, RHAMNA ASSOCIATION, SOLAR-UTION, INNOVATEL, ADRAR NOUH Cooperation, Novatirix, etc.

It's an award-winning competition, a hands-on science, technology, engineering, and mathematics (STEM) learning experience, and a workforce development program for African people. It was also one of the most ambitious and inspiring events in AFRICA. Solar Decathon AFRICA is all of this and more. Powering our sustainable future in many ways, the Solar Decathlon AFRICA is:

- An international competition that prepares more than 1,000 participating students for careers in clean energy and green buildings sectors on the African continent.
- A key programme to underpin the strategies of carbon-free energy systems in AFRICA.
- A proven training program that embraces an innovative method of teaching STEM.
- A demonstration of energy-efficient sustainable living that creates broader consumer understanding of how to save money at home with clean energy and energy efficiency solutions.
- A hugely popular public event that draws hundreds of thousands of visitors and gains the attention

It was a successful edition on all levels (figure 84).

Figure 84: SDA 2019 Solar village in Ben Guerir (Morocco)

There is no available specific information regarding competitions in Middle East and Latinamerica.

6. Evaluation of SD Competitions and Linked Events. Surveys and Key Performance Indicators for Assessing them.

6.1 About how to assess the impacts and performance of Solar Decathlon Competitions and linked events

In order to respond to the challenge of evaluating the objective and subjective impacts and performance of Solar Decathlon and associated events, both globally and for each of the 18 editions held around the world to date, a methodology based on five main areas has been designed.

Study of the **documentation** gathered and **in-depth knowledge** of the evolution of the rules and regulations, contests, strategies of the various organizing teams, and results obtained both from the point of view of the competition, as well as the events and activities directly or indirectly associated with Solar Decathlon competitions. The knowledge gained from the analysis of all the information gathered is reflected throughout the report.

- Preparation of **organization factsheets** by the organizing teams compiling the main objective data of each edition, from the defined objectives, strategies, budget, planning, risk management, solar village, competition, events, outreach, and main conclusions and lessons learned. The information included with these factsheets gathered in Annex 1 is described and analysed in section 5 about the organization and project management of university competitions.
- Conducting a **comprehensive global survey** in which, from a previous selection of qualifying questions, respondents were oriented about the different roles analyzed with the survey, such as **students, faculties and professors, professionals and industry, public and visitors, and organizers**. This survey has been complemented with another three surveys conducted in past years that show the real performance of the Solar Decathlon Competitions. All of these surveys are described and partially analysed in this section, and in section 7 «About Qualitative Assessment & Critical Analysis»
- The **identification of variables, indicators and key performance indicators** based on information from the Knowledge platform, Organization factsheets, Postcompetition Factsheets, and survey results, were defined and calculated to facilitate the **quantitative and qualitative** analysis (section 6).
- **Semi-structured interviews** were conducted with different stakeholders from different competitions. Some 70 interviews were conducted, distributed among decathletes from the SDE 2019 edition, faculties and professors (from SDE 2019 and others), professionals and companies (mostly from SDE2012), The knowledge gained from the analysis of all these interviews is incorporated throughout the report.

The most important interviews for the purposes of this report, have been conducted with the relevant people who created the Solar Decathlon Competition in the United States, those responsible for bringing the Competition to Europe, Africa, China, or Middle East, and those responsible for most of the organizing teams of the different competitions held around the world. The insights acquired from these interviews have served to enrich the analysis and to help identify the key drivers (section 8) and the main conclusions and lessons learned (section 9) from the perspective of their respective roles, all of which were important for the for the world-wide development of Solar Decathlon.

6.2 About the Surveys to Assess Solar Decathlon Competitions and Linked Events.

There have been many different surveys throughout the years and competitions, some of them focused on specific competitions (Solar Decathlon to assess US SD 2002, 2005, 2007 and 2009, or the survey SDE 2012) others with a worldwide scope (SDE 2014 or SD 2020 survey). Surveys have been conducted in Solar Decathlon with different approaches. They tackle the educational impact of the Solar Decathlon but not in the same depth. Table 10 brings together some of the surveys carried out for the purposes of this report, defining the scope, authors, target groups, number of participants, etc.

In Solar Decathlon USA Surveys the focus were homeownwers. For evaluation purposes, the audience was divided into the following three groups:

- "Visitor Homeowners": Homeowners who visited a Solar Decathlon. Their primary experience of the Solar Decathlon was a visit the Solar Decathlon village.
- "Aware Homeowners": Homeowners who were aware of the Solar Decathlon but had never visited one. They served as a second treatment group for estimating the impact of media and word-of-mouth, and also served as one of the comparison groups for the Visitor Homeowners.
- "Unaware Homeowners": Homeowners who had never heard of the Solar Decathlon. The Unaware Homeowners served as a comparison group for both Visitor and Aware Homeowners.
-

Competition	**Solar Decathlon USA carried out by a specialised company**		
Target groups	Homeowners, former Decathletes, non-Decathletes, former students		
Event time	2002,2005,2007,2009, 2011		
Total in survey	1 164 answers	Unaware homeowners	400
Visitor homeowners	200	Total former Decathletes	174
Aware homeowners	280	Total non-Decathletes, former students	110
Competition	**Solar Decathlon Europe 2012 carried out by the organizers**		
Target groups	SDE 2012 Teams and students.		
Event time	2012		
Total in survey	314 answers	Students	282
Professors	11	Others - Professionals	21
Competition	**Solar Decathlon Europe Worldwide 2014 Survey carried out by UPM for a workshop developed during the Competition SDE 2014**		
Target Groups	Present and past Decathletes, organizers and professors.		
Event Time	Worldwide survey		
Total in survey	236 answers		
Total Student	151 sent, 60 full answered	Total professors	85 sent, 39 full answered
Competition	**2020 Solar Decathlon Worldwide survey designed and carried out by UPM**		
Target groups	Past and present Decathletes, organizers, professors, citizens, institutions, professionals, and companies.		
Event Time	Worldwide survey		
Year	2020		
Total in survey	391 answers		

Table 10. Solar Decathlon Surveys

These Surveys (or a part of them) in which a specific educational approach was taken are described with the objective of reaching common overall conclusions. It is extremely important to conduct surveys / interviews on the Competitions so that, it is possible to have the feedback from the main stakeholders from

the different Competitions for a? overall analysis on the effectiveness of these events and to generate indicators that allow, in addition to assessing the impact of the Competition, improvements to be obtained to optimise the investment in a major event.

6.2.1 SD US 2012 Survey

The report «Impact Evaluation of the U.S. Department of Energy's Solar Decathlon Programs» (https://www.energy.gov/eere/analysis/downloads/impact-evaluation-us-department-energys-solar-decathlon-program) was submitted to the U.S. Department of Energy with the aim of evaluating the US editions from 2002 to 2011 and the main objectives of the Competition.

The survey also aimed to assess the contribution of SD in the United States and the role that the Competition played in the lives of post-Competition Decathletes. Furthermore, it was possible to improve the following editions because of the recommendations made by the participants of the first four editions.

The Solar Decathlon 2012 impact evaluation survey was carried out in three ways. Homeowner telephone, former Decathlete online questionnaire and non-Decathlete, former-student telephone questionnaires.

The survey focuses heavily on assessing the influence of Solar Decathlon competitions on users and homeowners. Some of these results are gathered in figures 85 and 86.

Figure 5: The Solar Decathlon gave me a better understanding of homes that use solar energy than I had before*

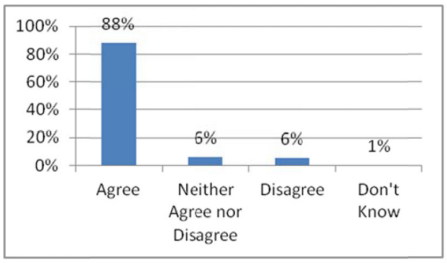
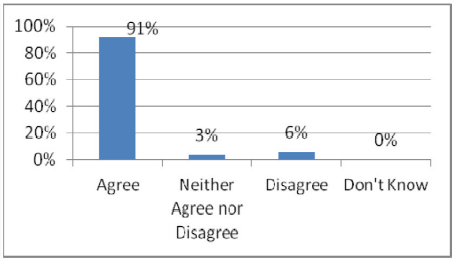


Figure 6: The Solar Decathlon helped me gain a better understanding of how a home can be made more energy efficient than I had before*



*Note: n for these charts = 198.

Figure 5: The Solar Decathlon gave me a better understanding of homes that use solar energy than I had before*

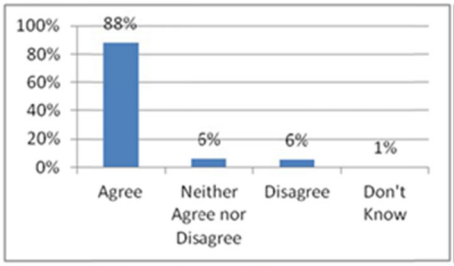
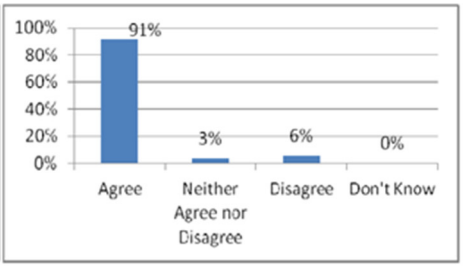
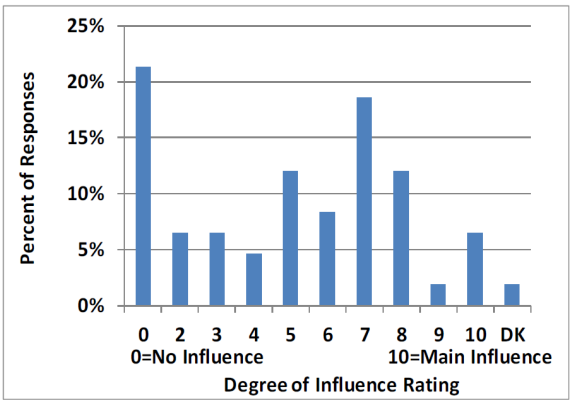


Figure 6: The Solar Decathlon helped me gain a better understanding of how a home can be made more energy efficient than I had before*



*Note: n for these charts = 198.

Figure 85: Left: Understanding of homes that use solar energy. Right: Understanding of energy effciency. https://www.energy.gov/sites/prod/files/2015/05/f22/solar_decathlon_impact_report2012.pdf



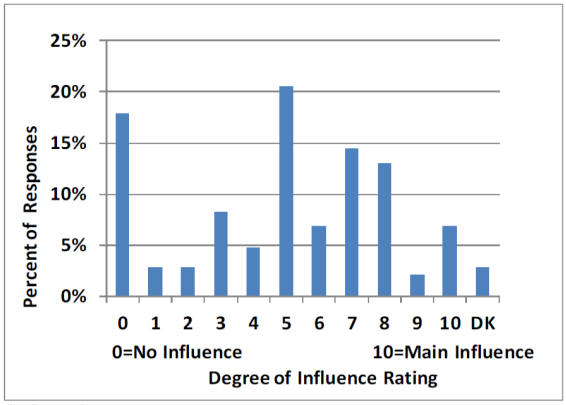


Figure 86: Left: Self reported degree of influence of SD on visitor home owners' and subsequent installations of energy-efficient appliances. Right: Self reported degree of influence of SD on visitor home owners' and subsequent installations of energy-efficient lighting.

The main outputs are suggestions and improvement for future editions of the SD, post-Competition feedback and the benefits gained from the Competition for students, professors, schools, cities, organizers, etc.

Some results related to the educational and professional skills aspects developed by the decathletes have been used in the analysis spread throughout the report, specially in content developed in section 7.1 and 7.2 of this report, about Impact related to Education in SD and the development of Professional skills

6.2.2 SDE12 Survey

The objective of this survey was to collate specific data from **Decathletes and teams** in order to draw up a general estimation of the perceived performance of the SDE 2012 Competition and to have statistical data on the teams and students participating in it (figure 87). In the SDE 2012 survey, the Decathletes who were competing, were asked questions to get an insight into the experience.

Simple questions related to number of participants, degree of study, gender information, qualification of professors, etc. were asked. The survey for the Decathletes is made up of an assessment of the participating students in relation to the Competition within the scope of rules, organization, communications, experience, etc.

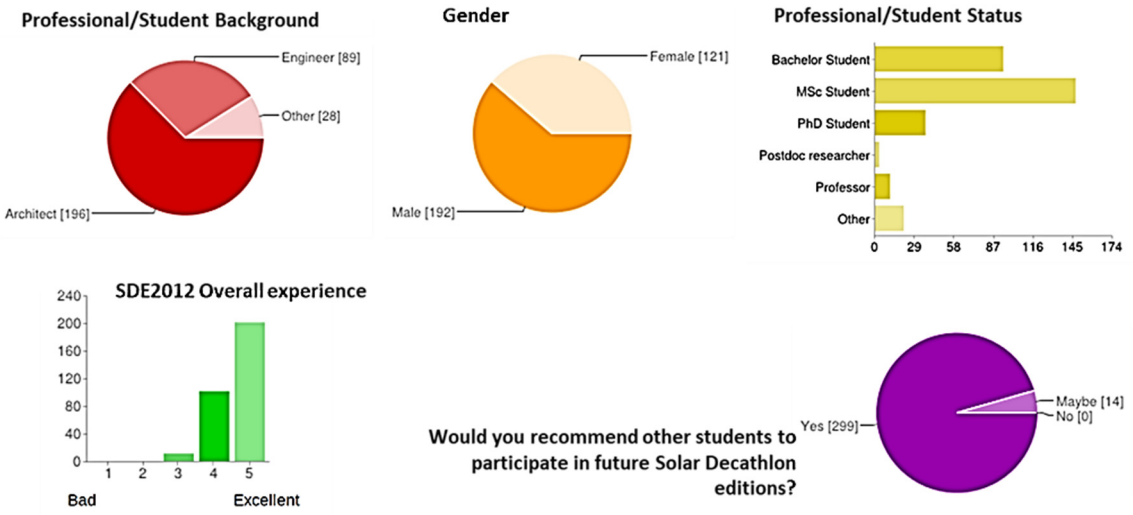


Figure 87: SDE 2012 Survey. Profile of the surveyors.

In the survey conducted for the 2012 competition, students and professors from all participating teams took part, **with a total of 313 respondents**. The majority were students of architecture and engineering, and most were Master and Bachelor, and to a lesser degree, PhD students.

Results related to the educational and professional skills aspects developed by the decathletes have been used in the analysis developed in Chapter 7 of this report.

6.2.3 SDE 2014 Worldwide Survey

The 2014 survey was oriented at **former SD students and professors worldwide** (figure 88). The main objective of SDE14 survey was to provide feedback on the experience of professors and students with the SD to be analysed and discussed at the Workshop on the Solar Decathlon Europe Educational and Research Approach in which how to share experiences from different universities in harnessing SDE to **make students aware of energy efficiency and the improvement in sustainable conditions in our buildings and cities** was discussed.

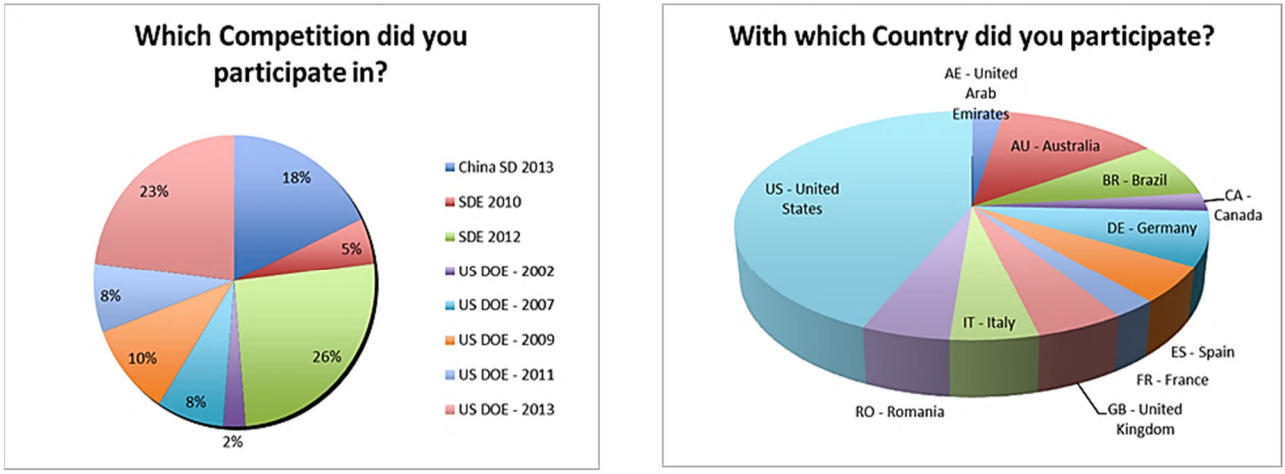


Figure 88: SDE 2014 Survey. Profile of the Professors Surveyors.

A general survey was sent to the Decathletes, organizers, and professors (figure 89), to learn about their experience, and to collate information on three different topics:

- Team launching & development: Institutional support, team members, organization, etc
- Educational approach: Strategic frame, specific courses, knowledge, and experience acquired, etc
- Research results: Strategic frames, PhDs. Theses, patents, innovation, etc

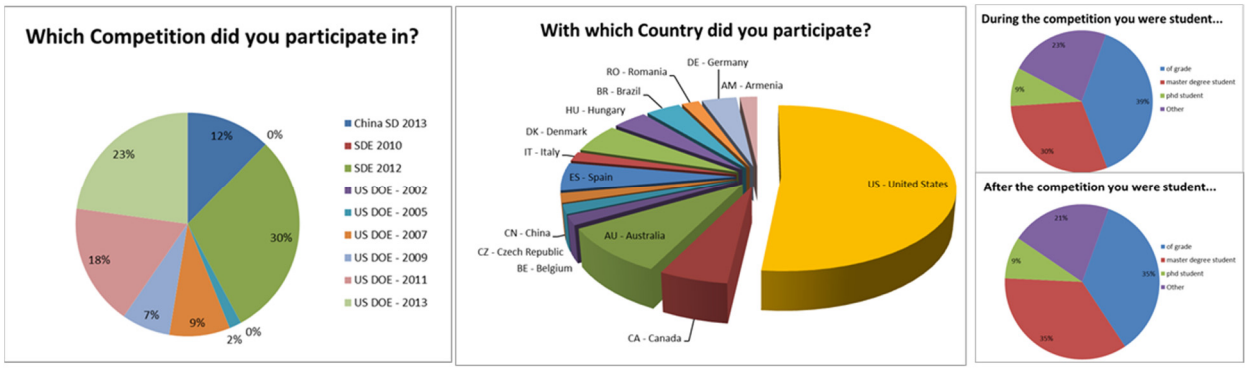


Figure 89: SDE 2014 Survey. Profile of the Students surveyors**.**

The survey carried out in 2014 was designed to be answered by two target groups: **students and professors**, with similar questions to allow for a comparative analysis. 151 students responded to the survey with just over half of them coming from the United States, contacted through the alumni association. 30% were former SDE 2012 decathletes. 39% were undergraduate students, 30% were Master''s Degree students, and 9% were PhD students. It can be seen that almost 5% of the total later became Master''s Degree students, most of them having been undergraduates.

The survey of academics was answered by 85 professors, mostly from the United States, and with a majority of respondents participating in the SDE 2012 and in US SD 2013 competitions.

The focus of this survey was a little different from the North American survey and focused more on **education and capabilities gained** through the SD Competition. It was to establish the impact of SD during the Competition in a context of skills and knowledge developed by the students throughout the process.

The options that had the most responses were communications, public relations, project management, scheduling, productivity, teamwork, construction, and leadership. Students also said that the main knowledge developed during their participation in the Competition were: architecture, engineering, integrated design, construction, and materials. The vast majority do not regret having participated and would probably participate in a following edition. Below are the graphs with the information generated by the survey in an educational context: The results of the surveys show the importance of the opinion of former Decathletes to continue in the following editions and how these results can influence the development and organization of the Competition. In the next chapter 7 of this report results and insights are analysed in depth.

The results related to the educational and professional skills aspects developed by the decathletes have been used in the analysis developed in sections 7.1 and 7.2 of this report, about Impact related to Education in SD and Professional skills development.

6.2.4 2020 Solar Decathlon Worldwide Survey.

The main objective of the SD 2020 survey is to reach people who have had some **direct relationship with any of the editions of Solar Decathlon worldwide** to date, in order to gather relevant information on their feedback, perceptions, experiences, etc.

The goal is to assess the impact of the Solar Decathlon in very different topics, education and training among others, to create a plan of what can be done to improve future editions.
The survey is aimed at people who have previously participated in an edition of SD, either as a student, or as a professor, institutions, organizers, companies/professionals in the field, or citizens. It was first launched on a preliminary basis in the SDE 2019 edition in Szentendre, Hungary, and it has been developed for almost a year.

The questionnaire was available on the Internet and it was spread through social media all around the world. There were several types of questions: multiple choice, yes/no, open questions, assess and select options. The survey is divided into three parts. The first one focuses on general questions, being equal for everyone. The answers allow the user to make a classification from an overview. The second part is the most extensive and is aimed at each stakeholder group. There are five target groups: students, institutions and professors, organizers, industry and professionals, and citizens. In this part, questions are aimed at finding out what was developed and used in the Competition. The last part includes open questions to establish the opinion of users and their suggestions about what could be implemented to improve the Competition.

The main output of this survey is to use the answers to **learn about the impact of Solar Decathlon** on many different topics and about suggested actions to improve future editions so that the event will be used in the best way from an economic, technological, and educational and awareness standpoints.

As regards the survey conducted in 2020, 391 responses were gathered among students, institutions and professors, organizations, professionals, companies and citizens (figure 90). Throughout this report, the relevant results of the surveys and interviews carried out will be presented. In general terms, the level of satisfaction with the experience is very high.

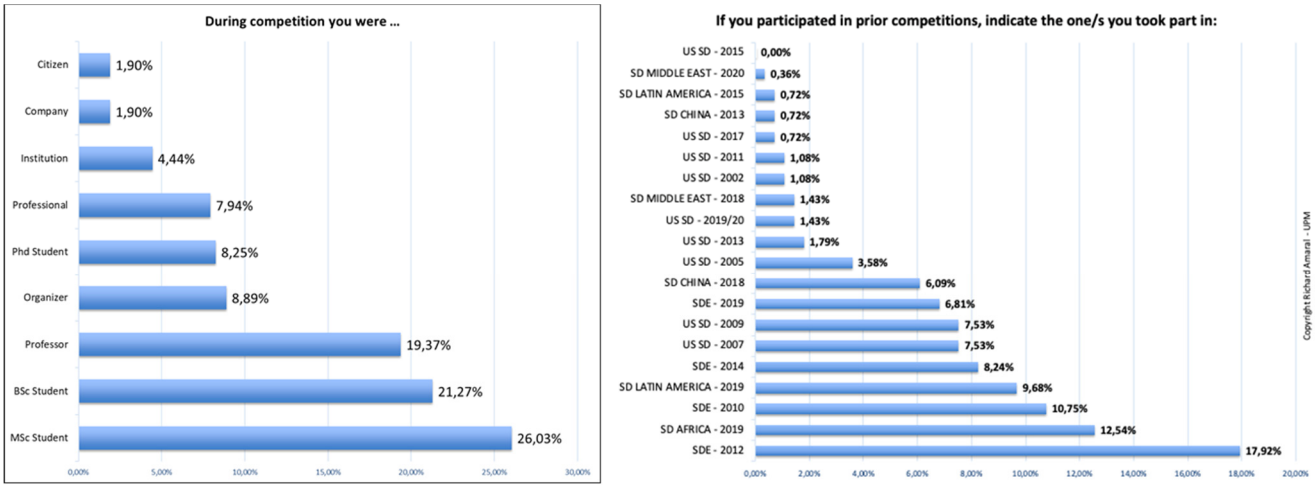


Figure 90: SDE 2020 Survey. Profile of the Surveyors.

In the 2020 SD worldwide survey 87% of the survey respondents would participate again, and 97% would recommend taking part in the Solar Decathlon. Most of the answers are from the latest competitions, participants from all the competitions the world over answered the survey 55.55% of the answers came from students, (26% MSc students, 21.27% BSc students, and 8.25% PhD Students) 19.37% from professors, 7.94% from professionals and 8.89% from the organizers. Other respondents came from Institutions, companies and citizens.

All of survey respondents considered both the Solar Decathlon and the overall experience positive, and when asked to choose the reason they are satisfied from a list of Items, 35% answered “all of them“, followed by 29.75% “ Innovation and knowledge generation“. When asked if it were possible, they would like to compete again, 87% answered yes, and if they would recommend taking part to others, 97% answered yes (figure 91).

Results from this worldwide survey have been spread throughout the report and analysed in many different chapters. The analysis carried out in chapter 7 about Qualitative Assessment & Critical Analysis (with five different approaches) must be highlighted. Some of these results have been also employed as variables from which some indicators and Key Performance Indicators have been calculated. They are described further in this chapter 6.

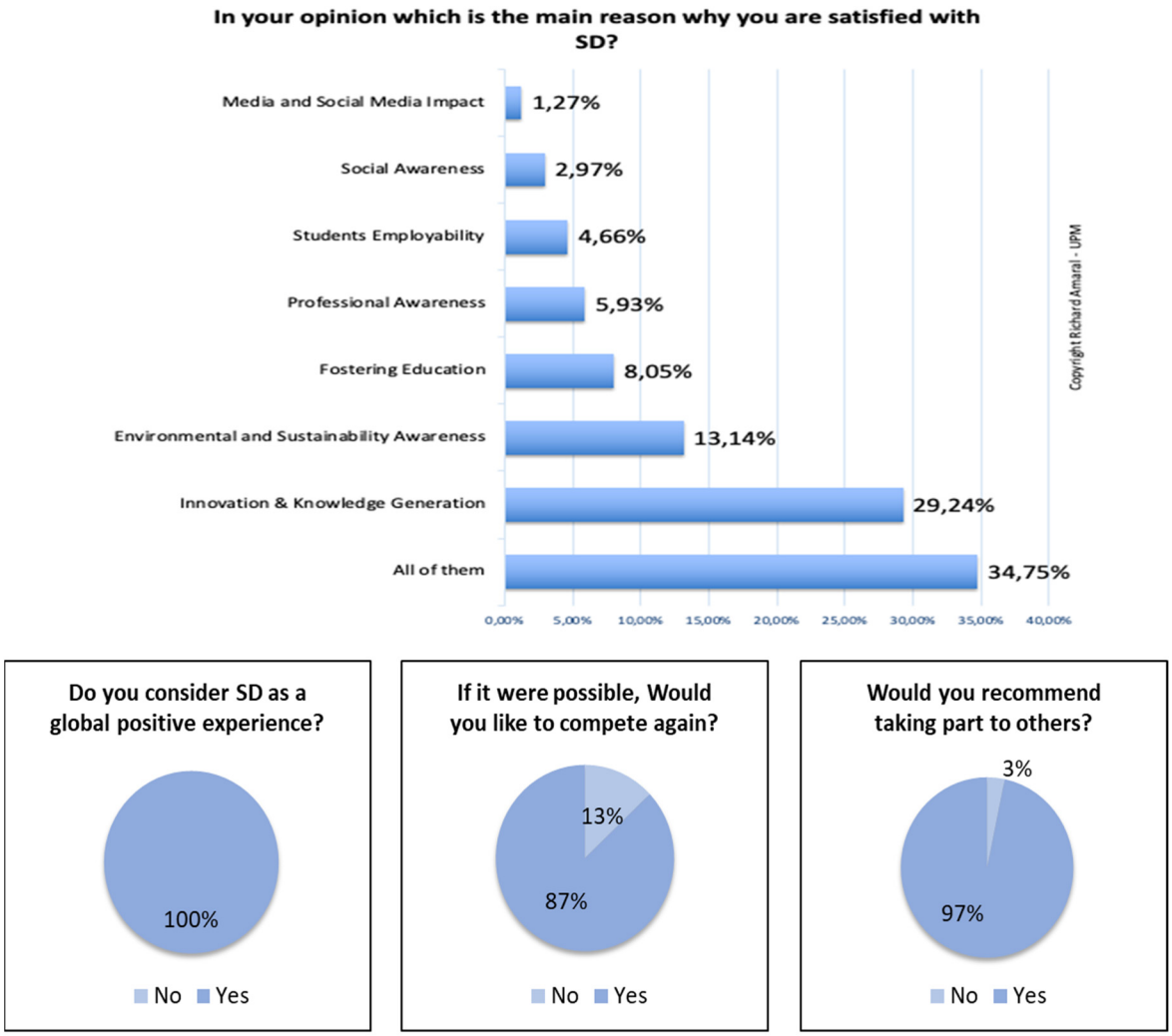


Figure 91: SDE 2020 Survey. Satisfaction of the surveyors

6.3 Semi-Structured Interviews to Enrich Survey Analysis

The output from the surveys and interviews are the basis for establishing how Solar Decathlon has impacted on students, professors, organizers, citizens, professionals, etc. Semi-structured interviews have been carried out with the main objective of **obtaining in-depth insights** and suggestions for improvements and feedback from the Competitions held.

Semi-structured interviews were conducted with different stakeholders from different competitions. Each of the interviews were subject to prior planning in which the objective pursued was defined, the objective and subjective information desired, and a set of questions that should be asked was elaborated, with a hierarchy according to the objective and priority information. However, this rigid framework was absolutely open during the interview, in whicha fluid and spontaneous conversation with the interviewee prevailed. In general, after sharing the objective of the interview, the conversation flowed flexibly, interspersing important questions throughout the conversation, but leaving the interviewee free to emphasise what he/she considered most significant. Many of the questions were very open-ended, asking for their opinion on specific topics such as “What do you consider to be the key drivers for a successful SD competition? or more general ones, such as “What would you suggest to improve the leveraging of SD’’s educational potential?

Although some of the interviews were conducted by the professors, the co-authors of this report, the vast majority were conducted by report co-author Richard Amaral, PhD candidate, and, in the case of SDME 2018, by PhD candidate Susanne Hendel. Interviews conducted to SD professors and faculties were coordinated by Richard Amaral (Europe) and Joseph Simon (US). The average lengths of the interviews with decathletes and professors was about 30'' (some up to 45''), while the lengths of the interviews conducted with companies and professionals, and those conducted with the various organizers of the competitions around the world, was about 60'' on average.

In total, more than 130 very selectively identified individuals have contributed with their personal experiences, insights to enrich surveys results and highligning key drivers and lessons learned. The different types of interviews carried out were:

SDME 2018 survey - interviews (during Solar Decathlon Middle East Competition) carried out by Susanne Hendel PhD candidate (Wuppertal University). Sample students and professors were from 12 different teams.

The objective of these survey-interviews was to obtain the opinion of the teams regarding their participation, development and learning in the Competition (figure 92). 80% of the participating teams were interviewed and the interview was divided into three parts. One of general questions, another of documentation and scientific relevance and finally the concept of the Competition.

The SDME 2018 Survey is very didactic, and it was designed for teams to score the questions asked. Among the questions, the teams had to rate the challenges of the Competition, what could be done to improve the rules, the contests, the organization of the event, the visitors, about the professionals, about the houses and everything involved in them.

It allowed the great challenges and problems faced by the teams to the evaluated, suggestions for improvements in future events, and the post Competition in the life of the Decathletes.

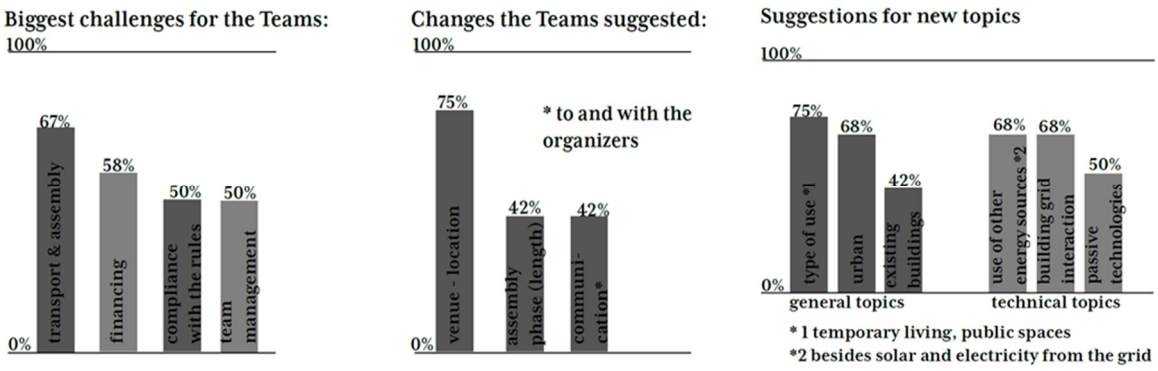


Figure 92: Extracted from Survey evaluation Dubai 2018 Report by Susanne Hendel

SDE 2019 interviews with students and faculty advisors (during Solar Decathlon Europe 2019 Competition held in Szentendre) carried out by Richard Amaral PhD candidate (Universidad Politécnica de Madrid). Students and professors from 10 different teams were interviewed.

The objective is to benefit from the Solar Decathlon Europe 2019 to obtain information on the setup of the event. A student and a professor from each participating team were personally interviewed during the Competition to determine the quality of the event and what could be done to improve future European editions.

The interviews were divided into seven parts: general questions, specific questions about participation, about the university, about the Competition, specific about the event and organization, market, and finally open questions.
The main objective of this survey was to collate the information necessary to generate improvements in future European editions. The results will be included in the Richard Amaral PhD Thesis. Some of the information has feeded the Variables, Indicators, and Key Performance Indicators (KPIs) included in this report in section 6.4.SDE 2020 interviews to faculty advisors and professors from SD US and SDE competitions.

A qualitative analysis regarding the educational balance of the Solar Decathlon Europe and the post-Competition use of the Solar Decathlon Europe is carried out via questionnaires sent to faculty advisors, mostly from American and European Competitions, coordinated by PhD student Richard Amaral and NREL's researcher Joseph Simon. 70 professors and Faculties filled in the questionnaries.

The objective was to obtain direct feedback from faculty advisors and professors mainly about the post Competition use of the houses and the key drivers to improve future Competitions. The questions were related to these topics:

- SD Participation
- Post competition & Living Labs
- Leverage opportunities
- Key drivers for sucessful SD competitions and Events
- Key drivers for sucessful Post competitions and Living Labs
- Recommendations
- Suggestions

These interviews resulted in deeper insights to enrich the analysis of the surveys and to determine the present use of the houses, how many of them are still in use, and to obtain proposals on the key drivers to prioritise action in the development of future Competitions.

6.3.1 SDE 2010 and SDE 2012 Industry and professionals' interviews

The objective of these interviews was to obtain direct feedback from a different point of view than just the academic. In February 2020, direct semi-structured interviews - conversations with the sponsors and professionals involved in the Solar Decathlon Europe 2010 and Solar Decathlon 2012 took place, conducted by UPM's professor Beatriz Arranz. The questions were directly related to the objectives of this report.

- 15 different interviews were conducted with complementary questions as follows:
- SD Company Participation
- Professional training of decathletes
- Leverage opportunities
- Key drivers for sucessful SD competitions and Events
- Recommendations
- Suggestions

The general output was significantly positive. However, the general opinion that **the impact of SDE in the market could have been much greater was remarkable**.

6.3.2 SD2014 Competition organizers interviews

With the first preliminary conclusions drawn from all of the tasks carried out (analysis of gathered information, surveys, indicators, interviews, etc.) we scheduled a final set of semi-structured interviews with people who have contributed significantly to the evolution of Solar Decathlon from relevant organizational positions. These interviews have been carried out to enrich the analysis of the rest of the results of the surveys and indicators and KPIs, and specifically to know their particular vision, from their personal experience. What are the main key drivers for the organization of successful competitions and their related events? What are the main lessons learned that they would highlight from their participation in the Solar Decathlon editions they attended?

14 interviews conducted by Prof., Sergio Vega, Beatriz Arranz, and PhD candiadate Richard Amaral, with people who have been considered relevant from an operational point of view to learn about organizational aspects and their impact on the competitions. In total, one-hour open interviews have been conducted with 14 relevant organizers of SD Competitions, with a special representation of American and European editions.

The organizers interviewed have provided knowledge about the organization of the competitions they led, and their perspective has helped to assess the experience gathered among all of them and to point out which have been the main key drivers for successful Solar Decathlon competitions, which are analyzed in section 8 of this report, and about the main conclusions and lessons learned, which are summarised in section 9 of this report.

6.4 Variables, Indicators, and Key Performance Indicators (KPIs) to Assess the Solar Decathlon Competitions and Linked Events.

To assess the real performance of the Solar Decathlon Competitions and linked events around the world and to develop a **cross-analysis of the information**, it was considered that **a set of variables, indicators, and key performance indicators** had to be defined as detailed in Annex 74.

Indicators and KPIs enable the measurement and quantification of diverse aspects of the competitions' performance and facilitates a cross-analysis of the information, which in turn, generates new indicators that enrich the analysis with insights that would otherwise go unnoticed.

This information will be used to create a **database to be given to the organizers of future SD competitions**, that will allow the cross-analysis and will define the relationship between strategies and performance gained, both measuring whether the actions taken are fulfilling their objectives, in improving the performance of future editions. This is the basis of continuous quality improvement (part of Quaility Management). It is difficult to analyze and improve what cannot be measured, and to measure something objectively, in this case the performance of Solar Decathlon competitions and their associated events, indicators and KPIs, that can be measured over time, are required.

It is also important to note that the Set of Indicators and KPIs initially designed (as an ideal) could not be implemented due to the absence of the necessary information for its completion. In this report we have only considered those indicators that we have been able to collect from enough competitions held. We hope that for future editions, all the data necessary to measure the different aspects of performance with indicators will be completed. Annex 2 includes the full set of indicators with their definitions and values.

Table 11 gathers the complete set of variables to assess SD organizing performance, indicators and Key Performance Indicators elaborated, and the information that could be gathered from all the competitions, identifying with colors (in the blue right-hand rectangle), the missing information.

INDICATORS AND KPI's TO ASSESS SOLAR DECATHLON ORGANIZING PERFORMANCE

AREA OF PERFORMANCE		VARIABLES		INDICATORS AND KPI'S		OBJECTIVES: DECRIPTION. What for: evaluation, diagnosis, comparison, follow-up? What do you measure?	METHOD TO GATHER THE INFORMATION
AREA	SUBAREA	VARIABLE 1	VARIABLE 2	KEY INDICATORS	KPIs		
ORGANIZING PERFORMANCE							
	INITIAL BUDGET	INITIAL BUDGET FORESEEN		INITIAL BUDGET FORESEEN		Total budget foreseen at the very beginning	Organizing Factsheet
	INITIAL BUDGET	INITIAL BUDGET FORESEEN	FINAL TOTAL BUDGET USED	% FINAL/INITIAL BUDGET		Total % budget used/foreseen at the very beginning	Calculation
	BUDGET&FUNDING	PUBLIC INVESTMENT		PUBLIC INVESTMENT		Total funding from public bodies	Organizing Factsheet
	BUDGET&FUNDING	PUBLIC INVESTMENT	TOTAL BUDGET USED		% PUBLIC EFFORT/TOTAL BUDGET USED	Total % effort of funding from public bodies	Calculation
		SPONSORSHIP FUNDING		SPONSORSHIP FUNDING		Total funding from companies in cash & in kind	Organizing Factsheet
		SPONSORSHIP FUNDING	TOTAL BUDGET USED		% PUBLIC EFFORT/TOTAL BUDGET USED	Total % effort of funding from public bodies	Calculation
		RATE OF RETURN ON SPONSORING THE TEAMS		AVERAGERATE RATE OF RETURN ON SPONSORING THE TEAMS/0,8		Subjective Rate of profitablelity in sponsoring the teams	Surveys for Industry&Professionals
		RATE OF RETURN ON SPONSORING THE ORGANIZATION		AVERAGERATE RATE OF RETURN ON SPONSORING THE ORG./0,8		Subjective Rate of profitablelity in sponsoring the organization	Surveys for Industry&Professionals
		DESIRE TO SPONSOR SD ACTIVITES		% DESIRE TO SPONSOR SD ACTIVITES		Subjective Rate of desire to sponsor SD activities	Surveys for Industry&Professionals
	BUDGET BREAKDOWN	BUDGET SPENT ON TEAM COSTS		BUDGET SPENT ON TEAM COSTS		Total budget spent on Organization Team Expenditure	Organizing Factsheet
		BUDGET SPENT ON TEAM COSTS	TOTAL BUDGET USED	% BUDGET SPENT ON TEAMS/TOTAL		% Budget spent on Organization Team Expenditure/Total used	Calculation
		BUDGET SPENT ON COMPETITION COSTS		BUDGET SPENT ON COMPETITION COSTS		Total budget spent on Competition Team Expenditure	Organizing Factsheet
		BUDGET SPENT ON COMPETITION COSTS	TOTAL BUDGET USED		% BUDGET SPENT ON COMPETITION/TOTAL	% Budget spent on Competition Expenditure/Total used	Calculation
		BUDGET SPENT ON INFRASTRUCTURE COSTS		BUDGET SPENT ON INFRAST. COSTS		Total budget spent on Infrastructure Solar Villa Expenditure	Organizing Factsheet
		BUDGET SPENT ON INFRAST. COSTS	TOTAL BUDGET USED	% BUDGET SPENT ON INFRAST/TOTAL		% Budget spent on Infrastructure Solar Villa Expenditure/Total used	Calculation
		BUDGET SPENT ON EVENT&OUTREACH COSTS		BUDGET SPENT ON EVENT&OUTREACH COSTS		Total budget spent on linked event & outreach Team Expenditure	Organizing Factsheet
		BUDGET SPENT ON EVENT&OUTREACH COSTS	TOTAL BUDGET USED		% BUDGET SPENT ON EVENT&OUTREACH/TOTAL	% Budget spent on linked event & outreach Expenditure/Total used	Calculation
	LENGTH OF EVENT	LENGTH OF SD COMPETITION AS A WHOLE		LENGTH OF SD COMPETITION AS A WHOLE		Length of SD Competition as a whole (from start to end milestones)	Organizing Factsheet
		LENGTH FROM START TO VILLA SOLAR		LENGTH FROM START TO COMPETITION		Total length from start to Villa Solar (first truck)	Organizing Factsheet
		LENGTH FROM TEAMS SELECT. TO COMPETITION		LENGTH FROM TEAMS SELECT. TO COMPETITION		Total length from Teams selection to Villa Solar (first truck)	Organizing Factsheet
		LENGTH IN THE SOLAR VILLA		LENGTH IN THE SOLAR VILLA		Total length in Villa Solar (assembly+competition+dissasembly)	Organizing Factsheet
		LENGTH OF ASSEMBLY PROCESS		LENGTH OF ASSEMBLY PROCESS		Total length of assembly process in Villa Solar (from first truck)	Organizing Factsheet
		LENGTH OF DISASSEMBLY PROCESS		LENGTH OF DISASSEMBLY PROCESS		Total length of disassembly process in Villa Solar (until last truck)	Organizing Factsheet
		LENGTH FROM VILLA SOLAR TO END		LENGTH FROM VILLA SOLAR TO END		Total length from Villa Solar (last truck) to end of SD Edition	Organizing Factsheet
		DAYS FOR THE EVENT/COMPETITION		LENGTH OF EVENT		Total length of Event+Competition	Organizing Factsheet
		TOTAL BUDGET USED	DAYS FOR THE EVENT/COMPETITION		BUDGET PER DAYS LENGTH SD	Dedicated Budget per lenth of Event+Competition	Calculation
	PUBLIC DAYS	DAYS WITH OPEN VISITS		DAYS OPEN VISITS		Nº Days open to public & professionals (D or 0,5 D)	Organizing Factsheet
		TOTAL BUDGET USED	DAYS WITH OPEN VISITS		BUDGET PER DAYS OF OPEN VISITS	Dedicated Budget per days of open visits	Calculation
	ORGANIZING TEAM	NUMBER OF CORE ORG. TEAM		NUMBER OF CORE ORG. TEAM		Number of core organizing team	Organizing Factsheet
		NUMBER OF ORG. TEAM IN COMPETITION		NUMBER OF ORG. TEAM IN COMPETITION		Number of organizing team during Competition	Organizing Factsheet
		NUMBER OF VOLUNTEERS		NUMBER OF VOLUNTEERS		Number of volunteers during Competition	Organizing Factsheet
	SPONSORSHIP	COMPANIES FUNDING IN CASH		COMPANIES FUNDING IN CASH		Nº of companies funding in cash	Organizing Factsheet
		COMPANIES FUNDING IN KIND		COMPANIES FUNDING IN KIND		Nº of companies funding in kind	Organizing Factsheet
	EFFECTIVENESS IN OBJECTIVE	RATE OF EFFECTIVENESS IN OBJECTIVES		AVERAGE RATE OF EFFECTIVENESS IN OBJECTIVES		Subjective Rate of effectiveness in fulfilling the objectives	Surveys for Organizers
		RATE OF PROFESSIONAL ORGANIZATION		AVERAGE RATE OF PROFESSIONAL ORGANIZATION		Subjective Rate of professional organization	Surveys for Organizers
		RATE "ON SCHEDULE" TASK PERFORMANCE		AVERAGE RATE "ON SCHEDULE" TASK PERFORMANCE		Subjective Rate of "on schedule" tasks performance	Surveys for Organizers
	TEAMS	APPLICANT TEAMS		APPLICANT TEAMS		Nº of applicants teams	Organizing Factsheet
		APPLICANT TEAMS	PARTICIPATING TEAMS		INDEX APPLICANT/PARTICIPATING TEAMS	Index of applying teams / participating teams	Calculation
		UNIVERSITIES INVOLVED		UNIVERSITIES INVOLVED		Nº Universities of participating teams	Organizing Factsheet
		UNIVERSITIES INVOLVED	PARTICIPATING TEAMS		INDEX UNIVERSITIES/PARTICIPATING TEAMS	Index of Universities/ participating teams	Calculation
	COUNTRIES	COUNTRIES INVOLVED		COUNTRIES INVOLVED		Nº Countries of participating teams	Organizing Factsheet
		COUNTRIES INVOLVED	PARTICIPATING TEAMS		INDEX COUNTRIES/PARTICIPATING TEAMS	Index of countries involved / participating teams	Calculation
		CONTINENTS INVOLVED		CONTINENTS INVOLVED		Nº Continents of participating teams involved	Organizing Factsheet
	DAYS OF COMPETITION	DAYS OF SCORING COMPETITION		DAYS OF SCORING COMPETITION		Nº Days with scoring Competition	Organizing Factsheet
	VILLA SOLAR	TOTAL AREA OF THE SOLAR VILLA		TOTAL AREA OF THE SOLAR VILLA		Total Area of the Villa Solar (competitcn + organization+event)	Organizing Factsheet
		ESTIMATED AREA OF SOLAR VILLA CENTRE		ESTIMATED AREA OF SOLAR VILLA CENTRE		Total Area of the Villa Solar Centre (only competiton)	Organizing Factsheet
		ESTIMATED AREA FOR EVENT&ACTIVITIES		ESTIMATED AREA FOR EVENT&ACTIVITIES		Total Area of the Villa Solar (organization+activities)	Organizing Factsheet
		ESTIMATED AREA FOR PARKING LOTS		ESTIMATED AREA FOR PARKING LOTS		Total Area of dedicated parking lots	Organizing Factsheet
		SUBWAY (METRO) ACCESS NEARBY (0 - 3)		SUBWAY (METRO) ACCESS NEARBY (0 - 3)		Did the Villa Solar have subway access nearby? (0 no, 1 > 20', 2 >15', 3<15')	Organizing Factsheet
		PUBLIC TRANSPORT NERARBY (0 - 3)		PUBLIC TRANSPORT NERARBY (0 - 3)		Did the Villa Solar have public transport nearby? (0 no, 1 > 20', 2 >15', 3<15')	Organizing Factsheet

IEA EBC Annex 74 "Competition & Living Lab Platform"
Workpackage B: Competition & Living Labs

INDICATORS AND KPI's TO ASSESS SOLAR DECATHLON ORGANIZING PERFORMANCE

SOLAR DECATHLON EDITIONS																		
GENERAL ANSWERS	US SD 2002	US SD 2005	US SD 2007	US SD 2009	US SD 2011	US SD 2013	US SD 2015	US SD 2017	SDE 2010	SDE 2012	SDE 2014	SDE 2019	SD CHINA 2013	SD CHINA 2018	SD ME 2018	SD LA 2015	SD LA 2019	SD AFRICA 2019
-									10.000.000 €	8.500.000 €		6.000.000 €						
-									87,70%	76,26%		103,43%						
-			$6.500.000	$8.400.000	$9.000.000	$6.000.000	$5.500.000	$3.000.000	7.446.639 €	5.300.000 €								
-			100%	100%	100%	100%	100%	41%	84,92%	81,76%								
-								$4.200.000	1.322.883	1.182.176 €								
-								59%	15,08%	18,24%								
-																		
-																		
-																		
-			$1.700.000	$1.700.000	$2.400.00	$1.100.000	$1.500.00	$1.500.000	1.018.106 €	1.538.691 €								
-			26%	20%	27%	18%	27%	50%	11.61%	23,74%								
-									1.938.174 €	1.831.764 €								
-									22,10%	28,25%								
-								$780.000	1.921.267 €	2.444.459 €								
-								19%	21,90%	37,71%								
-									555.906 €	667.263 €								
-									6,34%	10,29%								
-	913 days		660 days	913 days	913 days	913 days	913 days	730 days	913 days	1260 days		912 days	914 days					1047 days
-	913 days		600 days	913 days	913 days	913 days	913 days	730 days	610 days	566 days		822 days	810 days					601 days
-	876 days		540 days	876 days	876 days	876 days	876 days	730 days	479 days	435 days		435 days	415 days					443 days
-	10 days		11 days	10 days	10 days	10 days	10 days	10 days	38 days	84 days		110 days	35 days					38 days
-	7 days		6 days	7 days	7 days	7 days	7 days	9 days	10 days	13 days	10 days	14 days	15 days					23 days
-	5 days		3 days	5 days	5 days	5 days	5 days	5 days	5 days	14 days	5 days	14 days	5 days					No disassembly
-	935 days		620 days	935 days	935 days	935 days	935 days	754 days	150 days	450 days		30 days	103 days					
-	17 days		17 days	17 days	17 days	17 days	17 days	19 days	11 days	17 days	8 days	15 days	12 days					15 days
-			$382.352,95 per day	$494.117,65 per day	$529.411,77 per day	$352.941,18 per day	$323.529,41 per day	$378.947,37 per day	797.224,72€ per day	381.304,47€ per day		413.733,33€ per day						
-	7 days		11 days	10 days	10 days	10 days	10 days	10 days	21 days	21 days (17 visit houses)	19 days (22 visit houses)	75 days	2 days					15 days
-			590.909,10 per days	$840.000,00 per day	$900.000 per day	$600.000 per day	$550.000 per day	$720.000 per day	417.593,90€ per day	308.675,05€ per day		82.746,66 € per day						
-	3 people		6 people	5 people	3 people	3 people	3 people	3 people	25	30	30	20						< 25
-	15 people		15 people	8 people	15 people	15 people	15 people	15 people	60 to 100	60 to 100	60 to 100	250						50 to 80
-	not available		200 people	not available	not available	not available	not available	not available	243	400	400	100	450 people					<100
-	5 companies		3 companies	6 companies	5 companies	5 companies	3 companies	3 companies	5 companies	5 companies		1 company						15 companies
-			not available	11 companies	33 companies	15 companies	30 companies	5 companies	23 companies	50 companies		18 companies						15 companies
-	14 teams		30 teams						22 teams	33 teams	41 teams	16 teams						22 teams
-	1		1,5						1,29	1,74	2,05	1,6						1,22
-	14 universities		20 universities	24 universities	30 universities	30 universities	30 universities	20 universities	13 universities	30 universities	31 universities	44 universities	35 universities					54 universities
-	1		1	1,2	1,57	1,57	1,88	1,82	0,76	1,58	2,05	4,4	1,59					3
-	1 country		5 countries	3 countries	6 countries	6 countries	6 countries	3 countries	7 countries	15 countries	20 countries	16 countries	13 countries					20 countries
-	0,071		0,25	0,15	0,31	0,31	0,38	0,15	0,41	0,79	1	1,6	0,59					1,11
-	1 continent		2 continents	2 continents	3 continents	3 continents	3 continents	2 continents	3 continents	4 continents	3 continents	5 continents	3 continents					4 continents
-	6 days		6 days		7 days	8 days	8 days	7 days	10 days	10 days	10 days							15 days
-									166.400 m2	52.900 m2	not known	10.000 m2	205.000 m2					52.900 m2
-									32.000 m2	19.200 m2	not known	1.000 m2	132.000 m2					2.000 m2
-	48.000 m2			33.700 m2	33.700 m2	33.700 m2	33.700 m2	33.700 m2	38,400 m2	33.700 m2	not known	1.000 m2	73.000 m2					5.000 m2
-	0			6.000	6.000	6.000	6.000	6.000	1.000 m2	6.000 m2	not known	2.000 m2						6.000 m2
-	1		1	1	1	1	1	1	3	3	not known	0						No
-	1		1	1	1	1	1	1	3	3	1	2	1					1

Table 11: Key Performance Indicators

The KPI''s development process consisted of preparing a table in a factsheet format where all the information on variables collected, indicators generated, and key performance indicators defined were collected, determined, calculated, and could be compared.

