First Experience in Extending the Reach of an Energy Concept through an Advanced ESPC Model

Rüdiger Lohse

ABSTRACT

Many governments worldwide are setting more stringent targets for reductions in energy use in government/public buildings. The U.S. government has targeted annual energy savings of 3% (DOECC 2013). The European Union (EU) will have to refurbish from 1% to at least 3% of its building stock to meet its ambitious efficiency targets. This paper describes a small municipality that took advantage of an energy savings performance contract (ESPC) business model to refurbish a campus with school and administrative buildings and a swimming pool. The ESPC project presented here proves that the technical scope of ESPCs can be extended according to the customer's demand, from the typical HVAC and control system to more challenging measures like a biomass heating plant and a microheating grid and ambitious non-energy-related refurbishment measures like a swimming pool basin or other construction improvements. Furthermore, it shows that guaranteed significant energy and cost savings were largely achieved, and that the predicted investment costs were not exceeded. The guaranteed savings achieved in the project were successfully used to pay off the energy conservation measures (ECMs) and to partly fund the investment in deep refurbishment. The paper highlights the structures that were predicted to enhance coordination between stakeholders and presents an engineering analysis of the design process required to develop and implement the project. The paper also describes how careful project preparation minimized risk and eased the coordination between planners and contractors so the project could reach completion within the projected schedule. Finally, this paper provides specific lessons learned and recommendations for other similar projects.

INTRODUCTION: TWO BUSINESS MODELS FOR REFRUBISHMENT OF BUILDING STOCK

Building age, increasing energy requirements, and scarcity of public funding are common conditions that motivate public authorities to search for new ways to maintain and refurbish their building stock. In general, the rationale of how to create, deliver, and achieve that goal is called a *business model*. In the context of refurbishment, business models are the vehicle taken to carry out the project, to design and conduct the revenue streams, to create value propositions, and to stimulate incentives that encourage positive interactions between the parties involved.

The Owner-Directed Business Model

Most refurbishment projects are carried out using an owner-directed business model. In this case, the building's owner is responsible for hiring architects and engineers to design the major building renovation and the deep energy retrofit, for soliciting bids from the construction companies to implement the measures, and for supervising the construction process. After the construction phase, the building owner is responsible for the cost- and energy-effective operation of the refurbished building. As the energy efficiency and savings are not guaranteed, they cannot be considered as part of the project funding. Therefore, in an owner-directed business model, a significant amount of publicly appropriated funding must be budgeted (programmed) to cover the cost of the construction and the energy-related scope of the renovation. A shortage of public appropriated funds can slow the number and pace of major building renovation projects significantly.

Rüdiger Lohse is the head of the department of Energy Service Facilitation at the KEA Climate Protection and Energy Agency, Karlsruhe, Germany.

The owner-directed business model, which is considered a tool to achieve high cost and energy effectiveness, has some crucial structural weak points:

- *Limited funding sources*. The owner-directed business model is mainly funded by public money and bank loans. Under current budget constraints, these funding sources are becoming increasingly difficult to obtain. Increasing political demand for dramatically greater numbers of refurbishment projects will make such funding even more difficult to obtain.
- *A lack of incentives for energy and life-cycle cost-efficient solutions*. Architects and HVAC planners are responsible for planning, for procurement of the material and services, and for supervision of the construction phase. In many cases, projects will exceed their proposed budgets. Many projects cannot realize the most crucial performance indicators, such as accuracy of energy and life-cycle cost predictions. Tradesmen or general contractors carry out the construction activities, but it is the building owner who is responsible for managing and operating the refurbished building.
    - The owner-directed business model specifies a landlord-tenant relationship (DOECC 2013) between the owner and the contractor, in that it does not provide incentives for the planners and the tradesmen to achieve energy-efficiency and low annual life-cycle costs. The public building owner's decision-making process focuses primarily on the investment cost, which, in most cases, does not account for life-cycle cost, carbon footprint, etc.
    - One crucial side effect of that business model is that it lacks incentives to motivate the involved parties to evaluate the performance effects of implemented energy conservation measures (ECMs). Without those incentives, there is no impetus to optimize the planning and construction phases by evaluating and improving performance based on accumulated experience.
- *The lack of funding leads to sub-optimal technical solutions*. To avoid excessive debt, public authorities face restrictions in taking bank loans. This often forces deep refurbishment projects to be done in several separate sequential phases, which often leads to sub-optimal results, including increasing costs (Lohse et al. 2010). Consequently, large energy and cost-efficiency potentials remain unexploited.