The table is organized in two large vertical packages in red and blue rectangles, a detailed in the tables above. The red box corresponds to the definition of the different variables, indicators and KPIs, with their calculation formulas, conceptual definitions and data origin.

The blue box corresponds to the calculation of the indicators and KPIs for each of the competitions held in the world, and which correspond to each of the columns. These columns show the absence of data for 3 competitions, and that from many other competitions, much of the information necessary for their calculation is not available.

The table, by rows, is organized in the four major areas of performance to be analyzed, and in particular: Overall SD Performance, Organizing Performance, Competition and Teams Performance and Outreach Performance. Within these four groups, the information was divided into subareas, which made it easier to insert all the variables created.

In the **Overall SD Performance group**, we considered themes related to the competition in a general scope, so the sub-areas created were about budget, teams, SD impacts, recommendation to participate, impact of SD events, peoples' awareness and improvement of skills (Table 12). All of them in a general context.

Once these divisions were made, it was possible to include all the variables that we thought were important in this group. As an example of how it was possible to create the indicators, the following table provides a better understanding of the step by step process of how this planning worked. Only the reduced version of the table is shown with the indicators with enough information.

Within the budget subarea, we add the total budget used as variable 1 and the participating teams as secondary variables, estimated visitors, national impacts and total media impacts. Thus, it was possible to establish a comparison (division) between these variables and generate the KPI''s. In this case, the indicators created were budget per team, budget per visitor, budget per national impact and budget per media impact.

Area of performance: GLOBAL SD PERFORMANCE						
Subarea	Variable 1	Variable 2	Key Indicators	KPI's	Description	Method
Real Budget Used	Total Budget Used		Total Budget Used		Total Budget used in Dollars	Organizing Factsheet
	Total Budget Used	Participating teams		Budget per team	Dedicated Budget for every team	Calculation
	Total Budget Used	Estimated visitors		Budget per visitor	Dedicated Budget per estimated visitor	Calculation
	Total Budget Used	Nacional impacts		Budget per national impact	Dedicated Budget per national impacts	Calculation
	Total Budget Used	Total media impacts		Budget per total media impact	Dedicated Budget per international impacts	Calculation

Table 12: Area of performance: OVERALL SD PERFORMANCE

As shown in the table above, this same criteria was used in all three other Areas of Performance. In the group of **Organizing Performance**, we used variables related to the organization of the event. The subareas of this group are organizing team, sponsorships, effectiveness in objectives, villa solar and length of event.

In the **Competition and Teams' Performance group**, the variables are related to team members, award competition, scoring, competitiveness/emotion, teams employability, recommendation to participate, energy generation, improvement of skills, education and post competition usage of houses.

The fourth and last group, **Outreach Performance** had as sub-areas the themes related to the subjective impact of SD+events in relation to: market and professionals, scientific community, society, etc.

The information collated to produce the indicators comes from three different sources. Firstly, from the **Organization Factsheets** filled in by the organizers of each competition (that have provided useful information related to different aspects such as: budget, organization, event and outreach, solar villa, etc.).

Secondly, from the **Knowledge Platform**, which was developed by the University of Wuppertal and funded by the German Federal Ministry of Economic Affairs and Energy, its objective is to store information related to competitions held to date. It is possible to access data related to teams, events, contests, competition, etc.). The platform''s content was aided by an intense exchange of information with the organizers of previous events.

Finally, from **2020 Worldwide Survey** carried out by the Polytechnic University of Madrid (UPM), which created a survey aimed at anyone who had any direct relationship with the competition (students, professors, organizers, professionals, citizens). The survey's content varied according to each respondent, but its focus was to evaluate and analyze various themes related to participating editing.

Even with all this material, unfortunately it was not possible to create all the planned indicators (approximately 100) because in addition to some competitions providing us with incomplete information, in other competitions not even have the minimum information was available.

Therefore, among all the indicators that we managed to create, we selected the indicators that we considered most suitable for this report and they are described in table 13. We emphasise that not all competitions appear in the following charts due to missing information.

NAME	DESCRIPTION	METHOD
COMPETITIONS AND TEAM PERFORMANCE		
Index of concentration of 1st contest awards	Index of concentration of 1st contest awards	Calculation between teams with 1st award/Participation teams.
Statistical Range: Winner-Lower Scores	Statistical range of the competition: Winner score-lower score	Calculation Winner score/Lower score
Competitiveness/Emotion Index	Inverse of the difference between 1st and 2nd	Calculation between 1st and 2nd.
Improvement of Skills: Project Management	Subjective Rate of improvement of skills in Project Management	Average and standard deviation calculated from the responses obtained by the 2020 worldwide survey.
Improvement of Skills: Team Working	Subjective Rate of improvement of skills in Team Working	Average and standard deviation calculated from the responses obtained by the 2020 worldwide survey.
Improvement of Skills: Construction	Subjective Rate of improvement of skills in Construction	Average and standard deviation calculated from the responses obtained by the 2020 worldwide survey.
Improvement of Skills: Temperance under stress	Subjective Rate of improvement of skills in Temperance Under Stress	Average and standard deviation calculated from the responses obtained by the 2020 worldwide survey.
Improvement of Skills: Creativity	Subjective Rate of improvement of skills in Creativity	Average and standard deviation calculated from the responses obtained by the 2020 worldwide survey.
ORGANIZING PERFORMANCE		
Number of team members in core organizing team	Number of team member in core organizing team	Information obtained through the factsheets answered by the organizers of each competition.
Number of volunteers during Competition	Number of volunteers during Competition	Information obtained through the factsheets answered by the organizers of each competition.
Number of companies funding in cash	Number of companies funding in cash	Information obtained through the factsheets answered by the organizers of each competition.
Number of companies funding in kind	Number of companies funding in kind	Information obtained through the factsheets answered by the organizers of each competition.
Index Universities Participating Teams	Index of universities involved / participating teams	Calculation between universities involved and participating teams. Information obtained through the factsheets
Index of Countries /Participating Teams	Index of countries involved / participating teams	Calculation between countries involved and participating teams. Information obtained through the factsheets
OUTREACH PERFORMANCE		
Subjective Impact of SD + Events: Market & Professionals	Subjective Rate of impact into Market and Professionals	Average and standard deviation calculated from the responses obtained by the 2020 worldwide survey.
Subjective Impact of SD + Events: Scientific Community	Subjective Rate of impact on Scientific Community	Average and standard deviation calculated from the responses obtained by the 2020 worldwide survey.
Subjective Impact of SD + Events: Society – General Public	Subjective Rate of impact on Society	Average and standard deviation calculated from the responses obtained by the 2020 worldwide survey.
Subjective Impact of SD + Events: Market & Professionals	Subjective Rate of impact on Education	Average and standard deviation calculated from the responses obtained by the 2020 worldwide survey.
Subjective Impact of SD + Events: Sustainable Awareness	Subjective Rate of impact on Sustainable Awareness	Average and standard deviation calculated from the responses obtained by the 2020 worldwide survey.
Subjective Impact of SD + Events: Energy Efficiency/Saving Awareness	Subjective Rate of impact on Energy Efficiency/Saving Awareness	Average and standard deviation calculated from the responses obtained by the 2020 worldwide survey.
OVERALL ASSESSMENT		
Dedicated Budget for every team	Dedicated Budget for every team	Calculation between total budget used and participating teams.
Dedicated Budget for every visitor	Dedicated Budget for every visitor	Calculation between total budget used and participating teams.
Attendees recommendation rate.	Survey''s Attendees Recommendation Rate	Average calculated from the responses obtained by the 2020 worldwide survey.
Estimated Visitors	Number estimated of visitors as a whole	Average calculated from the responses obtained by the 2020 worldwide survey.
Participating Teams	Number of partipation teams in final Competition	Average calculated from the responses obtained by the 2020 worldwide survey.

Table 13: Indicators: overall SD performance

6.5 Performance Indicators to Assess the Competitions and Team Performance

Some graphs from Competitions and Team Performance indicators are shown below. The main objective is to present data related to the competitions and the improvement in the skills of the participants. The information for all competitions was not provided, so some graphs will not have information for all of them.

Index of concentration of 1st contest awards. The purpose of this indicator is to show the level of competitiveness among participating teams. The index shown in the graph is the quotient between the number of teams that have won 1st prize in a contest and the total number of participants. **The higher the index** means that there was a diversity of teams that won 1st prize in the contests, so it means that **the competition was fierce and the level of the teams was similar**.

According to information extracted from the Knowledge Platform, the four competitions that had the highest rate, coincidentally are North American. The competition that had the lowest number of teams with 1st prize award was SD US 2015 with 3 winning teams of 14 (figure 93). It is important to note that in this graph we are not counting the number of awarded teams, but the proportion between them per participating teams.

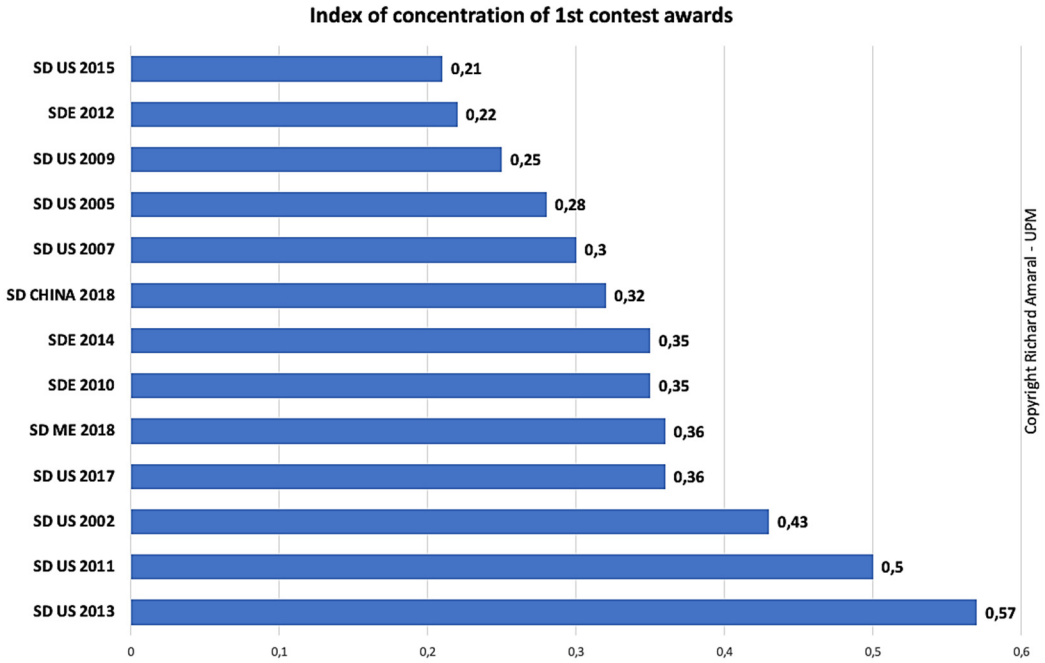


Figure 93: Index of concentration of 1st prize awards.

Winner score/Lower score. The next indicator shown is the gap between the first and last place score in the competition (figure 94). The **lower the index** means that the teams were more or less at the **same level of competitiveness**, that is, there was no discrepancy between the scores of all of the participating teams.

According to data extracted from the Knowledge Platform, the competitions that had this lowest rate were the editions of SDE 2019 and SD US 2013. It is worth noting that in this indicator, we do not consider the magnitude of the scores themselves, but the division obtained between them. As an example, the best/worst score in the SDE 2019 (853.483/691.556) are lower than those in the SD US 2013 (951.922/774.742) despite having similar indices. The competition that had the worst index was the SD US 2002, which curiously was the one that stood out in the previous indicator.

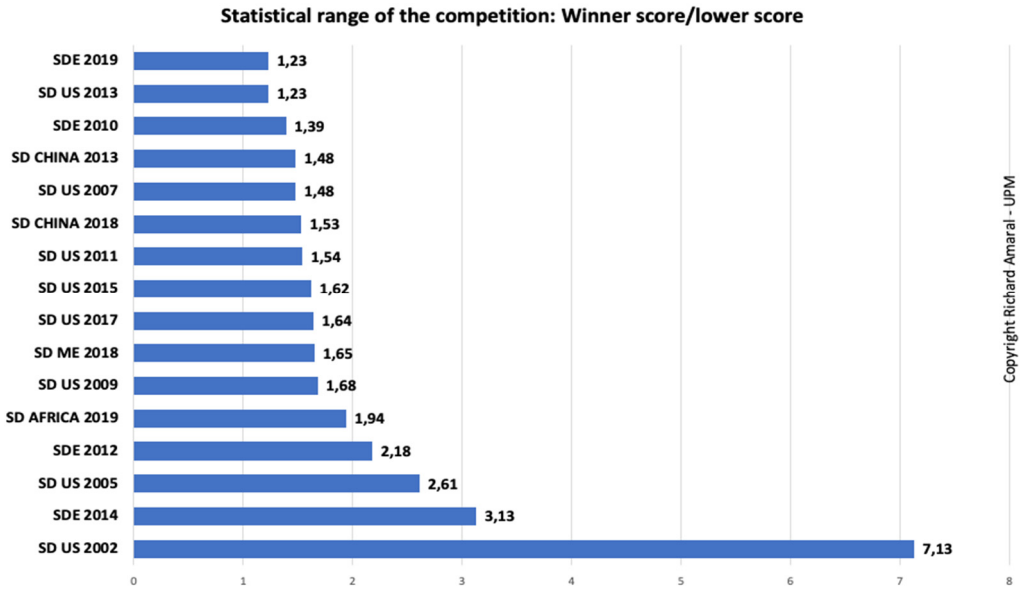


Figure 94: Winner score/ Lowest score.

Emotion/Competiveness Index. This indicator was calculated from the difference in score between first and second place (figure 95). The **smaller the indicator** means that the competition was **fierce**.

According to information obtained through the Knowledge Platform, European competitions were highlighted in this indicator. The three lowest (which are the best) indices shown in the graph below stand out for having a very small difference between them, confirming that three of the four European competitions held were editions in which the final result was “decided in the last minute of the competition“.

This means that the level of competitiveness and emotion in that edition was high. The SD China 2013 and SD US 2013 and 2015 competitions also had a very small difference. The North American competition of 2017 had the largest difference (50.23), which shows us that the first place won with “tranquility“.

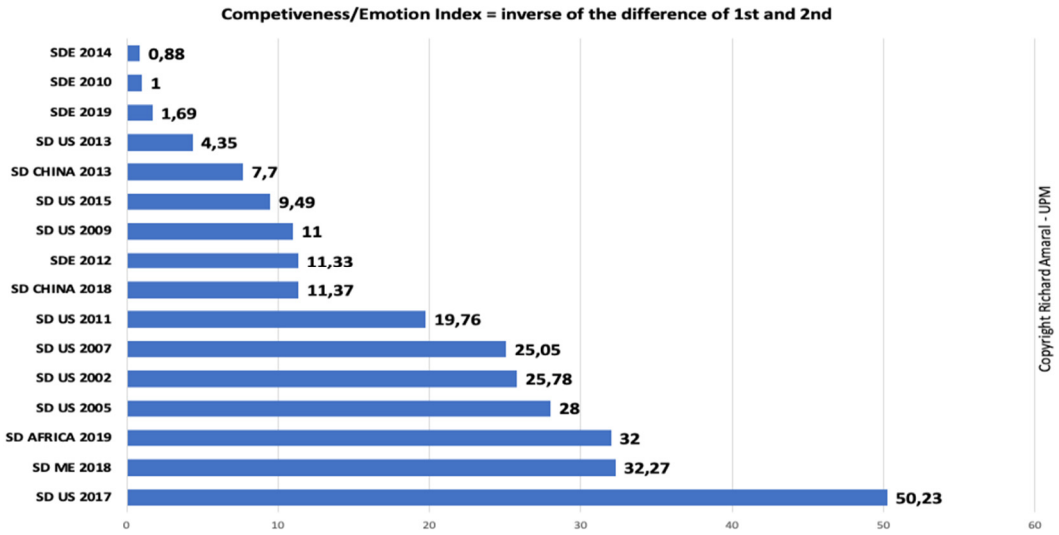


Figure 95: Emotion/Competiveness Index.

Improvement of skills indices. The following five indicators aim to present the subjective rate of improvement of skills in the opinion of the participants of competitions held to date. The values presented are very important because the evaluations are made by those who actually experienced the competition and also show in which aspect of the Solar Decathlon has been a success and in which it should look for alternatives to improve the next editions. Information from all competitions was not available, for this reason

some graphs will not have information of all of them. They had to grade from 1 to 6, 1 being the lowest score and 6 the top.

The graph shows the average score among respondents in blue. The standard deviation between the scores is shown in orange. Competitions that are represented in a light color, mean that they had less than five responses, so they can be considered unrepresentative.

We emphasise that the averages of the scores assigned by the participants are similar in making a comparison between the competitions, and highlighting that the respondents share the same thinking regardless of the competition presented in qualifying the indicators.

The averages presented in the first indicator below are related to **Project Management** (figure 96). Among the averages highlighted in the graph, it is possible to see that they are very similar. SD China 2018 was the one that best evaluated this point (5.36). It cannot go unnoticed that the participants of the 2007 North American competition gave very low marks and their average stands out (for worse) in the graph (3.14).

We call the **representative value index (RVI)** of the overall indicator, the value above which most of the competitions have scored, analogous to the characteristic value in a normal distribution (the value that has a 95% chance of being reached in the population, deducted from the statistical analysis of the sample), we estimate it for the purposes of the overall valuation of these indicators of the different editions, as the second lowest value of the indicator, eliminating the lowest as being somewhat less representative.

The representative value index (RVI) of Project Management skills is 4.89 out of 6, demonstrating a general perception that decathletes have developed these types of skills through SD competitions.

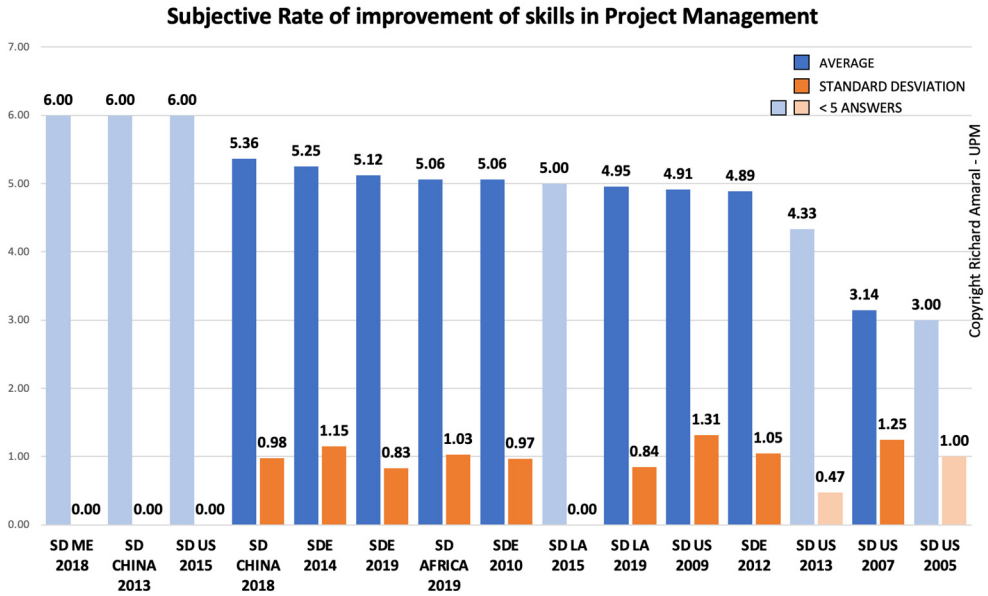


Figure 96: Rate of improvement of skills in Project Management.

The next indicator is the subjective rate of **improvement of skills in Team Working**. When we think of the Solar Decathlon competition, teamwork automatically comes to mind. Participation in this competition, regardless of whether you are a student, professor, organizer, teamwork will always be part of the spirit of the event. The averages presented in figure 97 confirm our thinking that this skill is highly developed throughout the process. The competition that best rated this topic was SD Africa 2019 and the one with the lowest average (it does not mean that the value is low) was SD US 2007. It is worth noting that we are taking into account and discussing only the results they obtained from more than five responses.

The representative value index (RVI) of Team Working skills is 5.09 out of 6, demonstrating a general perception that decathletes have developed these types of skills through SD competitions.

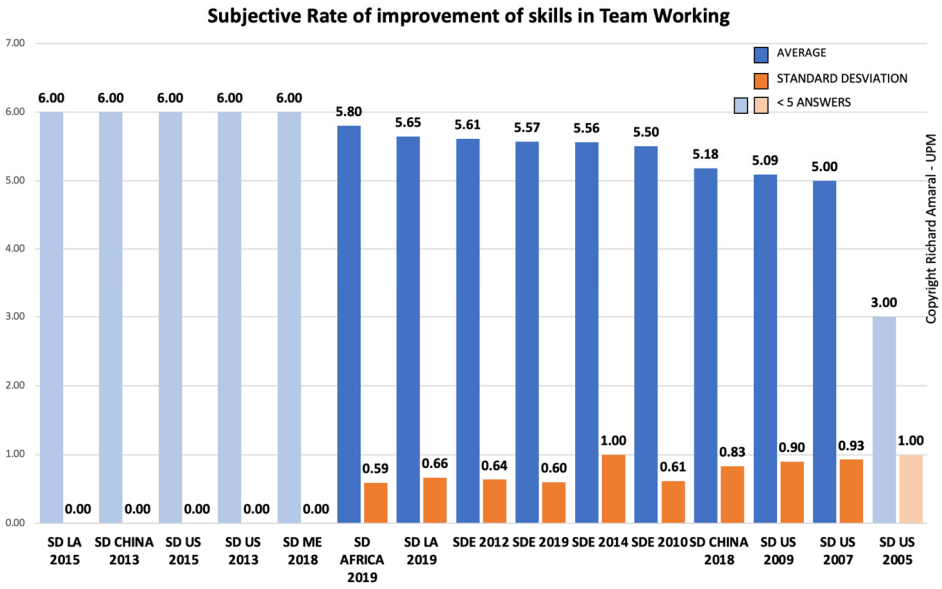


Figure 97: Rate of improvement of skills in Team Working.

Another topic that is directly linked to participation in SD is the **skill in construction**. To participate in the competition, the prototype must be built to be evaluated during the event and this skill is something that participants definitely acquire in this process. As in the last chart, the averages were high, which was to be expected. With the exception of SD Europe 2014 (4.69), all averages are above 5. The representative value index (RVI) of construction skills is 5.06 out of 6, demonstrating a general perception that decathletes have developed these types of skills through the SD competitions.

The averages indicated in the graph below regarding **skills in temperance under stress**, despite being considered high, they ranged between 5.50 (SDE 2010) and 4.64 (US SD 2009). The representative value index (RVI) of high temperance under stress skills is 4,78 out of 6, demonstrating a general perception that decathletes have developed these types of skills through SD competitions, although a little less clearly than in the other skills analyzed (figure 98).

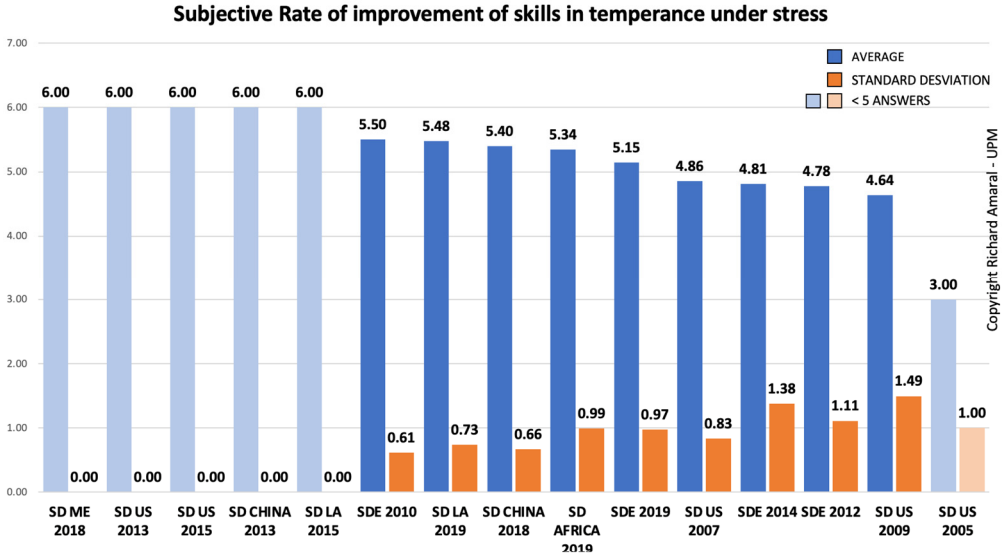


Figure 98: Rate of improvement of skills in temperance under stress.

Last but not least, the following indicator is related to improvement in **skills in creativity** (figure 99). Making a comparison between the other last four charts, this one definitely has a visible difference between the averages. This difference can be linked to several aspects such as the competition rules, which vary in each edition. In the chart below, the three editions that had the highest evaluation averages were SD Europe 2010, SD China 2018 and SD Latin America 2019 (5.44; 5.36 and 5.33, respectively). It can also be compared with the participants of the other European editions, 2012 and 2014 who gave a lower evaluation than the others. In addition, the lowest rated competition of all was the SD US 2007 with an average of 3.71 out of 6.

In this case also the representative value index (RVI) of high temperance under stress skills is 4,44 out of 6, demonstrating a general perception that decathletes have developed these types of skill through SD competitions, although a little less clearly than in the other skills analyzed.

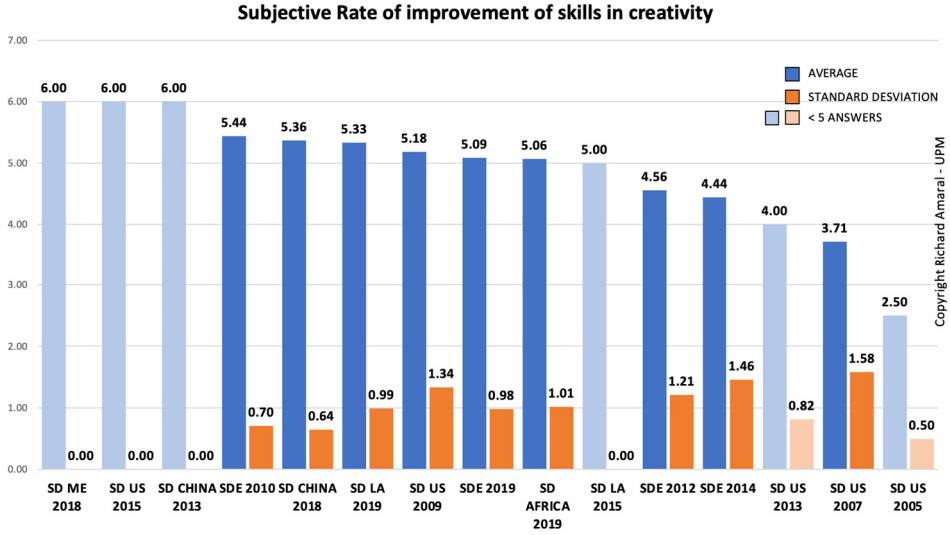


Figure 99: Rate of improvement of skills in Creativity.

6.6 Performance Indicators to assess Organizing Performance

The objective of the **organizing performance indicators** is to present general data related to the organization of the competitions. The data presented below is very important because, in addition to comparing other competitions, it is also possible to compare this data with other indicators, for example, those related to competition and team performance, presented above. We believe that the organization is a very important part of the success of an edition and being able to make this analysis of the organization''s data from other editions can certainly bring benefits for future competitions.

The indicators presented in the following four graphs are data related to the number of organizers, volunteers and sponsors (cash and kind). The information presented was obtained through the factsheets answered by the competition organizers. Some competitions are not present in the graphics as the information was not present in the factsheets.

Number of core organizing teams during the competition The indicator represented in the figure 100 below relates to the number of people who participated in the event organization team. What is interesting to see in the graph is the difference, which is very evident, in the number of organizers in the North American competitions, which are the ones with the smallest number, and the other competitions around the world, emphasizing the SDE and SD Africa, which had between 25 and 30 people. We are afraid there has been a misunderstanding in the question formulation. In US it has been understood as the head structure of the team, while in the rest of Competitions it was understood as the number of regular

members of the organizing team. In all cases, during the competition the team increases significantly, and volunteers strengthen the team.

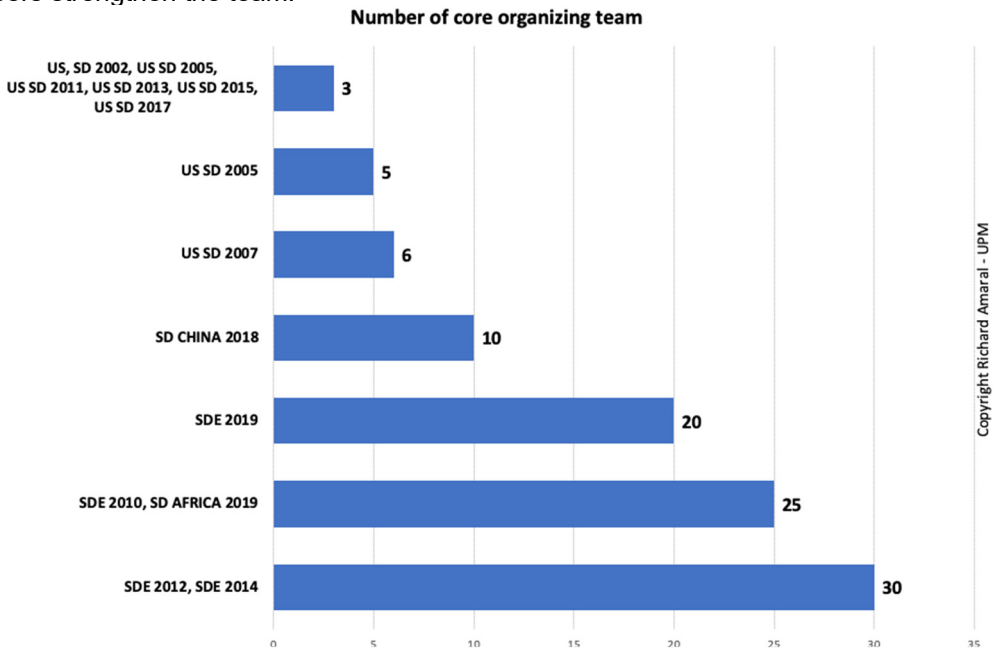


Figure 100: Number of core organizers during the competition.

Number of volunteers during the competition. Figure 101 shows the number of volunteers who participated in the competitions. We obtained less data on this topic, but we thought it important to present them because, according to the information we had, these values have a very large difference between them, which is worth analyzing. The competitions that had the highest numbers of volunteers were SD China 2013 (450) and SDE 2012 and 2014 (400 both). The ones that had the lowest number, SDE 2019 and SD Africa 2019, both with 100 volunteers, which represents approximately 25% of the volunteers in the competitions that had the highest numbers.

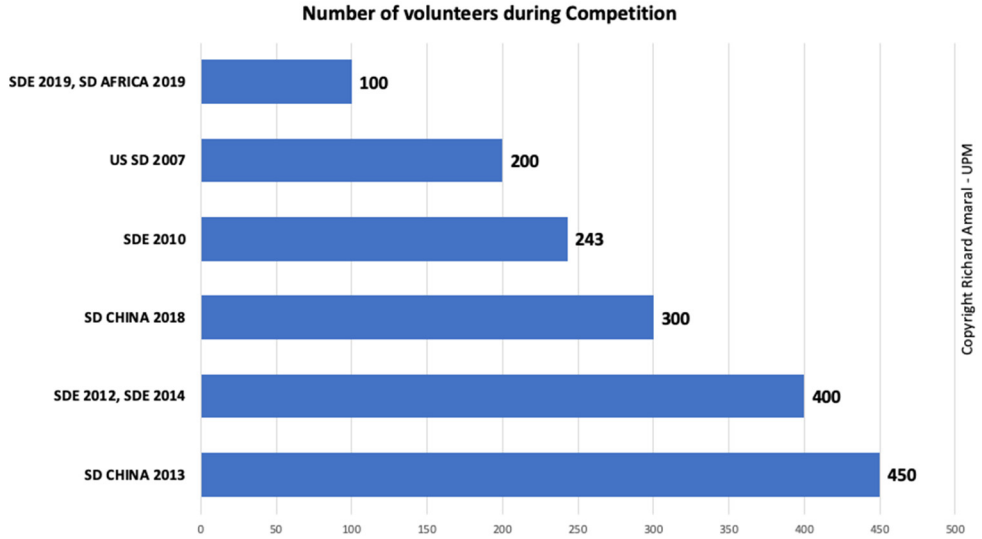


Figure 101: Number of volunteers during competition.

It is important to note that there is a direct relationship between the number of volunteers and the number of activities developed in the event that surrounds the competition, so this indicator should be related in a cross analysis with other indicators that show the outreach performance of the different editions.

Number of companies funding in cash. Companies funding the event, both in cash and in kind, play a very important role in organizing the event. The more companies interested in helping, the better for the competition, activities in the event, and public involved. In figure 102, we have the number of companies

funding in cash. SD Africa 2019 was supported by 15 companies, which is roughly 3x more than the other competitions that had an average of 5 companies. With only 1 company, SDE 2019 is the one with the lowest index. It is important to note that this indicator shows the number of companies (and the effort of the organizing team) and not the overall amount of funding in cash.

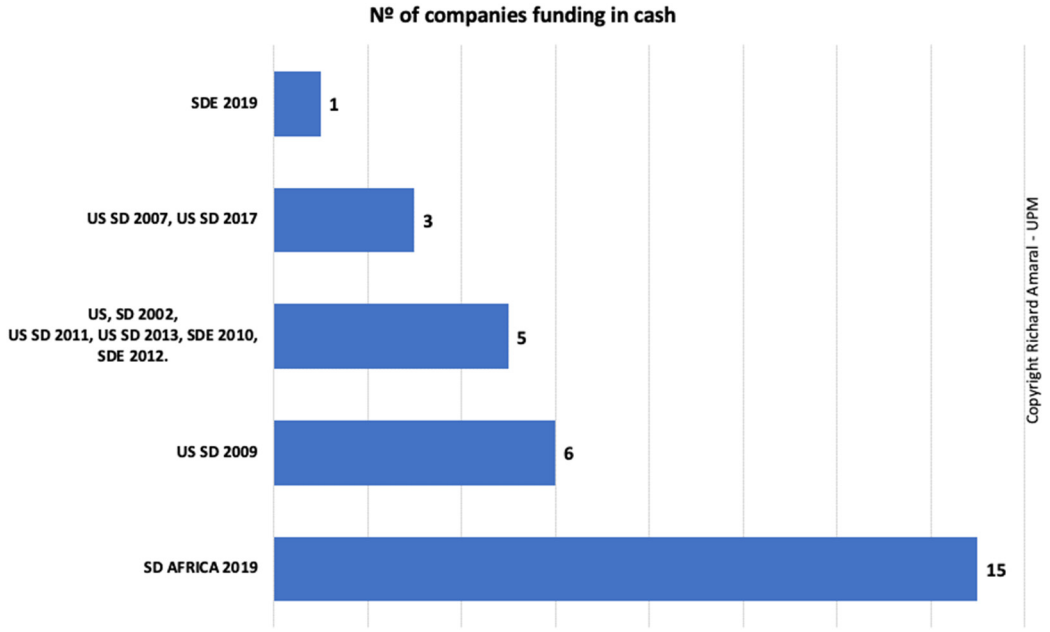


Figure 102: Number of companies funding in cash.

Number of companies funding in kind. Figure 103 represents the number of companies that funded in kind. The information presented shows that there was a diversity in the numbers, contrary to the previous graph. US SD 2007 had the lowest number of companies, totalling 5. The one that stood out the most was SDE 2012 with 50 companies, followed by US SD 2011 and 2015 with 33 and 30 companies respectively.

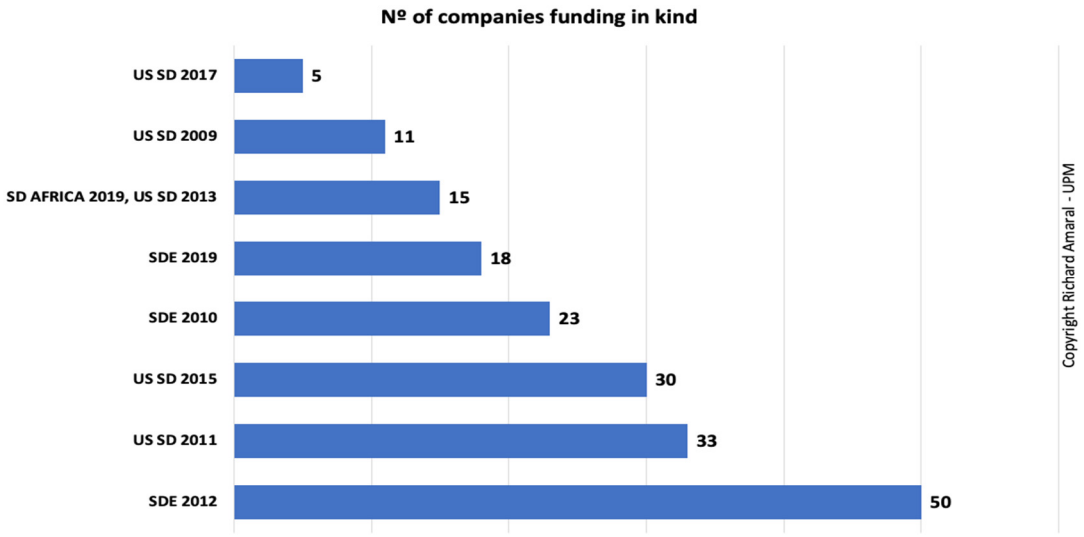


Figure 103: Number of companies funding in kind.

The next two indicators below are data related to the **index of universities and countries involved in the competitions**. The data used in both indicators come from factsheets. Not all competitions are represented due to lack of information on this topic. Regarding the indicator related to universities (figure 104), the value is from 1, it means that the number of universities exceeds the number of teams, which means that one team represented more than one university. The competitions that had the best rates on this graph were SDE and SD Africa, both held in 2019.

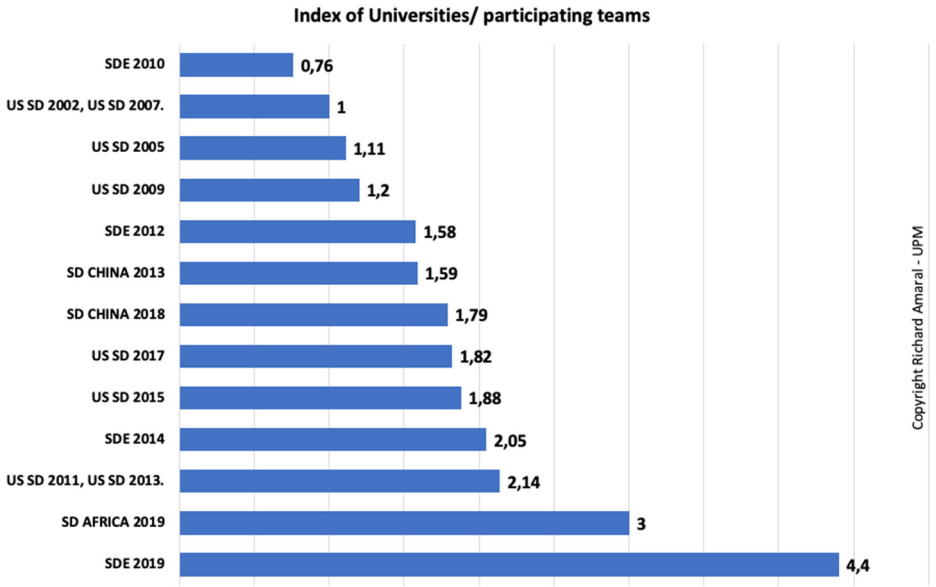


Figure 104: Universities/Participant teams.

As for the indicator related to countries (figure 105), the higher this index, the greater the number of countries that participated in the competition in relation to the number of teams. The competitions that had the highest number of participating countries, as in the last chart were SDE 2019 and SD Africa 2019.

Figure 105: Countries/Participant teams.

6.7 Outreach Performance Indicators to Assess SD Competitions and Linked Events.

Outreach performance indicators are related to the impact of the competition + events in the opinion of its participants. The following indicators were calculated based on evaluations answered in the worldwide survey carried out in 2020. They had to grade from 1 to 6, 1 being the lowest score and 6 the top. The criteria used for the representation of indicators was the same as for improvement skills. These indicators are very important for future editions. Making a comparison between them, it is very clear in which aspects the competition has a greater/lesser impact. There is no significant variation between the competitions, which can be said that the impacts, both the best and the worst, are similar in opinion of the respondent public.

Rate of impact on the Market and Professionals .Figure 106 is related to the impact on the Market and Professionals. The data presented below reveals that the average of the participants'' grades is between 4.75 - 3.50, which is relatively "low" compared to the other graphs. Considering only the competitions that had more than 5 responses, SD China 2018 and SD Latin America 2019 were the competitions that best evaluated this indicator. On the other hand, the editions of SDE 2010 and SD US 2005 had the lowest average.

The representative value index (RVI) of Rate of impact on the Market and Professionals is 3.59 out of 6, which shows a general perception that the impact of the Solar Decathlon on the Market and Professionals is high, although with room for improvement to be analyzed and implemented.

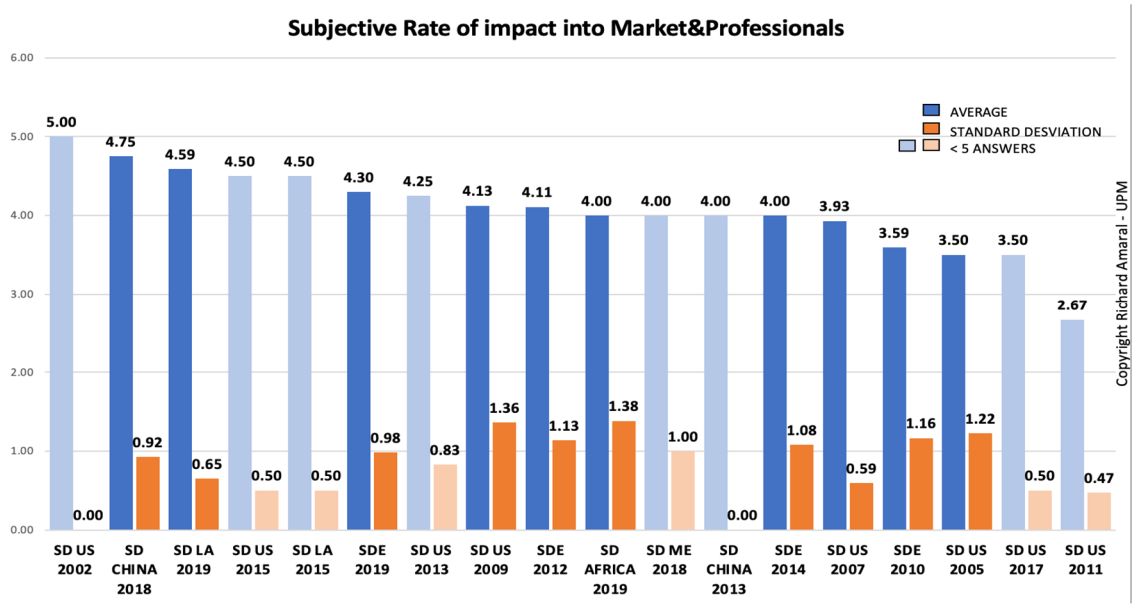


Figure 106: Rate of impact into Market & Professionals.

Rate of impact into Scientific Community.The impact on the scientific community is a fact that we consider important to present in this report because we believe that the event directly impacts researchers. According to figure 107 there is a wide range of averages. The 2018 Chinese competition considers that there was a great impact on the scientific community, according to the average grade given. On the other hand, SD US 2009??? and SDE 2010 stand out for having the lowest averages in the graph.

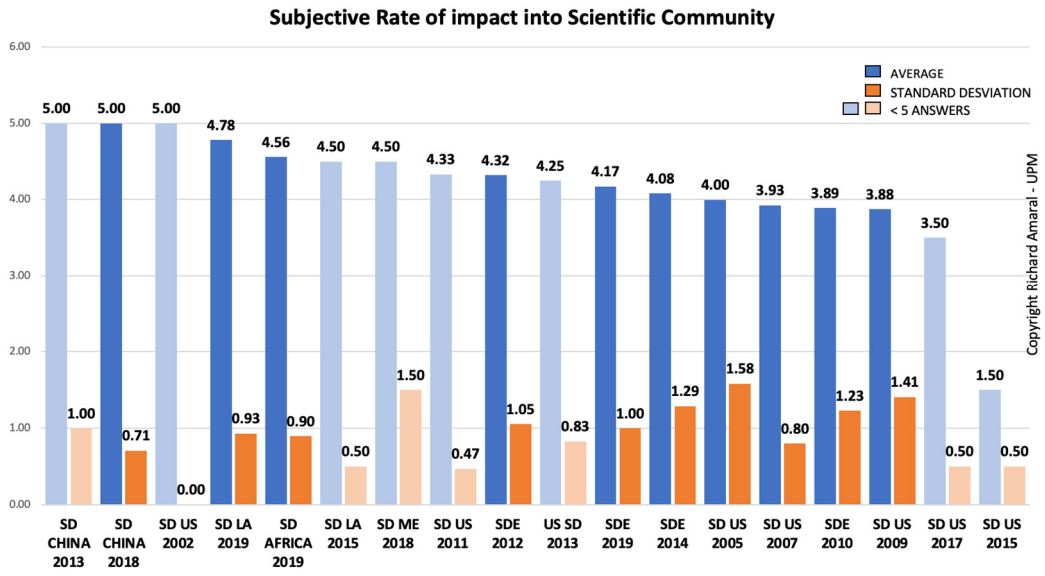


Figure 107:: Rate of impact on the Scientific Community.

The representative value index (RVI) of Rate of impact on the Scientific Community is 3.89 out of 6, which shows a general perception that the Solar Decathlon's impact on the Scientific Community is also high, although with room for improvement to be analyzed and implemented.

Rate of impact on Society – General Public. The impact on society (general public) was the indicator that had the lowest average in the competition evaluations in relation to the impact graphs. This means that this aspect is something that should be analyzed and improved for future editions. The greater the number of visitors, the greater the impact of the event on these people. The SD Latin America 2019 average was the highest. The interesting thing about figure 108 is that the four European editions had slightly lower averages when two of them (2010 and 2012) were the ones that had the largest number of visitors, compared to other competitions.

The representative value index (RVI) of Rate of impact on Society – General Public is 3.61 out of 6, which shows a general perception that Solar Decathlon impact into the Scientific Community is not so high, which leaves room for improvement, and it must be analyzed and implemented.

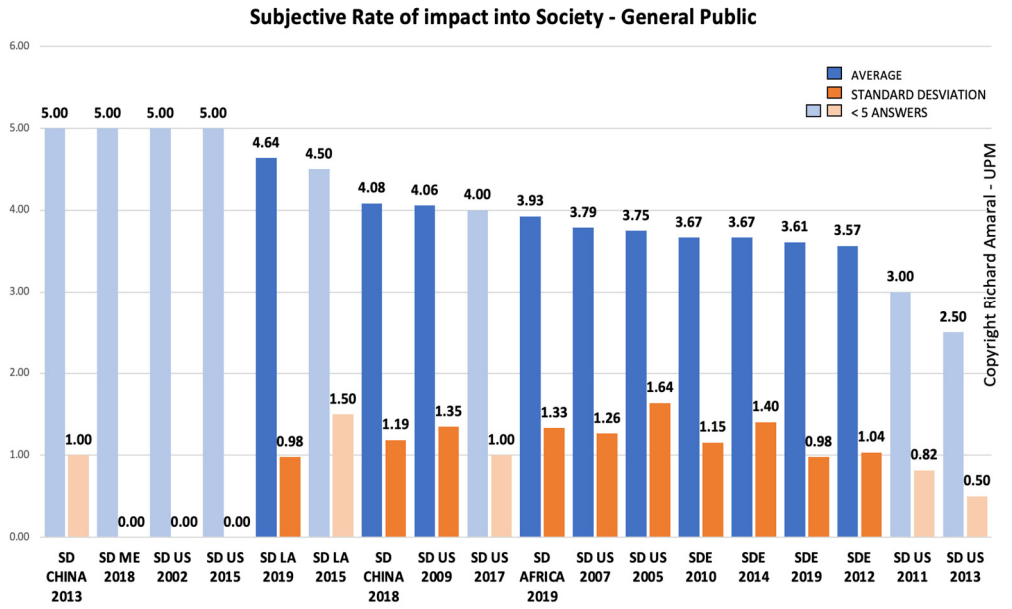


Figure 108: Rate of impact on Society – General Public.

Rate of impact on Education The impact on education is the indicator in which the averages are more balanced (figure 109). This means that the participants of the competitions analyzed share the same opinion. As shown in the graph below, SD China 2018 had the highest average (5.17) and SD US 2005 the lowest (4.13).
The representative value index (RVI) of Rate of impact on Education is 4.47 out of 6, which shows a general perception that all Solar Decathlon Competitions have registered very high impacts on Education although with room for improvement to be analyzed and implemented.

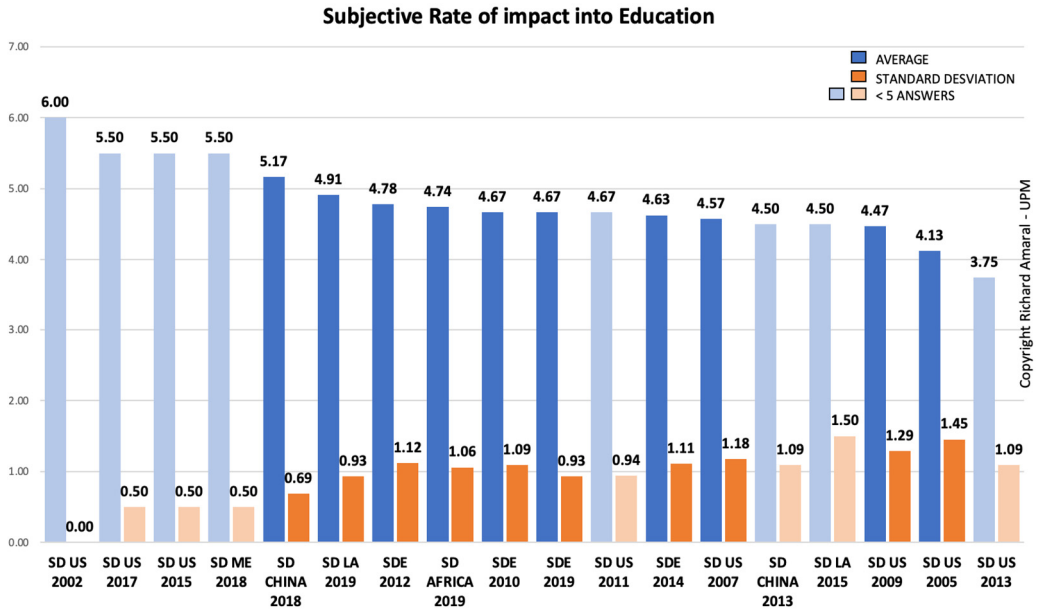


Figure 109: Rate of impact on Education.

Rate of impact into Sustainable Awareness . With relatively high averages in relation to the other graphs,figure 110 present the respondents'' opinion regarding the impact of competition in relation to Sustainable Awareness. SD Latin America 2019 and SD China 2018 were the competitions that had the highest averages (5.13 and 5.08, respectively). SD US 2005 had the worst average (4.00), despite it being a high value.
The representative value index (RVI) of Rate of impact on Sustainable Awareness is 4.42 out of 6, which shows a general perception that Solar Decathlon impact into Sustainable Awareness is high, although with room for improvement to be analyzed and implemented.

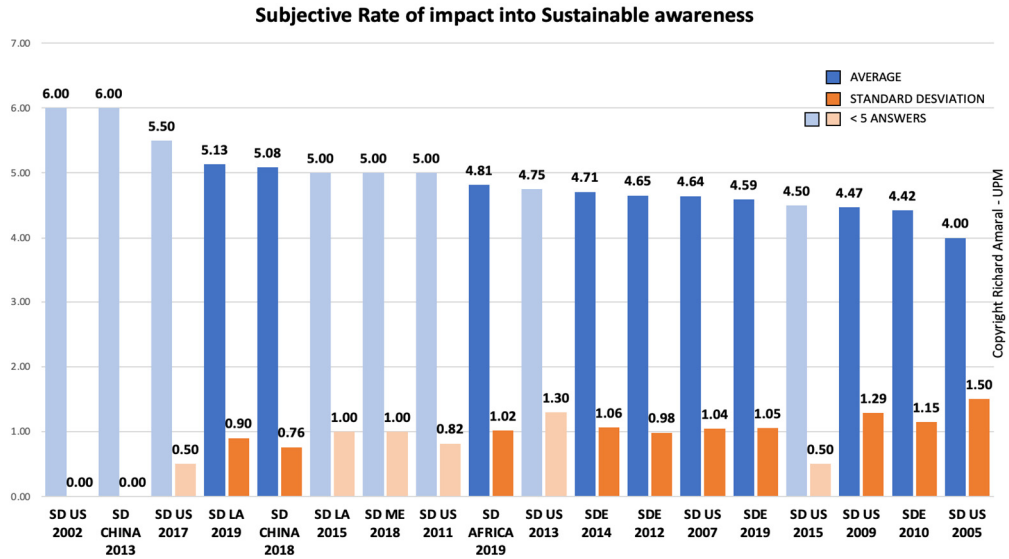


Figure 110: Rate of impact on Sustainable awareness.

Rate of impact into Energy Efficiency/Saving awareness. Figure 111 gathers the rate of impacts sets out the energy efficiency and saving awareness. Of the six graphs, this is clearly the one with the highest values, which means that according to the respondents'' opinion, this is the theme with the most impact. Looking at the graph below, US SD 2007 was the competition with the highest average. On the other hand, despite it being a high value, SD US 2005 was the competition that obtained the lowest results in relation to other competitions.

The representative value index (RVI) of Rate of impact into Energy Efficiency/Saving awareness is 4.74 over 6, which shows a general perception that Solar Decathlon impact on Energy Efficiency/Saving awareness is high, although with room for improvement to be analyzed and implemented.

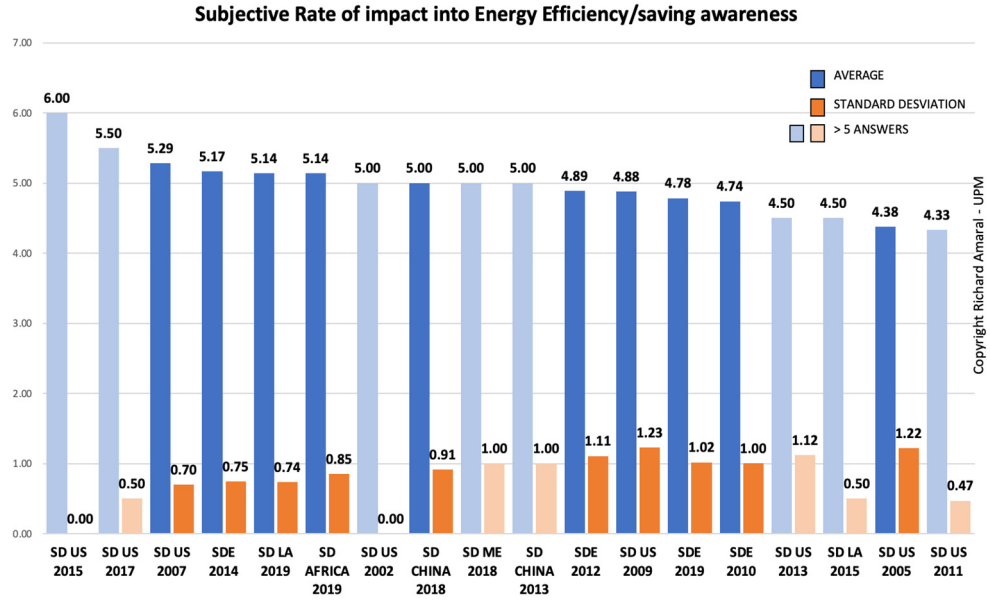


Figure 111: Rate of impact on Energy Efficiency/Saving awareness.

6.8 Overall assessment and Key Performance Indicators

The indicators related to the overall assessment aim to provide information on the data related to visitors and teams. With the content we had, it was possible to make indicators on the budget in relation to both the number of teams and visitors. The two graphs below illustrate these indicators in which the first represents the budget per team and the second the budget per visitor. Regarding both graphics, it is worth noting that the lower the value, the greater the number of teams/visitors, or the lower the budget is. The currency used to make this calculation was US Dollars. To convert Euro budgets to US Dollars, we consider €1 = $1.20.

The information from the graphs was taken from the factsheets and the competitions present in the graphs were those that informed the total budget of the event in the factsheets.

Dedicated budget per team. In this first indicator (figure 112), the competition with the highest budget per participating teams was SDE 2019 with approximately $744,720.00. This edition, which has the highest value, is not necessarily because it had the highest budget. In this case, the highest value on the graph is because in this competition there were few teams compared to the others, so this value is much higher than the others. In SD Africa 2019, which according to the graph, has the lowest rate, it is because despite having 18 participating teams, which is more or less the average number of teams in other competitions (except for SDE 2019 and SD US 2015 and 2017), their budget was lower than the teams presented, so the value is the lowest at all.

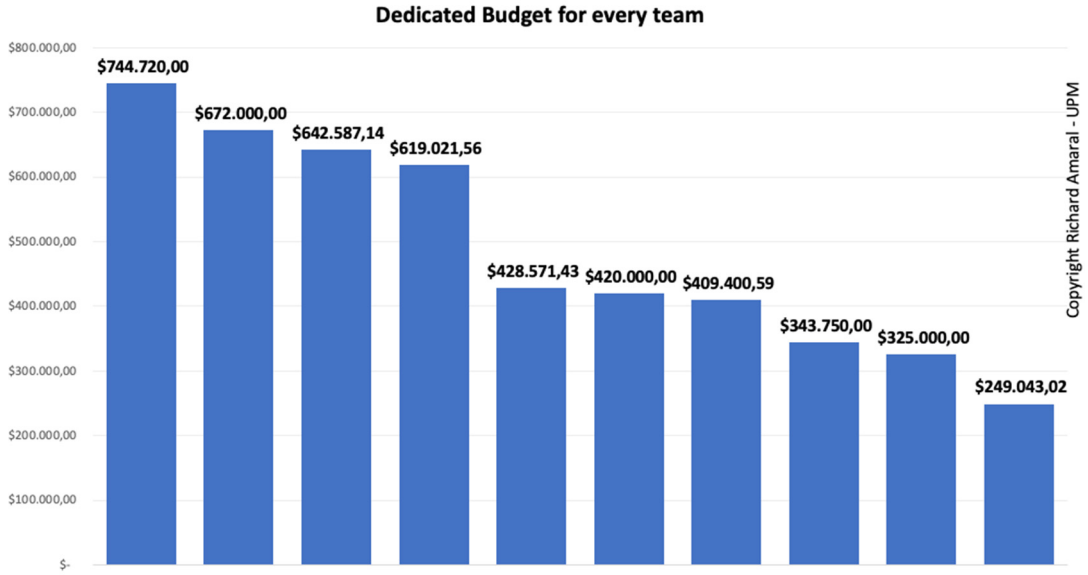


Figure 112: Dedicated budget per team

Dedicated budget per estimated visitor. In this second indicator (figure 113), it is clear that SDE 2012 and 2010 had the most favorable results because among all the competitions analyzed, they are the ones with the largest number of visitors.

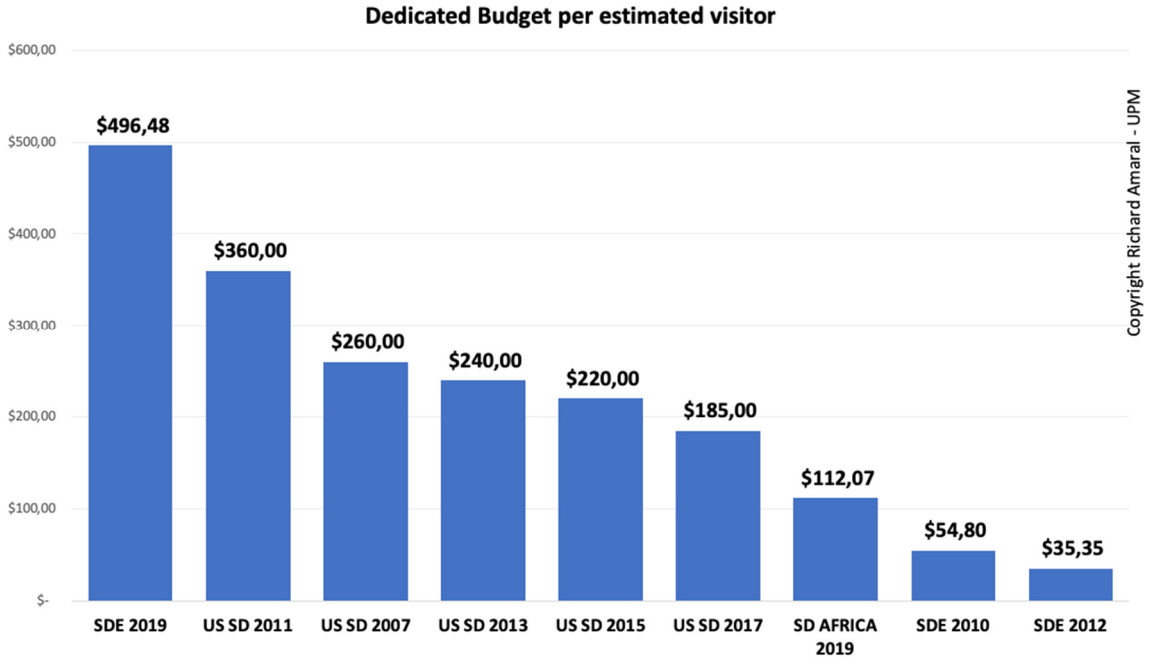


Figure 113: Dedicated budget per estimated visitor

Recommendation Rate. This next indicator (figure 114) is intended to show the percentage of participants who recommended the competition to others. Data were taken from the 2020 worldwide survey and the higher the percentage, the better the satisfaction among respondents. The percentages are all above 90% and the interesting factor is that there was unanimity (100%) in several competitions, in other words, all the answers coming from the audiences of these competitions were positive.

It is very representative and valuable that the representative value index (RVI) of Rate of Recommendation is around 94,44%, which shows a general perception that Solar Decathlon Competitions are a highly recommended experience to enjoy.

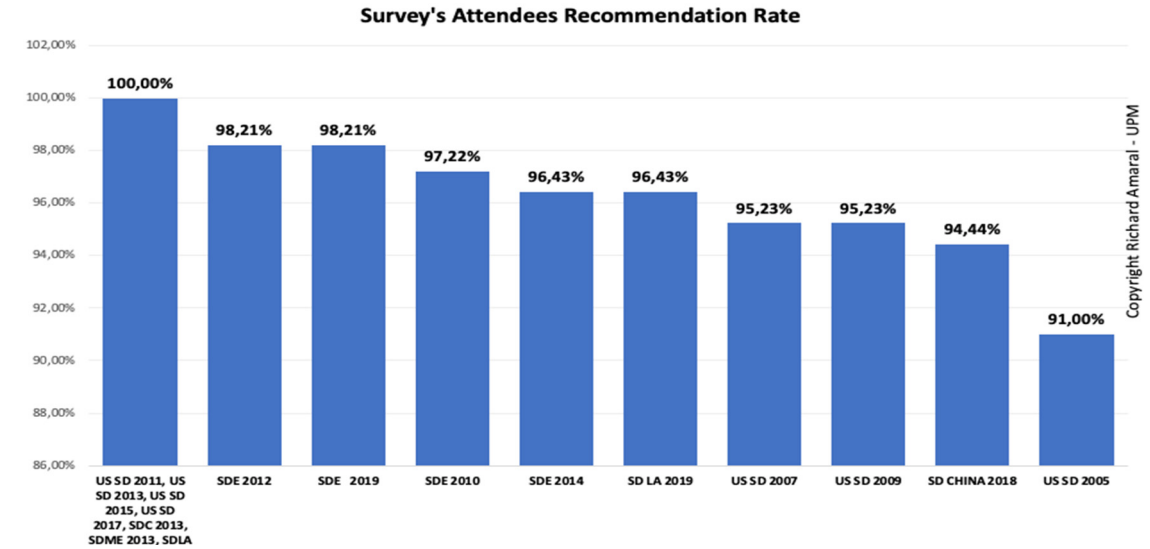


Figure 114: Recommendation Rate.

The next two indicators are data taken from the organizers' answers in the factsheets about the number of visitors and teams. The competitions that are illustrated in the graphs were those that responded to this topic in the factsheets. Regarding figure 115, the interesting point is that a comparison between events on the same continent can be made. For example, in European competitions, there was a large discrepancy in audiences as the difference between the competition that had the largest audience (Madrid 2012) and the

smallest (Szetendre 2019) was very large. Making an analysis between the years 2007 - 2011 of the North American competition, the amount of visiting public remained the same.

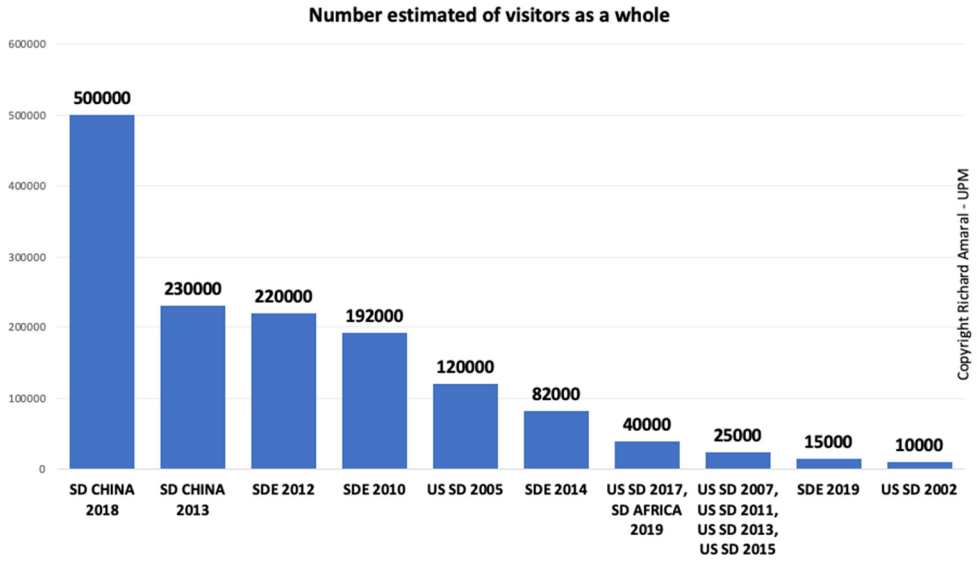


Figure 115: Estimateds number of visitors as a whole.

Making the same comparison in figure 116, among the European competitions, the 2019 edition had a lowest amount of participating teams compared to other competitions held on the European continent. Of all the competitions held to date, SD China 2013 had the highest number of participating teams.

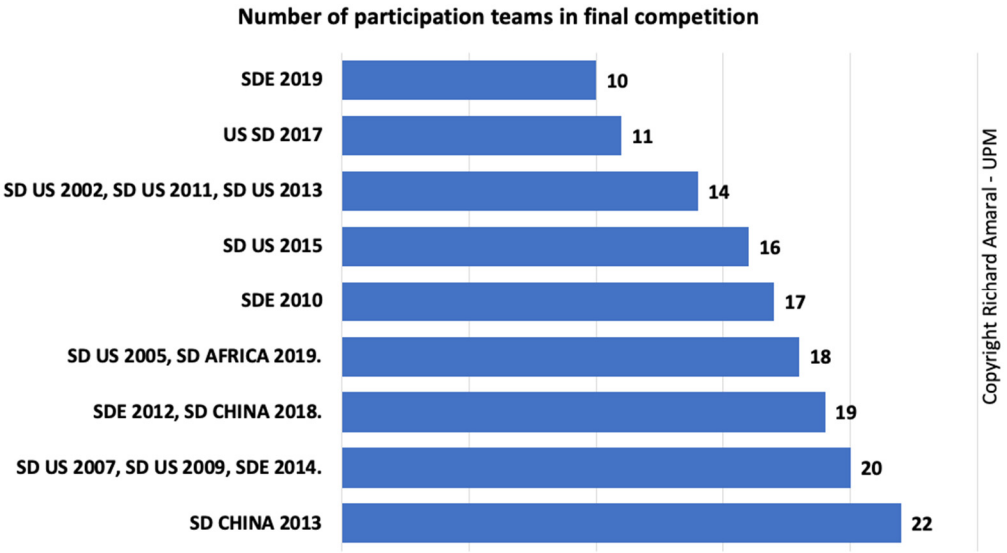


Figure 116: Number of participating teams in the final competition.

7. Qualitative Assessment & Critical Analysis

7.1 Impact related to Education in SD

As the Solar Decathlon Competition since its first edition in 2002 organized by the DOE (US Department of energy) has always had education as one of its declared objectives, so the Competition in Europe, China, Latin America, Middle East, and Africa, have had as its permanent objective the education of university students and the **preparation of a new generation of architects and engineers** who are aware of and committed to the environment, and to making our buildings and cities more efficient and sustainable.

The impact assessment of the SD Competitions on students skills' is one of the main aspects when carrying out these surveys. The knowledge and experience acquired and stimulated during their participation in the SD Competitions should be of great service to the former students in making an easier incorporation into the job market.

With tens of thousands of alumni and hundreds of schools who have participated, architecture and engineering programs have benefitted from the existence of the Solar Decathlon. The organizers have learned of schools who participated in Solar Decathlon to kickstart their creation of a design-build or living laboratory program at their school, ultimately finding follow-on partners and supporters after one-or-more times competing in the Solar Decathlon. Through participation, faculty are able to connect with other like-minded professionals and students learn about zero-energy building design and construction through hands-on activities. In 2012, the U.S. Department of Energy released an impact evaluation of the 2002-2009 editions of the competition, which is available here:

https://www.energy.gov/sites/default/files/2015/05/f22/solar_decathlon_impact_report2012.pdf
The following are relevant excerpts from the Executive Summary of that report:

The objectives of the Solar Decathlon Program are to:
- Demonstrate to the public the opportunities presented by cost-effective houses that combine energy-efficient construction and appliances with renewable energy systems that are available today.
- Educate student participants and the public about the many cost-saving opportunities presented by clean-energy products.
- Provide participating students with unique training that prepares them to enter our nation's clean-energy workforce.

The 2002 through 2009 college teams displayed their houses to the public on the National Mall in Washington, D.C. Approximately 500,000 visitors had the opportunity to tour the houses, see how energy-saving features can help them save money, and gather ideas for applying solar energy and energy efficiency in their own homes. The primary purpose of this evaluation was to determine whether the Solar Decathlon has been meeting its objectives. These findings indicate that the Solar Decathlon has been meeting its education objectives for the homeowner audience. The corresponding post-test-only and similar-group findings supported a conclusion that the Solar Decathlon has been achieving its education objectives for homeowners (figure 117).

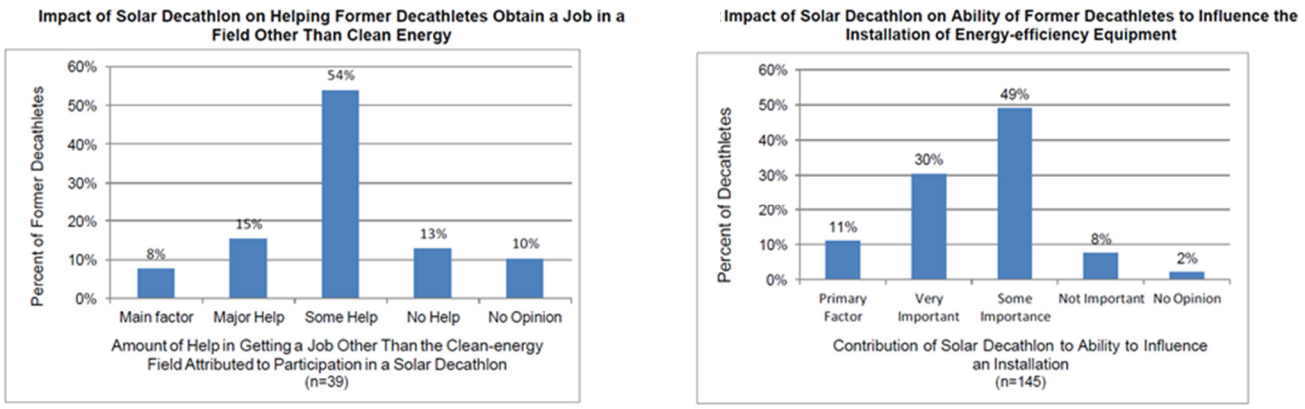


Figure 117: SDE 2012 Survey. Technical Education.

This survey also aimed at finding out the percentage of former students at the following points: Those who found a job in the clean-energy workforce and the influence of the Solar Decathlon on the job seeking of former Decathletes; the percentage of alumni who started a clean-energy business; the influence of Solar Decathlon on the success of ex-decathletes in encouraging solar energy installations and efficient equipment.

According to the results presented at the SD USA 2012 Survey, 92% of ex-decathletes claimed that their experience with solar decathlon helped them to get jobs. It was also found that five times more ex-decathletes worked in the field of clean energy after leaving college than non-decathlete students (76% and 15% respectively). The data from this survey is very important because it states that the main objectives of the Competition were achieved.

Findings from the three sources of information indicate that the Solar Decathlon has successfully been meeting its objectives for participating students.

- Former Decathlete Objective #1: Educate participating students about the many cost-saving opportunities presented by clean-energy products. To evaluate objective of the student education, former decathletes and non-decathlete students took an eight-question true-false quiz on the use of solar energy and efficient construction/products for houses. The former decathletes scored 11% higher than non-decathlete students In addition, 94% of the Former Decathletes claimed through a self-report that they learned more about the use of solar power and energy-efficient products in housing design from their Solar Decathlon experience than they would have in the course of their normal classroom work.
- Former Decathlete Objective #2: Prepare participating students to enter the nation's clean-energy workforce. The post-test-only and similar-group methods both found that five times as many Former Decathletes have worked in the field of clean-energy after leaving college as Non-decathlete Students (76% to 15%). Ninety-two percent (92%) of the Former Decathletes claimed that their Solar Decathlon experience helped them get these jobs. Sixteen percent (16%) of the Former Decathletes have started businesses in the clean-energy field since leaving college compared to 2% of the Non-decathlete Students after accounting for predispositions. Former Decathletes have more actively influenced the installation of renewable-energy systems since leaving college than Non-decathlete Students, and 89% of the Former Decathletes credit their Solar Decathlon experience with helping them exert their influence. The evaluation results indicate that the Solar Decathlon has been successfully meeting its education and career-preparation objectives for participating students.

- Conclusion Across the three methods used in the study approach, there were a total of 49 measures of outcome effects. The study found that 43 of 49 measures support the overall conclusion that the Solar Decathlon is achieving its objectives. Six of the measures provided inconclusive results. Considering the findings as a whole, the Solar Decathlon has been successful in satisfying its objectives for the homeowner and participating student audiences.

Overall, there is confidence that the Solar Decathlon – both in the U.S. and globally is having a significant impact on education.

Over 2,000 students participated in the first two SD China competitions. Some of them went on to become architects, engineers or entrepreneurs in green building and related industries. Some projects won prizes in related industry awards. More than 50 academic articles and books were published between 2013 and 2019. Over 10 studios were set up at SD China participating universities, offering regular workshops or courses for both graduates and undergraduates .

When a university decides to participate in a Solar Decathlon, the university not only takes on the challenge of designing an efficient, zero-energy prototype home, powered exclusively by the sun, that is attractive, healthy, comfortable and convenient to use, but also assumes all the challenges associated with managing the project, making it technically, economically and financially viable, both in its construction and the challenge of assembling and dismantling it in the shortest possible time, competing in unfavourable situations and under pressure. Considering the money that the university invests to make the project viable, the economic and human effort involved, the possible difficulties derived from the Competition, all the risks involved, etc. **Why do universities ask to participate in the Solar Decathlon Competitions?** Why some universities participate several times in a row?

There are many reasons that encourage universities to participate despite the challenges and risks associated with these Competitions, and without doubt, one of the most significant is **the educational potential that participating in a Competition like the Solar Decathlon represents for the university**.

The participation generates an **endless number of educational synergies of all kinds**, from the generation of **technical knowledge** and its application, to the development of **transversal skills** so necessary for the working life of the participants; from the integration of **complementary disciplines** from architecture or engineering, to the application of **project management skills.**

Although the **greatest educational potential derives from the Competition itself**, and the design and construction of the prototypes, in order to maximise the benefits and synergies of this potential, an **active commitment is needed from the universities and faculties** that participate, as well as from the organizations of the Competitions and related events, which have the means to foster the educational focus of the work of the teams, and to develop activities that promote the awareness and education of both the students and the visiting citizens in general.

Likewise, when a country, or a city, decides to take on the challenge of organizing a Solar Decathlon Competition, one of the many returns that it values is, no doubt, the potential for social and educational awareness that it represents for society. The communications potential of the Competition is very high, due to the attractiveness of the houses, the technical innovations they present, and the media interest they generate. This potential is therefore at the service of the awareness and education of children, young people, university students, professionals, and the public in general, one of the powerful reasons for taking on the organization of one of these prestigious Competitions. A locomotive for economic growth and to help create jobs in the African nations; the sector brings environmental, economic and energy security benefits.

7.1.1 Education coming from universities

The educational potential is very high, but there is no doubt that in order to take advantage of all the synergies, a willingness and planning of the university's teaching and educational activity is needed to enable it to be used, which, judging by the assessment of both students and professors in the 2012 (figure 118) and the 2020 surveys, is not always achieved.

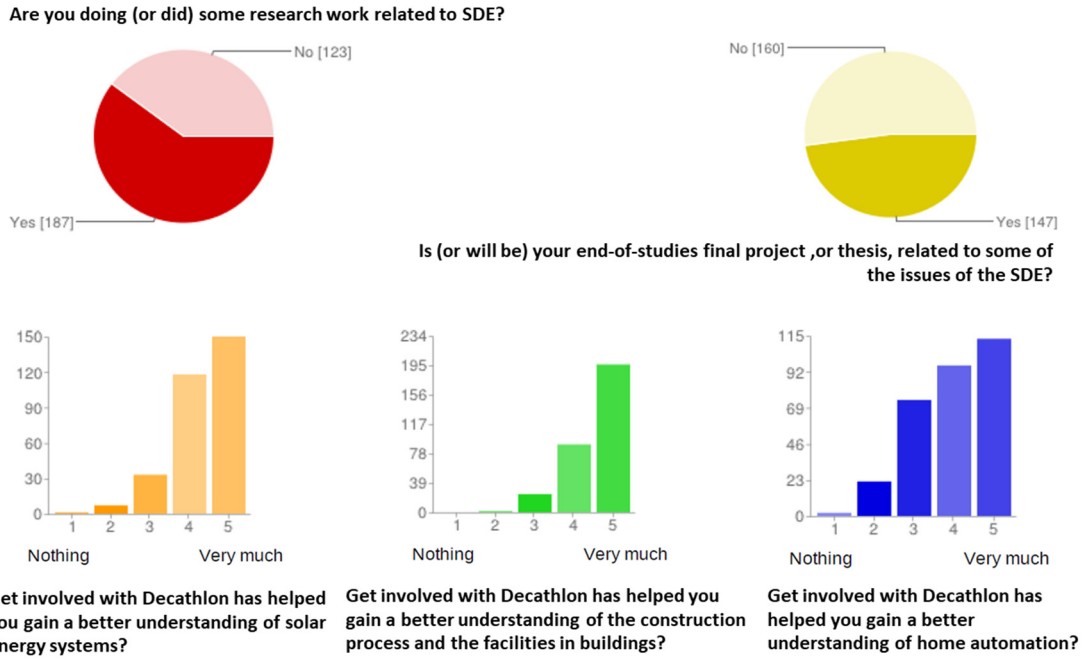


Figure 118: SDE 2012 Survey. Technical Education.

For example, when asked if Solar Decathlon is part of the university's training program and if **credits are recognized for participating in the team, only 38% of students agreed**, and the degree of agreement among professors is 3.5 out of 6, with a very high dispersion (1 in total disagreement, 6 completely agree) (figure 119).

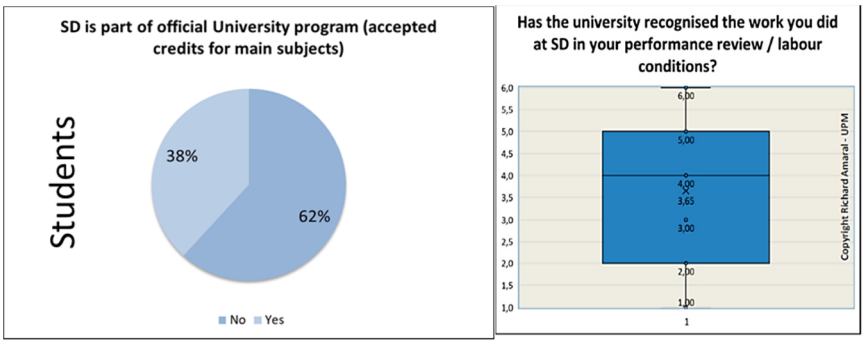


Figure 119: SDE 2020 Survey.

Similar results were achieved in the survey of Solar Decathlon Europe 2014, with a lower evaluation by students than professors. If we analyse the result of the survey during the SDE 2014 Competition, on whether the professors focused on the Competition in which they participated as learning activities, the average value would be 3.11 out of 5 for student perception, that is, it is recognized that it was generally tried, but it is not clear that it was achieved. However, for the professors, although the average value is 3.26 out of 5, which is similar to the overall perception of the students, it contrasts with the fact that 37% of

the professors surveyed considered the statement to be completely true, as opposed to 49 % of the students with this perception (figure 120).

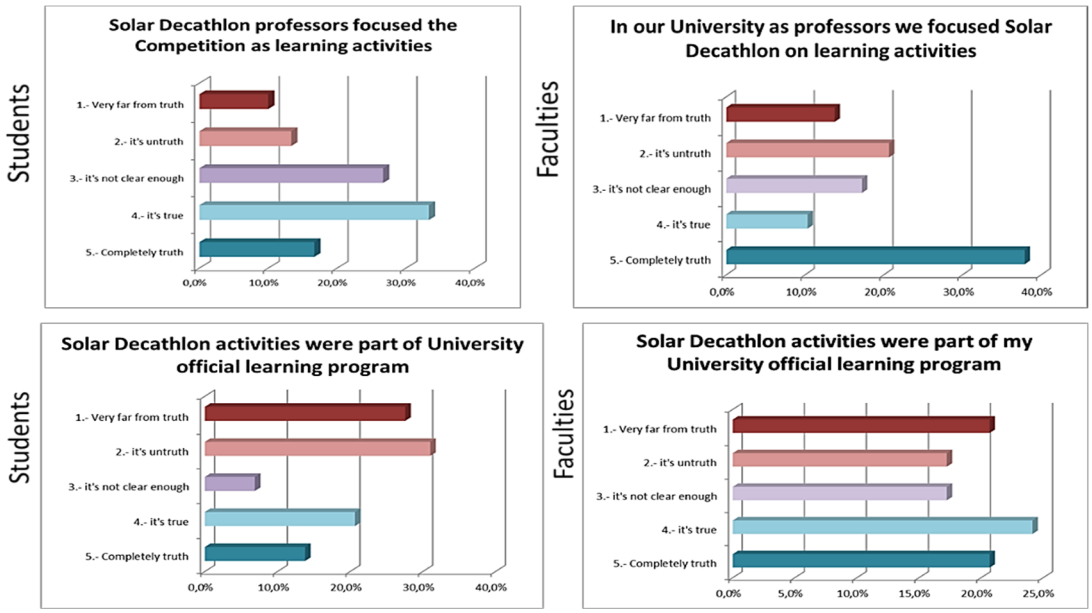


Figure 120: 2014 Survey.

It can be seen from the SDE 2014 survey that in most of the participating universities (figure 121), official credit was given to students who participated in the Solar Decathlon Competition, which is an explicit recognition of their educational and professional training potential.

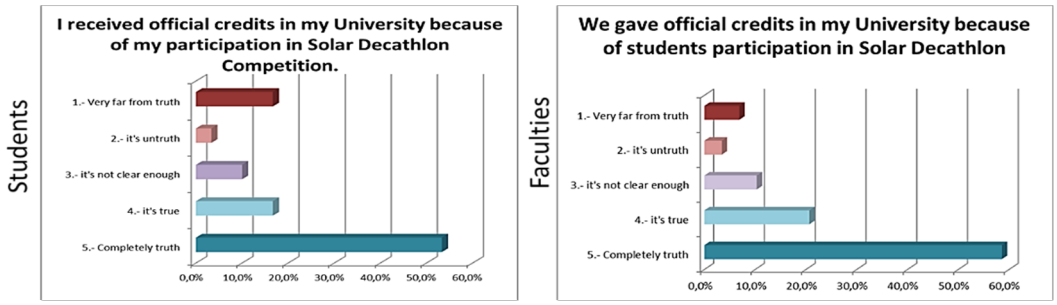


Figure 121: 2014 Survey.

This recognition of students by universities does not equally translate into recognition of their professors. In the 2020 survey, it is meaningful that universities do not always recognize the work and effort made by their professors to develop the project, did not affect their working conditions in a significant way. The average response value was 3.65 out of 6 (figure 122), with a very high dispersion, which implies a great variety of responses depending on the universities to which they belong. Some of them recognize more, many others do not recognize this activity at all.

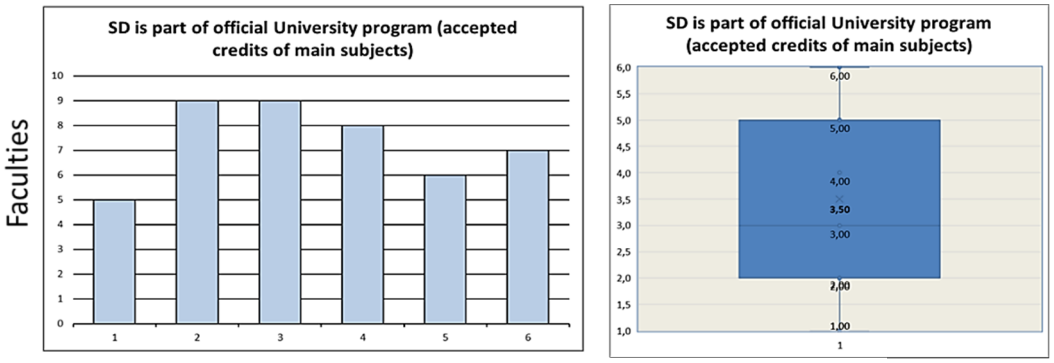


Figure 122: 2020 Survey.

Asked by the professors if the budget they considered for the Competition was sufficient to promote academic activities, the answer once again is an average value of 3.11 out of 6 (figure 123), with a somewhat lower dispersion than the previous cases, and which we interpret as meaning that there has not been clear support from the universities to promote specific educational activities within the university.

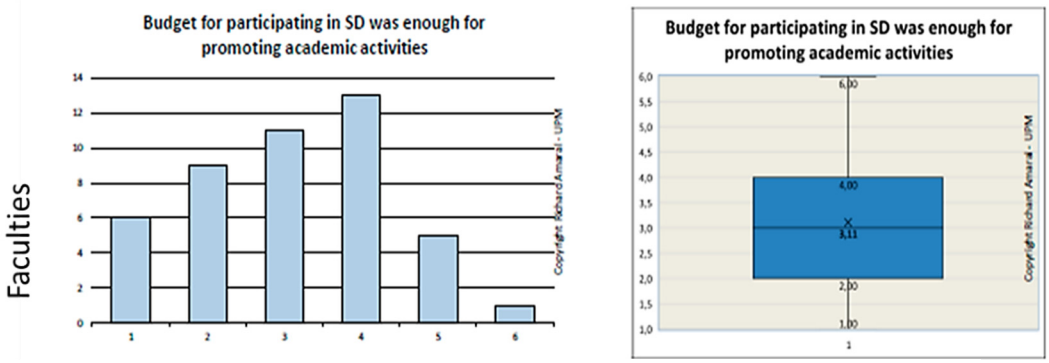


Figure 123: SD 2020 Survey.

7.1.2 Education Fostered by the Competition itself and its Organization

Beyond the educational approach that each university has given to the teams participating in the successive editions of Solar Decathlon,**the greatest educational potential lies in the Competition itself and its contests.**

As regards the Competition contests, there was a significant variation in the contests with respect to the American editions when the Competition moved to Europe, among other things **to adapt them to European sensitivities and values, and on the other hand to promote social awareness and education in important and sensitive aspects in Europe**. Subsequently, several of the European contests were incorporated into subsequent American editions, in a mutual process of continuous improvement.

Therefore, to the engineering contest was added the part related to construction, to communications was added the part of social awareness, and to the market viabilitiy contest points were added for industrialisation, which later varied by incorporating aspects of urban design, urban mobility, affordability, etc. Completely new contests were added, such as energy efficiency, sustainability, and innovation. In total **almost half of the points were adapted to the European edition between the SD 2009 in Washington and SDE 2010 in Madrid.**

The high level of coincidence in the perception between students and professors as to which of the contests in the European Competitions have contributed more to the education of the students is significant. The four contests that have contributed most (respondents had to choose only 2 out of 10 contests) are architecture, engineering and construction, energy efficiency and sustainability and circular economy (figure 124).

Also significant is the high level of agreement between students and professors as to what has improved the students'' knowledge due to their participation in a Solar Decathlon Competition. **Knowledge improved mainly in the following areas: architecture and engineering integration; energy efficiency and passive design; project management; renewable energies, and practical construction** (figure 125). In the survey carried out in the SDE14 (figure 126), with an open approach in which 3 words were freely selected by the respondents, the dispersion of concepts was greater, as a wider number of answer were offered. While **students valued learning about architecture and engineering Integration, construction**, materials, energy efficiency and passive design, sustainability, and organization and people

management; **professors highlighted knowledge in subjects such as project management, construction**, systems, design coordination, or energy efficiency and passive design.

From the organization there is also a great capacity to influence issues related to education, the development of personal skills, and awareness in university students.

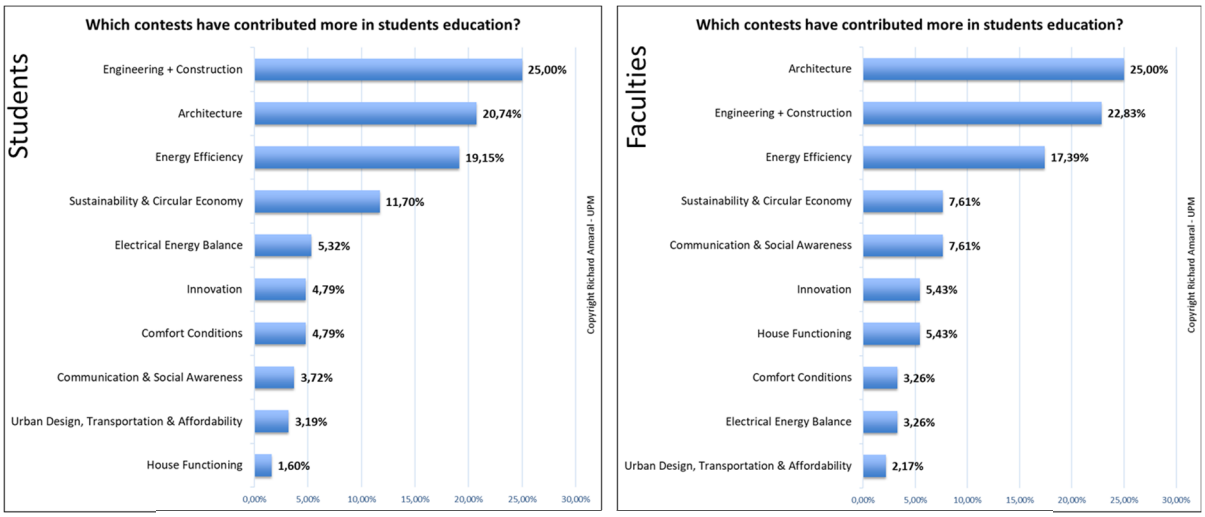


Figure 124: 2020 Survey.

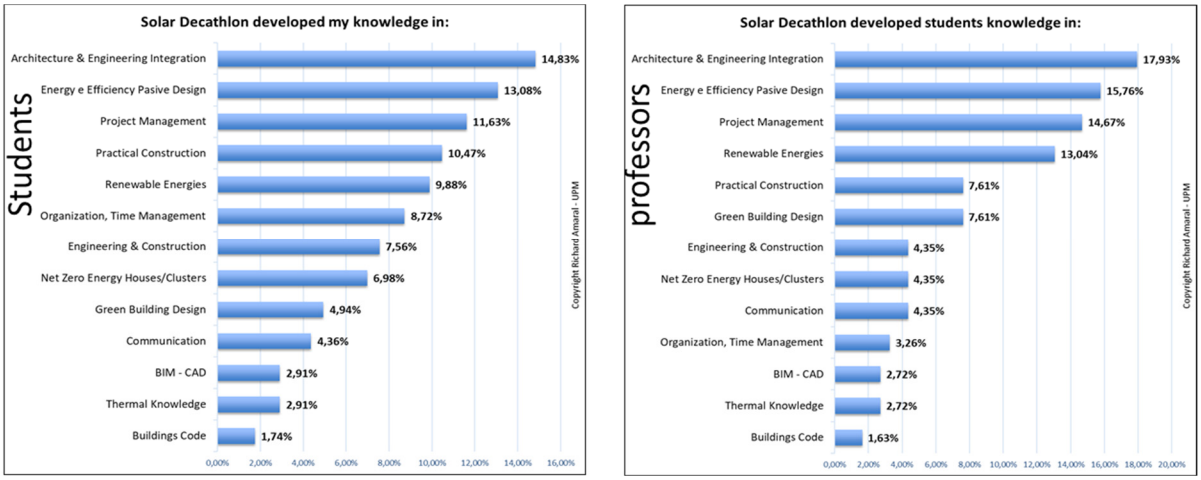


Figure 125: 2020 Survey.

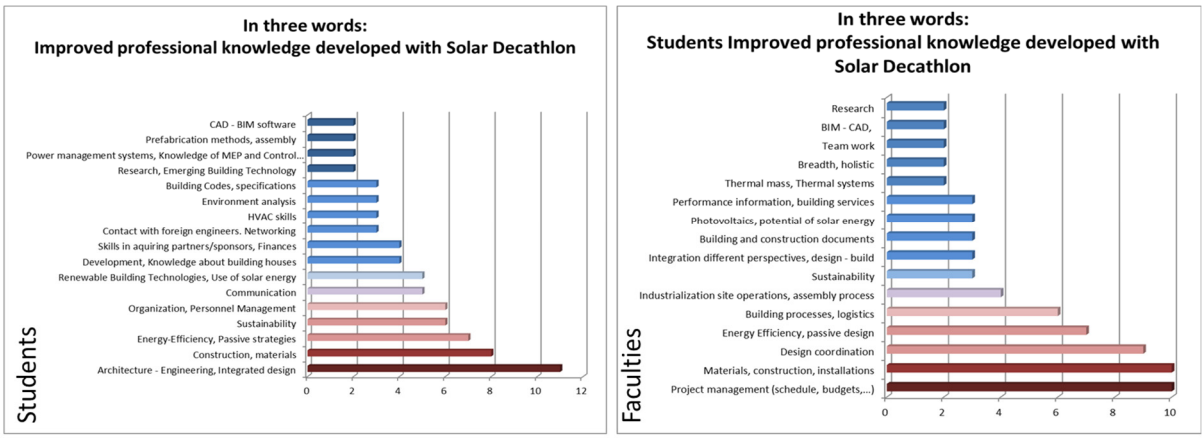


Figure 126: 2014 Survey.

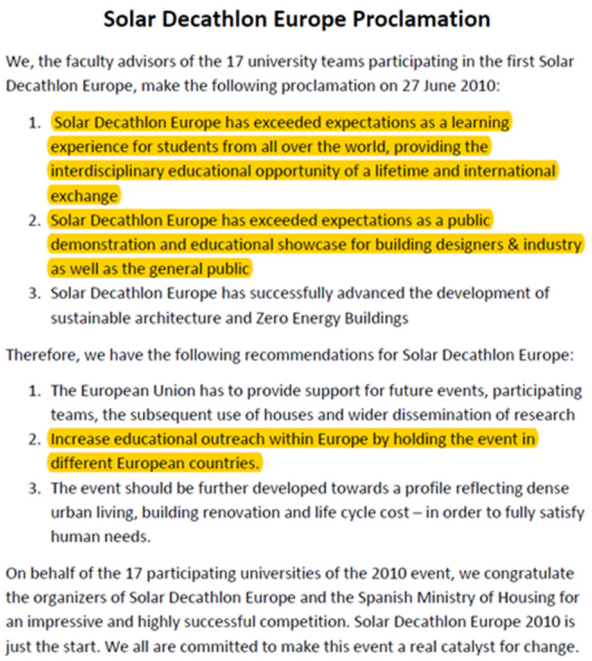
For example, at the Madrid workshop in October 2011 corresponding to the SDE 2012 Competition held in Madrid, various activities and team dynamics were developed to promote team building, the education of Decathletes, and the development of personal communications and leadership skills, etc.(figures 127,128)

Figure 127: Workshop SDE12 held In Madrid, October 201

Figure 128: Material from Workshop SDE12 held In Madrid, October 201

Another example illustrating the influence of organizers in the SDE education performance are the Rules and regulations of every edition. For Instance, there will be changes regarding education in the rules of the next SDE 2021 in Wuppertal with the intention of stimulating the educational impact on the participating universities through the requesting of a new report to the teams about, among others "*how is the participation in the Solar Decathlon (Europe) or comparable Competitions strategically integrated into the curricula and the broader strategy of the university? How are the Teams' SDE 2021 concept and corresponding urban transformation topics integrated into research and teaching?; strategic planning on different levels (bachelors / masters / PhD / research/ strengthening of connections and cooperation with other schools / fields of expertise /companies/authorities; and operative planning of measures on different levels (projects, publications, courses, field trips, scientific dissemination of results; implementation, assessment / controlling.*"

As regards the promotion of the educational aspects of the Competition from the organization, it is widely documented and recognized by the faculty advisors of the teams, as well as by the media, governments, and other public and private institutions.
For example, after the 2010 Competition, all faculty advisors, on their own initiative and outside the organization, signed a public letter called the Solar Decathlon Europe proclamation (figure 129). The letter clearly stated the educational potential of Solar Decathlon Europe for university students, professionals and the general public.



Solar Decathlon Europe Proclamation

We, the faculty advisors of the 17 university teams participating in the first Solar Decathlon Europe, make the following proclamation on 27 June 2010:

1. Solar Decathlon Europe has exceeded expectations as a learning experience for students from all over the world, providing the interdisciplinary educational opportunity of a lifetime and international exchange
2. Solar Decathlon Europe has exceeded expectations as a public demonstration and educational showcase for building designers & industry as well as the general public
3. Solar Decathlon Europe has successfully advanced the development of sustainable architecture and Zero Energy Buildings

Therefore, we have the following recommendations for Solar Decathlon Europe:

1. The European Union has to provide support for future events, participating teams, the subsequent use of houses and wider dissemination of research
2. Increase educational outreach within Europe by holding the event in different European countries.
3. The event should be further developed towards a profile reflecting dense urban living, building renovation and life cycle cost – in order to fully satisfy human needs.

On behalf of the 17 participating universities of the 2010 event, we congratulate the organizers of Solar Decathlon Europe and the Spanish Ministry of Housing for an impressive and highly successful competition. Solar Decathlon Europe 2010 is just the start. We all are committed to make this event a real catalyst for change.

Figure 129: Proclamation declared by the faculty advisors

As regards the promotion of the educational aspects of the Competition from the organization, it is widely documented and recognized by the faculty advisors of the teams, as well as by the media, governments, and other public and private institutions.
In the letter addressed by the US Solar Decathlon Director (Department of Energy of USA), Mr. Richard King, to the General Director of Energy of the European Commission, Mr. Philip Lowe, recommend that the European Commission provide support for the Solar Decathlon Europe. Mr. King stated, among other things that " *The inaugural event in Madrid last year proved how beneficial the Competition is. Hundreds of students and university faculty praised the event''s educational value. The 200,000 people who visited the houses to see the sustainable designs were equally impressed*" (March 31, 2011)

Later on, in the letter that the United States Secretary of Energy, Mr. Steven Chu, addressed to the European Commissioner for Energy, Mr. Günther Oettinger, support the proposal that the European Commission take an active role in the management of the Solar Decathlon Europe, Mr. Chu stated among other things that "*The event provides practical, hands-on training for student participants while raising public awareness of the opportunities presented by construction methods and technologies that are available today*." (October 25, 2011)

The support of the European Union and the United States for the joint commitment to Solar Decathlon Europe is demonstrated, for example, by the joint press release from the EU-U.S. Energy Council in Washington, 28 November 2011, which states, among many other points, that "*The EU and the U.S. intend to cooperate on continuing the Solar Decathlon Europe Competitions, transforming them into an initiative to foster sustainable economic development by creating markets on both sides of the Atlantic for integrating innovative technologies and renewable energy sources into new and refurbished low impact buildings.*"

7.1.3 High Potential of SDE to Foster Educational Innovation:

The education promoted by SDE Competitions is not only limited to the acquisition of new knowledge, or to the integration of different disciplines such as architecture with structural, construction, or installation engineering, but it also has a very high potential to promote educational innovation and integral education by developing personal experience, transversal skills, and professional training, all of them essential for the new generation of architects and engineers to make buildings and cities more efficient and sustainable.

Educational innovation provided by SD

Educational innovation could be defined as the systematic and planned incorporation of transformational practices, aimed at improving teaching and learning processes. It is usually associated with changes and improvements with respect to traditional training based exclusively on the transmission and learning of theoretical knowledge. Educational innovation is not a one-off activity without a dynamic process that helps students in experiential and collaborative learning, proving more effective than traditional teaching methods, and complementing the constantly necessary theoretical knowledge.

Reflecting on the innovative potential of SD, it is true that educational innovation implies the will to innovate and a planning of how to implement it, supported by theory, and a continuous process of reflection and improvement. In this sense, due to the temporary nature of the Competition and the lack of reflection by universities and teaching bodies, the innovative potential of SDE has probably not been sufficiently exploited. However, no one disputes this innovative potential, which allows for the identification of qualities associated with many of the main trends that are now recognized as effective educational innovation. Without being exhaustive, we are going to give a brief summary of some of these recognized trends in educational innovation, highlighting how SDE provides close values.

Gamification

We could define it as the didactic strategy of application of dynamics, metaphors, components, mechanics and principles of the games, in order to increase the motivation of the student in his/her learning process, to reach specific goals and to exercise specific skills and abilities. Among the wide variety of games that could be included in this strategy is undoubtedly that of university Competitions (teams in figure 130).
SD is an excellent example of where the university Competition impacts on the teaching-learning process, achieving significant results in terms of the high motivation of students who, by playing, learn the practical application of the knowledge acquired, improving in turn many of the students'' transversal skills, such as teamwork, creativity, reasoning and critical analysis, problem solving, tenacity, resilience, and the ability to make a living.

Challenge-based learning and design thinking

Challenge-based learning consists of an active learning strategy in which students solve a relevant and real challenge linked to the environment as a team, up to the dissemination of the achievements. The techniques of design thinking promote a dynamic and exploratory design method to generate innovative solutions. A student working on prototyping phase of design thinking methodology in figure 131.

Figure 130: SDE 2014 Competition in Versailles.

SDE is also a good example of these educational innovation strategies, as it focuses the student's interest on resolving the design of a prototype of a zero-energy house, with very high energy performance. The resolution of the challenge not only favours the necessary interdisciplinary collaboration and integration of knowledge and techniques of all kinds: projects, models, inventions, creative innovations, communications techniques, marketing techniques, social awareness, etc.(figures 132,133), but also the collaboration with professionals and industry, sharing with partners, sponsors, and collaborators the common challenge, promoting creative innovations and the application of new products and systems.

Figure 131: SDE 2104 Competition in Versailles.

This strategy applied in SD generates, and this has been confirmed by the results of the surveys carried out in 2014 and 2020, a high level of student satisfaction; it generates highly productive group dynamics; it improves applied and multidisciplinary knowledge linked to professional development. It promotes the integrated development of specific skills and transversal skills such as entrepreneurship, teamwork, leadership, organization and planning, logical thinking, problem solving, analysis and synthesis, creativity, collaboration, empathy, learning through research, digital culture, innovation and critical thinking, and communications skills (figure 134). It also has a high potential in scientific-technical subjects, and for creating links between academic and business activity.

Figure 132: Winner SDE 2014.Universitá Degli Studi de Roma TRE (Italy).

Learning by doing and hands-on experience

Learning by doing is an action-oriented methodology of educational innovation, and very close to the previously described methodology of challenge-based learning and design thinking. Ideas and concepts are still necessary but turning them into a tangible reality is a key factor for success. Main challeges of SDE 2014 are defined by the competition organizer in figure 135. Learning by doing' is born with this spirit by putting the ideas designed by a team of people into practice.

Figure 133: Winner SDE 2012. Ècole Nationale Supérieure de Grenoble

SDE is a good example of this trend in educational innovation. Learning derives from the application of studied knowledge and making it real in a tangible and authentic context, facilitating the resolution of

problems of each team in ordering the ideas to achieve the proposed objectives. The successes and mistakes are the basis of this methodology, which finds in experimentation a way to discover which elements work and which do not in each case. In this method, we aim for natural, team-based learning that supports their truthfulness in practice. Bringing ideas down from the conceptual world to the tangible world is key to achieving what a company needs.

Figure 134: German student In Madrid. SDE 2010 Competition

The learning resulting from SD derives from the stimulation of participation, activity, and materialism. It also encourages the sharing of ideas with colleagues, discovery through trial and error, and the development of basic competencies for the management of business resources, such as team leadership, analysis and common problem-solving. Knowledge, skills and tools are obtained through action, joint reflection (students and professors) that leads to open minds and expand horizons, and experimentation (trial and error).

Service-learning and experiential learning

Experiential learning is the process of learning through reflection on experience. Experiential learning is a form of experiential education, but it does not necessarily involve students reflecting on their product, but on their experience gained. The methodology based on service-learning is collaborative and equally experiential, in which the student carries out a service to the community, promoting critical analysis, understanding of social problems, and stimulating the proposal of solutions. The teachers who facilitate the process promote the students'' protagonism from the design of the experience to the celebration of the achievements.

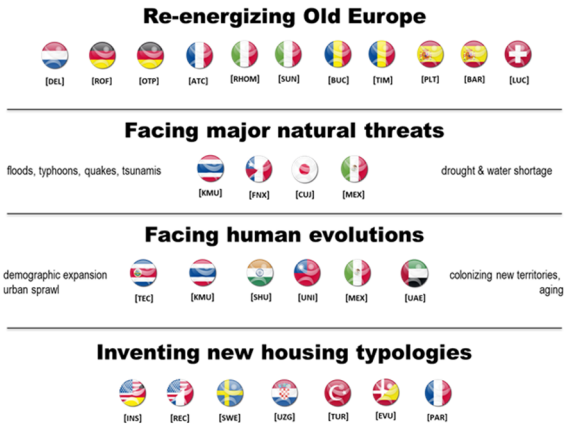


Figure 135: Main chanllenges faced in SDE 2014. (Pascal Rollet)

SD promotes experiential learning in accordance with David A. Kolb''s model.[4] Not only do you learn by designing an energy-efficient and functional house, but you also learn a lot from observing the real performance of the house under real conditions, as well as interacting with the rest of the teams in the Competition. The student learns from the analysis and reflection derived from the monitoring of the Competition, and from the objective score (by monitoring, or evaluation by juries of international experts) of each of the contests and sub contests, and from the general scoring. In order for experiential learning to be effective, the intention to learn is fundamental, and to this end students must be highly motivated, and be very proactive, conditions that SDE has been able to verify from the surveys carried out.

[4] https://educationaltechnology.net/kolbs-experiential-learning-theory-learning-styles/

Experiential learning also extends to service-learning.

In SD, experiences have combined technical learning with the provision of services to the community, in various areas of social interest such as social awareness on issues related to the responsible use of natural resources, responsible use of energy, or what each citizen can do for a more sustainable and low-carbon world. The objective shared, for example, with the teams of the SDE10 Competition, that each team should take advantage of the house that they have built to raise awareness of all these issues related to sustainability, together with the strategy of the 10Action project, led to an interesting activity of social awareness that was part of the values won by the students in the Competition, resulting in a very rewarding experience for students, teachers, universities and the participating organizations themselves. SD encourages the social commitment of university students and promotes the ethical dimension in academic training, strengthening the development of generic skills such as communications, teamwork, project management, social commitment, etc.

Another significant aspect is the challenge proposed by the organization of SDE 2014 in Versailles to the participating teams, that the houses proposed by the teams should respond not only to the Competition''s own requirements, but also to the social or technological challenges posed in their respective communities. This approach resulted in an enrichment of the Competition and a greater commitment of the students to respond to these challenges, mani prototypes integrate sharing-spaces o think about new housing typologies with service-spaces for the community (figure 136).

Figure 136: Université de Nantes. SDE 2014. Versailles.

Thus there were very suggestive proposals to respond to the great challenge of energy retrofitting in Europe, with proposals for zero energy industrialised units in existing buildings making the complete rehabilitation of the building feasible (Germany, Spain), or proposals to reuse and recycle existing buildings (Netherlands, Italy, Romania, France), or revitalise the sense of community by sharing spaces and infrastructures (Switzerland and Spain).

Other equally interesting proposals tended to be oriented towards responding to natural hazards such as global warming and the consequent floods and typhoons (Thailand), human growth and urban agglomerations without the necessary infrastructure, with problems of drought and water scarcity (Mexico), or problems derived from seismic activity with earthquakes and tsunamis (Chile and Japan). Other challenges posed by the teams attempted to bring together responses to human evolution with solutions to colonise new territories (UAE), of greater density to accommodate the expansion of the population in cities (India), or responses to the progressive aging of the population. (Costa Rica). Innovative solutions are also provided that reformulate housing in rows (USA, France, Taiwan, Italy), or in blocks (Sweden, Denmark, Spain, Turkey)

Learning in collaborative environments and team-building experience

Learning in collaborative environments fosters collective intelligence by linking the potential of digital technology and the web, to encourage collaborative knowledge building. It is linked to ubiquitous, flexible, open learning, giving rise to processes that address enriched student experiences, as well as the personalisation of experiences in knowledge communities and team-building experiences.

SDE is a Competition for multidisciplinary teams of university students that, with the support of faculty advisors, have to give an overall and effective response to the multiple and varied requirements of the

Competition, and only from the collaborative work of the team, and from the construction of a solid and united team, can it be done in a solvent way. The challenges posed favour both face-to-face and virtual collaborative dynamics, with a variety of tools such as team building strategies (many teams have come together through the association between two or more universities, in the same or different countries), collaborative repositories, agile collaborative tools, co-creation, co-development and co-construction techniques.

The interaction of SDE students in collaborative environments, and the use of social networks for formal and non-formal learning, have had a significant impact on the learning and development of transversal skills such as critical thinking, teamwork, intercultural and interdisciplinary competence, or internationalisation. Teams working and teams celebrating in SDE 2014 in figure 137.

Figure 137: Team working in SDE 2014 (left) cole Nat. Sup. d'Architecture et de Paysage de Lille. SDE 2019 (right)

Comprehensive education

One of the most significant contributions of Solar Decathlon Europe from an educational point of view, is the comprehensive educational model it provides to university students, which includes not only the application of the theoretical and technical knowledge of the different disciplines it covers (architecture, engineering, communications, marketing, management, etc), often linked to innovation and research into new proposals, but also its practical hands-on application, as well as the professional training demanded by the labour market, the development of the technical, management and transversal skills necessary for their work as professionals, and the enrichment of personal experience by promoting an active commitment to society.

Education linked to innovation and research

The education promoted by SDE in many cases comes directly from the innovation and research developed within the framework of Solar Decathlon. In the survey carried out at SDE 2014 to evaluate the participation of students in research activities associated with Solar Decathlon 50% of the professors surveyed said they had developed research projects linked to the Solar Decathlon experiences (figure 138) and 60% of both students and professors stated that they had participated in research activities during or after the development

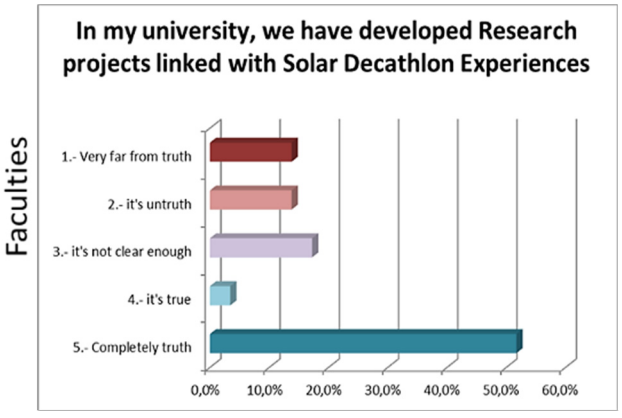


Figure 138: SDE 2014 Survey.

of the houses (figure 139), which confirms the educational potential associated with innovation and research.

In the student survey conducted in 2020, 49% of the students stated that they had been able to do research during the development of the Competition, or had done research after the Competition, linked to the Solar Decathlon prototypes.

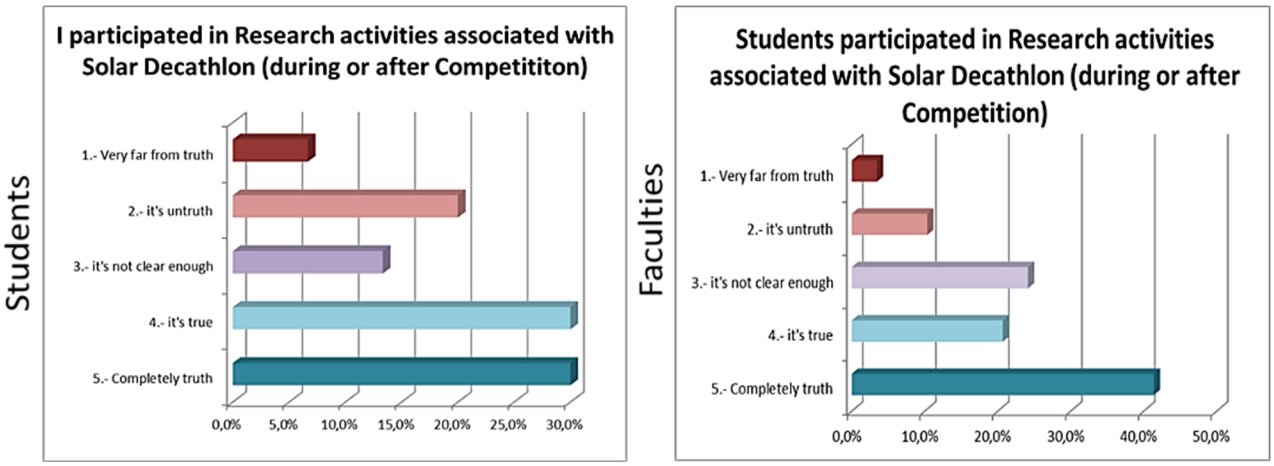


Figure 139: SDE 2014 Survey.

Hands-on and professional training

The potential of SDE to promote hands-on learning and professional training and qualification is important and enriching. However, the SDE 2014 survey notes from neither students nor professors planned professional training programs for Decathletes at their universities. 84% of students (figure 140) and 53% of professors stated that there were no such programs.

This data contrasts with the perception, especially that of the professors, that during the development of the Competition, educational and professional training activities were planned and carried out, with an estimated average score of 3.32 points out of 5, but with 47% of professors declaring that they had organized them. The students' perception was lower, with an average of 2.73. In any case, it is clear from the analysis of the results that there have been universities that have programmed educational and professional training activities, but many others that have not taken advantage of this potential.

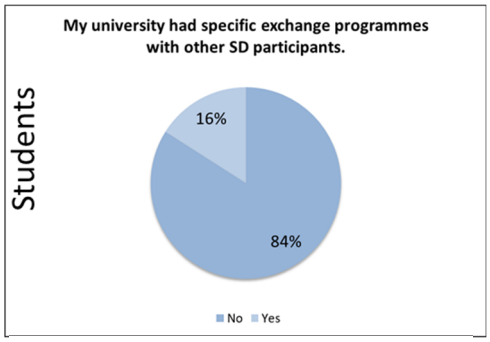


Figure 140: SDE 2014 Survey.

7.2 Professional skills development

Although not all universities have had a planned policy to promote education and professional development activities, it is very significant that there is great unanimity in considering that Solar Decathlon has contributed to the development of personal skills. Practically all professors, 97%, agreed or agreed strongly with this statement, with an average rating of 4.66 out of 5. This percentage drops to 81% in the case of students, with an average rating of 4.38 out of 5.

These data support the affirmation of the great potential that SDE has to develop personal skills which, SDE contributes to improving the employability of the Decathletes in the labour market. While students highlighted, in an open question in which they had to quote just three words, skills related to communications and public relations (17%), project management (16%), teamworking (11%), construction (9.5%) or leadership (6%); professors instead valued team building - collaboration (11%), project management (9.9%), construction with new materials (8.9%), design (8.9%), interdisciplinarity (7%), or communications (3.9%). The soft skills acquired in communication and public relations are the most valuable for students; however, professors do not have the same perception (figure 141).

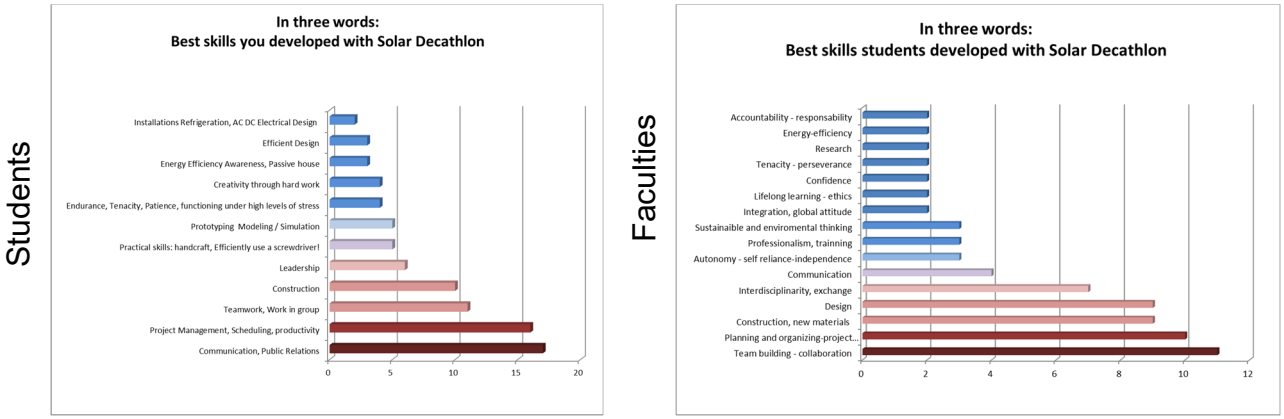


Figure 141: SDE 2020 Survey.

7.2.1 Personal experience enrichment

Similar results, but with more points of agreement between professors and students are observed in an open question in which they had to quote just three words, related to Improved personal experience developed with Solar Decathlon. While students highlighted communications (10%), teamworking (7%), friendship (5.9 %), Contacts, networking (5.9%), or open minded and less insecure (5%). Professors valued communications(11.9%), teamworking (9%), sharing with students (7.9%), friendship (6.9 %), hard working under stressful conditions (5.9%), or cooperation and Integration (3.9%). There is no doubt that Solar Decathlon enriched the personal experience of each of the students who participated in a Competition (figure 142).

In the 2020 survey, to the open-ended question of naming three inspirational words that leverage opportunities and synergies which arise from SD educational potential, the most frequent were related to team working, learn by doing, practice, and Innovation, energy efficiency, sustainabilit etc.
Finally, it is worth highlighting that Solar Decathlon could encourage exchange programmes between students from different universities participating in the Competitions, but so far only small occasional operational exchanges have taken place for the coordination of mixed teams, thus wasting a potential that could be enriching for university students. In the 2020 student survey, only 16% of students stated that their university had specific exchange programmes.

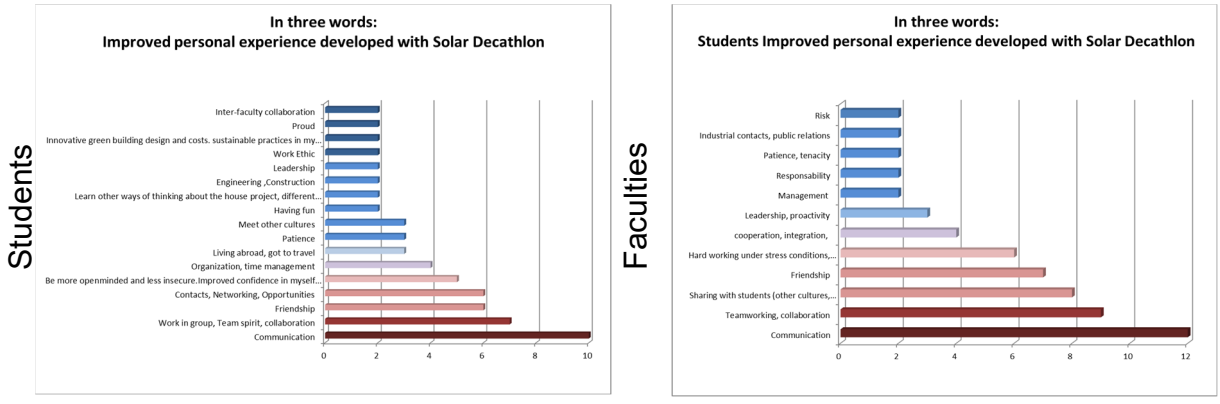


Figure 142: SDE 2020 Survey.

7.2.2 Impact related to Workforce

The shift to a low-carbon economy implies structural changes across sectors and occupations as new 'green' occupations have arisen or grown in demand. Energy-efficient and sustainable buildings will play a key role in order to remain on track to full decarbonisation. However, installing the technologies needed to make Europe''s building stock greener requires a **skillset** that the **construction industry is struggling to supply**[5].

Accoding the report «Labour market shortage» [6] the construction sector has been affected by a **skill mismatch.** The difference between the qualification level of jobseekers and the job requirements can take the form of **over qualification or under qualification**. The construction sector in **Europe** has one of the **highest levels** of **over qualification**, with about one third of workers being overqualified for the job they do.

Skill shortages and mismatches in the construction sector are associated with several **structural barriers**: the **decrease** in the number of **young skilled workers**, the ageing of the construction sector's workforce, **migration,** and the **misalignment** between **vocational and educational training** (VET).

At the same time, **innovation in the sector and EU regulation** are creating **new drivers** for the development of the sector and **desired skills** for its workers. Some of the skills acquiring greater importance include management, planning, numeracy, and communications skills, as well as ICT, renewable energy and energy-efficiency skills.

Although training in green building skills has increased over recent years, employers still face difficulties in finding qualified people to undertake certain jobs. Greater coherence and **coordination between education, training, employment, and low-carbon policy** will be needed to engender an effective job-rich, sustainable energy transition.

As described in detail in the European Construction Sector Observatory analytical report on **"Improving the human capital basis"**[7], the energy efficiency targets need a **transformation of the skills required during all stages** of the building process, from planning to design, production, maintenance and renovation and finally demolition.

At the **pre-design** phase of the project, the professionals will be required to have knowledge about any relevant climate considerations, appropriate passive sustainable design strategies and environmental resources, as well as an understanding of the energy performance goals of the final construction.
During the **design phase**, professionals will need skills related to the technical solutions necessary to tackle and address such sustainability issues, for instance ensuring the final construction includes the necessary infrastructure to face long-term climate change challenges such as the increase in rainfall and flooding.
Similarly, during the actual **production stage**, site workers need to be trained to develop the necessary skills to carry out sustainable construction practices on-site, whereas managers will be required to have the skills to be able to organize the logistics of the construction process sustainably.

In the **maintenance/operation (+refurbishment) phase** some of the key skills needed will include effective communications with clients regarding energy-efficient renovation, installation of energy-efficient

[5] Skills for green jobs: 2018 update: European Synthesis Report. Cedefop. Luxembourg: Publications Office of the European Union, 2019 https://www.cedefop.europa.eu/files/3078_en.pdf
[6] European Parliament, Labour market shortages in the European Union. March 2015. http://www.europarl.europa.eu/RegData/etudes/STUD/2015/542202/IPOL_STU(2015)542202_EN.pdf
[7] PricewaterhouseCoopers (PwC), European Construction Sector Observatory – Analytical report on TO2 - Improving the human capital basis, April 2017. https://ec.europa.eu/growth/sectors/construction/observatory/analytical-reports_en

building automation systems, post-installation follow-up services and enhanced cooperation among all professionals involved in this stage.

Finally, new skills will be increasingly needed at the **demolition stage** during the dismantling, reuse, recovery, or disposal of building materials. Consequently, workers skilled in the removal of waste from the site and in detecting leakages, pollution and emissions will be particularly sought-after in order to prevent the contamination of materials while project managers should provide the overall strategy and strategic knowledge to instruct and train the workers.

However, beyond tackling the problem with efforts to increase the levels of qualifications, it is important to note that Member State economies are heterogeneous, and that needs for specific skills in the construction sector in the short term need to be **contextualised**, future needs for skills in the short term will be characterised by **different levels of skill qualifications and education across countries**[8].
Skills in **designing and conceiving new green buildings** are likely to be appropriate particularly in emerging economies. For developed countries, the greater emphasis is likely to be on **building energy retrofitting.**

Research into the identification of skills shortages[9] indicates that sectors with critical shortage or surplus have important effects on national education and training programmes. Country level research suggests that architecture is a key occupation in developing green business, and one in which it can be difficult to find people with the right skills. For architects, as for engineers and consultants, technical skills (such as an understanding of passive design techniques and renewable energy technologies) are very important, but so too are softer skills, such as environmental awareness and an ability to communicate.

As well as the skills needed for the specific occupations, there is a set of core skills[10] which are needed by those working in all areas of green building. Given the rapidity of change, there is a requirement for adaptability to change. There is a need for adequate environmental awareness. Green building also calls for interdisciplinary skills, including the ability to work effectively with people from other disciplines as well as individually having skill sets which cross traditional occupational boundaries. Finally, teamworking, coordination and leadership skills are important core skills in all areas of green building.
Aligning the competences of the workers to the requirements imposed both by policy drivers and market demand will result in a more productive, profitable, and competitive construction sector. **Solar Decathlon participates in the reduction of the aforementioned existing gap, regarding both technical skills** (green building design, understanding of heating, ventilation and air conditioning systems, solar thermal and photovoltaic technologies, the energy efficiency characteristics of materials, energy monitoring, etc.) and **softer skills (environmental and social awareness and** communications**).**

Results from the Survey carried out in 2020 approach this matter, students are asked about their perception (figure 143). 100% of the students think that their participation in SDE has enhanced their employability. They are also asked to score from 1 to 6 how much they consider SDE

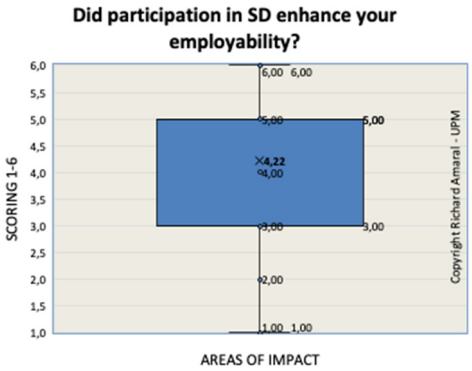


Figure 143: Students answer to "Did participation in SDE enhance your employability?" (SDE 2020 Survey)

[8] UEAPME, Business Europe, CEEP. The cost-effectiveness of apprenticeship schemes. 2016. https://be-extranet-prod.s3.amazonaws.com/publications/2016-05-27_employers_final_report_on_apprenticeships.pdf
[9] CEDEFOP, Skills shortage and surplus occupations in Europe. Briefing note, November 2016. https://www.cedefop.europa.eu/en/publications/9115
[10] Skills for green jobs: 2018 update: European Synthesis Report. Cedefop. Luxembourg: Publications Office of the European Union, 2019 https://www.cedefop.europa.eu/files/3078_en.pdf

has enhanced their employability. Their perception is SDE has indeed enhanced their employability scoring 4.22 on average.

7.2.3 Enhancing Professional Capabilities through SDE

The **core skills**[11] important in all areas of green building: adaptability to change, environmental awareness, interdisciplinary skills, cross traditional occupational boundaries, teamworking, coordination and leadership skills are empowered in Solar Decathlon Teams. These skills, particularly the soft skills, are not usually included in the curricula of technical degrees.

The main value regarding **technical skills** is that Decathletes put into practice the theoretical knowledge acquired during their years of university studies, information regarding architecture, engineering, green building design, monitoring and data management and logistics. Project management is coordinated in a small but complex project which allows the student to get an overall perspective of the building process.

Students and professors taking part in Solar Decathlon acquired expertise that usually goes beyond their activity. As regards architects, they will take part in the building performance evaluation. The houses are not only designed and built using innovative sustainable criteria design and new technologies, but they are also tested. The Teams go through pre-design, design, and production phase but not only that, they evaluate monitoring comfort parameters and energy performance, checking how solutions really perform, they go thought most of the construction phases considering the whole life construction process (figure 144).

This is a valuable expertise. The requirement for monitoring building performance is currently being incorporated into European Building Regulations. The Solar Decathlon has implemented this testing in their houses since 2002.

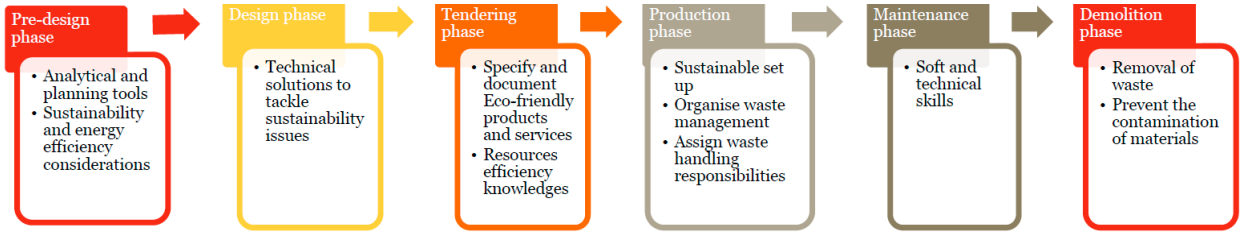


Figure 144: Skills needed across the construction process (PwC / ECSO Analytical report TO2) https://ec.europa.eu/growth/sectors/construction/observatory/analytical-reports_en

Solar Decathlon teams usually consist of 30 or 40 members, the hierarchy is not always clearly established. Team structure is predominantly bottom up or quite democratic which leads to a need to develop tolerance and flexibility in the work process. The **core skills** important in all areas of green building are essential in this type of participatory and collaborative work structure, particularly **adaptability to change and teamworking**.

Teams competing in Solar Decathlon are **interdisciplinary** including mainly architects and engineers but also students from other disciplines (environmental studies, building physics, communications, economy, marketing, graphic design, interior design, lighting design, social science, etc.) which teaches students to work in multidisciplinary teams (monitoring indoor quality in figure 145), to evaluate problems from different angles

Figure 145: OTO Team in SDE 2012

[11] Skills for green jobs: 2018 update: European Synthesis Report. Cedefop. Luxembourg: Publications Office of the European Union, 2019 https://www.cedefop.europa.eu/files/3078_en.pdf

and to value the contribution of other disciplines to solve a common problem. In short, to be part of a solution without necessarily leading the way. **Coordination** and **leadership** skills are also empowered in Solar Decathlon Teams.

Some of the teams are not only large and multidisciplinary but trans-regional and trans-national. In these cases, the coordination difficulties are greater, but so is the educational value of the experience. Collaboration between countries working remotely is necessary to solve the global problems we face, students who have gone through this process will be better prepared to be part of international projects.

The educational value of Solar Decathlon Europe also addresses professors, for whom continuous learning is of great importance. During the Competition, they not only learn from putting the theoretical knowledge they teach into practice, but they are also part of a team (team celebrating in figure 146), they also develop skills in **communication, teamwork and leadership skills.**

The student''s acquisition of skills during Solar Decathlon Europe is diverse, depending on the student and professor's implication in the projects and the construction. The perception among the students as to the skills they developed with Solar Decathlon is high. In SDE 2012 Students were asked to score how SDE has helped them to improve aspects such as communications skills, teamwork, multidisciplinary team working, etc (figure 147)

Figure 146:. OTO Team in SDE 2012

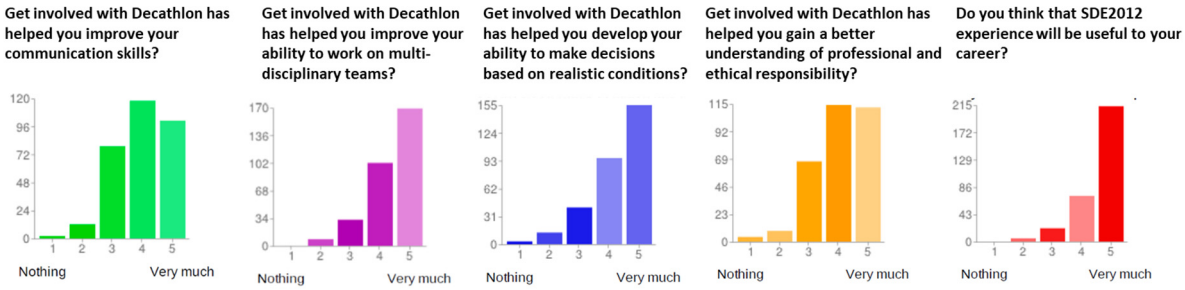


Figure 147: Students answer to SDE 2012 Survey.

In SDE14 the students and professors were asked the same question about the skills students developed with Solar Decathlon. The students' perception of the skills developed is high but a little bit lower than that perceived by the professors (figure 148).

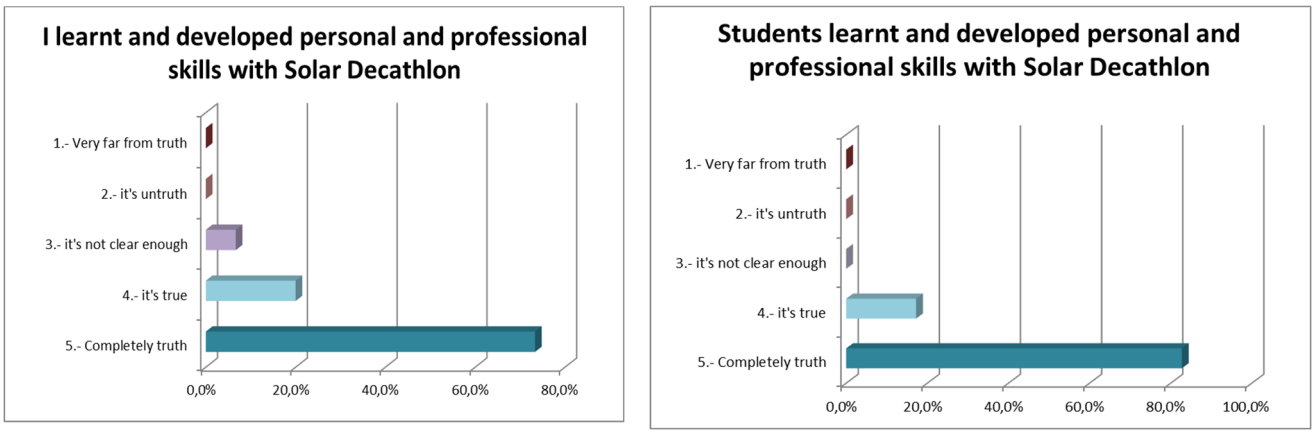


Figure 148: Students answers to SDE 2014 Survey (left), professors answers (right)

There are usually not specific training activities and Solar Decathlon is not used as a training program from the universities, as mentioned in the **Comprehensive education** section, nevertheless, practical learning occurs even though it is not programmed, it being a consequence of the accomplishment of the Solar Decathlon Europe challenges, both during the time of the project and the Competition event. When professors and students were asked to give a free answer about which specific professional knowledge the students developed in SDE (figure 149), the answers of students and professors were quite in tune regarding the items they mentioned, professors think students especially develop in “Project management, materials, construction and facilities and design coordination”, and students think they develop in “Architecture and engineering integrated design, materials and construction”.

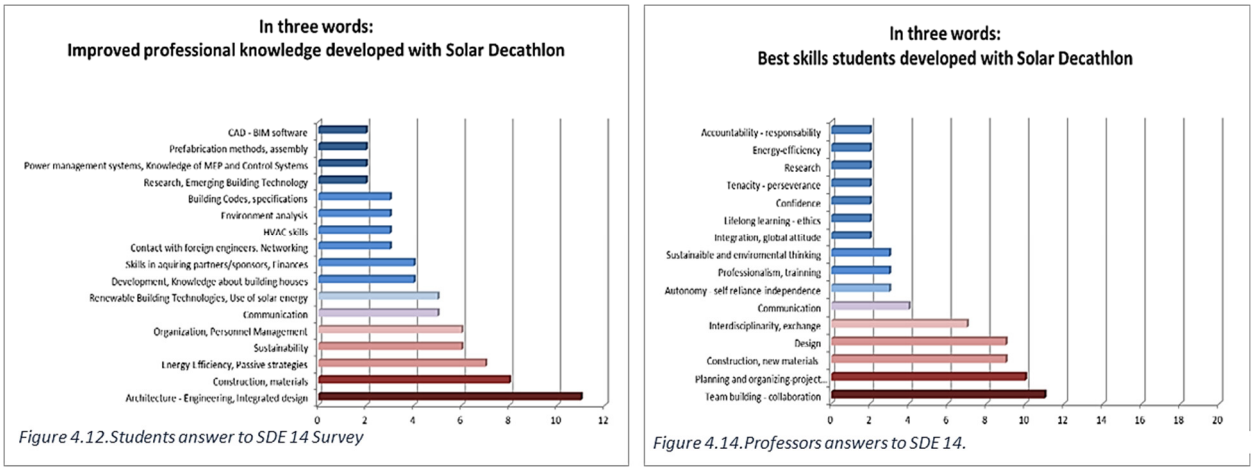


Figure 149: Answers to SDE 14 Survey.Students (left); professors (right)

Most of the students must carry out communications and awareness activities (figure 150), for the first time in their lives, developing capabilities not explored so far, acquiring new skills, and overcoming fear. In this process of communicating there is a self-awareness, an interesting transformation experience by students and professors alike. **Learning Solar Decathlon Europe** potential is doubtless and has still to be optimised. To accomplish it there is much more that could be done. A protocol to guide teams to optimise this potential should be developed approaching the aforementioned issues: teamwork, multidisciplinary, collaboration, flexibility, tolerance, environmental awareness and integrating other issues needed to face the challenges of the future to enhance creative and thinking outside the envelope, not only in students, but professors, professionals and the public alike.

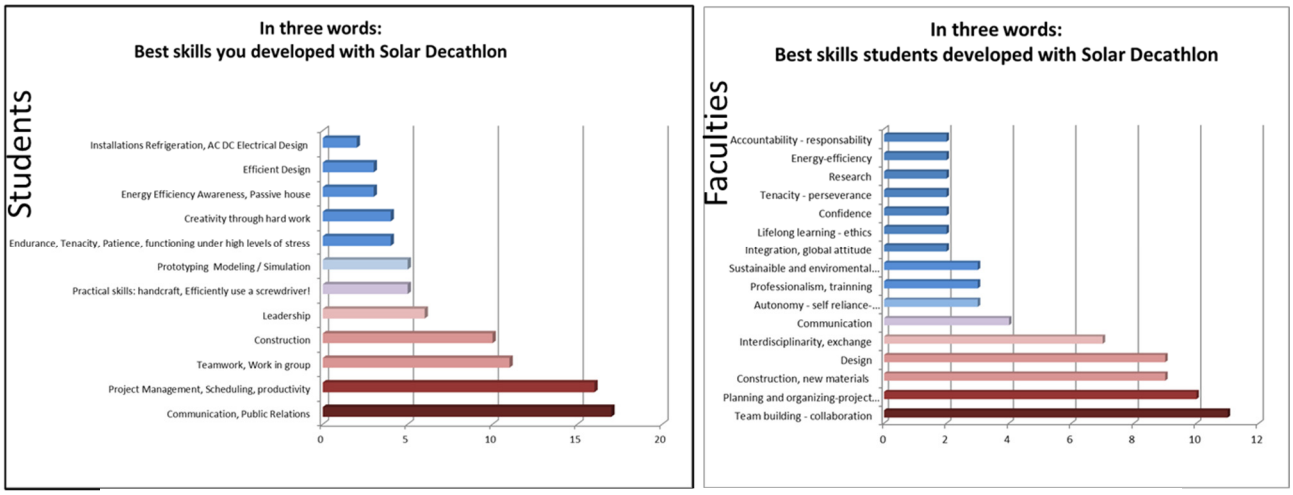


Figure 150: Answers to SDE 2020 Survey.Students (left) ;professors (right)

In the 2020 survey a similar open-ended question of naming three inspirational words that leverage opportunities and synergies which arise from SD workforce profiles, the most frequent were related to teamworking, friendship, participation, creativity, resilience, leadership, etc. (figure 151)

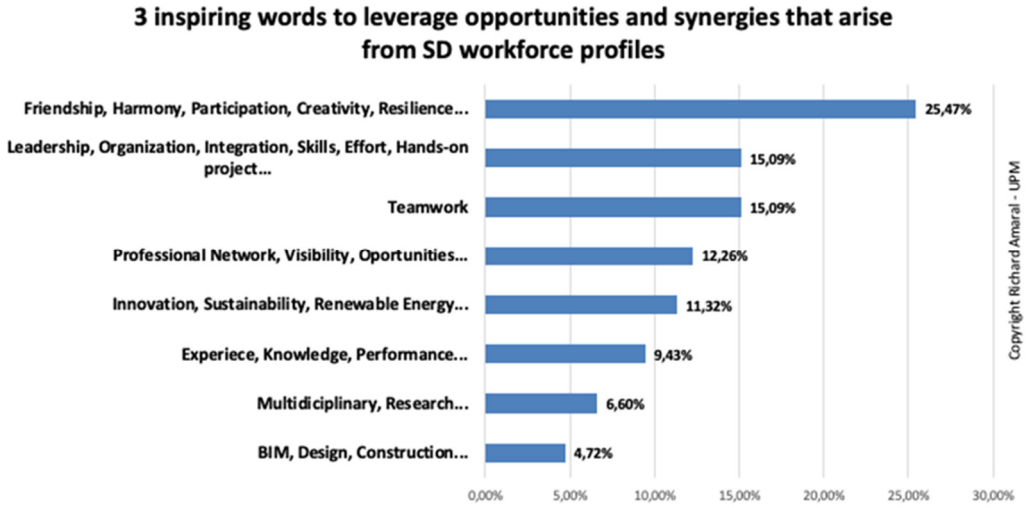


Figure 151: SDE 2020 Survey

Based on the lessons learned in previous Competitions Solar Decathlon Europe is in a process of continuously self-improvement. As regards education, Solar Decathlon 2021 has implemented the evaluation of the effects of Solar Decathlon Europe in the student's education. With the aim of stimulating the educational impact on the participating universities, the team's faculty advisors need to report issues such as how is the participation in the Solar Decathlon Europe has been strategically integrated into the curricula or how are urban transformation topics have been integrated into research and teaching. A guide for a communications report applied to the specific is proposed in the Rules and Regulations.

7.3 Empowerment Synergies from industrial Participation

Solar Decathlon has brought university and industry together to demonstrate that Solar Buildings are a reality. First editions had their focus on the demonstration of market ready solar technology solutions to society and nowadays, the focus has been extended to achieving sustainable cities.

Synergies among Solar Decathlon Europe and industrial participation is the basis of Solar Decathlon Europe. Team funding is possible due to the collaboration between university, public sector, and industry. This collaboration enables the participation of the teams, carrying innovative technologies further along the innovation cycle to bring them to the market.

The feedback from industry after being part of Solar Decathlon Europe is very positive. Companies found profitable sponsoring both, Teams and SDE Organization as shown in figure 4.72. 75% of them affirm that would sponsor the Solar Decathlon Europe again (figure 152).

Companies and professionals are invited to score from 1 to 6 if after visiting the SD Competition they decided to instigate training in new sustainable technologies, the average score is 3.72 which implies there is an input of SDE in the improvement of sponsors and professionals (figure 152).

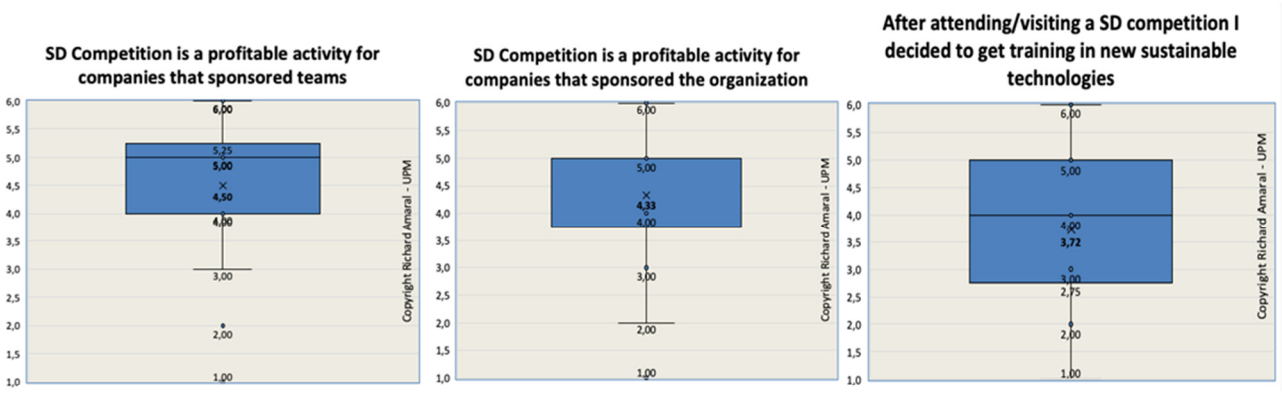


Figure 152: Sponsors answer.

Joint or coordinated efforts to achieve greater impact and efficiency can clearly be identified between Solar Decathlon and industry as amplifying the communications strategies and the research and innovation impact or combining different forms of innovation and knowledge. Nevertheless, synergies in obtaining greater impacts in the training and competitiveness of Decathletes are still latent and not so clearly manifested as a general result of the collaboration between university and industry in most of the Teams.

Solar Decathlon accumulates young talent from the whole world and from many disciplines. Sponsors are aware of it, some of them are quite impressed with the Competition results. Not only with the houses and technology demonstrated but also with the idealism, spirit of collaboration and teamwork, the energy of students and professors is perceived, felt, and spread. Relationships and even friendships are established, in many cases they lead to the employment of students by the sponsors.

In green building design, an architecture or engineering degree per se does not make a big difference between jobseekers but those architects or engineers who have participated in a Solar Decathlon Competition are more prepared to face the challenges of innovation. Employers are expected to rate this experience as positive which should facilitate the employability of Solar Decathlon students. Companies with an innovative spirit look for young talent to train it. For this they need to get close to the university, Solar Decathlon accelerates and facilitates this connection.
In the SDE 2020 Survey, to the question “Would you prefer to contract a student participant in a Solar Decathlon Competition?” 100% answered they would prefer to do so and to the question “Do you think Solar Decathlon participation improves student employability?” 100% also answered positively. These statements from professionals are far from the perception of the students of whom 55% considered that the goal of fostering students’ employability was not achieved.

The perception of students, professors, and professionals as to how SD has developed students’ experience in different items is compared in figure 153. All of them agree that the main aspect to value is Team working, professionals especially emphasise it. Communications is the second item ranked for all of them as valuable. Apart from these two items in which there is a relative coincidence in the responses then a variation in the different perceptions can be observed. Students value their experience in management, leadership, and friendship. Professors value student experience in management, leadership, sharing with other cultures and networking. Professionals value student experience in sharing with other cultures, risk management and resilience.

In the case of Europe, the success of the Solar Decathlon Europe Competition is largely due to the commitment of the Solar Decathlon Europe organizers, the University Team members (professors and students), the industrial partner and the public institutions. The motives and interests behind this important commitment are diverse and mainly based on a specific result expectation.

The motivation of the students to participate in Solar Decathlon Europe are probably different, they can be related to a variety of areas of interest around the project, but a common driver could be the interest in being part of a project that aims at the necessary improvement of today''s world. This ambitious goal makes the students efficient, creative, and productive.

When it comes to building a successful team, **commitment makes all the difference**. Solar decathlon Europe requires a highly committed team, with high motivation. Students showcase engagement by heading up activities **outside their comfort zone**, leading a volunteering initiative, actively seeking out ways to improve their performance, working long days, etc.

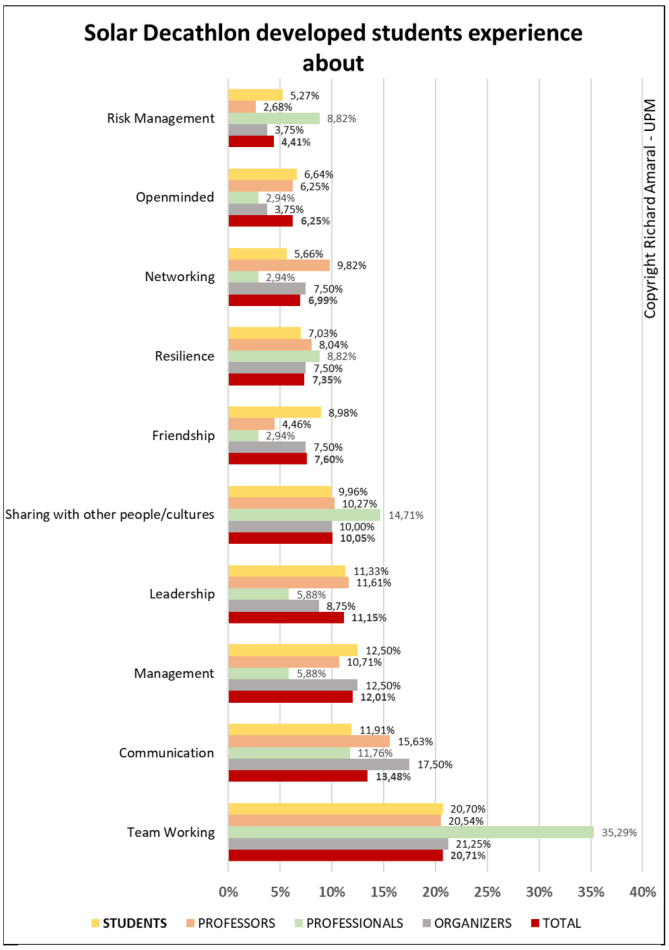


Figure 153: SDE 2020 Survey answers.

To count on a committed workforce, industrial interests and society interests must be aligned. The students who have committed themselves to the Solar Decathlon are more likely to commit themselves again when the goal is linked to a common good. Once a Solar Decathlon Competition has finished students have gained knowledge, abilities, and expertise, and more importantly, they have gained resilience, as an outcome of successfully adapting to difficult or challenging experiences, especially through mental, emotional, and behavioral flexibility and adjustment to external and internal demands. They have gone beyond what was expected of them and they have demonstrated their commitment. They have gone beyond limits, sometimes self-imposed, realizing that it is possible and rewarding to strive to achieve great challenges. Most of them would commit themselves again to projects aiming at a better society. The **challenge after each Solar Decathlon Europe Competition edition has finished is to be able to exploit these "needed" workforce profiles** to face future crises.

A more stable and fluid continuity between editions would guarantee a **long- and medium-term involvement of industry**. For instance, the continuity between European editions has been uneven; in Solar Decathlon Europe 2010 and 2012 there was continuity because the organization Team was the same, since then, from one organization to the next there has been a transfer of information and lessons learned, but an overall transfer of knowledge in all areas has not been achieved. To remedy this, a **professionalisation and continuity of the Solar Decathlon Organization Team would be advisable.**

To maximise impact and efficiency in this matter, in order to achieve such an interesting synergy as a coordinated university-industrial training, the Solar Decathlon Europe and industry should have a medium to long-term perspective strategic approach, a wider approach integrating all layers of stakeholders at a regional, national and European level. To achieve this, it is crucial to align strategies and define common roadmaps but to do so, Solar Decathlon Europe needs to provide a stable and permanent setting ensuring a perspective of continuity, it needs to be supported in a medium to long-term approach.

In Solar Decathlon Africa the objectives, through this competition, are to provide a solid platform for empowering the young generation and educating the broader public to improve energy efficiency in buildings, to push the envelope on clean energy technologies, ensure financial sustainability and finally, to unveil the advantages of local raw materials. The Solar Decathlon Africa is a milestone event to help put the continent on a sustained pathway for a clean electrical energy system and lay out the groundwork for a sustainable and healthy building environment.

Solar Decathon AFRICA contributes to empowering our sustainable future in many ways. The program is:

- An international competition that prepares more than 1,200 participating students for careers in clean energy and green buildings sectors on the African continent.
- A key programme to underpin the strategies of carbon-free energy systems in AFRICA.
- A proven training program that embraces an innovative method of teaching Science, Technology, Engineering and Mathematics (STEM).
- A demonstration of energy-efficient, sustainable living that creates a broader consumer understanding of how to save money at home with clean energy and energy-efficiency solutions.
- A hugely popular public event that draws hundreds of thousands of visitors and attracts the attention of millions through worldwide media coverage.

The organizer is doing more than ever to support solar and sustainable building industries in Morocco and Africa through the international Solar Decathlon Africa collegiate competition and leading a continentwide effort to train and educate its students to join Africa’s rapidly growing solar and green buildings Market. The dedicated outreach and training effort enable Africa to increase the number of Africans who can fill the predicted skilled workforce shortage and ensure the continent is prepared for the changing landscape of energy production and distribution.

The bid, through this competition, is to provide a solid platform for educating and empowering university students, form a well-trained workforce and increase awareness within the broader public on the perks of sustainability and solar energy. Also, to enhance the approach of a market-oriented innovation and applied research.

7.4 Improving the Workforce and Practical Job Skills

Solar decathlon students and professors develop the job skills necessary for the achievement of a decarbonised society. Architects and engineers learn to use procedures and tools to design with the aim of transforming our cities towards sustainable cities. They learn about **innovative technologies, implementing them, testing them, quantifying their costs, and communicating them to the user**. Students from other disciplines learn about technology and **sustainability; linking it to marketing, design and physics.** The whole experience is based on **practical learning.**

Solar Decathlon Europe is a very ambitious project in terms of the infrastructure it requires and the means it deploys. Its objectives are largely covered in each edition. However, there are items that, without being a specifically proposed objective, are results obtained collaterally, such as the workforce and practical job skills. Paying them more attention and defining them as main objectives would result in a greater impact for society without implying a greater investment.

The perception of students, professors, and professionals as to how SDE has improved the students' skills in different areas is compared in figure 154. A list of skills selected from the results of the survey conducted in the SDE 2014 was proposed to the respondents. From these topics, the respondents had to select four skills.
The perception of the professionals as to the impact of SDE in the improvement of student skills is, in general, higher than the students' or professors' perception, valuing aspects like team working and temperance under stress more positively. Students value creativity and the aquisition of practical skills more positively.

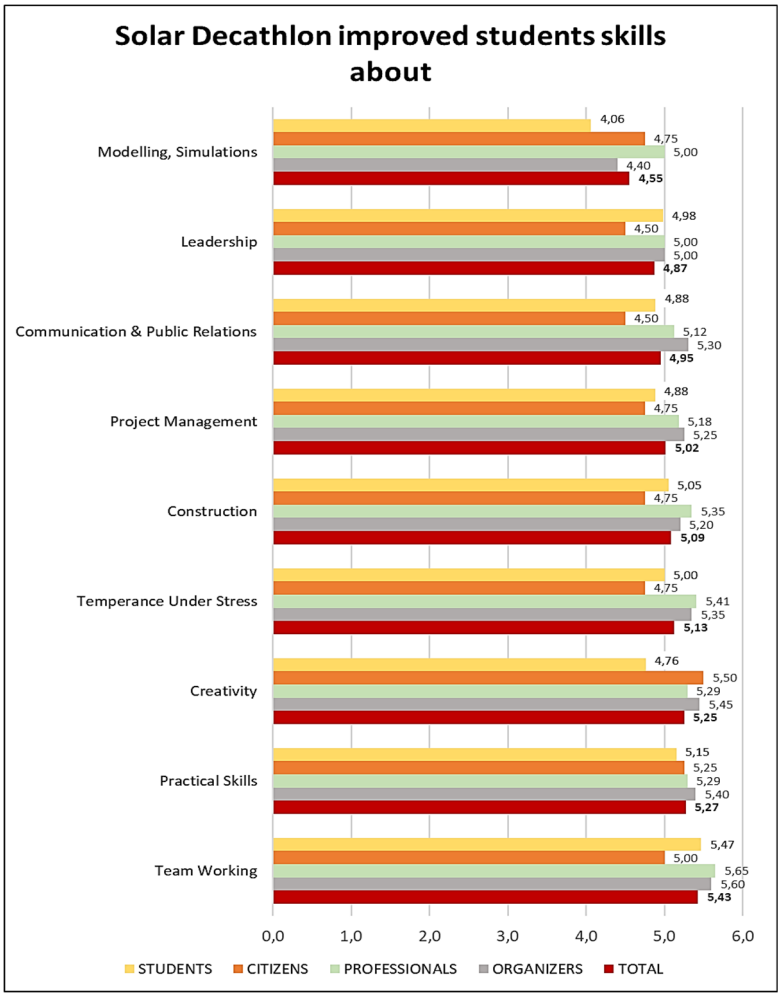


Figure 154: Students answer. SDE 2020 Survey

A university-industry partnership on a medium to long-term basis would provide a combination of private and public funding to develop specific solutions for sustainable cities and could use Solar Decathlon as the spearhead of testing, prototyping and communicating new technical and social ideas, aiming to increase the competitiveness of Solar Decathlon students in worldwide industry. Cooperation between research and education institutes and industry is inherent to the specialisation and practical approach and can help to improve the workforce and skills levels around the world.
This cooperation could lead to new forms of practical education, focusing on the specific challenges Europe, and the world are facing, and with a view to better targeting the education and training supply to the need for skills, which can be crucial for the success of the transformation of our cities.

The international feature of Solar Decathlon makes it a good platform to support the internationalisation of human resources in the **workforce and practical job skills**. A network of Solar Decathlon participants already exists and with support, specific programs could be designed to coordinate research results with the needs of industry to ease the process of transforming our cities into sustainable cities. The Solar Decathlon network should attract innovation talents by including training in practical and entrepreneurial skills among its priorities and thus providing the professionals our society needs to achieve the transformation. Solar Decathlon is an attractive project for innovation talents, which include among its priorities, implementation mechanisms, the development of post-graduate courses, entrepreneurial skills, and other training in practical activities.

Common methodologies between European countries are needed to encourage researcher and student's mobility, aiming to create a network of skilled workers providing the qualities necessary for the aforementioned transformation. Solar Decathlon houses can be crystallisation points for the testing of common protocols. The Solar Decathlon Platform would be a useful tool to amplify or make further use of Solar Decathlon Houses to achieve a durable education and research impact on innovation and sustainable building.

Technology is often not enough to provide successful innovation links to a real transformation. Even though the Global Challenges are common to all countries, the possibilities for tackling them are very different in every territory. Solar Decathlon can serve to highlight the differences present in different countries and continents, which are the source of our strength and weakness, leading cooperation among countries and regions in terms of research, education, creative thinking and entrepreneurial skills and reinforcing the transformation capacity of the world.

7.5 Leveraged Opportunities

In the first Solar Decathlon competitions held in US and Europe, innovative technologies and systems were available, networking between industry and university had been created but there was not yet a critical social mass demanding these solutions. Industrialized SDE house is being assembled in figure 155. At that moment, the Solar Decathlon was ahead of the market needs. Nowadays, building regulations support the use of renewable and nearly zero energy buildings. It is no longer a choice but an obligation to build nearly zero-energy houses in EU.

Figure 155: Construction in SDE 2012

Opportunities will increase by promoting Solar Decathlon synergies and cooperation among, higher education, research, and innovation of the highest standards, including the fostering of entrepreneurship (figure 156). Integrating all of the stakeholder's creativity to face the Competition will leverage innumerable kinds of opportunities, since opportunities on many occasions arise from adversity. In this way the Solar Decathlon Teams overcome multiple difficulties before reaching the final phase as well as during the Competition itself.

Opportunities can arise spontaneously or be encouraged by intervening stakeholders. A key driver in fostering the leveraging of opportunities is to prioritise interests and enhance those aspects of greater general interest.

Figure 156:SDE 2014 Survey.

Some clear and relevant items to be enhanced are education, innovation, research infrastructures, the promotion of partnerships, transfer of knowledge, dissemination activities, use of the houses after the Competition, involvement of industrial associations, research into Solar Decathlon houses (international/national/regional), the connection of disciplines and trans-territorial connection. Teams from different countries together in figure 157.

Solar decathlon has become a very attractive showcase that can be shared by university, industry, policy makers and many other potential stakeholders that until now have not had a relevant involvement. The traditional sponsors of Solar Decathlon are the manufacturers of building materials and products and equipment. An effort should be made to broaden the focus towards promoters, who have not yet found a relevant role and are closer to the user and the final product, having more reliable knowledge of what society is demanding.

Figure 157: SDE 14 Teams (SDE 2014 web site)

Specific sectors close to the final user could be involved, such as the tourism sector, which may find in Solar Decathlons a differentiating factor to attract customers or other innovative accommodation solutions such as co-living models bringing together a social network which can benefit many groups, particularly those more likely to experience loneliness such as older people, or newcomers to a city.

Problems must be addressed by all stakeholders together, everyone must be linked to Solar Decathlon Europe from the beginning, join forces, be generous and generate mutual learning. Solar Decathlon Europe generates a marvellous environment for this, it is an excellent setting for opportunities in all the aforementioned items and through further items which will emerge naturally by searching for opportunity though adversity.
Having the specialists and tools to support the process, the opportunities and their use will be greater.

7.6 Impact Related to Communication and People Awareness

Although Solar Decathlon has always focused on the education of young university students, it was not until the first edition in Europe when it raised the specific objective to take advantage of the media and social interest in the Competition to promote educational activities and social awareness for the public in General.

This strategy was reinforced by the development of the 10Action project financed by the European Union within its Intelligent Energy Programme, and through the strategy of sharing the objective of contributing to raise the awareness of European citizens in their city environments with the SDE 2010 teams. The final balance of Project 10Action has meant:

- 9,350 European children who have actively participated in the 10Action activities and games organized for them
- 6,967 European teenagers who have participated in the debates and Competitions 10Actions organized for them in various countries
- 2,086 university students from 12 European countries who have participated in the workshops, conferences, debates, and Competitions organized by 10Action
- 43,854 professionals from the construction sector who have participated in the exhibitions and conferences organized throughout Europe
- 142,803 European citizens who have participated in the model exhibitions, visits and demonstrations held in the various European countries involved.
- In total, 180,514 European citizens of all ages who have actively participated in 10Action activities, and have had the opportunity to reflect and learn about the responsible use of energy and how to contribute to making cities and buildings more sustainable, with a total estimated impact of 4 million European citizens who have heard about these activities organized in 12 European countries by 10Action.

10Action can be considered a deep draft project; overall results as well as partial results have reached more than the objectives of the project. Figure 158 shows the Final Results (in red) of each target group impacts compare to the project impacts indicators (in blue).[12]

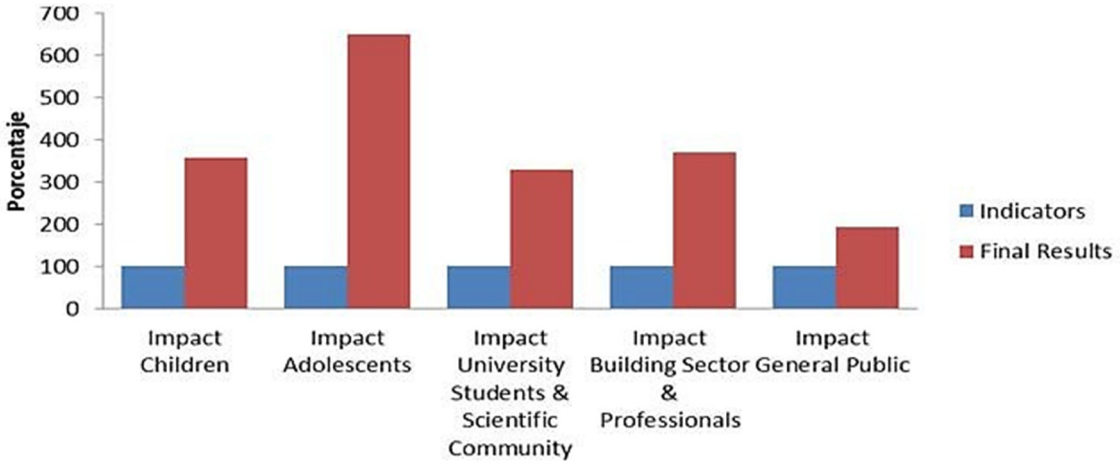


Figure 158: Final results vs target group.

SDE 2012 has benefited from the implementation of an extensive programme of educational and awareness-raising activities for all ages, many of which were organized by the 10Action team. Despite the impact of the crisis and budget cuts, 220,000 visited the solar village, the houses and took part in the

[12] Final Technical Implementation Report (FR) Period covered: from 14 May 2010 to Due date: 14 November 2012. https://upm365-my.sharepoint.com/:b:/g/personal/beatriz_arranz_upm_es/EVhVXpBzj2tIuyZKs9-ek_gBPI-LLUxcSt-2WCe5jw4XKA?e=8R38ss

organized educational activities. SDE 2014 continued with similar social awareness objectives, but the budget cuts resulting from the crisis, the absence of a European framework programme such as 10Action, and the location selected for the solar village, reduced the number of visitors. However, there were still more than 85,000 visitors to this edition.

The success of the European (figure 159) and Chinese editions in the Solar Decathlon Competitions, encouraged a greater interest in the development of strategies and the organization of activities to promote the education and social awareness of young professionals and the public in the American Competitions.

However, the relocation of the Competitions from Washington (where the first five editions were held) led to a progressive reduction in the number of visitors to the California (SD 2013 and SD 2015) and Denver (SD 2017) editions, in all cases due mainly to the remoteness of the locations of the solar villages in the cities, and limited public transport, while the number of activities organized for children by staff and the general public increased. The process of reflection associated with the evolution of Solar Decathlon has led to a change in the format of these university Competitions, with a result that is not yet possible to assess, given that the first edition with the new format was held held in 2020.

Figure 159: Inauguration. June SDE 2014.

In any event, as stated on its website (https://www.solardecathlon.gov/education.html), The U.S. Department of Energy Solar Decathlon offers a powerful learning experience for more than just the competitors. Homeowners and consumers, building industry professionals, students and educators can explore these educational resources to learn more about renewable energy and energy efficiency. They have a complete list of educational resources to complement solar and energy efficiency courses as well as energy career resources, for both professionals and children and teenage students, based on NEED''s work (National Energy Education Development Project)

In the last edition of SDE 2019 held in the Hungarian city of Szentendre, the number of visitors was reduced to 15,000 visitors as a consequence of the location of the solar village, poor public transport, and a lack of strategy to organize activities that would attract the public, and allow the promotion of education and social awareness of citizens.

The Competitions held in Latin America have brought together many visitors, with a high potential for social awareness. The Competition held in Morocco (Solar Decathlon Africa 2019) had more than 40,000 visits, with many activities organized for children, public, and professionals. In Dubai, UAE Solar Decathlon Middle East 2018 had, however, little impact in this regard because its location and the lack of interest in becoming a public event to make people aware.

7.6.1 Awareness Activities and the Education of Visitors in Solar Decathlon Competitions

The strategy to promote the education and awareness of the citizens who visited the Solar Decathlon Competitions has varied from one edition to another. For instance, in Europe the difference between the first three SDE editions 2010, 2012, and 2014, where this objective was clear, and the last one held in 2019, at which it was not considered a priority objective made a very big difference.

In the first three editions, the strategy was based in attracting members of the public of all ages to the solar villages (figure 160), and organizing activities for each of the target groups that were defined. One of the lessons learned from SDE 2010 was that holding the Competition in June, with the colleges and universities closed, did not allow for the successful organization of activities for children and young people.

Figure 160: Public visits in SDE 2014.

Therefore, the 2012 edition of the SDE was organized in September, allowing 5,000 children and adolescents who participated in the activities, and 2,000 University students who made study visits during the assembly and disassembly processes.

Figure 161: School visit in SDE.

One of the key drivers for attracting audiences of all ages was to organize specific activities for each target group, with the valuable support of 10Action Project's team and SDE 2010 team faculties.

Workshops were organized for children and teenagers,in which activities ,such as drawing and painting rooms, clues to discover the solar village, workshops to design your own city, solar inventions, "Focus on energy" photographic Competition, etc. were developed.

In all of the editions of SDE, attempts were made to organize school visits to the Solar Villa (figure 161), and develop educational activities for children, although only in the SDE 2012, at the beginning of the school year, there were systematic school visits from Madrid with a real programme of playing and educational activities, with the full complicity of their teachers. Many of these schools ended up collaborating for more than a year in activities linked to the 10Action project.

Figure 162: Professionals Event in SDE 2012.

Another of SDE's target groups has been professionals, for whom multiple visits and activities have been organized in the four editions of Solar Decathlon Europe. Activities, conferences and workshops have been organized sometimes by the sponsoring companies themselves (for example, Schneider Electric in the first three editions), and at other times by partner companies, by national or International organizations, or professionals that have organized congresses and meetings, or by the organizers themselves (figure 162).

Figure 163: Awareness Area in SDE 2012.

Of special significance was the synergy with 10Action during SDE 2012, which resulted in the organization of 21 workshops, talks, and conferences held at the Villa Solar during the Competition, with an average capacity of over 150 people (some up to 300 people). In addition to these events, dozens of visits to the Villa Solar were organized for professionals, both during the assembly and disassembly phases of the houses, as well as during the Competition itself (figure 163). A total of 6,000 professionals participated in some type of activity. All of them without counting the multiple exhibitions of models, participation in construction and energy fairs, national and international congresses, conferences organized in Spain and European countries, up to 43,854 professionals who have participated in activities organized throughout Europe, and which are described in the EC TENDER ENER/C2/2016-502: Solar Decathlon Europe Competitions. Thematic Report 3.[13]

Many professionals from the world of architecture and construction engineering, took part in the Solar Decathlon Competitions (figure 164). However, the level of environmental awareness and innovation achieved from a practical point of view has not been excessively relevant, as can be seen in the 2020 survey of professionals who attended the Competition: 3.44 out of 6, with a wide dispersion of answers (figure 165).

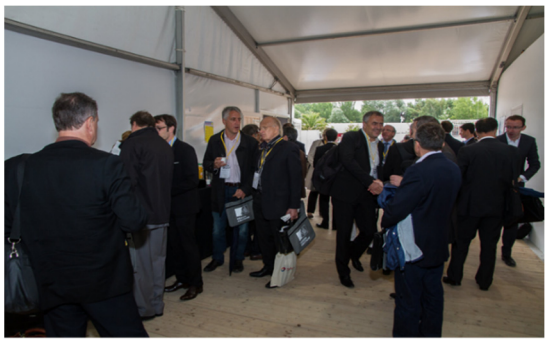


Figure 164: Professionals Event in SDE 2014.

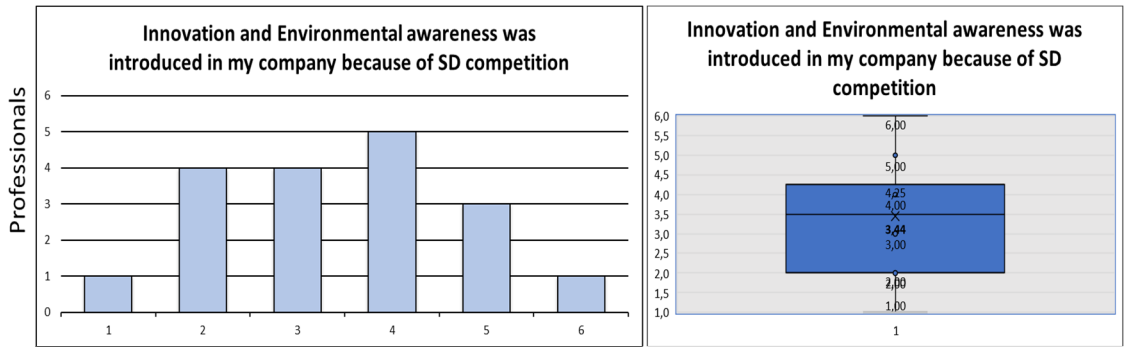


Figure 165: Professionals answers. SDE 2020 Survey.

On the question of whether, after attending or visiting a Solar Decathlon Competition, the professionals decided to take up training in new sustainable technologies, a wide dispersion of responses was observed with an average value of 3.72 out of 6 (figure 166).

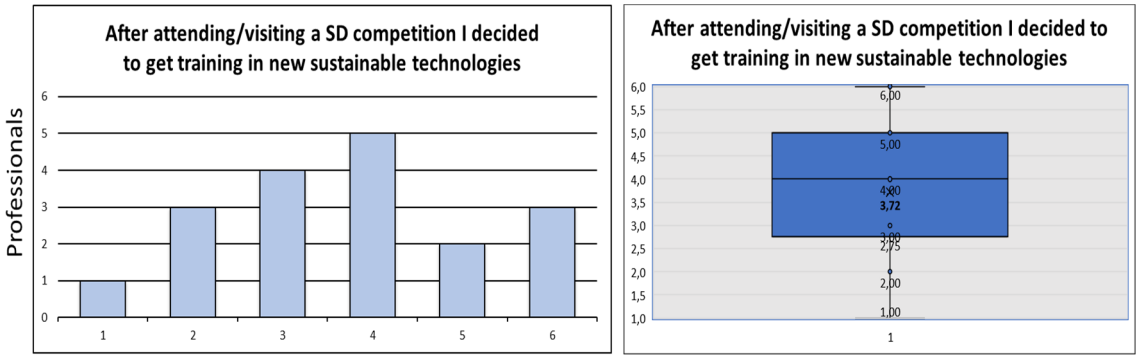


Figure 166: Professionals Event in SDE 2014.

[13] EC TENDER ENER/C2/2016-502: Solar Decathlon Europe Competitions. Thematic Report 3. https://building-competition.org/publication/show/ECPROJECT

The education and social awareness of citizens, is one of the key , for that there are several factors that are relevant such as a good location, good public transport to access the area, a dissemination campaign in the city and in the media, the preparation of attractive activities for the families.

Unfortunately, the organizing teams have historically had little margin to select the location of the Solar Villages, coming in many cases from the cities and the technical constraints of the organization of the Competition itself (cranes and trucks of great size and tonnage). What is in the hands of the organizing teams, although with little margin from the budgetary point of view, is the organization of attractive activities for families, and the promotion in the city and in the media.

Despite all the budgetary limitations suffered by all the editions of SDE so far, the social and media impact achieved with the Competitions in Europe has been very relevant, with 192,000 visitors in SDE 2010 and the highest media impact of the European editions; 220,000 in SDE 2012 with an equally high media impact; 85,000 in SDE 2014; and some 15,000 in SDE 2019 during the Competition period, even though the Villa Solar continued to be set up as a National Sample House Park demonstrator for many more months, open to visits from schools, professionals and the general public (figure 167).

Figure 167: Public visits in SDE 2019.

This impact is far from that achieved in the two Chinese editions of Solar Decathlon, with 230,000 and 500,000 visitors, but significantly higher than the rest of the editions held in the world. The average of the first editions in the United States was around 100,000 visitors on average, and decreased significantly in the California, editions. Later in Denver it grew to 40,000 people. A similar figure was registered in SDA in 2019. While the Latin American editions have also attracted a significant number of visitors. The edition in The Middle East, have registered a lower number of visitors because they prioritised other objectives.

Figure 168: Public visits in SDE 2010..

The success of the first two editions held in Madrid in terms of audience and media impact has different explanations with the common denominator of an organizing team from the *Universidad Politécnica de Madrid*, with clear objectives in relation to the importance of attracting as many people as possible to educate and raise awareness among citizens. The SDE 2010 (figure 168),edition had a more central, visible and accessible location than SDE 2012 (figure 169),next to the River Manzanares, a common place for the people of Madrid to walk. It also had the full and active support of the Spanish government, which resulted in the visit of the European Union''s housing ministers, many government ministers, the then Prince of Spain (now the King of Spain), etc., which in turn generated a great media interest. The Solar Villa was open for a week of the Competition and the weekends before and after it (10 days in total), and many activities were organized for all audiences.

Figure 169: Public visits in SDE 2012.

The edition of the SDE 2012 Competition was located in a more attractive area in terms of landscape, but less accessible to the public, although the means of public transport were reinforced from various areas of Madrid, as well as from the nearby metro station. With the change of government in Spain, the support for the Competition was substantially reduced, as was the availability of the budget, which was cut by two million euros. The experience gained in organizing the first edition, the synergies with the European 10Action project, the extension of the Competition by another week (a total of 17 days), the transfer of the Competition to September, and the large number of activities developed throughout the Competition for all audiences (less than half of the activities initially planned were carried out due to the budget cuts) meant that, although a lower media impact, the total number of visitors was higher than in the first edition.
In this edition of SDE 2012, a special effort was made to raise public awareness, organized around five major areas for the general public designed to inform and raise the awareness of citizens on specific issues: IDAE''s site on energy saving and what each citizen can do about it; Ministry/UPM''s site on sustainable development and energy efficiency in buildings and cities, and energy retrofitting; electric car area, on sustainable mobility; renewable and clean energy technologies on the different solar, geothermal, hydrogen, wind technologies, etc; and smart grid centre (developed by Schneider) with the monitoring of the smart grid of the solar village and its management system.

Although the surveys carried out in 2020 on visitors to the Solar Decathlon Competitions are not representative due to the low number, it is still interesting to confirm that 100% of those surveyed agreed that the visit to the Villa Solar was worthwhile, that they would recommend the visit to others, that they had heard about the Solar Decathlon Competitions before their visit, that if they had the opportunity they would visit a new edition in the future, they had noticed changes in their city because of SD Competition, or that they had learned about sustainability at Solar Decathlon. 75% of those surveyed agreed that SD had influenced renovation decisions at home, and lifestyle decisions with them or their family.

7.6.2 Awareness activities and education for university students linked to SDE.

The educational values, knowledge and skills developed by the university students who have participated in Solar Decathlon Competitions have been documented simply by participating as Decathletes, and often reinforced with activities and initiatives organized by the universities, or by the Competition organizers.
Beyond these values, the organizers of the Competitions and linked events, and of initiatives such as 10Action, have organized multiple activities in each edition aimed at the education and social awareness of university students (figure 170), in whose hands lie the most immediate future, and the firmest bet of a next generation of professionals committed to the environment and a more sustainable world.

Figure 170: UPM's summer school, Sustainable Architecture.

In three of the four European editions of SDE, the Competition was held in June or July, outside the universities'' course calendar, which resulted in a less systematic participation of university students. Even so, university activities were organized both during the Competitions and during the period of the 10Action project, with visits (figure 171) and activities by university students in the European countries of the competitors in SDE 2010, courses and conferences, teaching material prepared for European university professors on sustainability, energy efficiency and energy renovation, university workshops and debates such as "More with less (emissions)" (figure 172), or summer courses organized by the *Universidad Politécnica de Madrid*. In total, 2,086 university students from 12 European countries have participated in the workshops, conferences, debates and Competitions organized by 10Action.

Figure 171: Visiting group of university students in SDE 2012 in Madrid.

During the SDE 2012 Competition held in September, coinciding with the start of the university academic year, visits were organized for groups of university architecture and engineering students, from public and private universities, in Madrid and other cities in Spain, both during the assembly phase of the houses and during the Competition itself. In conjunction with these visits, workshops were also organized with each of the six juries who evaluated the contests in the Competition, lectures by some of the most distinguished jurors, technical explanations of the strategies and technologies of each of the competing houses, as well as other courses and conferences organized for the professionals. 2,000 university students, apart from the Decathletes, participated in these study visits and associated activities.

10Action "More with Less (Emissions)" competition

Figure 172: 10Action "More with less (emissions)" Competition

According to the SDE 2014 survey, there seems to be a consensus that Solar Decathlon has raised awareness among students about sustainable and energy efficiency issues in buildings (figure 173). The average rating of the students in this regard is 4.21 out of 5, with 78% of the students confirming this. 90% of the Professors also supported the statement, with an average of 4.63 out of 5. In terms of where social awareness was highest, freely defining three words, students highlighted sustainability (10.9%), energy efficiency (8.8%), integration of emerging technologies (5.9%), communications and media attention (4.9%), life cycle cost (3.9%), and social awareness and education (3.9%). On the other hand, Professors also emphasised energy efficiency (7.9%), sustainability (7.9%), social awareness (3.9%), Global world (3.9%), and industrialised modular construction (3%).

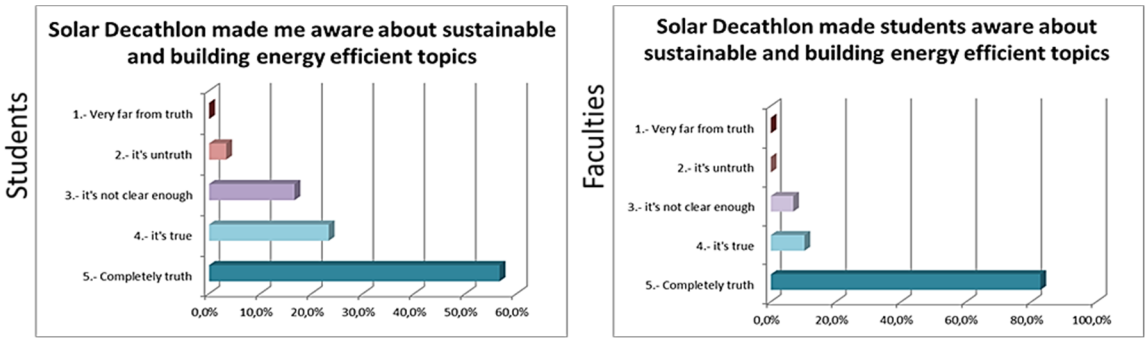


Figure 173: SDE 2014 Survey.

The results from the 2020 surveys are similar but with some differentiating nuances. For example, students highlighted teamwork (12.11%), innovation & emerging technologies (11.91%), energy efficiency (11.72%), solar energy (11.52%), sustainability (11.33%), and passive strategies (10.16%). Less variation is observed in the professors'' scale of assessments, with the emphasis on energy efficiency (17.27%), sustainability (15.45%), passive strategies (10.16%), solar energy (14.09%), teamwork (10%) and innovation and emerging technologies (8.18%) (figure 174).

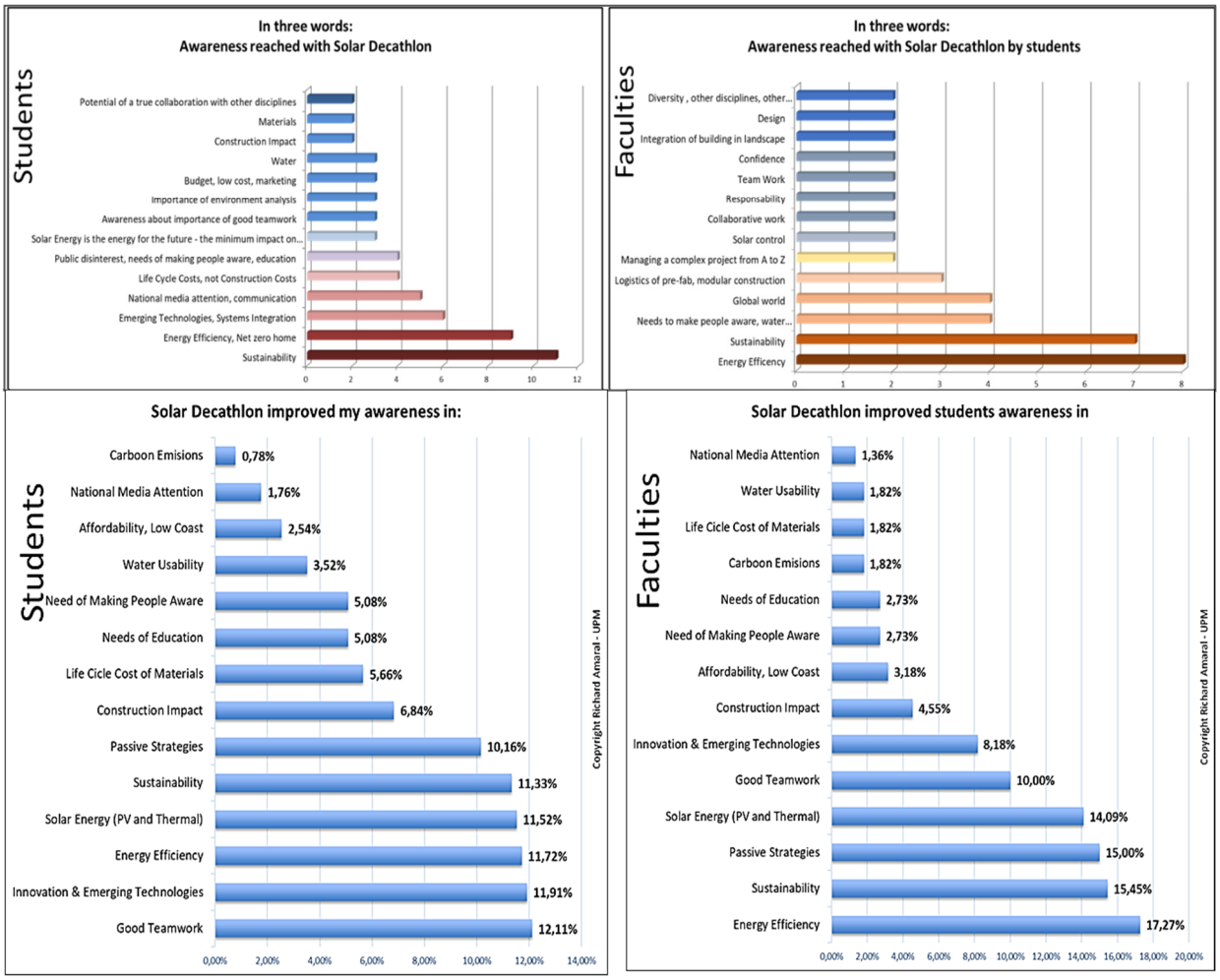


Figure 174: SDE 2014 - 2020 Survey.

It is also interesting to look at the impact of the Competition contests on social awareness and media impact, and on issues of awareness regarding sustainability and energy efficiency. With respect to the first, it is worth noting the agreement between students and professors regarding the potential of the contests on communications and social awareness, architecture, and innovation. The students also highlighted the

contests on urban design, transport and affordability, sustainability and circular economy, and the functioning of the houses; while the professors emphasised the contests on sustainability and circular economy, energy efficiency, and the functioning of the houses. (figure 175).

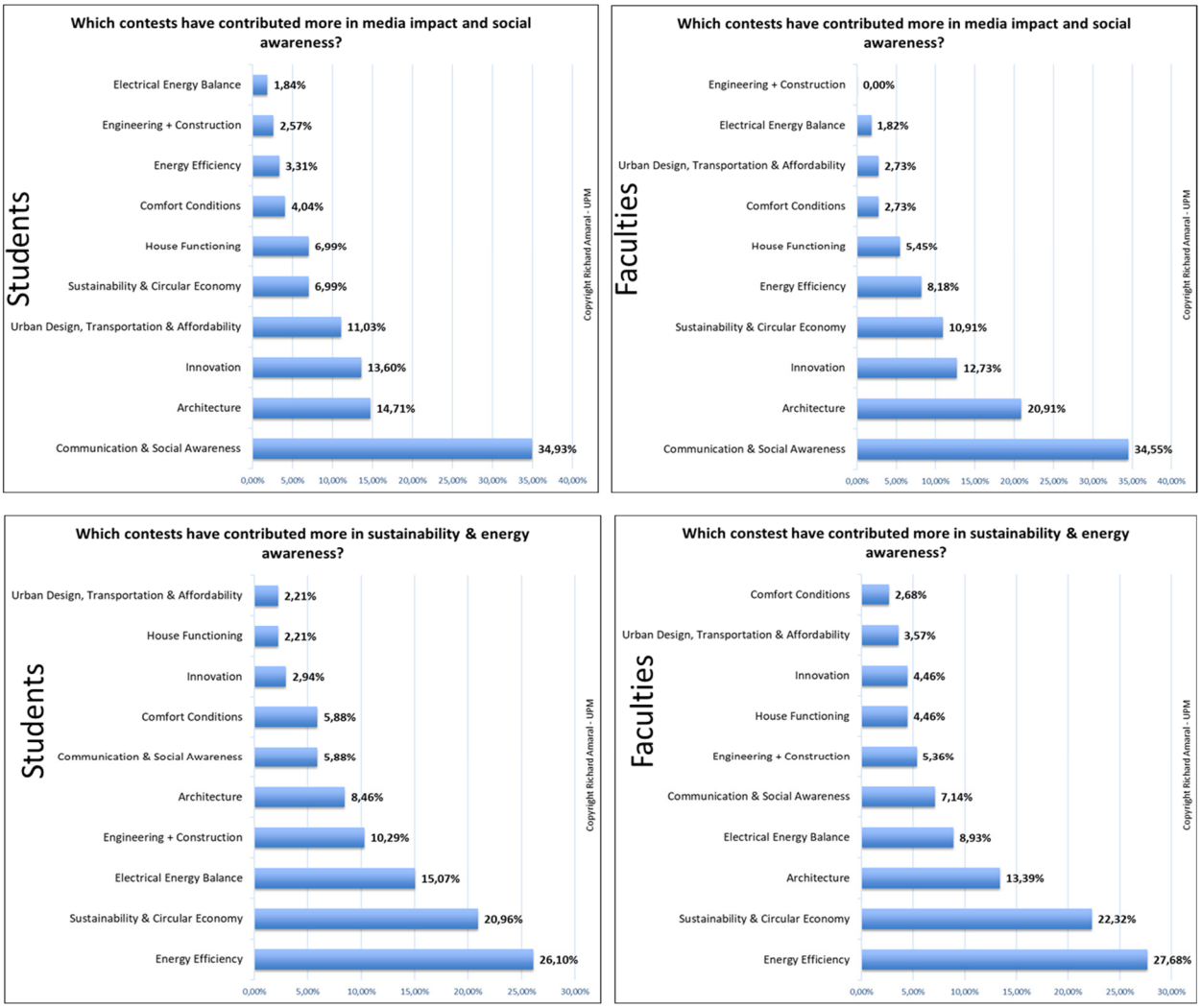


Figure 175: SDE 2020 Survey.

With regard to the most influential contests for sustainability and energy efficiency awareness, students and professors coincide with the contests of energy efficiency, and sustainability and circular economy, although later students highlight the contests of energy balance and engineering and construction, while professors emphasised architecture, energy balance, and communications and social awareness.

7.6.3 Perception of the Educational Potential by the Key SD Stakeholders

From the detailed analysis of the SDE 2014 surveys and that carried out for the 2020 study, there is no doubt that the main focus of the Solar Decathlon university Competition has been on the education and social awareness of the young university students, professional architects and engineers of tomorrow, who have the construction of more energy-efficient and sustainable buildings and cities in their hands.

To the question:¿Which of the objectives of the SD Competition have been achieved? More than 4 out of 6 have have been obtained, with a variability of these averages between 3.98 and 4.88, which represents a perception of the fulfilment of these objectives (figure 176).
The average value obtained for the objectives, in order of the best or worst value, was environmental and sustainability awareness 4.88 out of 6; fostering education 4.83 out of 6; innovation and the generation of knowledge 4.82 out of 6; professional awareness 4.38 out of 6; social awareness 4.05 out of 6; media and social media impact 3.98 out of 6 (figure 177).

Analysing some of the areas of greatest impact achieved with the Solar Decathlon Competitions, it is worth highlighting first the positive assessment achieved in the area of education, with 5.08 out of 6. This is followed by the impact on the university community with an average value of 4.82 out of 6, research with 4.68, innovation transfer with 4.51, professional workforce with 4.24, social awareness with 4.03, and finally the Media impact with 4 out of 6. It is also worth mentioning the high rating of the impact of the SD Competitions in all the selected areas, considered by the majority of the people surveyed.

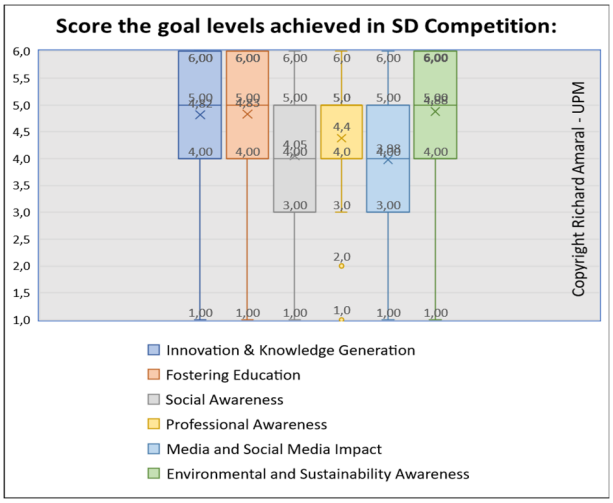


Figure 176: SDE 2020 Survey.

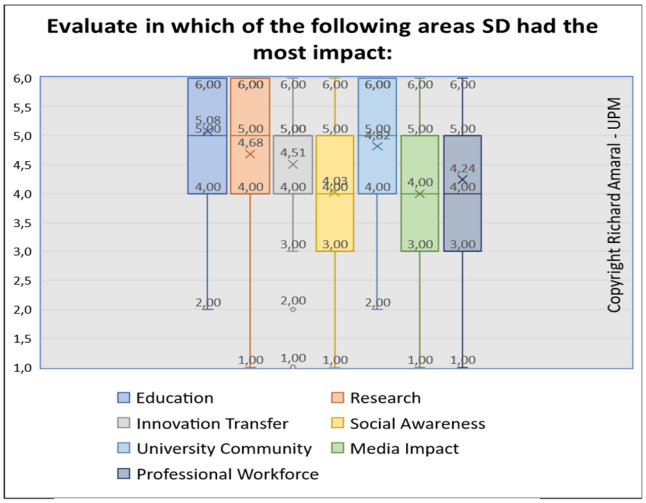


Figure 177: SDE 2020 Survey.

With a similar question most of the respondents in 2020 awarded value as objectives perceived as best achieved: fostering education, innovation and the generation of knowledge, environmental and sustainability awareness, professional awareness, social awareness, media and social media impact, and finally student employability (figure 178).

It is remarkable that in the 2020 survey 100% of the people surveyed stated that they consider the Solar Decathlon to be a positive overall experience. Asked later as to the main reason they are satisfied with SD, the overall opinion of the respondents was as follows:

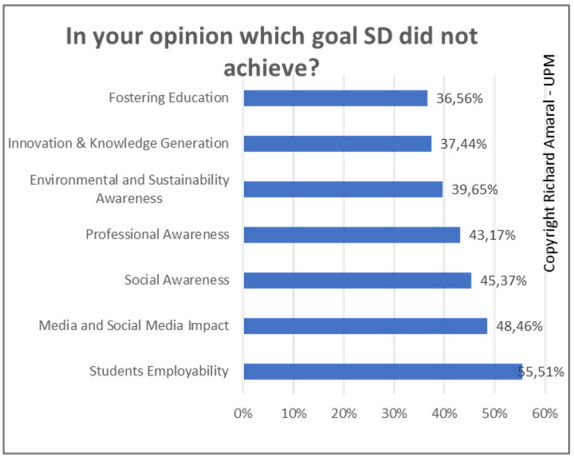


Figure 178: SDE 2020 Survey.

innovation and knowledge generation 64% (which goes up to 69% in the case of student estimation), environmental and sustainability awareness 48% (49% students), fostering education 43% (similar for students), professional awareness 40% (45% students), student employability 40% (43% students), social awareness 38% (40% students), media and social media impact 36% (39% students) (figure 179).

For a correct interpretation of these results it should be clarified that the respondents could choose only one option from among the reasons selected, among which there was a last option to select all of them. 34.89% of all people surveyed in 2020 selected this option out of all of them, which rises to 38.06% in the case of students surveyed, 38.89% in the case of professionals, and it falls to 32.14% in the case of professors and 26.09% in the case of the organizers.

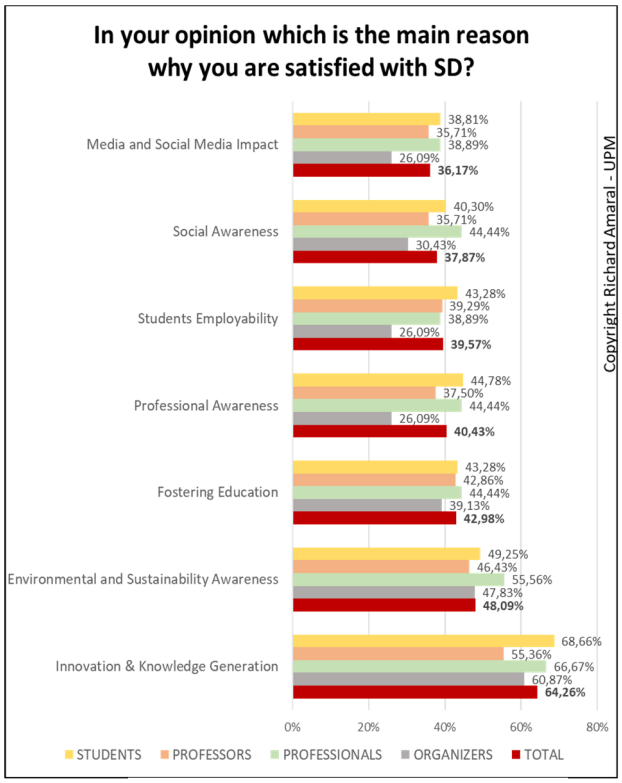


Figure 179:SDE 2020 Survey.

As regards the opinion of the survey respondents as to which contests have contributed most to the **education of students** (figure 180), considering that they could choose only two of the ten contests.

The total average estimate of the most significant were engineering + construction with 24.88% of the choices, architecture with 21.33%, energy efficiency (19.19%), sustainability and circular economy (9.00%), and with smaller percentages electrical energy balance, innovation, comfort conditions, communications and social awareness, house functioning, urban design, transportation and affordability.

Students have a similar perception of all the contests, although with small variations in the percentages.

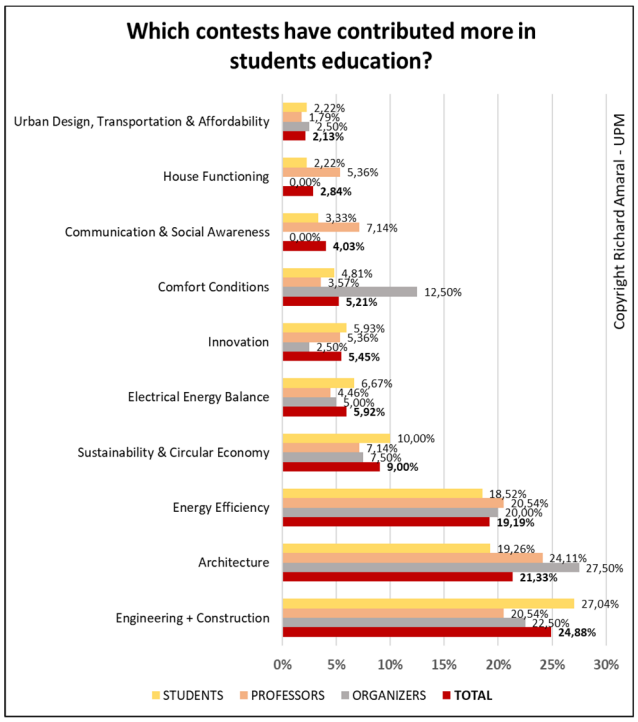


Figure 180:SDE 2020 Survey.

However, the professors and organizers consider that the most relevant contest for the education of students is architecture, with 27.5% for organizers and 24.11% for professors.

It is also worth noting that the organizers gave the contest on comfort conditions a higher score, with 12.5%, compared to 5.21% for the total number of respondents.

In order to establish the subjects in which students have acquired the most **knowledge through the Solar Decathlon Competitions** (figure 181), the 2020 survey asked the students, professors, organizers, professionals, and the general public the question encouraging them to select the 4 most significant areas of Knowledge from a list selected from the results of the SDE 2014 survey.

The total score of the respondents in the main subjects was architecture and engineering integration (15.32%), energy efficiency and passive design (13.60%), project management (12.87%), renewable energies (10.54%), and already below 10% practical construction, green building design, engineering and construction, organization, time management, net zero energy houses/clusters, communication, thermal knowledge, BIM - CAD, or building codes.

Students and professors have a similar scale to prioritise these topics of knowledge, with small differentiating nuances and figures. The high percentage that professionals give to the integration of architecture and engineering as the main knowledge acquired by the students with the Solar Decathlon is very significant, with 37.93% compared to the average of 15.32%.

In relation to the topics in which Solar Decathlon **improved the awareness of students** (figure 182).

By selecting 4 from those surveyed on the list selected based on the SDE 2014 survey, the most notable were energy efficiency with 14.14% (of the total), sustainability 13.64%, solar energy (pv and thermal) with 12.02%, innovation and emerging technologies 11.14%, good teamwork 11.14%, passive strategies 10.64%, with all other subjects below 6%: construction impact, need of making people aware, needs of education, life cycle cost of materials, water usability, affordability, low coast, national media attention, carbon emissions.

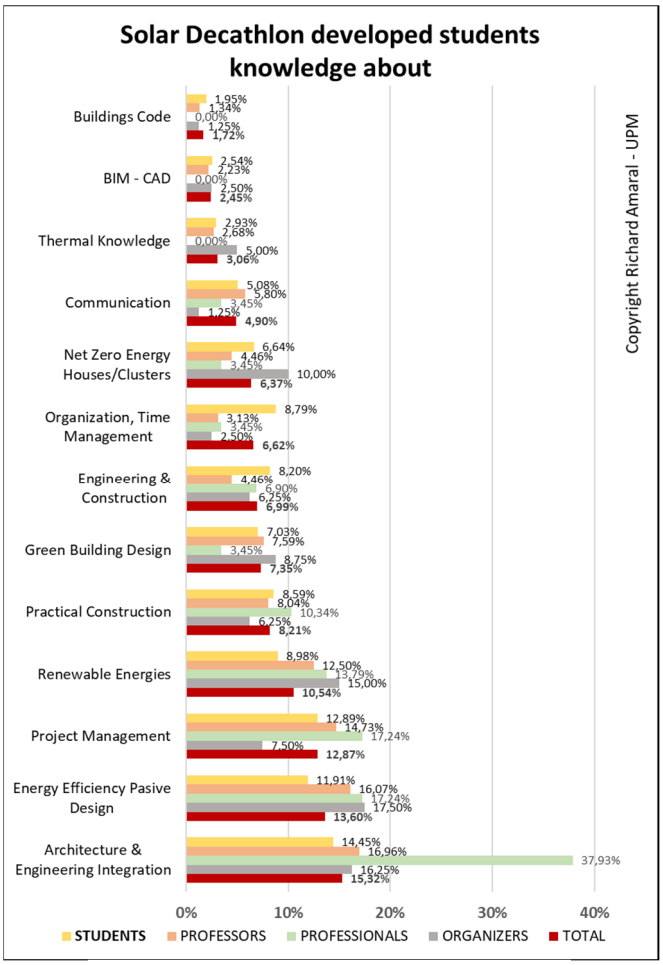


Figure 181: SDE 2020 Survey.

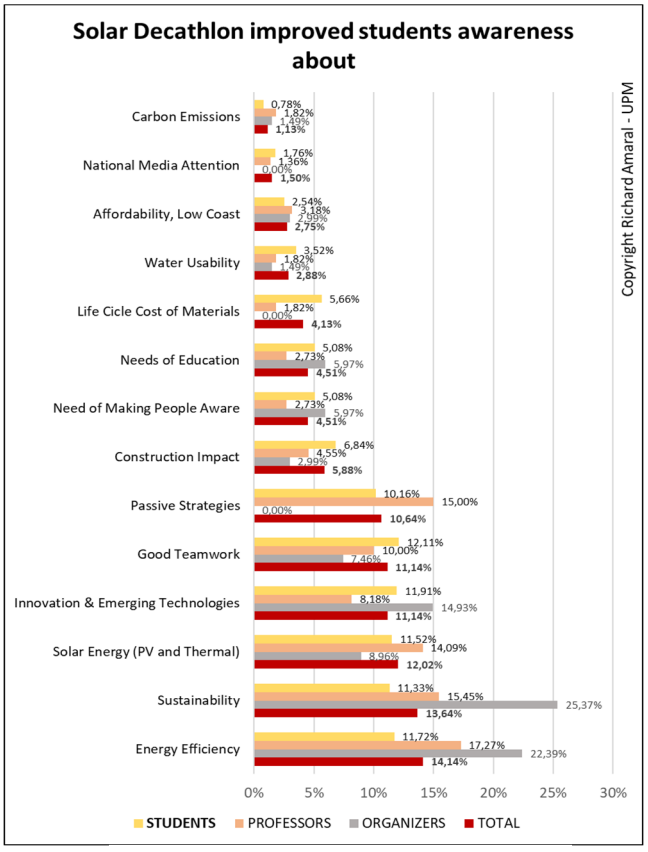


Figure 182: SDE 2020 Survey.

Professors and students rank the subjects with similar criteria to those of the total number of people surveyed, while the organizers value sustainability significantly higher with 25.37%, energy efficiency with 22.39%, and Innovation and Emerging Technologies 11.14%.Selecting two each of the survey respondents in 2020, the contest that has contributed the most to **social awareness in sustainability and energy efficiency** (figure 183) is the energy efficiency contest with a total of 27.96%, reaching up to 40% according to the organizers. Sustainability and circular economy with 20.85%, electrical energy balance 13.51%, architecture with 9.24%, are the other most influential contests.

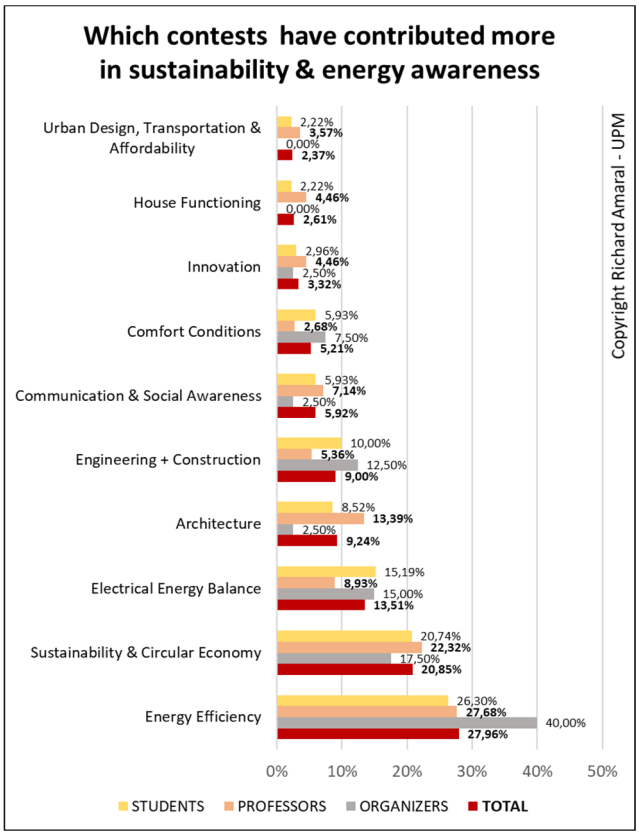


Figure 183:SDE 2020 Survey.

There is greater overlap between the groups of survey respondents in the choice of two contests in the Solar Decathlon Competition events that have contributed **most to media impact and social awareness** (184). By a large majority and unanimously, the most effective contest in this regard was the communications and social awareness contest with 34.29% of the total number of respondents. architecture with 16.9%, innovation with 12.86%, and sustainability and circular economy with 8.57% of the total, are other contests that have also been influential.

It is remarkable that despite the diversity of contests in the Competition, all of them show a greater or lesser influence on both the media impact and social awareness, as well as on sustainability and energy awareness.

Finally, mention should be made of the personal skills developed by the students during the Solar Decathlon Competitions. The SDE competitions have proven to be a very powerful vehicle in demonstrating and communicating the potential and benefits of energy-efficient construction to a wider public, ranging from building professionals to academics and the general public. In SDE 2010 (partially) and SDE 2012 the communications strategy was strengthened by the 10Action Project.

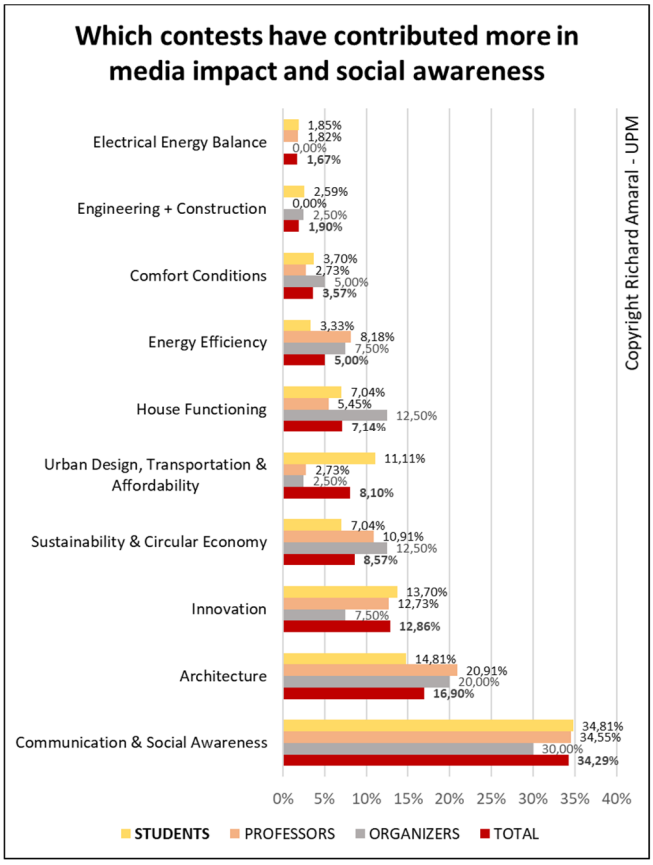


Figure 184: SDE 2020 Survey.

7.6.4 Policy Makers

Solar Decathlon Organizations have had the capacity to link the interest of governments, the private sector and universities in the achievement of shared common goals. Policy makers are the engines of the system, to achieve substantial changes, they need to be aware and involved. In the communications strategies of the different SD Organizers an effort has been made to catch the policy makers' attention. Policy makers are already working to reach a future sustainable society, specifically in building construction, which in the last decade has experienced substantial changes. For instance, the Energy performance of buildings directive (EPBD - 2010) in Europe is, together with the Energy efficiency directive (2002 and 2011 recast), the main legislative instruments to promote the energy performance of buildings and to boost renovation within the EU. Nevertheless, the real implementation in the member states of the EU is slow, and more needs to be done.

All the organizing countries should be interested in finding a way to get more out of the knowledge the competition generates. The **quality and level of maturity of the research** and innovation involved in Solar Decathlon is diverse, but certainly it goes from the **exploration of ideas** to the demonstration of **cutting-edge market ready technologies**. In any case, all of proposals contain interesting items to be explored and whose implementation would contribute to more sustainable buildings and cities. Unfortunately, when the competition finishes it is also the end of the road for some of these ideas and solutions. The degree of **development and impact on the market could readily be higher with greater institutional involvement**. But not only that, the administration can also indirectly incentivise and attract private investment to reinforce sustainable development.

Policy makers could accelerate SD technological innovation to reach the market by facilitating access to already existing tools to the universities, for example Horizon 2020 (Now Horizon Europe) in the EU. However, in the some of the last editions of Solar Decathlon there has been an interesting change, now innovation tackles social and territorial issues, the social impact of some of the proposals, that would be substantial if they were implemented. SD Africa and SD Europe have advanced in this sense.

Administrations are key drivers here, not only because they could be the promoters of some ideas but also because implementing some of them (sharing and coexisting, common spaces, rooftop modules, façade modules) require **changes in the local Urban or Building Regulations to be made.**

Solar Decathlon has already worked on the establishment of interesting partnerships, the presence of politicians and high representatives of different states in Solar Decathlon have been outstanding.

There have been multiple visits to houses and Competitions by Heads of Governement (Spain, Hungary). US Secretaries of Energy (figure 185), ministers, officials of all kinds, visitng the various Solar Villas of different Competitions. Multiple presentations in international forums with the presence of senior officials from different countries, from United States, European Union, China, etc. Multiple presentations at Universities in many dozens of countries, with the presence of senior officials and numerous presentations at trade shows in different countries with the presence of politicians and senior officials.

Figure 185: Visit of Secretary of Energy Mr. Steven Chu during US SD 2009 Competition

For instance, among the events organized in Spain with Casa Solar (Prototype of SD US 2007 of UPM Team) to raise society awareness, multiple visits were made from Ministers, Mayors, and the Head of the Spanish Government (figure 186) who visited the house in the “España Solar“ event with two Ministers of the Government of Spain, whose politicians’ awareness led to its involvement and support, which was necessary to reach the agreement with DOE to organize the Competition in Europe.

Figure 186: SD 2007. Visit of the President of the Spanish Government and two Ministers.

In the SDE 2010 Competition, the current King of Spain visited the “Villa Solar“(figure 187), several ministers (Housing, Energy, Environment and Infrastructures), the Head of the Regional Government of Madrid, the president of the Regional Government of Extremadura, the Head of the Regional Government of Aragón, the Head of the Generalitat de Catalonia, also the mayors of Madrid, Barcelona, among others. There also multiple Secretaries of State, Technical General Secretaries and General Directors. The visit to the Solar Village of all the Housing Ministers of the European Union (Figure 188) was especially Interesting.

Figure 187:. Visit of Prince Felipe, (current King - Head of State of Spain) with the Ministry of hosing, SDE 2010.

Figure 188: Visit of the EU Ministers of Housing summit in the Solar Decathlon Europe 2010 Solar Village

In SDE 2014 Mayor of Versailles Francois de Mazieres opened the welcome ceremony (figure 189) and the President of the Palace of Versailles, Ambassadors of different participating countries and the Minister of Housing and Territorries Equality visited the Solar Village. In SDE 2019 the President of Hungary and the Minister of Innovation and Technology (figure 190) also visited the Solar Village.

There have also been contacts at the highest level between the European Commission and the US Government, with an exchange of letters between the Secretary of Energy and the European Commissioner of Energy concerning the Solar Decathlon Europe.

In the EU-U.S. ENERGY COUNCIL held in Washington, 28 November 2011, with the participation of US Secretary of State Ms.Clinton and US Secretary of Energy Mr. Chu, EU High Representative Ms. Ashton and EU Commissioner for Energy Mr. Oettinger, the Joint press statement says ***The EU and the U.S. intend to cooperate on continuing the Solar Decathlon Europe competitions, transforming them into an initiative to foster sustainable economic development by creating markets on both sides of the Atlantic for integrating innovative technologies and renewable energy sources into new and refurbished low impact buildings***

Figure 189: Mayor of Versailles,Francois de Mazieres. Opening ceremony of SDE 2014.

Figure 190: President of Hungary visit to SDE 2019.

7.6.5 New technologies fostered by competitions and their evolution.

Solar Decathlon Organizers have been working on the establishment of partnerships since 2002, it has been a pertinent and valuable strategy, aligned with **The Sustainable Development Goals** (SDGs) since 2015, when UN countries adopted the 2030 Agenda, specifically, with SDG 17 “Partnership for the Goals”[14]. Solar Decathlon strategy has been successful, but more needs to be done. Now, as stated in SDG 17, *“Urgent action is needed to mobilise, redirect and unlock the transformative power of trillions of dollars of private resources to deliver on sustainable development objectives.”*

Impact related to Research & Innovation

Solar Decathlon has pursued essentially **similar objectives** from the first edition (SD US 2002), but the introduction of **wider and more current ambitions** since then has had impact in the competition results. As mentioned, the achievement of these objectives has led to **some changes in the competition Contest**, following the structure of the Olympic decathlon, the Solar Decathlon was conceived to have ten different contests. These contests are designed to gauge how well the houses perform, how liveable and how sustainable they are.

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[14] SDG 17 "Partnership for the Goals": A successful sustainable development agenda requires partnerships between governments, the private sector and civil society. These inclusive partnerships built upon principles and values, a shared vision, and shared goals that place people and the planet at the centre, are needed at the global, regional, national and local level.

All the houses of the Solar Decathlon have some degree of innovation. This innovation can be attained in many ways: it can be implicit into the philosophy of the project, for example by posing an absolutely conceptual analysis, questioning our lifestyle, in other cases innovation can be embodied in the architectural or urban approach, or in others it can be about technological innovation. Innovation does not have a specific form. As a result, the Solar Decathlon has a wide range of innovative aspects, whose transfer to the market is not always immediate or evident.

In this section, an analysis of this innovation is carried out with the intention of addressing the task of demonstrating the great impact that Solar Decathlon had and have, nowadays, on the market. First, we'll analyze the strategy "innovation versus affordability", revealing the link between cost and innovation, a controversial topic present in the different editions of the SD. Secondly, a glance to the innovative technologies and concepts fostered by SD is presented, without the intention of elaborating a catalogue of all the technologies present in all the editions but to transmit the implicit creativity contained in the proposals.

Innovation and **affordability** are two concepts evaluated in Solar Decathlon with greater or lesser importance in the different competitions. Table 14 collates the points obtained in each competition as regards to innovation or affordability (market viability, viability, market). The evaluation of these items has change from one edition to another both in US and in Europe. **In SD EU 2010 for the first time 80 point were specifically** attributed to promote innovation, without ignoring industrialisation and market viability, in previous editions innovation had no specific points. In the following European editions, the promotion of innovation has been maintained and it is remarkable to observe its influence in the design of the houses and the technologies incorporated in each edition.

The evolution of the proposals implemented over the years in Solar Decathlon Europe is not by chance. Behind the changes proposed by the organizers there is a philosophy. The intention is to boost the students' creativity, interest and effort towards the **materialisation of new ideas** and **resolution of current issues**, aligned with needs and policies. Students are required to consider the reality of taking their designs to market at this early prototype stage, but innovation is also a key focus of the competition.

	SD US 07	SD US 09	SDE 10	SD US 11	SDE 12	SD US 13	SDE 14	SD US 15	SD US 17	SDE 19
Market Viability	150	100								
Industrialization and Market Viability			80		80					
Innovation			80		80		80		100	
Affordability				100		100		100		
Market Appeal Contest				100		100		100		
Urban Design, Transportation & Affordability							100			
Market Potential									100	
Neoghbourhood integration & impact										100
Innovatopn & Viability										100

Table 14. Scoring regarding contest related to innovation, affordability and market in US an EU Editions.

The most substantial changes in the European competition are the evaluation of innovation, sustainability, industrialisation and awareness in SDE 2010; passive energy efficiency performance, affordability and multifamily houses in SDE 2012; urban design and transportation in SDE 2014 and Neighbourhood integration and impact in SDE 2019. Innovation and sustainability contests since SD EU 2010 were evaluated interwoven with the other eight contests, each contest had direct point regarding the specific contest and specific points reserved to asses sustainability and innovation ragarding that specific contest (figure 191).

The students' attention was drawn to, not only designing and building the houses, but also **integrating innovation** and sustainability into each of their **decisions** during the design and building processes.
A positive integration of **innovative technology** was observed in SDE 2010 compared to previous editions in which innovation was not a contest. The organization approach led to a more innovative house design, innovative construction solutions, innovative sustainability approaches, and overall innovative technologies.

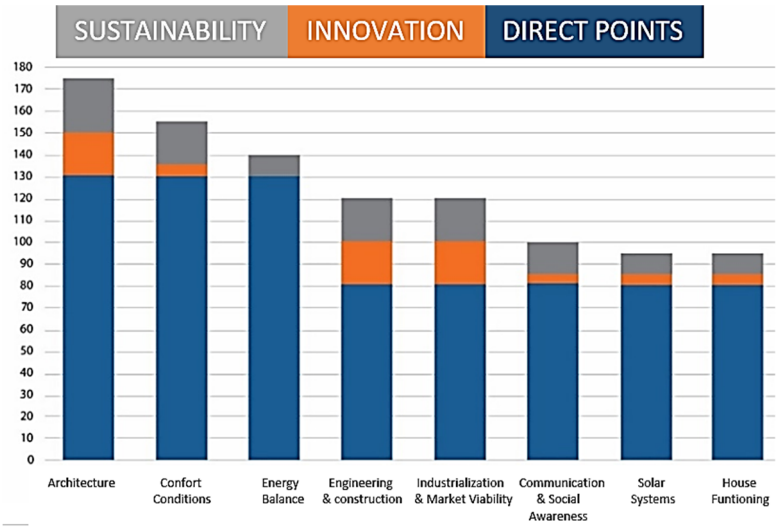

Figure 191: Scoring regarding Innovation and sustainability SDE 2010.

In the Solar Decathlon 2012 **passive energy efficiency performance, affordability** and multifamily houses were considered.

Then, a wider range of possibilities for sustainable building practices and solar energy were proposed. From modest proposals where a **single dwelling** in a rural environment is given the task of teaching an entire country about sustainability to highly sophisticated proposals for **dense urban** conditions.
In Solar Decathlon 2014 when "**Urban design and transportation"** was included, the house designs brought more conceptual complexity, trying to solve problems for the first time considered in Solar Decathlon.

Some new approaches were: home co-sharing, buildings on top of existing buildings to be retrofitted, plug-in cities, terraced house refurbishment, proposals facing major natural threats (floods, typhoons, earthquakes), proposals facing social contemporary problems (demographic expansion & urban high density, aging population (figure 192), **sustainable mobility**, etc.

In Solar Decathlon 2019, including "Neighbourhood integration and impact", led to some interesting approaches considering the retrofitting and renovation of suburban areas, rural settlements and vulnerable regions, not only adapting building to current requirements but adding value to the existing building environments and territories. Most of the proposals (all except 1) focus on the inherited architectural environment, emphasizing the value of the existing structures, preserving and upgrading them and considering the impact in its inhabitants. In this last Solar Decathlon edition, innovation focused on social challenges. *"This is*

Figure 192: Tropika House. SDE 2014. Explores sustainable housing for older people.

Figure 193: Project Aura 3.1. SDE 2019 explores interdisciplinary and sustainability.

Figure 194: Project inhabit2030. SDE 2019 (h2030) explores sharing and exchange strategies.

not a house" is the Project Aura 3.1 slogan (Figure 193), *"this is a strategy based on urban, social and environmental regeneration".* Through this proposal the Team exhibits its inquisitiveness for interdisciplinary issues and sustainability. In the inhabit2030 project (Figure 194) the human being is placed at the core of the approach of the Team. At the scale of the neighbourhood and the community, they emphasise the **sharing and exchange of energy production and services.**

There is some contrast between innovation and affordability, which leads to assuming some kind of incompatibility. Innovation understood within the scope of technology could be limited by cost but **innovative ideas** not always entail a large budget, on the contrary, sometimes the most brilliant ideas can be simple to implement.

In short, integrating a certain philosophy into the competition, making it evolve towards the solution of current problems leads to a more interesting competition, **producing excellent references,** which can influence the whole sector: students, professors, researchers, professionals, and industry. Sponsorship from innovative companies grows as well as public interest in visiting the Solar Village. Since the media and social media are so important nowadays, it is an appropriate strategy to stimulate innovation, creativity and research. Innovation especially can arouse social interest.

Detailed information about the objectives of each prototype, the architectural design, the construction, materials and systems can be found on the web sites and in some specific publications[15].

Systematically organized technical Information on the building design and construction of all SDE houses is documented in the European Smart Cities Information System databases (*https://smartcities-infosystem.eu*) and the IEA EBC Annex 74 knowledge platform (*www.building-competition.org)*, whose major activity is to secure the information, experiences and data from building and energy competitions such as the Solar Decathlon and living labs worldwide. It is funded by the German Federal Ministry of Economic Affairs and Energy and assisted by intensive information exchange with the organizers from the past events around the world.

In order to mitigate global climate change, intensive growth of sustainable design, energy efficiency and RES (Renewable Energy Sources) use must be achieved especially in the building sector.

In the competition, the different solutions proposed through each house were clearly the result of a variety of approaches, responding to diverse climatic conditions and cultures. Therefore, all the houses placed special emphasis on passive design: insulation, thermal inertia, ventilation and evaporative cooling, shading systems, bringing back traditional techniques conveniently adapted to current needs. Once the energy demand is minimised due to an optimised architectural design, **efficient** appliances and equipment are used and then the **solar systems** are integrated. Building Automation and Control Systems (BACS) and Building Energy Management Systems (BEMS) has been used in most of the houses.

The **sustainable energy in buildings goal should not be to produce as much energy as possible, but to consume as little as possible.** Therefore, its conditioning is largely passive. SD has not only successfully confirmed that such a goal is reachable, but even more, the around 300 houses, with their harmonised passive/active architecture/construction/HVAC/RES/smart-grid integrated energy efficiency, have opened up a new frontier for sustainable energy in buildings and settlements of the future.

[15] SDE 2010 and SDE 2012
Web site: http://www.sdeurope.org
Books (digital available): "Solar Decathlon 2010. Towards Energy Efficient Buildings"; "Solar Decathlon 2012. Improving Energy Efficient Buildings". Both books include a competition overview and a description of all the participating houses.
SDE 2014, Web site: http://www.solardecathlon2014.fr, Publication (digital available):"Project Profiles: Solar Decathlon Europe 2014."
SDE 2019, Web site: http://www.sde2019.hu, Publication (digital available):"Visiting guide"

Passive systems

All the participating houses included **passive design strategies**. Many of them achieved an excellent balance between envelope, orientation, geometrical aspects and other passive strategies. The results of the **Passive Monitoring Period** implemented since SDE 2012, show that the use of passive design strategies helped to maintain the interior comfort of the houses while consuming zero or very low energy. Fifteen SDE 2012 houses were analysed to see if they could be classified as Zero-Energy Buildings (ZEB). It was discovered that all of them had maintained a positive energy balance in both the annual energy simulations and during the **monitored period at the 'Villa Solar'**. If the annual energy balance of the houses is like the estimated one, they will not only be ZEB, but **Net Plus Energy Buildings** too.
These results should encourage the stakeholders of the building sector to introduce passive design into their promotions, not only to build sustainable buildings but also as a marketing tool and a better positioning in the market.
A wide range of conditions for sustainable building practices and solar energy ready to be transfered to the market were proposed: **from cutting edge technologies to the very thoughtful use of passive solar strategies.**

Daylighting and solar control integrated devices

For all the houses taking part in the Solar Decathlon Competitions, especially in Europe, architectural design considered an **appropriate exploitation of solar gains**. In high solar radiation climates, the effect of the large amount of light and the usual lack of daylight control devices cause exterior sunscreen abuse, paradoxically generating artificially illuminated interior spaces.

Integrated Devices provide healthy and efficient interiors. The benefits of daylighting in the building sector are well known, the consequences of living in areas with not enough daylight go beyond the impact on electricity consumption. The technology is ready to be implemented.

The winning house, from the **Virginia Polytechnic Institute & State University** (SDE 2010), **Lumen Haus** uses a series of mobile devices, enabling the exploitation or avoiding solar gains depending on the indoor activity and the outside climate conditions. (Figure 195)



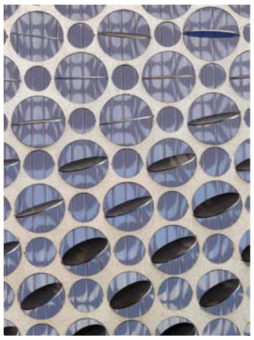

Figure 195: Lumen Haus. SDE 2010. Articulates the architectural space differently though combinations of sliding panels.

The University of **Applied Sciences Rosenheim** (SDE 2010), used solar protection based on zig-zag panels, which apart from allowing the control of solar radiation entering the house, contribute to its very interesting architectural design (figure 196). Solar protection devices can contribute to the high-quality design of windows and glass roofs. The **RE:FOCUS**, project from the **University of Florida** provides a good example (SDE 2010) (figure 197). From Tongji University, the Para Eco-House space dynamically combines a vertical garden, shading, and a ventilation system on the western facade. (figure 198).

Figure 196: RE: FOCUS House. Solar Control Devices, SDE 2010.

Figure 197:. RE: FOCUS House. Solar Control Devices, SDE 2010.

Figure 198: Para Eco-House space, combines vertical garden and shading

Shape Optimisation

Optimal Shape of the house is explored by some Teams**, FabLab House**, from Instituto de **Arquitectura Avanzada de Catalunya** suggested that “form follows energy”, they calculated the optimal solar enveloped, which resulted in a paraboloid shape. The dwelling is not a machine anymore, but an inhabited organizm. (Figure 199)

Figure 199: FabLab House. SDE 2010.

Evaporative Cooling

Evaporative cooling is a key strategy for the cooling periods in warm climates. 67% of the houses used evaporative cooling systems. The Andalucia Team, with **Patio 2.12 House**, introduces an innovative cooling technology based on the principle of the botijo, a clay bottle popularly used in Spain to keep drinks cool. (Figure 200)

Furthermore, for the cooling periods, 17% of the houses took advance of the typical clear sky of Madrid and included night sky radiant cooling systems. The low temperature radiant surfaces provide an efficient way to heat or cool buildings, especially if they have natural thermal sources as in the SDE 2012 houses. 60% of the houses used radiant systems. These systems were installed on the floor, on the ceiling, or in both places.

Figure 200: Patio 2.12 Houses. SDE 2012.Contemporary interpretation of home spaces and traditional building technologies.

Thermal Energy Storage

Another key strategy is Thermal Energy Storage (TES), used both for cooling and heating periods. 87% of the houses used one or more TES system. Some being Sensible TES systems (based on heavy materials such as concrete, stone or sand), and others Latent TES systems (based on the thermal storage capacity of Phase Change Materials (PCM)). From the earliest competitions, phase-change material has been used, contributing nonstructural high thermal inertia and significant storage capacity to the thermal treatment systems. Therefore, compared to the SD 2005 competition, where only some PCM use was observed, the SDE 2012 competition was a confirmation that these materials provide a reliable solution as they have already passed through the experimental phase. In the 2012 competition, the PCM were used in both passive and active applications.

The Rome Team, with their **Med in Italy House**, an indoor/outdoor house designed for a Mediterranean climate, whose layered walls contain sand in aluminium tubes and coatings of natural insulation, is designed to ensure the thermal balance. (Figure 201)

Figure 201: Med in Italy House. SDE 2012. Tradition and innovation are the two fundamental criteria behind its design.

BIPV. PV integration and sustainability

The students' attention was drawn not only to designing and building houses, but also integrating technology to build "homes", searching for new ways to **improve the construction and integration of the building's solar components and systems**, using new approaches to engineering, to generating knowledge of sustainable solar buildings, and to reducing waste and energy consumed during manufacturing.

Figure 202: Casa Solar. SD 2007.BIPV shading.

UPM''s Casa Solar (Figure 202) in US SD 2007 Competition incorporated for the first time the design of translucent solar panels arranged in a double sliding skin facing south, which, in addition to its bioclimatic use, combining cold-heat, day-night strategies with its automated louvres in the double skin, shielded the solar radiation from the south, providing a surplus of energy generation of 3 KWh.

Figure 203: Black and white house. SD 2009. BIPV façade system.

UPM''s Black &White House (Figure 203) in US SD 2009 Competition incorporated for the first time Photovoltaic solar panels with manual tracking systems both on the mobile facade panels that tracked the sun in three of its four orientations (except north) and had a large roof panel with a simple solar tracking system throughout the day.
Solar Decathlon houses make extensive use of solar-PV energy, ranging from flexible panels integrated in the building, as in the case of the Instituto de **Arquitectura Avanzada de Cataluña** (SDE 2010) (figure 199), to concentration systems that enable the generation of electric power and domestic hot water (DHW), as in

Figure 204: Napevomo House. SDE 2010. Innovative electricity domestic hot water (DHW) co-generation systems.

the case of the house presented by the Arts et Métiers Paris Tech, **Napevomo House** (Figure 204).

The University of Florida (SDE 2010), **RE: FOCUS House** used tubular photovoltaic modules (Figure 205). Apart from fulfilling a solar protection function, they can be integrated into the facade, while generating electric power.

Figure 205: RE: FOCUS House. SDE 2010

The **Virginia Polytechnic Institute & State University** used bi-facial PV-modules whose inclination is adjustable. **CEU University** (SDE 2010), the **SML House**, used slim-layer PV-modules integrated into the facade (Figure 206).

Some teams also used solar energy to produce domestic hot water. Some of them came along with very innovative solutions, like the hemispherical skylight-collectors proposed by the Instituto de Arquitectura Avanzada de Cataluña (SDE 2010) (figure 199). Building Integration Photovoltaics (BIPV) has been an inspiring constant in most of the proposals, and one of the key drivers for innovative, successful and attractive houses.

Figure 206: SML House. SDE 2010.

The photovoltaic system of the **ECOLAR-house** from the University of Applied Sciences Konstanz is the main feature of the building, visible throughout the design (figure 207). The photovoltaic design therefore aims to integrate the modules into the construction, they developed a mixed photovoltaic and thermal solar system.

From Hochschule für Technik Stuttgart, **Home+,** roof and facades are visually connected using different colours for the cells, forming a unique 'pixel design'. (figure 208).

The Omotenashi House, from Chiba University (Japan), uses roof tile-shaped solar panels. They are highly efficient but do not take away the quiet dignity, characteristic of Japanese housing. (figure 209).

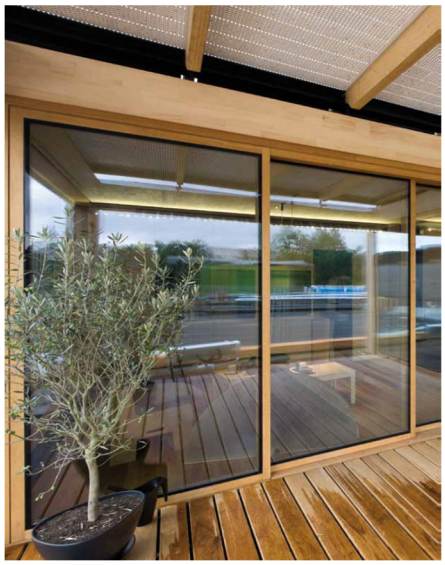

Figure 207: ECOLAR House. SDE 2012.

The **MOR House**, from Delf University of Technology integrates tile-coloured solar panels into the façade, designed for easy assembly/disassembly, serving a practical and aesthetic function. (figure 210)

These panels were used for generating electricity, and hot and cold water. The system is simple; a water plate is placed behind the PV panels to improve their performance. The hot water generated is stored to be used later. During the night the process is repeated, however, in this case, the cooling of water is caused by irradiation to the sky, and the cool water is used for indoor air conditioning: directly or through the PCM accumulators.

Figure 208: Home+. SDE 2010

Figure 209: Omotenashi House. SDE 2012

Figure 210: More House. SDE 2019

Heat recovery

The SDE houses included commercial or custom-made heat recovery systems to reduce the heating and cooling loads for ventilation. In their functioning, thermal energy is exchanged through moving currents, typically air, which is entering and leaving the house. The entrance air is pre-heated or pre-cooled without the use of energy from heating or cooling equipment.

In Figure 211 ventilation air passes through a heat exchanger using PCM befone entering the house to be tempered.

Figure 211: Phase Change Material based air tempering system. Detail of the closed ducts system. Napevomo House. SDE

Building automation and control systems (bacs) and building energy management systems (BEMS)

Building Automation and Control Systems (BACS) and Building Energy Management Systems (BEMS) played a decisive role in most of the houses, providing an efficient energy demand management. With some of them it is also possible to know the house's energy production and consumption in real-time, obtain advice on the operation of active systems as well as information aimed at improving the energy consumption habits of the occupant.
User-centred technologies were implemented in most of SDE 2019 houses. Like IoT technology through apps, smarts phones connect houses with the users, activating systems anticipating to the users' arrival to their homes or speech-based emotion detection.

7.6.6 New concepts fostered by competitions

Projects also focus on building sustainable energy communities. This new urban and social approachs of the European competition was fostered by the inclusion of the "Urban design and transportation" Contest in 2014 and the "Neighbourhood integration and impact" in 2019 whose result is a richer conceptual approach of the architectural design, understanding architecture as a transforming element of the environment, gaining a great prominence in each of the proposals, providing singular solutions to different cities and countries. A great distinctive character is present in each of the prototypes.
The urban approach

The Rhône-Alps Team, with their CANOPEA House, was the first SD House to introduce a very interesting solution, pertinent to an urban environment. They built a prototype, which could be stacked one on top of the other, up to six times, presenting a real alternative and a very practical solution for limited urban spaces. While most submissions thoughtfully considered the modularity of their homes.

The Rhône-Alps team really applied this concept to the extreme which yielded them honourable mention on sustainability, and overall winner of SDE 2012 competition. (Figure 212)

Figure 212: CANOPEA house. SDE 2012.

In SDE 2014, fourteen teams explored the intervention in specific existing urban environments, proposing symbiotic relationships between new and existing structures. TEAM Prêt-à-Loger, in SDE 2014, with the Home with a skin project proposed a new housing typology for retrofitting typical Dutch row houses by adding a new skin on top of existing buildings (Figure 213). TEAM Plateau, with the SymbCity project calls for the “colonisation“ of rooftops, creating a harmonious additional floor (Figure 214).

The Project OnTop, from the University of Frankfurt, consists of new housing typologies on top of buildings to densify cities by analysing the growth of city populations . (Figure 215)

Figure 213: Home with a skin. SDE 2014

Figure 214: SymbCity House. SDE 2014.

Figure 215: On Top, SDE 2014

Resilient Design, Neighbourhood Integration and Impact

In 2014, for the first time in SDE, resilient design gained prominence. Universities from Mexico, Chile, Costa Rica, Japan and Thailand focused on solving or minimizing the effects of natural disasters. Showing the climate emergency already present in some parts of the planet. Ecological motivation is certainly important, but it does not matter much if a building becomes uninhabitable due to flooding, earthquake, power outages or some other natural disaster.

Adaptive house (Bangkok, Thailand) can survive floods. A cluster of such houses could create a sustainable and adaptative village. (Figure 216). *The flood strategy is used to design community housing that can withstand flooding as a whole, not only on an individual house basis. The house itself can also withstand flooding up to 60 cm high, until the flood reaches the ground floor. In a worse case scenario that the ground floor is flooded and not functional, the second floor is still operable with electricity and water. Once the flood reaches a height of 100 cm, the electricity needs to be cut off for safety, although living area is provided on the second floor as an evacuation space for disaster situations. Materials specifications for the first floor arewater resistant, to minimize maintenance after flood*[16].

Project RenaiHouse from TEAM Chiba (University Japan), proposes a solution for rebuilding Fukushima area after the 2011 tsunami disaster. (Figure 217)

[16] KMUTT TEAM SDE 2014 Project manual report 6 (https://building-competition.org/EU2014)

Project Casa FENIX (Valparaiso & La Rochelle Universities) is a post-earthquake sustainable housing unit composing a sustainable community for relief. (Figure 218). Casa Felix evolves from a basic Survival Modules module (14m^2) to a complex of Eco Village/Housing Complex. This process cover the stage of Emergency, Rlief and Reconstruction, The progression allows the Survical Module to become a final home.[17]

Figure 216: Adaptative House. SDE

Figure 217: RenaiHouse. SDE 2014.

Figure 218: Casa Fenix. SDE

In 2019, actions are introduced in territories that go beyond a purely urban environment, focusing on the social impact of the proposals, proposing solutions to a variety of starting conditions. The Over 4 Team, (University of Bucharest) developed a renovation project of a condominium built in the communist era in Romania (Figure 219). The goal of the AZALEA Team (University of Valencia) is to preserve the orchard of Valencia and its typical house, the “barraca”, this typology works as a nexus between urban and natural living (Figure 220). The SOMEshine Team (University of Miskolc, University of Pécs University and Blida) use the simple ideas of the vernacular Hungarian architecture to address the renovation of 800,000 outdated houses. The project puts emphasis on social integration (Figure 221).

Figure 219:. Over4. SDE 2019.

Figure 220: AZALEA. SDE 2019.

Figure 221: Hungarian Nest +. SDE 2019.

The impact of user behaviour is also explored in SDE, the TO Team (University of Catalonia) proposes a physical and social space that allows the inhabitants to reflect on how their behavioural habits relate to sustainability with the aim of triggering an ecosystem change, proposing a revision of daily activities, ways of living and of the inhabited spaces that have been inherited from the past. (Figure 222)

Figure 222: TO House. SDE 2019.

The philosophy behind the projects is more powerful in the later editions of the SDE, sometimes it can be seen that the motivation and creativity of the students is more linked to the resolution of social problems than to win the competition.

[17] Casa FELIX. Project Manual #7. (https://building-competition.org/EU2014)

7.6.7 Research, innovation and Market Opportunities.

Promoting innovation and generating knowledge to improve the performance of energy-efficient buildings and transferring this knowledge to industry and professionals has been a general challenge experienced by all of the organizing teams, even becoming one of the declared objectives in the case of the first editions of Solar Decathlon Europe.

Research and innovation can be found at different level of maturity in the Solar Decathlon Europe Competition. It is a Universities Competition, so behind each proposal there are fresh ideas, enthusiasm, creativity and energy developed by students and professors (in the early stages of development) which are built and/or monitored for the first time during the competition. More mature systems developed at the Universities' Research Structures are also implemented in many prototypes, using them as real life demonstrators and test facilities.

Solar Decathlon is also an event highly supported and sponsored by companies, so much of the technology, materials, systems are market ready and the houses are used as demonstrators of cutting-edge products already available in the market.

The involvement of companies in SDE is remarkable. Table 14 collates the number and type of companies that have sponsored the Organization of the European competitions. From large industrial groups and multinational companies to small and medium-sized enterprises (SMEs) have been actively involved in SDE competitions, including individual professionals and collaborators.

	SDE 2010	SDE 2012	SDE 2014	SD 2019
Industry involved	**5**	**5**	**3**	**3**
Companies Involved	**2**	**2**	**8**	**6**
SMEs involved	**24**	**24**	**18**	**3**
Collaborators	**10**	**45**	**59**	**5**

Table 14. Companies sponsoring SD Europe.

As regards research, Solar Decathlon was organized in US by the Department of Energy, and on behalf of them, by the National Renewable Energies Laboratory, a highly recognized research center in the world.

Solar Decathlon Europe was organized by UPM University in 2010, and 2012, and by Research Centres in 2014 (CSTB) and 2019 (EMI). Solar Decathlon Africa was organized by IRESEN (the Moroccan Research Institute in Solar Energy and New Energies). In all these cases the organization had an interest in promoting research, coinciding with the teams'' own interests, From 2010, the objective of the Organizers is to encourage the creation of shared research. During the competitions, links were established that still exist today and have generated new projects and initiatives. Books, scientific articles, PhD theses and conference papers were produced from each university.

Industrialisation and market viability are contests incorporated into the competition to close the gap with the market, encouraging teams to be creative in this matter. The approach is very different from one team to another as many Teams proposed prototypes with innovative industrialisation systems. It is worth mentioning Andalucía Team in SDE 2012, with their Patio 2.12 House which is a prototype exploring an innovative concept consisting of living prefabricated modules with clear marketable potential. Other teams with designs inspired by their local traditional buildings, for example the Romanian and Italian Teams in

SDE 2012, understood standardisation as adjusted and set up for centuries, and as a spirit which should be transposed into a modern house.

In the SDE 2014 many innovative proposals were linked to marketable opportunities. For instance, the proposals of University of Applied Sciences of Frankfurt, or Universidad de Alcalá (Madrid) with the development of industrialised modules for the retrofitting of typical existing collective buildings. The proposal of France Phileas in Nantes, to retrofit a historical Landmark on the banks of the River Loire, within an urban renewal project based on urban agriculture. The prototype represents an apartment + greenhouses on the top floor. The University of Delft proposed an industrialised skin for the retrofitting of a typical Dutch terraced house, which could have also a high potential in the market.

Some dwellings in the exhibition also showed that we are still trying to work out old ideas, like those of Dr. Maria Telkes, the M.I.T. pioneer scientist who invented the first solar panels to be used in a house in 1948, collaborating with architect Eleanor Raymond in attempting to integrate the new-fangled technology into a vernacular architectural language. These examples remind us of how long it takes for ideas – even good ideas – to influence and change the modus operandi of industries, the academy, and, more importantly, the public and private agents that build and change the physical environment.

In SDE 2019 most of the proposal were conceived to preserve important elements of the urban environment or to solve the current social problems of our cities. The houses, with a strong social component, should not be analysed in terms of economic viability, as the benefits are more wide-ranging. Its scope is territorial, concepts like sharing and coexisting are very interesting for future intelligent living. Sustainable intelligent cities must necessarily consider the integration of the habitant as an active member in society as opposed to the current growing individualisation of society.

Professional and Industry

The Solar Decathlon Competition relies on the involvement of industry, no competition could have been organized and no teams would have been able to particpate without the sponsorship from industry. Industry has voluntarily taken on the sponsorship of the SDE Organization, University Teams and testing building innovative products in all Solar Decathlon editions.
A valuable partnership has been established between universities and industry and between the organizers and industry.
The strategy of Solar Decathlon Communications has considered professionals from the construction sector as key drivers towards the decarbonisation of the building sector. They need to be aware, but they also need to know which sustainable and cost-effective solutions and tools are available to be used, and to be prescribed in their projects. Specific activities were organized, professionals participated in conferences, workshops, and courses developed during the competition there were numerous visits to the houses. There was also a relevant participation of experts from the different fields involved in the Organization of the Competition: during the design phase, the competition phase and for the organization of the event itself.

Professional Participation and Awareness

More than 25,000 professionals from the construction sector participated in conferences, workshops, and courses developed specifically for this group.
Approximately 469,000 professionals visited the International Trade Fairs organized. Five Conferences for professionals were organized with 1,500 professionals attending.

During the Solar Decathlon Europe Competitions, thousands of professionals visited the houses both during the assembly process, and the competition, technical tours were organized for them in every edition.

The organizing teams have been mainly made up of students, researchers and professors from the Universities and research Institutions. Nevertheless, for the development of specific tasks, the organization leaned on the work and experience of many professionals in all three Organization Areas: Competition, Infrastructure and communications.

In the Organization Team professionals oversaw administrative tasks, the elaboration of the rules and regulations, the revision of the Teams' deliverables and the communication with the Teams.
Specifically, in the Assembly phase, experts oversee the inspections of the houses and the Solar Village, to assure compliance with Building and Urban Regulations.

During the Competition Phase, the Juries were made up of 18 national and international professionals of renowned prestige. It is worth mentioning the participation of the Pritzker Architecture prize winner Glenn Murcutt, who was Member of the Architecture Jury of first Solar Decathlon (2002) and of first Solar Decathlon Europe (2010).

"Having been a member of the first Solar Decathlon conducted in Washington D.C. in 2002 I can confirm that the standard of design reached in this Solar Decathlon exceeds the quality achieved in Washington by a large measure. It has been an enormous improvement." [18]

In order to link professionals and industry with the competition, extra-competition awards are proposed to associations or professional groups. These prizes enrich the scope of the competition, in some cases evaluating aspects relevant to connect technologies and prototypes to the market, such as interior design, lighting design and in other cases evaluating aspects that, although important, the official contests do not contemplate, such as accessibility, building sustainability certification SDE meeting with social housing.

These awards were supported by associations such as The Association of Lighting Professionals (APDI), The ONCE Foundation and the Spanish Committee of Representatives of People with Disabilities (CERMI), The Green Building Council Spain, The European social housing agency CECODAS. Extra-competition juries were also experts of renowned prestige.

The Solar Village infrastructure required the collaboration of multiple professional: the electrical infrastructure project and implementation, the environmental lighting project and implementation and the optical fibre infrastructure and telecommunications project and implementation. These works were coordinated by the SDE Organization in collaboration with the local administration and various companies in the sector.

Synergies from industrial participation

The first and most important synergy to be highlighted is undoubtedly the active collaboration of many hundreds of companies that have supported and sponsored both the participating teams and the organizers themselves, both "in cash" and "in kind ". A more systematic list of the major sponsors of the various editions of Solar Decathlon held around the world is included in the appendix containing the Organization Factsheets, and in chapter 5, dedicated to the organization of the competitions, some considerations are made in this regard.

The repercussion of synergies from industrial participation goes beyond Solar Decathlon Competition and prototype technologies. In several cases links have become solid, Solar Decathlon is a very intense experience for all of the stakeholders involved, including industry, the links have lasted over the years,

[18] "Solar Decathlon 2010. Towards Energy Efficient Buildings"; word of *Glenn Murcutt, (Architect* and winner of the 1992 Alvar Aalto Medal, the 2002 Pritzker Architecture Prize and the 2009 American Institute of Architects Gold Medal).

generating further collaboration in other research and development projects. An atmosphere of trust and generosity is created in Solar Decathlon, after which the links in many cases have been maintained. The presence of some industrial partners in the university has been reinforce and vice versa, common goals are being achieved. This is a reality in The University Teams but also in the Organizer Teams.

As an example, UPM links with Saint-Gobain and Kömmerling (SDE 2010 and SDE 2012 sponsors) have led them to be partners in two national research projects focused on building retrofitting and comfort conditions (SIREIN Project and BALI Project). The transfer of knowledge has also been encouraged from university to industry, university professors are invited as speakers in communications events, and from industry to universities when technicians from industry participate in master classes at the university. The links established in Solar Decathlon are somewhat fragile, since they rely on specific people (professionals, students or professors) who are in contact during the Competition time.

Preserving these links in time and expanding them towards more members of institutions and companies is an interesting way of reniforcing the impact of Solar Decathlon.

From the interviews conducted in the «Thematic Report 3: Increasing impact for the smart cities Community» [19]we have chosen the words and reflections of the main sponsors of Solar Decathlon Europe 2012 to illustrate the synergies between Solar Decathlon and industry:

“The competition was a great occasion to bring to the public innovative technologies and design strategies for buildings – all that in a very beautiful environment. Such technologies could also be tested and led towards original collaborations between the scientific world and the business sector. Several collaborative researches were conducted together with businesses. Solutions and outcomes from these researches were successfully applied to the Solar Decathlon’s prototypes which used, tested, and presented new products available on the market.

As a result, the competition encouraged similar initiatives from different organizations throughout Europe, therefore increasing the number of activities explaining the values we share with the Solar Decathlon Europe.

Values for the future. The importance of the Solar Decathlon Europe 2010 competition for the Main Sponsors”

The great goals of Solar Decathlon together with its visibility and the exciting and emotional component of participating in a competition places teams in a good position to capture the interest of industry and get their sponsorship. Sponsors are very interested in donating materials and equipment, typical sponsors are companies focusing on PV and thermal Solar Systems, efficient and Innovative HVAC systems, evaporative cooling systems, heat recovery systems, innovative lighting systems, thermal insulation, innovative glazing, sustainable building finishes, PCM, Building Automation and Control Systems.

Sponsors use Solar Decathlon houses as showrooms to present their new products, they make sure students know the specifications so they can explain them to the visitors (general public, professionals, politicians). In most of the houses it can be relatively easy to get innovative materials and systems, especially those whose visibility (such as interior finishes, exterior finishes, furniture, façade material and of course PV and thermal panels).Solar Decathlon is also a place where links between industry and policy makers have been estabilised , again the atmosphere of trust that is generated around the event generates personal links that have facilitated subsequent negotiations between industry and government, this was an unexpected result of the competition for some of the sponsors.

[19] *C TENDER #: ENER / C2 / 2016-502* «Thematic Report 3: Increasing impact for the smart cities Community» (https://building-competition.org/publication/show/ECPROJECT)

8. Key drivers for a Successful SD Competitions and its Events

Once all the information from the work carried out during these years had been gathered, and having analyzed the results of the surveys carried out, especially the last one conducted in 2020 as it was the most global and focused on assessing the impacts of the Solar Decathlon competitions, the different complementary interviews carried out with Faculty Advisors, Decathletes and other stakeholders, and with the last evaluations using the variables, indicators and key performance indicators, with the first preliminary conclusions drawn, we proceeded to undertake the last planned task.

This consisted of conducting a series of semi-structured interviews with people who have contributed significantly to the evolution of Solar Decathlon from relevant organizational positions. These interviews have been carried out to enrich the analysis of the results of the surveys,indicators and KPIs. Specifically to know their vision, from their experience and perspective, about what are the main key drivers for a successful competitions, as well as the main lessons learned.

An effort has been made to contact all the people who have been considered relevant from an operational point of view, and not so much from a more political point of view, who, although having an interest, do not know so much about the organizational aspects and their impact on the competitions. In total, 14, one-hour open interviews have been conducted with relevant people, who are in chronological appearance:

Richard King, creator of the Solar Decathlon and director of the American SD competition in the first 6 editions: SD 2002, SD 2005, SD 2007, SD 2009, SD 2011, and SD 2013, and, probably the single-most person who has had the richest global perspective having actively participated in a relevant role in all the editions held of Solar Decathlon in the world.

Cecile Warner, NREL technical staff. She came to SD from previous experience in solar car Racing, and participated as Project Manager of the three first editions in US SD 2002, SD 2005, SD 2007.

Sergio Vega, Professor and Researcher at UPM was Faculty Adviser of UPM Team in 2007 (UPM participated in SD 2005, SD 2007, SD 2009), and fostered the agreement and MOU beteween the Spanish and US governments to move the competition to Europe. Sergio was the General Director – Project Manager of the first two editions in Europe held in Madrid SDE 2010 and SDE 2012. Principal Investigator of European 10Action Project. Collaborator organizer of SDE2014 in Versailles, and supporter of SDE 2019 and SDE 2021 from the Board of Directors of the Energy Endeavour Foundation.

Edwin Rodriguez, Team Leader of UPM Team in 2007 and Competition Manager of the first two editions in Europe held in Madrid SDE 2010, SDE 2012, and SDE 2014 in Versailles. General Director - Project Manager of SDME 2018 (Middle East), held in Dubai, and SDME 2021 to be held in November 2021.

Claudio Montero Head of the Organizing Competition Team in the first two editions in Europe held in Madrid SDE 2010, SDE 2012, and later in SDE 2014 in Versailles. He has actively supported organizer teams of SDME 2018, SDE 2019, and SDE 2021 to be held in 2022 in Wuppertal, the last two from his position at the Energy Endeavour Foundation.

Joseph Simon, Senior Engineer and Project Manager at the National Renewable Energy Laboratory served as Competition Manager for the U.S. Department of Energy Solar Decathlon in 2011, 2013, 2015, 2017, and 2020. He was student project manager for the University of Illinois team in 2009 and was a member of the architecture subteam for Illinois in 2007. He has served as a juror for Solar Decathlon China and Solar Decathlon Europe and a technical consultant to Solar Decathlon Latin America, India, Middle

East, China, and Europe. He is a licensed Architect in the State of Colorado, USA and leads technical assistance work for solar manufacturing and competitiveness. In addition to the Solar Decathlon, he supports other renewable energy-focused challenges including the Solar District Cup and the EnergyTech University Prize.

Karsten Voss, Professor for building physics and technical services at Wuppertal University since 2003. Researcher at the Fraunhofer Institute for Solar Energy Systems for 12 years. He works as expert for the International Energy Agency. Beside a large number of scientific articles, he has published books on energy-efficient buildings, zero-energy buildings and building performance. He was faculty advisor of “Team Wuppertal“ at SDE 2010. Since then, he is actively involved in the continuous development of the format within IEA Annex 74. He is competition director of SDE 2021/22 in Wuppertal, Germany.

Peter Russell, Professor and Researcher at Delft University, was Faculty Advisor of RWTH Aachen University in SDE 2012, and part of Organizing team in SDE 2014. Council of Experts of the Energy Endeavour Foundation.

Yuan Tian, a member of the organizing team for the three SDC competitions so far with the positions of Project Manager of SDC 2013 in Datong and in SDC 2018 held in Dezhou and Executive Deputy Director of SDC 2021 in Zhangjiakou. Focus on competition rules, university teams, international interactions and educational outreaches.

Louise Holloway is an internationally positioned entrepreneur, creative director, and educator in the fields of communications strategy, managing her Paris-based communications consultancy, advising public organizations, institutions and consumer brands, specifically in the sectors of the building environment. Ms. Holloway was a lead communications official for the SDE 2014 and is the co-founder and director of the Energy Endeavour Foundation, the governing body of the Solar Decathlon Europe.

Holly Carr, High officer of the US DOE (Department of Energy) and Director of the American Solar Decathlon.

Karoly Matolcsy, Deputy director for development, head of international R&D, of the ÉMI Building Quality Control Innovation Nonprofit Ltd, SDE 2019 competition director.

Badr Ikken General Director of the Institut de Recherche en Energie Solaire et Energies Nouvelles (IRESEN), Director of Solar Decathlon Africa 2019.

Samir Kaitouni Idrissi, is an Energy and Environment Research Engineer and Energy Efficiency Group Leader at The Green Energy Park (IRESEN & UM6P). Samir was the project leader of Solar Decathlon Africa 2019. With more than 5 years of professional experience, he is a Renewables, Energy-Efficiency & environmental engineering professional. His ambition is to develop new innovative sustainable solutions, contributing to enhancing the shift to a clean sustainable environment in Africa.

For the drafting of this point of key drivers for successful SD competitions and its events, we have considered the results of the analysis of all the results obtained, the contributions of all the interviewees, and finally it has been contrasted and nuanced by all the members that make up the Annex 74 working group, gathering below in a synthetic way the main conclusions of these key issues in each of the points in which this assessment is composed: successful competitions, relevant linked events, key drivers for making people aware about sustainability and energy efficiency, for a high media impact and social media activity, and key drivers to promote innovation and education at universities.

8.1 Main Key Drivers to Assure Successful University Competitions

The main key drivers identified are described in the following section.

8.1.1 Budget

It is impossible to organize a Solar Decathlon competition without having the necessary budget to carry out the competition, completely assured, and with a known income calendar compatible with the development of the competition. In previous editions, there have been serious budget cuts that have affected the competition itself (beyond the organization of the event and the communications strategy, which have been the main victims), reducing the subsidy allocated to the teams, which puts their participation at risk.

8.1.2 Organizing Team

The organization is absolutely key with a sustained work throughout the years that lasts throughout each of the competitions . There must be a leadership of the organizing team that ensures the recognition and respect of the participating teams. The organization must be committed to the competition''s values and objectives and must work as a team without any kind of fissure.

Throughout the various editions, different organizing teams from different backgrounds have managed the organization of Solar Decathlon competitions. The most frequent models have been public energy agencies (NREL, IRESEN), public construction agencies (CSTB, EMI), public universities (UPM, BUW), or companies, associations, public or private foundations (EEF, DEWA, CODA) or a consortium of public agencies and ministries in the case of the SDLAC. Experience shows that it is not so much a question of the organizing institution, but of the project manager and the organizing team.

An aspect that should also be highlighted is the convenience of having former organizers, faculties of previous editions' participating teams, or former decathletes, in the organizing team because they have the vital experience of the competition and its values incorporated into their DNA, facilitating the continuity of the spirit of the competition.

8.1.3 Competition wrapped up in an event

A widely held view is that competition should not be understood as a stand-alone event. When it has been approached in this way, it has had a much lower impact both socially, with less public participation, and in the media, with no appearance in the media, which in turn affects its visibility and its possibilities for both public and private funding. The competition cannot shine without being understood as part of an event that surrounds it, that enhances it, that makes it attractive to the public, and that increases the visibility and, therefore, the possibilities of funding for public entities and private sponsorship.

8.1.4 Location and accessibility of the solar village

From the perspective of the need to attract the public in order to have visibility, media attraction, and real possibilities of public and private funding, the location of the Solar Village is undoubtedly critical. The first editions of SD US held on the National Mall in Washington had an average of 100,000 visitors per edition, as the solar village was located in the most touristic area of the city. When the competition moved to Europe or China, the Solar Villages were also located in areas accessible by public transport in large cities, which also attracted hundreds of thousands of people. When the Solar Villages have been located outside the cities, in less accessible areas, the number of visitors has been drastically reduced, diminishing the potential of the competition.

Also, for the teams themselves, having locations in representative cities is an added incentive, more attractive than being in remote and poorly communicated areas.

8.1.5 The Rules & Regulations

One of the key drivers for a successful competition is that the dynamics of the competition must be known to all so that there are no conflicts with and between teams. The body of rules & regulations must be clear and not allow interpretations that could lead to claims, complaints, and “noise“. The organization has to be exquisitely neutral, and the complaint committee mechanism has proven to be effective in resolving the small conflicts that have arisen.

In this sense, the monitoring contests, if not sufficiently tested and based on a robust data collection and analysis system, is a source of conflicts that question the results of the competition, and serious problems have arisen in the recognition of the final rankings that have tarnished the competition. All teams have their own measurement systems, so it is important that the results are published in real time, so that they can be checked by all participants, however the system has to be sufficiently robust and reliable. The evolution of manual systems with Excel sheets has progressively improved to integrated systems designed for real-time open publication, which, if correct, avoids doubts and problems.

There are different points of view among competition organizers. For some, following the American model, the rules and tests should be kept as simple as possible so as not to generate disputes, and with as many points as possible that can be monitored and measured objectively, minimizing the tests assessed by expert juries. For others, following the European model, the rules are there to promote the values to be enhanced by the competition, and therefore the rules are at their service, considering that many tangible and intangible aspects must be valued, which leads to a higher proportion of points valued by juries of recognized prestige. Even if the rules are somewhat more complicated, if they are clear there is no problem, and in fact there never has been.

It is important to note that in the case of evaluation by juries, especially in Europe where up to 6 contests are evaluated by juries, the key to a respected evaluation lies in the prestige of the jurors, and it is worth the effort to select juries of the highest international level and respected professionals. These same juries provide a very good opportunity for educational and social awareness activities for students and professionals alike.

8.1.6 Passing on the experience from one edition to the next

In many of the editions held there has been a transmission of experience from one organizing team to the next, so that it has been possible to maintain or improve the competitions without losing experience and without repeating mistakes that have already been overcome. However, the leap of competition from the United States to other continents has not always had the ideal continuity of experience. In the case of Europe, the leap of competitions from some countries has been solved in the first editions with the participation of people in the successive organizing teams, and more recently with the participation of the Energy Endeavour Foundation that tries to give continuity to this experience to guarantee the success of the competitions.

8.1.7 Continuous improvement and profiling

It is worth noting the attempt of some organizing teams to systemise this transmission of experience from one edition to another with a process of critical analysis of the previous edition and lessons learned with suggestions for improvement for the next edition. This process of continuous improvement was one of the keys to the successful SDE 2010 and SDE 2012 competitions. Up to 20 people from the SDE 2010 team participated as “shadows“ attached to the US SD 09 organizing team and then issued an internal (not published as it was confidential) Critical Analysis and lessons-learned report. A similar critical exercise was

conducted after the SDE 2010 and SDE 2012 competitions, resulting in significant changes that brought about an evolution in the SD Competitions held to date.

8.1.8 Risk management

Like any valuable project that aims to achieve its objectives, it is important to make an effort from the point of view of Risk Management, identifying all the uncertainties (threats and opportunities) that may compromise the scope of the competition and the objectives defined for it. Neutralizing or mitigating threats and enhancing opportunities is one of the necessary strategies for a successful competition.
In this sense, several of the organizers interviewed highlighted the importance of, for example, the safety of the decathletes both during construction and the competition phase, as well as that of the visiting public.

Any mistake, any accident, can lead to the cancellation and closure of the competition, or at least have a very negative impact on public opinion. It is therefore essential to invest effort and means in raising awareness among students (who are not professionals and may lack judgment), and to carry out an intense control and surveillance of both the safety aspects and technical quality control of structural safety, access, fire, electrical installation, etc.

8.2 Main Key Drivers for Successful Events

8.2.1 The event as a support and enhancement for the competition

As mentioned in the previous point, some opinions clearly point to the need to understand the competition and the event that is organized around it as a whole that has to be very well planned and managed, and therefore needs to have a good location, a good budget to organize it in time, a good management team, etc to be successful.
The location is essential to attract professionals and families, the public, but for this it is necessary for it to be well located, accessible by public transport. The environment should be relaxing and shaded, but without affecting the solar envelope of the houses, so that the public can enjoy it.

8.2.2 Organizing team and good planning

Just as the Competition can be organized by professors, researchers, even university students, etc. the organization of the event requires a certain level of professionalism so that it is really optimally organized, especially in terms of communications, signage, media, etc
Both the competition and the organization of the event around it require an exhaustive and well conceived planning, shared with the members of the team that links and engages them in an active way.

8.2.3 Decision makers and public authorities

A successful event requires strong and decisive support from local authorities, public administrations and policy makers. Not only because of the sponsorships they can provide, but also because of the endless administrative authorisations that have to be documented and requested, with long periods of time needed for their processing and approval. An administration committed to the competition and the event, efficient in management, well coordinated with the organizing team and with a good communications policy with them are essential to simplify and speed up procedures.

8.2.4 Attracting the public

Attracting the public it is not only a matter of them coming to see the competing houses and their innovative and inspiring proposals, which of course is the main objective, but it is necessary to organize activities for all profiles and age ranges: activities for children, teenagers, university students, professionals, families, general public, etc. The event must offer added value to all participants so that they really come to visit the solar village, and at the same time play, educate, learn, get inspired, etc.

But it is not only about attracting the public in quantity, but also about providing them with a quality experience. The goal has usually been to make the public aware that there can be a more sustainable way of living, where just as buildings and cities need to be more efficient and sustainable, our own way of life can also contribute to this common challenge. To this end, we have to design activities and a highly oriented communications campaign, and tailored to each target group.

8.2.5 Educational and recreational activities for all

Events and competitions have more visibility and attract more public and generate more social and media impact if attractive activities are organized for each of the target audiences, and must meet the characteristics of serving for education and social awareness, while giving them an unequivocally playful and attractive approach for children, young people, professionals, students, or the general public.
For young and middle-aged people, organizing a thematic concert to reinforce the messages to be transmitted can be a good activity that attracts many young people, favoring their active engagement.

8.2.6 The solar village as an object of visits

In some of the editions in Europe and the USA, the Solar Village itself has become a great demonstrator of the new trends in smart, highly energy efficient and sustainable cities. For example, at SDE 2012 and SDE2014 there was a center for the energy management of the entire solar village organized by one of the main sponsors. In other cases, the Solar Village has become a showcase of solutions that improve social sustainability, or technical solutions for energy rehabilitation of the building (SDE 2019 or SDE 2021).

8.2.7 Mobilisation of synergies with other actors to organize activities.

Given the budget limitations that in general have affected not so much the competitions, but directly the events linked to them, and the development of activities, one of the strategies that have proven to be most effective in organising successful events has been to promote synergies between the teams themselves, public and private sponsors, foundations, social entities, etc. to organize activities of all kinds linked to the Solar Decathlon, facilitating the organization of activities for children, young people, university students, professionals, families, and the general public, enriching the variety of activities associated with the Competition and the Solar Village, attracting more selective audiences and and giving shine to the whole.

8.2.8 PROJECT 10Action

Finally, one of the keys to the success of the SDE 2010 and SDE 2012 editions was the development of the 10ActioN project financed by the European Union through the Intelligent Europe program. This project, which is described in detail in other chapters of this report, made it possible, for example, to organize many of the more than 100 activities during the SDE 2012 competition, providing a memorable event for the 220,000 visitors to the Solar Village.

8.3 Key Drivers for Making People Aware about Sustainability and Energy Efficiency

8.3.1 Impact of the competition and associated event

The impact cannot be measured exclusively by the number of people who visit the Solar Village, especially in those cases where they are located in central areas of cities heavily visited by tourists, as many of these tourists will walk through the Solar Village as part of a tour that will however have very little subsequent influence on their lives. This impact should be measured in terms of visits by people who have gone specifically to visit the Villa Solar because they were interested in the subject, and have learned and become aware of it, leaving an experience that influences the perception of citizens.

8.3.2 Awareness and education of the students themselves

The education of the next generation of architects and engineers being one of the main objectives of the competition, one of the key drivers for the sustainability and energy efficiency of our buildings and cities is the education and awareness of university students, so the design of the contests and subcontests of the competition itself has become key. Being the contests of energy balance, architectural design, engineering, important in this awareness and educational role in all competitions, from the beginning.

In the European competitions, a special reinforcement of these objectives has been highlighted with the incorporation, for the first time in the Solar Decathlon, of a specific Energy-Efficiency test, with subtests that evaluated passive and active energy efficiency measures, or the Sustainability Jury, which consisted of multiple evaluations from aspects of architectural design, combination of passive and active strategies, to social, economic, communications aspects, etc.

8.3.3 Communications and communications and social awareness contests

Undoubtedly the most impactful and inspiring activity is the organization of visits and the students themselves explaining their houses, their strategies, their technologies, their experiences... including a Communications contest, or Communications and Social Awareness contest depending on the editions, in which the communications capacity of the teams is valued through their websites, their social media activity, the activities they organize in their respective universities, the “marketing“ of their houses, the posters and means of communication, their virtual tours, their face-to-face tours, etc. All of this helps in this work of social awareness of citizens on issues of Sustainability and Energy Efficiency.

8.3.4 Activities

The awareness and education of students, as well as social and professional awareness can, and should, be reinforced in the opinion of many of the organizers interviewed, with complementary activities that are part of the event that surrounds the competition, and that properly designed for each target audience allows the social awareness of citizens, professionals, families, children, students, etc. to be complemented and amplified.

One of the target audiences should be children, and the organization of activities for them is considered an important aspect in which most of the activities have focused, organizing visits and games for children and teenagers of all ages. Visits have been organized for schools that have raised awareness of Solar Decathlon among thousands of children, and in some cases, game workshops, drawing, solar devices, track games, etc. have been developed, achieving a high capacity of influence on children.

For university students, many of the SD competitions have also organized specific activities beyond the decathletes, for university students, such as visits to the houses during the assembly and disassembly process, in addition to those of the solar village, but also workshops based on challenges (social, technological, improvement ideas), discussion and analysis workshops, summer courses, design competitions, etc. in addition to the opportunity to participate on a voluntary basis as guides, supervisors, etc. of the competitions. The international juries of some of the contests have made it possible to organize conferences and round table discussions for university students and professionals.

International or national conferences have been organized for professionals, simultaneously with the competitions and with tours of the Villa Solar. Participation in large professional and thematic fairs has been organized many times, showing the models of the SD houses, their strategies, their innovations, etc. Conferences of prestigious architects have been organized (several Pritzker prizewinners among others) who have either participated as jurors or have visited the Solar Villas. It has also been made easier for major sponsors to organize professional events which give them visibility and attract professionals to the Villa Solar.
For the public, in addition to guided tours of the Villa Solar and each of the houses, it is important to organize specific social awareness activities. We have organized exhibitions of models, visits to professional fairs open to the public with the presence of SD, thematic exhibitions associated with the Villa Solar: solar cars, renewable energies, that we can have in our daily lives, etc.

8.3.5 10Action Project

As explained above, the main objective of the 10 ACTION project, financed by the European Union through the Intelligent Europe program, was to raise awareness among European citizens and encourage a change of behavior towards a more responsible use of natural resources and energy. In addition to the multiple activities organized during the SDE2010 and SDE2012 competitions in the Solar Village, dozens of activities were organized for children, teenagers, university students, professionals and the general public, with the active participation of the SDE2010 competing teams, resulting in more than 186,000 people participating in activities in 12 European countries, increasing the visibility, repercussion, and impact on social awareness of Solar Decathlon Europe, it being one of the main key drivers in the first European editions.

8.3.6 Post-Competition Living Labs

The evolution of the last editions of SDC 2018, SDME 2018, SDE 2019, or SDA 2019 has been remarkable. Especially how they have been organized after the Competition, leaving the best houses forming Living Labs as demonstrators for the purposes of research, education, and open to visits from university students, teachers and the general public which allows the possibilities of social awareness on issues of energy efficiency and sustainability to be expanded. The new competitions being organized, such as SDE 2021 in 2022, are also planning to leave the Solar Village after the competition with a reduced number of houses, as a Living Lab that allows the extension of educational and social awareness activities.

8.3.7 Books and Publications

The production and publication of Solar Decathlon compilation books describing the houses participating in Solar Decathlon is another tool to facilitate the education and social awareness of university students and professionals. It is worth mentioning the publications of the Solar Decathlon Europe 2010 and 2012

The multiple web pages in which the experiences of the competitions are collected (https://www.solardecathlon.gov/ ; https://solardecathlon.eu/ ; http://sdchina.org.cn/ ; https://solardecathlonlac.com / ; https://www.solardecathlonme.com/ ; https://www.solardecathlonafrica.com/, with descriptive information of the houses playing an important role.

8.3.8 the Knowledge Platform

An initiative that will be key to this work of education and awareness of university students, professionals, and the general public is the one derived from the work of this IEA EBC Annex 74 with which information from the competitions and the houses participating in the SD worldwide has been incorporated into the Knowledge Platform, completing the work that the Bergische Universität Wuppertal, Universidad Politécnica de Madrid, and Energy Endeavor Foundation have developed by incorporating all the information from the European Competitions to the Knowledge Platform financed by the German Government. The result of all of these joint efforts is to have a repository open to everyone with most of the Solar Decathlon houses documented, with their designs, active and passive strategies, and their performance in competition, etc.

8.4 Key Drivers for a High Media Impact and Social Media Activity

As we have seen, having a high media impact and a good social media activity are key to being able to attract audiences to the Villa Solar and, as we have also outlined, all this is, in turn, key to attracting sponsors and raise funds for activities, etc. What are the Key drivers for a High Media Impact and Social Media activity?

8.4.1 VISIBILITY IS KEY DRIVER FOR SUCESSFUL COMPETITION & EVENTS

Most of the interviewees highlight the importance of the visibility of the event, and for this the main factor for large scale visibility is the appearance in the press and social media. If there is visibility of the competition, the public visits the Solar Village, giving added value, generating in turn more expectation, more media, more public. Visibility is what allows companies to sponsor, and one of the reasons that administrations use to sponsor and finance the organization of competitions.

8.4.2 STRATEGIC PLANNING

One of the key drivers is undoubtedly the conviction of the organizers of the importance of the communications strategy for a successful competition and associated events. In cases where this importance has not been given, the final result has been tarnished by the lack of visitors.
In addition to the necessary will, good strategic planning is required at all levels, because success will be measured in terms of number of impacts on TV, radio, print and digital media, or in the number of virtual visits, access to the website, movement on social networks, number of likes, etc. but the strategies to achieve them are many and varied and require planning.
In successful cases of management, communications work starts almost from the very beginning, first explaining what a solar Decathlon competition is, and creating social interest through a dosed drip of media appearances that facilitates the progressive capillarity, so that when the time comes for the competition, all media want to reflect the news, and the public wants to live the experience.

8.4.3 Budget availability and professionalisation

One of the key drivers is also the existence of a budget to be able to count on specialised professionals. The relationship with the media requires journalism professionals who have been in contact with the media

for years and can access the media easily. The budget must also cover a team of professionals who develop communications material, identify and plan messages, reach the public, politicians, professionals, companies, etc. The strategic approach must cover all fields of communication.

The strategic approach should cover all fields of communication: internal communication, communication with different stakeholders (teams, sponsors, decathletes, policy makers, supporters, professionals, etc.), the external relationship with the media, activity on social networks with their own dedicated community managers, generation of audiovisual material (photos, videos, written content for different targets, etc.). Another aspect that attracts the media is the development of activities throughout the whole process, and not only at the end in the Solar Village. Conferences, model exhibitions, congresses, professional fairs, summer schools, science weeks, school visits to solar houses, etc. are activities that can have a small media repercussion that promotes the aforementioned capillarity.

8.4.4 Involvement of all: teams, sponsors, etc.

It is important for this purpose to ensure the commitment of all teams, collaborators, sponsors, etc. so that everyone tries to do activities and exploit possible synergies that may arise, giving visibility to the logo, the competition, and the activities that will be developed. A strategy of commitment is necessary of all throughout the two years of competition to have the right impact during the competition in the solar village.

8.4.5 University community manager

The role of social networks in the young half of the population is undoubtedly crucial today, and this requires a community manager belonging to the organizing team to proactively energize social networks. To do this you need to generate content, activities, news and dose them properly so that both social networks and the website itself is dynamic enough to generate traffic. If the professional is also a young university student, the degree of connection with young university students will probably be even greater. These social networks should be interconnected with other existing and thematically close networks, so that synergies with them can be promoted and exploited.

8.4.6 Synergies with sponsorship

The movement in the networks and the appearance in the media is usually of maximum interest to sponsoring companies, so sponsorship management must be closely linked and integrated into the communications policy of the organizers. Part of the sponsorships can come “in kind“ in the form of press or radio-television campaigns, either direct or indirect, in which reference is made to the event, or to SD activities, with its logo, etc. Guaranteeing sponsors some kind of impact in the media can be a good way of getting sponsorship, as long as you are in a position to guarantee it.

This might be difer from one country to another, it is a critical topic. e.g in Germany sponsors cannot be involved in projects with large national ministry support. They may be called supporters.

8.5 Key Drivers to Promote Innovation and Education at Universities

As described in Chapter 6 of this Report, the main focus is on the education and training of the next generation of architects and engineers committed to more sustainable and efficient buildings, cities and communities, and the impact related to these issues is discussed in detail at this point. What are the main key drivers in promoting innovation and education?

8.5.1 Contests and subcontests that promote innovation

The main contests of architecture, construction, energy balance, energy efficiency, etc. are oriented at demonstrating how to innovate from design to solve current challenges. The differential character of other contests in some competitions such as in the US, emphasizing aspects of replicability and affordability, is another way of encouraging an innovative approach to facilitate technologies to reach the majority of the market by being economically accessible and replicable.

In other editions, such as the European editions, the commitment to innovation is translated into a specific innovation contest that assesses innovation in each of the remaining contests such as architecture (evaluated by the architecture jury), engineering and construction, energy balance, energy efficiency, sustainability, industrialisation and market viability, etc. Practically all of the organizers interviewed from Europe, Africa and Middle East point out the importance of promoting innovation through a specific innovation contest.

The organization itself and the Rules & Regulations have promoted innovation as a fundamental part of the showcase that represents the Solar Decathlon competitions, with each organization emphasizing specific aspects such as solutions for higher building density, the solar village as Smart cities, response to social challenges, or specific challenges of their communities, more sustainable mobility, energy retrofiting of buldings and neighbourhoods.

Many of the teams that have participated in the Solar Decathlon competitions have invested energy and effort in the parallel development of research projects that have made it possible to optimise construction aspects, active and passive energy efficiency strategies, the monitoring of building management systems, etc. It depends on each team and each university how much importance they want to give to innovation and the strategy to promote it.

Furthermore, some of the interviewees point out the importance of having Rules & Regulation that are clear, but flexible to promote innovation. Excessive rigidity of the rules does not contribute to the innovation of technical solutions, strategies, etc.
Some of the interviewees think that the affordability testhas the disadvantage of discourage innovation since it usually increases the cost of construction.

One of the organizers interviewed, with which most of the interviewees disagree, downplays the value of innovation, emphasizing that it is about promoting affordable homes for the average American family. Real homes that can be built by any builder in any location. Affordability and replicability are more important. He advocates placing value on environmental assessment and life cycle assessment instead of the innovation contest.

8.5.2 Recognition and awards in out-of-competition thematic innovations

A strategy followed in many competitions to promote the innovation of singular aspects has consisted of the existence of special prizes for certain thematic contributions with public recognition, and small “in cash“ prizes that recognize very innovative and attractive aspects, as for example in accessibility issues, or the perception of the public, or rewarding air quality, etc.

8.5.3 The competition as a whole fostering education

The most powerful and comprehensive tool for educating young university decathletes is the competition itself. The opportunity for students to respond to a real challenge, in a competitive and measurable

environment, makes students highly motivated and proactive in solving the associated technical challenges, designing efficient solutions, in attractive and inspiring home environments, building and managing them as a team, which leads to the development of many transversal skills needed for the job market such as organization, discipline, leadership, management and project management skills, teamwork skills, communications skills, and a social commitment and active engagement with more sustainable buildings, cities and communities.

One key driver in fostering innovation and education through Solar Decathlon is the comprehensive educational model it provides to university students, which includes not only the application of the theoretical and technical knowledge of the different disciplines it covers (architecture, engineering, communications, marketing, management, etc), often linked to innovation and research into new proposals, but also its practical hands-on application, as well as the professional training demanded by the labour market, the development of the technical, management and transversal skills necessary for their work as professionals, and the enrichment of personal experience by promoting active commitment to society.

The organization of the successive editions has the ability to favour educational activities for the decathletes and for the rest of the university students, such as developing a team of volunteers to assist and advise in the guided visits to the solar village, organizing conferences, workshops with the juries, visits of architecture and engineering students in the phases of assembly and disassembly of the houses, summer schools, etc. Many of these activities can also be shared with the professionals of the relevent sectors, also facilitating educational synergies that can be of great interest.

8.5.4 Education in universities

The challenge of competition for students already justifies its educational interest, its associated social commitment, and the added value in their professional training. However, a good educational strategy of universities can further enhance educational achievements by extending them to all, or a good part, of their students beyond the decathletes. A key driver is the university''s willingness to involve many more students in solving specific challenges that allow them to acquire knowledge, skills, and social commitment, using the Solar Decathlon as a generator of dynamics.

One of the key drivers that has been identified in the integration of the Solar Decathlon in the curriculum of students, recognizing the added value that participation in the competition means in terms of knowledge, training, and transversal skills acquired, but not only that, but also as a life experience and active social commitment.

The experience that is being planned for SDE 2021 in 2022 in Wuppertal, with adjustments to the Rules & Regulations to promote education and research in the participating universities, are promising and may form a successful key driver for future editions.

8.5.5 Educational innovation

Solar Decathlon is also a brilliant showcase not only of inspiring houses and efficient technologies and strategies, but also of educational innovation strategies that support the learning and training of university students. To highlight some of these innovative learning trends favored by the Solar Decathlon, we have Challenge-based learning and design thinking, Learning by doing and hands-on experience, Service-learning and experiential learning, Learning in collaborative environments and team-building experience, gamification, etc..
One of the key drivers in the opinion of several interviewees to promote innovation and education is to define challenges for students and facilitate them to try to solve them in an original way, encouraging the

commitment to replicability. It is important that students understand how to design and think to solve problems.

8.5.6 The added value of post-competition use of the houses and living labs

A key driver in amplifying the possibilities of innovation, research, education, and potential for social and media awareness, comes from the universities making use of the participating houses as living labs for research, education, showcase for students, professionals, industry, children, general public, etc. It is a way that universities should exploit to give an additional added value.

8.5.7 The innovative and educational potential of the knowledge platform

Gathering the experience of the different editions of solar Decathlon in the world as a whole and having documented all the Solar Decathlon houses that have competed in the world, their strategies, their technologies, their innovations, their actual behavior in competition, etc. It opens up a field of possibilities and synergies to exploit the innovation and educational possibilities of solar Decathlon beyond the competition itself and the possible future use as living labs.

9. Conclusions and Lessons Learned

Once the work described in this “Competitions & Living Labs. Impact and performance “ Report has been concluded, and after the analysis carried out to provide insight into the real impact of the Solar Decathlon competitions and linked events, we include the main findings and recommendations to improve the Solar Decathlon in the future.

These conclusions and lessons learned are based on the analysis of gathered information from Solar Decathlon Worldwide competitions related to the houses, their technologies, their performance in the competition, the organization factsheets, surveys and interviews conducted to assess the impact on both university students, including education, training capabilities and transversal skills and experiences, and the education and awareness of people, from children and teenagers, to professionals and general public, about the responsible use of energy, and sustainability improvement of our buildings and cities, semi-structured interviews to faculty advisors and organizers,etc.

The Solar Decathlon competition transcends the usual architectural design competitions that abound in universities around the world, and **focuses not only on conception and design, but also on the construction of the prototypes** designed by the students, with occasional support from professionals and a high level of participation from industry, and, most importantly, **on the performance of the house and the teams** in the 10 contests that they must pass and in which the score obtained allows the evaluation, with objectively evaluated monitoring contests, and qualitative contests assessed by independent juries of great prestige.

The other fundamental characteristic that makes the Solar Decathlon competition so unique is that all the universities assemble their houses making up the Solar Village and compete against each other, but with camaraderie and shared objectives, transmitting the knowledge and their experiences to the thousands of people who visit these Solar Villages. The result is a unique life experience for students who learn and train professionally and that is so intense that leaves a mark and commitment for life, as well as thousands of professionals and companies sensitized and committed to innovation, and hundreds of thousands of people aware to the need to make buildings and cities more efficient and sustainable, and that we can all contribute to this shared goal.

One of the keys to the success of these competitions is to understand that Solar Decathlon is more than just a competition, and that it must be wrapped in an event that attracts the participation of the public, who learn and become aware of the inspiring houses and the messages associated with the necessary improvement in sustainability, giving visibility to the competition, drawing the attention of the media, which in turn multiplies its visibility and participation. The competition cannot shine without being understood as part of an event that surrounds it, that enhances it, that makes it attractive to the public, and that increases its visibility and, therefore, the possibilities of support and funding from public entities and private sponsorship.

From all the work carried out, information gathered, and its analysis, we arrive at the following main conclusions and lessons learned, which are organized in five points related to:

- Main Conclusions and Lessons Learned about the Competition and its Contests
- Main conclusions and Lessons Learned about the Events and Activities
- Main conclusions and Lessons Learned about the Organization Experience
- Main conclusions and lessons Learned about the Performance and Impact of Solar Decathlon from many different perspectives such as: the education and training capabilities of university students,

workers skills, citizen awareness, communications potential, innovation potential and transferring it to the market, potential impact of post-competition houses as living labs, scientific approach…
- Final conclussions

9.1 Main Conclusions and Lessons Learned about the Competition and its Contests

The degree of influence that the competitions has had as a vital experience on all students, professors and professionals who have participated, has been amazing, to the extent that 100% of those surveyed consider SD to be a positive experience overall. There is consensus in surveys, and in interviews with decathletes, faculty advisors and Organizers that Solar Decathlon is a wonderful example of well-focused competitions with a high level of participation of universities, involvement and commitment of students, participation of companies and professionals and a high attraction of public that enjoys the showcase of inspiring, efficient and sustainable houses.

Solar Decathlon has demonstrated over the years that it has a high performance and impact in terms of satisfaction from an educational and professional training point of view, development of transversal skills, social awareness on sustainability, energy efficiency, renewable energies, inspiring innovation in different strategies and technologies.

For the competition to be recognized as such, it must have clear and defined rules, with an organizing team that is recognized by all as impartial. There must be leadership from the organizing team that facilitates recognition and respect from the participating teams. The organization must be committed to the values and objectives of the competition and must work as a team without any fissures. Another aspect that should also be highlighted is the convenience of having former organizers, faculties of participating teams, or former decathletes on the organizing team, because they have incorporated the vital experience of the competition and its values into their DNA, facilitating the continuity of the spirit of the competition.

In interviews with various organizers, most of them have pointed out that the rules and events should be adapted to the needs and sensibilities of the organizing countries and regions, and that far from being a detriment to the competition, it is an opportunity to enrich and improve the competition. In this sense, the jump of the competition from the United States to Europe is paradigmatic, in which more than 50% of the points of the competition were renewed to adapt it to the European sensibility, enriching the competition with contests that are currently in all of the editions.

The contests must be sufficiently defined to be univocal and fair for all, but sufficiently flexible to allow innovation in the approaches, strategies and technologies developed by the teams. Perhaps, for those following the American model, the rules and contests should be kept as simple as possible so as not to generate disputes, and with as many points as possible that can be monitored and measured objectively, minimizing the tests assessed by expert juries. For others, following the European model, the rules are there to promote the values to be enhanced by the competition, and therefore the rules are at their service, considering that many tangible and intangible aspects must be valued, leading to a higher proportion of points valued by juries of recognized prestige. The key to a respected valuation lies in the prestige of the jurors, and it is worth investing effort in selecting top international jurors and respected professionals. These same juries provide a very good opportunity for educational and social awareness activities for students and professionals.

It is important to highlight the importance of the contests in the awareness and education of the students themselves, which is one of the main objectives of the competition. One of the drivers of sustainability and energy efficiency of our buildings and cities goes through the education and awareness of university students, so the design of the contests and sub-contests of the competition itself becomes key. The most

oriented contests in this sense are those of energy balance, architectural design, engineering, Energy Efficiency, or the Sustainability contest, which consisted of multiple sub-contests that evaluate the combination of passive and active strategies, to social, economic and communications aspects, etc. from aspects of architectural design.

Another major objective of the Solar Decathlon competitions is communication and social awareness, reinforced by the communications contest, or communication and social awareness (depending on the edition), which assesses the communications capacity of the teams through their websites, their social media activity, the activities they organize in their respective universities, the “marketing“ of their houses, posters, leaflets, and means of communication, their virtual tours, their in-person tours, etc. All of this helps in this work of social awareness of citizens on issues of Sustainability and Energy Efficiency.

In the Rules and Regulations, beyond the contests to be passed by the teams, there are also aspects that have an important impact on the subsequent results of the competition and on the message to be conveyed to university students and teachers. Perhaps one of the most significant aspects in this regard has been the limitation of the photovoltaic capacity of the houses. In the first editions SD 2002 to SD 2009 there was no limitation on the installed photovoltaic capacity, which led to the fact that the more the better, which resulted for example in houses like the one in Darmstadt 2009 with photovoltaic facades on all facades even when the cost-effectiveness ratio was absurd on three of its facades. In the European edition of SDE 2010 it was limited for the first time to a capacity of 13 kWh with very interesting proposals for photovoltaic integration in the facades. In SDE 2012 it was limited to 10 kWh with less integration in the facades. In SDE 2014 it was lowered to 5 kWh which resulted in maximizing cost-effectiveness, but at the cost of sacrificing PV integration (BIPV). For the next edition of SD Middle East 2021 it is planned not to limit the PV production capacity but the inverter capacity, in an attempt to recover the innovation in PV integration.

Some of the key drivers that we can conclude for the organization of a Solar Decathlon competition are the availability of a sufficient budget to carry out the competition, fully secured, and with a known income schedule compatible with the development of the competition.
The organizing team is another key factor for a successful competition, with different origins from one organization to another, sometimes with public energy or construction agencies, or university teams. Experience shows that it is not so much a question of the organizing institution, but of the project manager and the organizing team.

The concern of the organizing teams for a process of learning and continuous improvement that leads to systematizing a transmission of experience from one edition to another with a process of critical analysis of the previous edition and lessons learned with suggestions for improvement for the next edition, is undoubtedly one of the key factors in progressively enriching and improving the competition. It is necessary to document it and it is a challenge how to transmit it to the new organizing teams so that they really take advantage of the previous experiences, and the competition is progressively improved and enriched. Innovations introduced from one edition to the next have not always had the expected favourable effect, and for this the process of critical analysis and well-articulated continuous improvement is also important. For example, in the SDE 2014 edition it was decided to consider for the purpose of measuring comfort temperatures with adaptive temperatures, which in oscillating weather such as there was in Versailles resulted in some noticeable mismatches in real temperatures.

Another key lesson learned is the location and accessibility of the solar village. In order to have visibility, media attraction, and real possibilities for public and private funding, the location of the Solar Village is critical. The most successful editions have been located in well-connected areas, with public transportation, in attractive cities. When the Solar Villages have been located outside the cities, in less accessible areas, the number of visitors has been drastically reduced, diminishing the potential of the competition.

All of the organizing teams have had to deal with all kinds of unforeseen events, often jeopardizing the continuity of the competition itself. It is important to highlight the importance for a good competition to develop a good strategic planning that ensures the fulfillment of the proposed objectives, including a good risk management identifying all the uncertainties (threats and opportunities) that may compromise the scope of the competition and the objectives defined for it. Neutralizing or mitigating threats and enhancing opportunities is one of the necessary strategies for a successful competition.

The planning resulting from budget cuts and aspects such as the safety of the decathletes both during construction and during the competition phase for them and the visiting public, are identified as important risks for which specific strategies are needed, for example, an intense control and monitoring of both the safety aspects, such as technical quality control of structural safety, access, fire, electrical installation, etc.

9.2 Main conclusions and Lessons Learned about the Events and Activities

To take advantage of the synergies linked to the Solar Decathlon Competitions, a global strategy, beyond the Competition itself, must be well designed and developed for every single target group, and many different activities must be implemented to make a successful impact.

It has been possible to confirm the generalised opinion among the organizers of the importance of the communications strategy for a successful competition and associated events. In those cases in which this importance has not been given, the final result has been tarnished by the lack of visitors. This communication, inherent to the event, requires good strategic planning at all levels, because success will be measured not only in terms of the number of impacts on TV, radio, print and digital media, or in the number of virtual visits, access to the website, movement on social networks, number of likes, etc. but also by the number of visitors.

The impact cannot be measured exclusively by the number of people who visit the Villa Solar, especially in those cases where they are located in central areas of cities heavily visited by tourists, since many of these tourists will walk through the Villa Solar as part of a tour that will have very little subsequent influence on their lives. This impact should be measured in terms of visits by people who have gone specifically to visit the Villa Solar because they were interested in the subject, and have learned and been sensitized , leaving an experience that influences the perception of citizens.

The Key drivers identified for communications, and therefore, a successful event that enhances the Solar Decathlon competitions, are the result of a good strategic orientation, the availability of an adequate budget to organize activities, and being able to count on specialised communications professionals who draw up communications materials, who identify and plan messages, who reach the public, politicians, professionals, companies, press, etc. The strategic approach must cover all the fields of communication: internal communications, communications with different stakeholders (teams, sponsors, decathletes, policy makers, supporters, professionals, etc.), external relationship with the media, activity on social networks with our own and dedicated community managers, generation of audiovisual material (photos, videos, written content for different targets, etc.).

There is also unanimity on the decisive role of social networks today in the communications strategy of Solar Decathlon competitions, and for this a community manager belonging to the organizing team is needed to proactively invigorate social networks. It is necessary to generate content, activities, news and dose them properly so that both social networks and the website itself is dynamic enough to generate the desired traffic.

Success also requires good planning for the entire development time of the project, because the communications work must start almost from the beginning, first explaining what a Solar Decathlon competition is, and creating social interest through a dosed drip of media appearances that facilitate the progressive capillarity, so that when the time comes for the competition, all the media want to reflect the news, and the public wants to live the experience.

The awareness and education of students, as well as social and professional awareness can, and should, be reinforced in the opinion of many of the organizers interviewed, with complementary activities that are part of the event that surrounds the competition, and that properly designed for each target audience allows the social awareness of citizens, professionals, families, children, students, etc. to be complemented and amplified. For children, the organization of games and workshops are key. For teenagers, they should be challenged to think about how to organize and solve everyday problems, awakening their curiosity and capturing their attention on issues related to the sustainability of our way of life.
For university students, many of the SD competitions have organized specific activities beyond the decathletes, such as visits to the houses during the assembly and disassembly process, in addition to those of the Solar Village, workshops based on challenges (social, technological, improvement ideas), discussion and analysis workshops, summer courses, design competitions, etc. in addition to the opportunity to participate on a voluntary basis as guides, supervisors, etc. of the competitions.
For professionals, international or national congresses have been organized to coincide with the competitions and with visits to the Villa Solar. Participation in large professional and thematic fairs has been organized many times, showing the models of the SD houses, their strategies, their innovations, etc. Furthermore, the large sponsors have organized professional events that have attracted professionals to the Villa Solar. For the general public, in addition to guided tours of the Solar Village and each of the houses, it is important to organize specific social awareness activities. Exhibitions of models, visits to professional fairs open to the public with the presence of SD, thematic exhibitions associated with the Villa Solar: solar cars, renewable energies, what we can do in our daily lives, etc. have been organized.

It is important for this purpose to ensure the commitment of all teams, partners, sponsors, etc. so that everyone tries to carry out activities and exploit possible synergies that may arise, giving all visibility to the logo, the competition, and the activities that will be developed. A strategy of commitment is necessary throughout the two years of competition to have the right impact during the competition in the Solar Village.

The movement in the networks, the appearance in the media, the organization of activities to attract the public to the Solar Village, the fact that people identify with a strong Solar Decathlon brand, to which the logo of their company can then be linked, are key aspects of maximum interest of the sponsoring companies and corporations, so sponsorship management must be closely linked and integrated into the communications policy of the organizers and in the planning of the event that involves the Solar Decathlon competition. Part of the sponsorships can come “in kind“ in the form of direct or indirect press or radio-television media campaigns, in which reference is made to the event, or to SD activities, with its logo, etc. Guaranteeing sponsors some kind of impact in the media can be a good way of obtaining sponsorships, as long as you are in a position to guarantee it.

9.3 Main conclusions and Lessons Learned about the Organization Experience

One of the most relevant and, at the same time, obvious conclusions is that Solar Decathlon competitions have become very inspiring events for students, professionals and the general public, with an international scope and with very notable possibilities for social and media impact. The organization of the event cannot be left to people without organizational experience. One of the keys for success will be to select a project manager who preferably has theoretical training and applied experience in project management, who is

sensitive and committed to the world of sustainability and energy efficiency, and who has great leadership skills.

Therefore, the Project Manager must recruit a good team, well endowed financially to have all the necessary means, balanced between young, dynamic, creative and highly motivated and committed people, with people with a more senior profile and professionals who, with their expertise, guarantee the viability of the key areas in a solvent way. Given that the team is large and from different backgrounds, it will be necessary to apply “team building“ strategies, a training and coaching plan that complements the shortcomings of the team, and a good organization of the whole team, distinguishing between the organization of the competition, and the organization of the event around it.

Several of the interviewees who have organized the competition with university teams have emphasised the added value of having university students, young, dynamic, creative, and very committed to society and the project, becoming one of the great assets of the project. It is very likely that after the selection of the team it will be necessary to provide the members with the necessary training complements in order to have a work methodology and organization shared by all.

The teams must be well sized so that they really have adequate control and coverage capacity. The average teams have been around 30 people in general, and up to 50 during the competition plus hundreds of volunteers who have complemented the logistical needs of the teams.

One of the key points highlighted by many of the organizers interviewed is to define specific objectives beyond the obvious ones of the competition, and then define an effective strategy to achieve them. In this sense, the strategies proposed by the UPM to meet the objectives defined for the SDE 2010 and SDE 2012 competitions held in Madrid are very illustrative. This information can be found in the respective Organization Factsheets.

There is also a good unanimity on the need to have a good strategic planning for the development of the projects, so that from the beginning the whole team is committed to the timing of the project, and all the universities have the time frame set out in the Rules and Regulations. The strategic planning must also consider how to monitor and control the time, cost, quality, risks, etc.

Budget and project finance are two of the major challenges facing organizing teams. The budget necessary to organize the competition and the subsidy traditionally given to the teams must be assured from the beginning, as well as a defined payment schedule with certain guarantees. Based on the experience of many of the competitions, a lot of the activities planned for the organization of the event, the communications item, activities designed for all audiences, even the scope of the Villa Solar, may be unconsolidated, depending on the income obtained from sponsorships.

This, which unfortunately has affected the organization of many editions of Solar Decathlon competitions, has conditioned the final result due to the high volatility of sponsorships, the difficulty of specifying with the sponsors the contributions “in cash“ and “in kind“, and above all, the extreme delay of the companies in providing the money in cash, with the associated uncertainties until the last moment.

The consequence of these scenarios is that they need to be managed with multi-scenario strategic planning, with milestones and deadlines defined for each of the identified scenarios, and in which, if a sponsorship has not been signed or the money has not been received, certain planned and developed activities ready to be implemented will no longer be active. The consequence of this dependence on project fundrising and sponsorship has resulted in budget cuts that have usually been concentrated in the communications budgets and that of and activities organized for the public, children, university students, professionals, etc. resulting in a much lower social and media impact, tarnishing the competition.

A lesson learned by all organizing teams is that no matter how well planned the project may be, they have always had to deal with unforeseen events of all kinds, often jeopardizing the continuity of the competition itself. It is important to highlight the importance for a good competition of developing a good strategic planning of risk management to ensure the fulfillment of the proposed objectives. It is essential to identify all the possible uncertainties facing the project, both threats and opportunities, analyze them qualitatively and quantitatively, plan the response to neutralise or mitigate the threats, and enhance the opportunities, incorporating the appropriate reserve analysis into the strategic planning.

It is also necessary to plan how to monitor and follow up the main risks identified with the necessary early warning notices and the organization and procedure of the responses to be given in each case. One of the risks to which special attention has always been paid by the organizing teams has been the safety of the decathletes both during construction and during the competition phase itself, and that of the visiting public, planning specific strategies of, for example, intense control and surveillance of safety aspects, such as technical quality control of structural safety, access, fire, electrical installation, etc.

Other risks identified and managed in one way or another, have to do with government budget cuts, delays in payments producing severe tensions in the cash flow of the projects, or not reaching the expected funding through sponsorships, or its late arrival. Other risks are of a political nature, risks of terrorist attacks, problems associated with the Villa Solar, construction delays, risks associated with the simultaneous operation of 20 teams working under pressure with cranes and machinery that involve risks, inclement weather of all kinds, with floods during assembly, temperatures of 44ºC, snow, etc., the removal of equipment in the final stretch leaving plots of land unbuilt, programs for monitoring management that are not on time or are not sufficiently reliable, the need for teams to work at night with the associated risks, etc. In short, proper planning and risk management is critical for coping with the possible contingencies of the competition, with some guarantee of success despite the most unexpected problems.

Another important lesson learned is to have a feedback system from previous experiences. The most significant advances have occurred when processes of critical analysis and lessons learned have resulted in significant qualitative leaps that have enriched the competitions, as in the case of the leap from the US competition to Europe, and the leap from SDE 2010 to SDE 2012. The UPM drew up an elaborate report on lessons learned from SD 2009, SDE 2010 and SDE 2012 that substantiated the changes introduced in the first European editions with respect to the American ones, in order to adapt them to European sensitivities and priorities.

As regards the Postcompetition and living labs, they have never been regulated by the Rules and Regulations, so that after the competitions, each team has done with its house what it has considered appropriate. In some cases they have been thrown away and have not even returned to their country. In other cases they have been sold, and in most cases, the houses have returned to their universities of origin and have been used as living labs, as educational centers for university students, as research objects, as offices, social centers, demonstrators for companies, etc. Among the organizers interviewed, there is a certain consensus that the houses are underutilised, and that the organization of the competitions can promote the planning of a second life for the SD solar houses in order to take advantage of them from an educational, research, social, professional, children’’s, etc. point of view.

The trend of the last editions of Solar Decathlon held as SDME 2018, SDE 2019, or SDA 2019 point to leaving the Solar Village after the competition with all the houses, or a substantial part of them assembled and in operation, forming a large Living Lab that can extend research activities and educational activities with awareness visits of professionals, schools, and the general public for several more months. In this sense, the SDE 2021 edition to be held in 2022 as a result of COVID 19, promises to be a milestone,

having planned from the beginning to leave 8 houses set up in the Solar Village for social and scientific use.

Finally, it is worth mentioning the process of internationalisation and progressive globalisation of the Solar Decathlon competitions. In the SD 2005 competition, the UPM was the first non-American university to participate in the competition. In SD 2007, in addition to the UPM, the University of Darmstadt also participated. In the first European edition of SDE 2010, universities from 7 countries and three continents participated, reaching the milestone, for the first time, of visitors on the web during the competition, coming from 102 countries from five continents. Progressively universities from all over the world have been incorporated into the successive editions, as well as extending the custom of participation of teams with two universities from different countries. In this sense, it is also worth mentioning the strategy of SDA 2019 to promote technology transfer between African universities and the rest of the world, giving rise to joint teams between universities, one of which must always be African. The outcome of the experience was indeed very enriching.

The connection between people, students and professors from so many different and distant universities has added value to the Solar Decathlon competitions around the world, enriching the human dimension and the life experiences of the participants.

9.4 Main Conclusions and Lessons Learned about the Performance and Impact of Solar Decathlon

To assess the performance and impact of Solar Decathlon competitions, a methodology was followed that combined the collection of information provided by the different organizing teams of the different editions of Solar Decathlon around the world and uploaded to the SD Knoweldge platform (https://building-competition.org), related to the information on the competitions, and of the different participating houses with their technical and formal descriptions and their performance in competition, as well as their own organizational processes collected in the Annex of Organizations Factsheets. A worldwide survey has also been carried out to assess the performance and impacts perceived by the people who have participated in them qualitatively be they decathletes, faculty, professionals, public, or organizers. The results of this 2020 worldwide survey have been contrasted and evaluated with three other surveys carried out previously: two in 2012 (one in the US SD, and one in SDE 2012), plus a worldwide SDE 2014 survey. With the results of the organization factsheets, the SD Knowledge Platform, and the surveys, a series of variables, indicators and Key performance indicators have been defined that have given rise to a quantitative approach to the performance and impact of the different competitions.

A set of indicators and key performance indicators (KPIs) has been defined for a cross-analysis of impacts and performance of Solar Decathlon. Although many of the indicators could not be used for analysis because the necessary data could not be collected from past competitions, the set of indicators has proven to be effective for cross-analyzing data and drawing conclusions, and more importantly, it identifies multiple variables, indicators, and KPIs that should be taken into account when measuring the impact of future competitions.

It is difficult to improve what cannot be measured. The set of indicators is one of the great contributions of this study since it allows a measurement system that can be correlated with the defined strategies. It is the basis for the continuous improvement of these competitions, and should be part of the Quality Management of the organizing teams. Chapter 6 of this report goes into more detail on this subject.

This analysis has been qualified by conducting interviews with students, professors and faculty advisors, and finally with organizers and people with a particularly relevant role in the development and evolution of the competition in the world, these being especially useful for the preparation of the last two chapters of this

report. In total, more than 130 very selectively identified individuals have contributed with their personal experiences, insights to enrich results of the survey and highlight key drivers and lessons learned.

For the analysis of the performance and impact of solar Decathlon, it is necessary to evaluate multiple complementary approaches related to the educational potential, the promotion of professional skills needed to work, the impact on the professional world and on the construction industry, the ability to influence the awareness of citizens, children, teenagers, professionals, and the university students themselves, the communications potential it holds, the transfer to the market of innovations inspired by SD, both at the level of buildings and Smart Cities, the scientific impact derived from the Solar Decathlon competitions, or the potential opportunities offered by a good strategy with the use of the houses after the competition as demonstrators or living labs. These benefits and impacts should be complemented by the technical inspiration promoted by the competitions and by the innovative responses given by the creative teams, which, due to their magnitude, are described and analyzed in another of the reports produced within this Annex 74 [20].

The evaluation of the conclusions as regards the performances and impacts resulting from the various experiences were generally very positive both in the surveys and in the interviews, and several lessons learned can be highlighted in the various areas considered. In summary, the Solar Decathlon Competitions have proven to be a very effective tool in fostering the development of education, training and workforce capabilities, and professional skills to the next generation of architects and engineers. SD competitions have also shown themselves to have a very high capacity as regards the social awareness of citizens, as it is a useful way of promoting new knowledge and innovation in energy efficiency and sustainability in our buildings and cities. Transferring this knowledge to the market is possible, especially, if it is accompanied by specific strategies on how to influence professionals and industry.

The main conclusions and lessons learned regarding the performance and impact of Solar Decathlon competitions worldwide in the different topics covered are:

9.4.1 Educational potential

One of the most important reasons for encouraging universities to participate in a Solar Decathlon competition is the educational potential that participating in a competition like SD represents for the university. This potential has been widely recognized and documented throughout this report. However, it is clear from the surveys and interviews conducted that not all universities have been able to develop this potential effectively. A clear willingness, specific objectives, and an adequate strategy and planning are needed in order to optimise the educational impact in the university as a whole. It can be seen from the 2014 survey that in most of the participating universities, official credit was given to students who participated in the Solar Decathlon competition, which is an explicit recognition of their educational and professional training potential, but when students are asked in 2020 if Solar Decathlon is part of the university''s training program and if credits are recognized for participating in the team, only 38% of students agreed. Professors'' answers suggest that in some cases they do manage them as part of the university''s official programme, and in many other cases, clearly not. This is also verified by 47% of professors who intend to focus SD on learning activities, while 33% have said they will not do so, equally ratified by the students.

Beyond the educational approach that each university has given to participating teams, with a diverse and subjective perception, the greatest educational potential lies in the competition itself and its contests, in addition to all of the activities linked to the events around the competitions. Surveys have shown that almost all SDE contests are of interest. The four contests that have contributed most to the education of the students are Engineering and Construction, Architecture, Energy Efficiency, and Sustainability and the

[20] https://annex74.iea-ebc.org/publications

Circular Economy. Knowledge improved mainly in the following areas: Architecture and engineering integration; Energy efficiency and Passive design; Project Management; Renewable energies, and Practical construction.

From the organizers of the competitions there is also a great capacity to influence issues related to education, the development of personal skills, and awareness of university students. Rules and Regulations (for instance changes regarding education in the rules of next SDE 2021 in Wuppertal with the intention of stimulating the educational impact on the participating universities), workshops (for example the Madrid Workshop in October 2011 corresponding to the SDE 2012 Competition), or many different activities organized within the framework of the SD organization in all editions, are good evidence of this ability to influence. SD competitions worldwide as a whole have proven to have a high educational potential, with wide internal recognition (for instance the SDE 2010[21] and SDE 2014[22] proclamations, which stated the educational potential of Solar Decathlon Europe for university students, professionals and the general public), and wider external acknowledgement by the media, governments, and other public and private institutions.

The education promoted by the SD competitions is not only limited to the acquisition of new knowledge, or to the integration of different disciplines such as architecture with structural, construction, or installation engineering, but it has a very high potential to promote educational innovation and integral education by developing personal experiences, transversal skills, and professional training. This report documents the SD''s high potential for educational innovation, with qualities that link it to many of the major trends known to be highly effective in terms of educational innovation: Gamification, Challenge-based learning and design thinking, Learning by doing and hands-on experience, Service-Learning and Experiential Learning,

Learning in collaborative environments and team-building experience has not been sufficiently exploited due to the temporary nature of the competition and the lack of reflection by universities and teaching bodies. There is no doubt that the possibilities of effectively improving the education and training of university students, and their university colleagues, with SD, are amazing and we must foster and exploit them efficiently.

One of the most significant contributions of Solar Decathlon from an educational point of view, is the comprehensive educational model it provides to university students, which includes not only the application of theoretical and technical knowledge of the different disciplines it covers (architecture, engineering, communications, marketing, management, etc.), often linked to innovation and research into new proposals, but also its practical hands-on application, as well as the professional training demanded by the labour market, the development of technical, management and transversal skills necessary for their work as professionals, and the enrichment of personal experience by promoting an active commitment to society.

9.4.2 Fostering worker skills

Surveys carried out in 2014 and 2020 show that 60% of both students and professors stated that they had participated in research activities during, or after the development of the SD houses. Although 88% of students and 53% of professors stated that there were no specific professional training programs for decathletes at the university, there is great unanimity in considering that Solar Decathlon has contributed to the development of personal skills. Practically all professors, 97%, agreed or agreed strongly with this statement, with an average rating of 4.66 out of 5, (81% in the case of students). Students highlighted communications and public relations, project management, and teamworking as main personal skills and

[21] https://upm365-my.sharepoint.com/:b:/g/personal/beatriz_arranz_upm_es/EYYOiCenrFxIg1XrvKyXhL8BVJjlpFTzNCLumKKxV4D6rQ?e=Ie8a9q
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experience enrichment. Only 16% of students stated that their university had specific exchange programmes with other universities, although it could be an important asset in the educational potential of SDE.
The core skills important in all areas of green building: adaptability to change, environmental awareness, interdisciplinary skills, cross traditional occupational boundaries, teamworking, coordination and leadership skills are empowered in Solar Decathlon Teams. These skills, particularly the soft skills are not usually included in the curricula of technical degrees.

The main value regarding technical skills is that decathletes put into practice the theoretical knowledge acquired during their years studying at university. There are not usually specific training activities and Solar Decathlon is not used as a training program from the universities, nevertheless practical learning occurs even though it is not at all programmed, it being a consequence of the accomplishment of the Solar Decathlon Europe challenges, both during the time of the project and during the competition event itself.

A protocol to guide teams to optimise this potential should be developed as follows: teamwork, multidisciplinary, collaboration, flexibility, tolerance, environmental awareness and integrating other issues needed to face the challenges of the future to enhance creative and brave thinking not only in students, but professors, professionals and the public.

9.4.3 Potential influence of SD on industry and professionals

Solar Decathlon can be the spearhead of testing, prototyping and communicating new technical and social ideas, aiming at increasing the competitiveness of Solar Decathlon students in worldwide industry. Cooperation between research and education institutes and industry is inherent in specialisation and a practical approach and can help to improve the workforce and skills levels in every country.
Synergies among Solar Decathlon and industrial participation is the basis of Solar Decathlon. The feedback of the industry after being part of Solar Decathlon is very positive.

In order to achieve a coordinated university-industrial training, the Solar Decathlon and industry should have a medium to long-term perspective strategic approach, a wider approach integrating all layers of stakeholders at the regional, national and continental level. To achieve this, it is crucial to align strategies and define common roadmaps but to do that Solar Decathlon needs to provide a stable and permanent setting ensuring a perspective of continuity, it needs to be supported in a medium to long-term approach.

The international feature of Solar Decathlon makes it a good platform to support the internationalisation of human resources in the workforce and practical job skills. Solar Decathlon networks should attract innovation talents including, among its priorities, training in practical and entrepreneurial skills, thus providing the professionals our society needs to achieve the aforementioned transformation.

Opportunities will increase by promoting Solar Decathlon synergies and cooperation among, higher education, research, and innovation of the highest standards, including by fostering entrepreneurship.
Integrating all stakeholder creativity to face the competition will give rise to all kinds of opportunities, since opportunities on many occasions arise from adversity, in that matter Solar Decathlon Teams overcome multiple difficulties before reaching the final phase and during the competition itself.

Some clear and relevant items to be enhanced are education, innovation, research infrastructures, the epromotion of partnerships, transfer of knowledge, dissemination activities, use of the houses after the competition, involvement of industrial associations, research into Solar Decathlon houses (international/national/regional), the connection of disciplines and trans-territorial connections.

Problems must be addressed by all stakeholders together; everyone must be linked to Solar Decathlon from the very beginning, join forces, be generous and generate mutual learning. Solar Decathlon generates a suitable environment for this, it is an excellent setting for opportunities regarding all of the aforementioned items and through further items which will emerge naturally by searching for opportunity though adversity.

The exhibitions of energy-efficient houses are an impressive way of informing professionals and public alike about new innovative technologies in a practical manner. From the feedback received, the exhibitions proved to be a significant tool for raising the energy awareness. For this reason, it is important for SD organizers and Universities to plan and prepare exhibitions and visits for the general public.

For instance, the Conference-debate on "Nearly zero-energy buildings: new construction and refurbishment" held in Madrid on May 24, 2012 during the GENERA 2012 Exhibition, was considered an innovative format (debate + broadcast online) which proved to be very interesting for the professional associations. In order to reach the largest possible audience, this event was attended by 714 professionals.

9.4.4 Citizen awareness

From the detailed analysis of the SDE 2014 surveys and that carried out for this study in 2020, there is no doubt that the main focus of the Solar Decathlon university competition has been on education and social awareness of the young university students. In scoring some of the objectives of the SD competition, all cases averaged values of more than 4 out of 6, with a variability of these averages of between 3.98 and 4.88, which represents a reasonable perception of the fulfilment of these objectives, taking into account the different performance of the various editions of SDE as a whole.

Environmental and Sustainability Awareness, and Fostering Education, are the most appreciated. It is remarkable that in the 2020 survey 100% of the people surveyed stated that they considered Solar Decathlon to be a positive overall experience. Asked later about what the main reason they are satisfied with SD is, the overall opinion of the respondents was as follows: Innovation and Knowledge Generation 64% (which goes up to 69% in the case of student estimation), Environmental and Sustainability Awareness 48% (49% students), Fostering Education 43% (similar for students), Professional Awareness 40% (45% students), Students Employability 40% (43% students), Social Awareness 38% (40% students), Media and Social Media Impact 36% (39% students).

The most notable areas in which Solar Decathlon improved the awareness of students, were energy efficiency with 14.14% and Sustainability 13,64%, this is significant considering a total sample of 14 topics. The contests that have contributed the most to social awareness in sustainability and energy efficiency are the Energy-Efficiency contest with a total of 27.96%, reaching up to 40% according to the organizers, and Sustainability and Circular Economy (20.85%). All contests show a greater or lesser influence on both the Media impact and social awareness, as well as on sustainability and energy awareness. All of the skills selected were highly valued by all of the people surveyed, with measured values ranging from 4.55 out of 6 in the lowest case to 5.43 in the best valued case. The top ranking of these values, were Team Working with a score of 5.43 out of 6, Practical Skills scoring 5,27, and Creativity 5,25.

Many editions of the SD competitions all around the world have been highly successful, providing an internationally recognized added value with respect to other editions. Particularly noteworthy is the European commitment to sustainability, energy efficiency, innovation, and citizen awareness. In all of the editions, the proposed general objectives have been achieved satisfactorily, although its social and professional impact has been uneven.

The SDE 2012 edition, for instance, has had the greatest social and media impact in Europe. It was due to the planning of activities not only in Madrid, but in other European countries with the collaboration of Energy Agencies and universities from some countries through the EU 10Action Project, and the active participation of the SDE2010 universities in becoming a focus of dissemination and awareness to transform and improve their environment. 10Action has proven to be an excellent tool for facilitating the synergies generated by the Solar Decathlon Europe.

9.4.5 Children and teenager awareness

It is extremely important to look for alliances when addressing children and teachers, as it is not that easy to have direct massive access to schools. It is not necessary to have a huge marketing budget, but it is important to select the appropriate channels of communication. The main strategy to reach children was to cooperate with ministries of education or networks of schools in each country, Playing and educational activities for children must be offered continuously. The motivation of teachers makes all the difference for adolescents.

The integration of the subject in the curricula or making continuous education in the area compulsory are necessary to achieve a continuous impact on the target group. The collaboration with education authorities is necessary to get the subjects of renewable energies and finite resources included in the school curriculum.

The collaboration between the Universities and the local schools to establish continuous school visits to the exhibitions is very effective for the students. It is an interesting environmental tour that improves the students' knowledge in energy issues. This is clear from the feedback received from exhibitions at which most visitors were children and young people

9.4.6 Communications potential

Most of the organizers interviewed in this study emphasised the importance of Solar Decathlon''s communications and social awareness power, some identifying communications as the main raison d''être, essence and ultimate goal of these competitions.

University competitions and the mobilisation of universities to sensitize their environments on issues related to the improvement in energy efficiency and sustainability have proven to be an effective communications tool, both because of the creative capacity and for the enthusiasm transmitted by university students when they are motivated and actively committed.

For SDE 2012 in Madrid, an ambitious strategy of communication was planned, which, facilitated by the 10 Action project, allowed a professional, social and media impact that reached more than 12 European countries, expanding knowledge and activities to make people energy aware, promoting their change in behaviour, to improve the sustainable conditions of our buildings and cities. 220,000 people visited the Solar Decathlon Europe 2012, 67 activities took place, as well as debates, conferences, and students from more than 30 universities from all over the word visited the Villa Solar.

It is also noteworthy that the visitor successes achieved in China with the editions of 2013 and 2018 in which, thanks to its location in large cities, in a well-kept and accessible environment, and thanks to the idiosyncrasy of Chinese citizens, more than 230,000 people visited the competition in SDC 2013 and around 500,000 citizens visited the competition in SDC 2018.

9.4.7 Fostering innovation and transferring it to the market

Although there is not always a consensus when it comes to promoting innovation through Solar Decathlon competitions, we all agree that they have evolved towards the solution of current problems. The houses are excellent references, which can influence the whole sector: students, professors, researchers, professionals and industry. Sponsorship interest from innovative companies grows as does public interest in visiting the Solar Village.
Since the media and social media are so important nowadays, it is an appropriate strategy to stimulate innovation, creativity and research to foster inspiration and attractiveness of both houses and the Solar Villa itself.
In the competition, the different solutions proposed through each house were clearly the result of a variety of approaches, responding to diverse climate conditions and cultures. Therefore, some houses placed special emphasis on their insulation, some on thermal inertia, and others on ventilation and evaporative cooling, bringing back traditional strategies and techniques conveniently adapted to current needs. Stakeholders from diverse climate zones and countries will find relevant solutions for their specific local circumstances in the SD competitions.

The Students' attention was drawn not only to designing and building houses, but also to developing new concepts, strategies, and integrating innovative technologies into building "homes", searching for new ways of improving the construction and integration of the building's solar components and systems, using new approaches to engineering, to generating knowledge in sustainable solar buildings, and to reducing waste and energy consumed during manufacture.

All of the participating houses included passive design strategies and energy-efficient systems. Many of them achieved an excellent balance between envelope, orientation, geometrical aspects and other passive strategies. Most of the Solar Decathlon houses can be classified as Net Plus Energy Buildings.
The nature of the Solar Decathlon, to build houses and make them compete, underlies the intention that the prototypes showcase solutions that lead to specific market applications. The Solar Decathlon illustrates some of the strategies and major trends that are currently being developed in this field.

It should be interesting to find a way to get more out of the knowledge the competition generates. The quality and level of maturity of the research and innovation involved in Solar Decathlon houses is diverse, but it certainly goes from the exploration of new ideas and new strategies to the demonstration of cutting-edge, market-ready technologies The degree of development and impact on the market could easily be higher with greater institutional involvement. But not only that, the public administration can also indirectly incentivise and attract private investments to reinforce sustainable development.

Industry has voluntarily sponsored the SD competition Organization, University Teams and tested innovative building products in all Solar Decathlon editions. Synergy between the SD organizers and the market is demonstrated by the involvement of big industries, Companies, and many dozens of SMEs and hundreds of professionals and collaborators were involved just in the Organization of the event and to which must be added those industries, companies and SMEs involved in the sponsoring of the University Teams.

Students, researchers and professors mainly make up the organizing teams of Solar Decathlon editions, nevertheless for the development of specific tasks, the organization relied on the work and experience of many building industry professionals.

Innovation now tackles social and complex areas. The social impact if some of the proposals were implemented would be substantial. Public administrations are key drivers here, some of the innovative ideas could be applied in social housing and neighborhoods as "Lighthouse" projects, exploring its implementation in the market, disseminating new strategies and technologies and revitalizing vulnerable

areas and attracting private investment. New business models based on the modernisation of classic homes by making them more efficient and sustainable, on the optimisation of urban space and on the attractive initiatives to encourage the repopulation of rural areas and the revaluation of the rural environment, etc. are fostered by SD competitions.

9.4.8 Sustainable cities

Solar Decathlon competitions have generated professional awareness, knowledge and expertise in many different topics to a greater or lesser extent, depending on the specific competition and the proposed objectives, related to sustainable buildings, cities, and communities, including scopes in:

- Sustainable districts and built environments in order to mitigate global climate changes and the intensive growth of energy efficiency and Renewable Energy Source utilisation must be achieved in the building sector. The Solar Decathlon has successfully confirmed that such a goal is reachable.
- Integrated infrastructures and processes are two of the current challenges. A low-tension microgrid was created in the Solar Villages of different competitions, that interconnected the houses and their solar panels, linking them directly to local and global grids and thereby helping to create net-zero energy homes (Net ZEH) and net zero energy clusters (Net ZEC), balancing the energy flows, and adapting the energy supply to the demand in real time.

Some Solar Decathlon Grids integrate Solar Houses, Organization buildings and electric cars. The surplus energy obtained from the houses is used for Solar Village events and for transportation, fostering sustainable urban mobility.

For instance, the Solar Decathlon European organization introduced some changes in the rules and regulations to favour the attainment of the objective of evaluating industrialisation, market viability and affordability of the prototypes advancing in business models, finance and procurement.
Many Solar Decathlon competitions looked for ways to encourage behavioural changes in citizens making them aware about the responsible use of energy and natural resources. In the first two European editions, with the 10Action project, the strategy has reached almost 600,000 (190,000 SDE 2010+220,000 SDE 2012+184,861 10Action) European citizens who have learned, and thought about energy and sustainable issues, with specific activities for them, and many millions of European citizens have received news about the values promoted by these projects.

Integrated planning, policy and regulations: Institutional leadership is crucial for the Solar Decathlon to fulfil its objectives. Solar Decathlon rules are aligned with the the objectives of sustainable development (OSD).as they encourage the reduction in energy consumption, water and chemical reduction, the increase in building energy efficiency and the use of renewable energies. The Solar Decathlon has strengthened and revitalised partnerships between universities, policy makers and the private sector. For instance, the current King of Spain, the President of Hungary, the Spanish Prime Minister, many different Secretaries of Energy, Ministers from the different Governments, all the Housing Ministers of the European Union, Regional Governments, ambassadors, mayors and high officials all visited the Solar Villages of the different SD Competition.

To reach sustainable cities it is necessary to promote outreach projects, like the Solar Decathlon. It has proven to be effective due to its global reach: based not only in increasing awareness in society, but demonstrating and testing innovative sustainable technologies, providing creative urban and social solutions and strengthening essential alliances between all of the stakeholders involved.

9.4.9 Scientific and technical impact

Although innovation has been part of the core business of Solar Decathlon Competitions, it has never been intended to have a high impact from a scientific point of view, as it is a competition for university students. Even so, many of the teams have developed research projects directly linked to the Solar Decathlon houses, as is the case, for example, of the INVISO research project[23] (Industrialisation of sustainable housing) in which the UPM participated and which served as the basis for several of the innovations of the UPM''s SD 2007 house and, later, of the headquarters building of the SDE 2010.

Some PhD theses have been developed focused exclusively on technologies, houses, and experiences of the Solar Decathlon competitions, and many others have partially used these houses, strategies and technical solutions for the development of specific theses (BIPV, PCMs, lightweight enclosures, etc.). Dozens of scientific papers have been published by many houses that have competed in many different competitions. Among these it is worth mentioning the Special Issue of the Energy and Buildings Journal entitled "Science Behind and Beyond the Solar Decathlon Europe 2012".

The production and publication of Solar Decathlon compilation books containing the description of the houses participating in Solar Decathlon is another tool to facilitate the education and social awareness of university students and professionals, while the technical description of the strategies also confers an interesting scientific value. It is worth mentioning the publications of the Solar Decathlon Europe 2010 editions (https://solardecathlon.eu/sde-2010-book/)) and SDE 2012 (https://solardecathlon.eu/sde-2012-book/))
Also playing an important role are the many web pages on which the experiences of the competitions are collected with descriptive information on the various houses that have competed (https://www.solardecathlon.gov/ ; https://solardecathlon.eu/ ; http://sdchina.org.cn/ ; https://solardecathlon-lac.com/ ; https://www.solardecathlonme.com/ ; https://www.solardecathlonafrica.com/). It is also worth mentioning the large number of pictures and videos that exist on the networks of most of the houses that have competed.
An initiative that will be key to this work of education and awareness of university students, professionals, scientific community and the general public is derived from the work of this Annex 74 with which information from the competitions and houses participating in the SD worldwide has been incorporated into the Knowledge Platform, completing the work that the Bergische Universität Wuppertal, Universidad Politécnica de Madrid, and Energy Endeavour Foundation have developed incorporating all the information from the European Competitions to the Knowledge Platform, funded by the German Government. The result of all the joint efforts is to have a repository open to everybody with most of the Solar Decathlon houses documented, with their designs, active and passive strategies, and their performance in competition, etc.
All this set of information is complemented by the analysis developed in the Science & Technology report developed by the Annex 74 team[24].

9.4.10 Post-competition & living labs opportunities

The houses, now located around the world continue to serve numerous research and educational projects, some are being monitored, occupied, and used as Living Labs, generating knowledge; other houses are used for education purposes, or by sponsors as demonstrators and training centres, or in the universities as useful spaces or by administrations for community-oriented functions.
Exploiting the houses after the Competition has some mayor challenges and difficulties mainly related to the need for space and funding for the reassembly, maintenance and operation and initial exploitation costs

[23] https://solardecathlon.eu/sde-2010-book/ Prototype SDE 2010 (UPM), Energy and Buildings 83 (2014) 225–236
[24] https://annex74.iea-ebc.org/publications

that the Universities are not able to provide most of the time. Some recommendations extracted from successful experiences are:

- A medium to long-term exploitation plan scenario is necessary to obtain medium to long-term funding. Which can ease the way to succeed.
- From the first stages of the design phase of the houses it is advisable to work with a post competition use and location in mind.
- Somehow guarantee the involvement of the Team after the competition, which can ease the way to succeed.
- When Teams and students are involved in the management of the houses it is advisable to have a professor responsible for the project to ensure its continuity.
- Some Universities have internal administrative problems to recognize the prototypes as a research infrastructure, which makes it difficult to fund the research. It is advisable to work on this from the first stages of the process.
- When the prototype has been used as neighbourhood centre or a facility for educational use the maintenance and operation costs are covered, or people take care of it. People keep the prototype active and alive.
- Start with collaboration between SD universities to conduct shared research across participants.

The Solar Decathlon Community is completely aware of these challenges and difficulties and has a general concern about the lack of optimal exploitation of the after-life potential of the houses. The last editions of the Solar Decathlon around the word have approached this matter and there have been different proposals to amplify the impact of the houses longer than the Competition period.

The evolution of the last editions of SD China 2018, SD Middle East 2018, SD Europe 2019, or SD Africa 2019 has been remarkable. These have been organized after the Competition, leaving the best houses as Living Labs as demonstrators for research, education, and open to visits of university students, professors and the general public, which allows the possibilities of social awareness on issues of energy efficiency and sustainability to be expanded. The new competitions being organized, such as SDE 2021 in 2022, are also planning to leave the Solar Village with a reduced number of houses after the competition, as a Living Lab that allows the extension of educational and social awareness activities. SD Middle East 2018, SDE 2019 and SD Africa 2019 are good examples of this new tendency to be explored. In the “Competition & Living Labs Report” produced in this IEA EBC Annex 74[25] Task force a deeper analysis in both single and collective living labs is performed.

9.5 Final Conclusions

To conclude this “Competitions and Living Labs. Impact and performance “ Report after the analysis carried out to provide insight into the real impacts and performance of Solar Decathlon competitions and linked events as a whole, we’d like to highlight:

1. There is unanimity in surveys, and in interviews with decathletes, faculty advisors and Organizers that Solar Decathlon is a magnificent example of well-focused competitions with a high level of participation of universities, involvement and commitment of students, participation of companies and professionals and a high attraction of public that enjoys the showcase of inspiring, efficient and sustainable houses. Solar Decathlon has demonstrated over the years that it has achieved a high performance and high impact in terms of satisfaction from an educational and professional training point of view, development of transversal skills, social awareness on sustainability, energy efficiency, renewable energies, favouring and inspiring innovation in photovoltaic design and integra-

[25] https://annex74.iea-ebc.org/publications

tion, in active and passive strategies, in technological and social innovations of all kinds. A successful initiative around the world for which we have to be collectively proud, and grateful to the great idea of Mr.Richard King and the US Department of Energy in late 20th century.

2. The reason why the Solar Decathlon competitions are unique in the world and stand out from typical architectural design competitions is that they focus not only on conception and design, but on the construction of the prototypes designed by the students, and, most importantly, on the performance of the houses and the teams in the 10 contests that they must pass. Universities assamble their houses making up the Solar Village and compete with shared objectives, transmitting their knowledge and experiences to the thousands of people who visit these Solar Villages. The result is such a unique life experience for students who learn and train professionally and that is so intense that it leaves a mark and commitment for life.

3. One of the keys to the success of these competitions is to understand that Solar Decathlon is more than just a competition, and that it must be wrapped in an event that attracts the participation of the public, who learn and become aware of the inspiring houses and the messages associated with the necessary improvement in sustainability, giving visibility to the competition, drawing the media, which in turn multiplies its visibility and participation. The competition cannot shine without being understood as part of an event that surrounds it, that enhances it, that makes it attractive to the public, and that increases its visibility and, therefore, the possibilities of support and funding from public entities and private sponsorship.

4. The surveys and interviews conducted in the 2012, 2014 competitions and 2020, clearly show the great educational and social awareness potential of the Solar Decathlon Europe competitions and the degree of influence that the competitions have had on all students, professors and professionals who have participated, to the extent that 100% of those surveyed consider SD to be a positive experience overall. However, the analysis of the surveys also indicates that the educational potential is not fully exploited either at the level of the participating universities or at the level of the organizers themselves, not to mention the lack of specific strategies to facilitate the exploitation of the synergies offered by the network of solar houses participating in SD competitions to organize activities in multiple countries, optimizing the education and social awareness of our citizens.

5. Promoters of Solar Decathlon in the world, and the organization of every single SD competition, should encourage participating universities to plan a strategy of integral educational exploitation, and to invest in the necessary resources to maximise a comprehensive education and professional training potential, as well as the cross-disciplinary development of skills, enhancing the SD experience. In this sense, the adjustment of the Rules & Regulations for SDE 2021 in Wuppertal, Germany, asking for the documentation of each university''s strategy to stimulate the educational impact, for its evaluation in competition, is considered a very good initiative.

6. Organizers of Solar Decathlon competitions should define strategies to encourage the use of the full potential of educational innovation that SD has at its disposal, to favour the comprehensive education of university students, including the enrichment of the SD personal experience, the development of transverse skills and the improvement in professional training with an integral education model. That educational innovation implies the will to innovate and a planning of how to implement it, supported by theory, and a continuous process of reflection and improvement.

7. Universities participating in a SD competition must include a strategy and planning for the reuse of the houses after the competition, with programs to exploit the full potential of the houses for educational use by the whole university, to develop research programs and projects, as well as the potential for raising awareness among university students of sustainable energy efficiency issues,

and where appropriate, for raising awareness among children (schools), professionals, and the general public.

8. The attractiveness of a university competition such as SD, on its own, does not justify the huge amounts of investment it needs in terms of money and human effort, both for universities, as well as for the organizing countries-cities, and sponsoring companies. Universities need to exploit the full potential of innovation, research, and education for the university, both through the competition and through the subsequent use of the SD houses, as well as through the potential for communications and social visibility that it represents. Host countries need to take advantage of the social and environmental impact of SD to educate and raise the awareness of their citizens, from children and young people (the future) to professionals and the public (the present), providing a sufficient return in public image. Likewise, companies that sponsor teams and organizations need a return in media and social visibility. Without a doubt, one of the key drivers for a successful edition of Solar Decathlon is to understand the competition and the linked event (with the development of activities for the public) to attract the maximum number of visitors and media, to increase SD visibility, sensitivity and disseminate innovations among professionals, and to educate and raise awareness among citizens.

9. The challenge of attracting as many visitors as possible, can be enhanced by a good location in a central and well-intended area of the city (which it is not that easy because of the technical constraints derived from cranes and trucks of great size and tonnage), good public transport to access the area, a dissemination campaign in the city and in the media to draw attention to the event, the preparation of a program of attractive activities for families, so that they can go with their children with some guarantee that they will have a nice time. Budgetary limitations suffered by all the editions of SDE so far, are translated into the cutting of communications and educational and social awareness activities that are one of the keys to attracting families, schools, professionals, and educating them. To attract children through school visits and groups of university students for learning during the process of assembling the houses and during the competition, it is necessary that these are held during the school year, the beginning of the academic year (September and October) it being the ideal time to maximise the organized presence of young people.

10. The harnessing of the educational and social awareness potential of SD competitions in countries is necessarily linked to a greater commitment by the governments to SD through organizing activities and supporting programs to enhance social awareness. The success of the European 10Action project (Supported by Intelligent Energy Europe) has allowed 180,514 European citizens to participate in educational and social awareness activities in 12 European countries between 2010 and 2012 (3 years), with an investment that has served to leverage the work of SDE and the SDE 2010 teams by taking these activities to their countries of origin. The prestigious Communications Award obtained by SDE in the Sustainable Energy Europe Awards Competition in 2011, highlights the interest of Europe''s support to these initiatives.

11. The promoters and organizers of Solar Decathlon worldwide, should favour the formation of collaborative networks of the SD university community (hundreds of universities around the world), and articulate collaborative exchange channels both for research projects and to foster initiatives that promote education and social awareness of universities and their environments, taking advantage of the potential of SD houses. The timeframe for the organization of a competition and the limited budget available do not allow for the planning of activities in other countries, or for project initiatives with this approach, in the medium term. The financial support of public bodies is mandatory to promote this growing network of SD universities, and to approve 10Action type projects that allow limited investments to generate and leverage a high media and social impact, and with the commitment and complicity of SD universities, to educate and raise the awareness of millions of citizens worldwide concerning the efficient use of energy and natural resources, and improving the energy

efficiency and sustainability of our buildings and cities, some of the key aspects for achieving the "zero carbon" challenges, and the objectives of sustainable development (OSD).

12. A policy of strong government and public body support for Solar Decathlon competitions, would allow a strategic alignment of these university competitions with the governments' research, education and social awareness priorities, in order to promote technological innovation, raise the awareness of professionals, and better harness the potential from educational innovation for the training of the next generation of architects and engineers who will build the sustainable society of the 21st century worldwide.

10. Index of Annexes to the Report

ANNEX 1.- FACTSHEET OF ORGANIZATION OF SD COMPETITIONS
ANNEX 2.- PERFORMANCE INDICATORS

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ANNEX 74

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