Still, most of the decision makers in the public sector will opt for the owner-directed business model, as they are not yet familiar with such "exotic" approaches and the information needed about alternative business models is not present at the point of decision making. Building owners who are considering the initiation of a deep refurbishment using the owner-directed business model must express their targets very clearly in the contracts for architects, engineers, and craftsmen. Also, they have to play a strong role in conducting and monitoring the planning and the construction processes from their perspective. In the operational phase, after the refurbishment is complete, building owners have to set up a stringent energy monitoring and management program to ensure the optimized energy performance is realized.

The ESPC Business Model

Building owners may select from several, non-owner-directed business models available to refurbish their building stock: public-private partnerships, leasing, and different contracting formats. In recent years, the energy savings performance contract (ESPC) has proven to be a very successful business model for building refurbishments. In the ESPC business model, the energy service company (ESCO) is responsible for providing the planning, design, and calculation of investment costs for ECMs; modeling of energy savings and funding; and the implementation of ECMs on site. In Germany, as in most European Union (EU) countries, the ESCO has to guarantee the savings, which means that the ESCO's revenues equate with savings that are approved and verified in the annual monitoring and verification process. These revenues cover the ESCO's annual costs for capital, maintenance, monitoring, refurbishment, and other services included in the ESPC. The customer pays only for the energy and recoups the cost savings.

The ESPC business model overcomes many weaknesses of owner-directed models by stimulating contract parties to achieve a high degree of energy efficiency, cost-effective processes (which contribute to a better savings-investment ratio), and a better overall life-cycle cost effectiveness. The life-cycle-cost-orientated structure of ESPC business models clearly provides more added value than does the owner-directed business model approach. To date, ESPC projects save, on average, from 25% to 40% (JRC 2014), which allows a payback of the investment and life-cycle cost of HVAC retrofits, combined heat and power plant, and biomass implementation within 5–15 years.

Other considerable advantages of ESPC business models are:

- ESPC investments and services are almost entirely paid off by energy cost savings; they do not depend on scarce public funding or restricted loan programs.
- ESPC provides strong economic incentives for energy- and life-cycle-cost-efficient solutions. The ESCO, who is paid off by the energy cost savings, has a strong incentive to achieve at least the guaranteed savings.
- The ESPC business model requires the involved parties to evaluate the performance effects of implemented ECMs to improve performance based on accumulated experience.

Nevertheless, in many countries, the number of projects funded by ESPCs still do not form a significant part of the total investment budgeted by public institutions for energy retrofits. The International Energy Agency–Energy in Buildings and Communities (IEA-EBC) program's Annex 61 aims to increase the acceptance of ESPCs and to broaden the implementation of deep energy-use reduction by refurbishing existing buildings using ESPCs and related or new business models.

To date, ESPCs have been used primarily as instruments for retrofitting HVAC, lighting, and controls. Implementation of some individual measures (e.g., building envelope insulation and improved airtightness, cogeneration) result in significant reductions in building heating and cooling loads, or in minimization of energy waste, but require significant investments with long paybacks. However, when different technologies are implemented together, or are "bundled," they can result in significant energy use reductions, require smaller investments, and consequently have faster paybacks. To achieve ambitious energy efficiency objectives, it is necessary to provide the market with integrated solutions and corresponding business models. ESPC, for example, is not yet the chosen vehicle for integrated retrofit projects that include the building thermal envelope. Research under Annex 61 will improve the decision-making process for deep energy retrofits of government/public buildings (office/administrative buildings, dormitories/barracks, education buildings, etc.), starting with the determination of bundles of technologies that have been demonstrated to work in real-world situations and corresponding business models using combined public and private funding.

ESPC MARKET FOR PUBLIC BUILDINGS IN GERMANY

The United States has more experience than Germany with ESPC projects in the public sector. The first German experience with ESPCs in the public sector was in 1992, when the Stuttgart State Gallery used the process to adjust and optimize newly installed HVAC and building control systems. In 1996, the Energy Saving Partnerships program in Berlin consolidated 26 building pools, of 1300 public buildings, to achieve an average savings rate of 26% (12 M €/yr), of which 9.5 M € were captured by the ESCOs and 2.5 M € were returned to Berlin's public accounts. The program kicked off 53 M € of ESCO investments; all projects were administered by the Berlin Energy Agency (BEA). The average contract period was 11.7 years (BEA 2013). The BEA shared its experience with the city-state of Bremen, where the regional energy agency has conducted several ESPC projects since 2010.

The state energy agency Klimaschutz und Energieagentur Baden-Württemberg, GmbH (Climate Protection and Energy Agency of Baden-Württemberg, GmbH) (KEA) conducted the first municipal ESPC in 2002 in the city of Freiburg. Meanwhile, KEA has facilitated more than 50 energy-supply contracting and 20 ESPC projects, mostly for municipal building pools. KEA has developed ESPCs for large, medium, and small buildings; conducted the first multi-municipal ESPC tendering; and introduced biomass technology into the ESPC process. After being rewarded with the European Energy Service Award in 2009, KEA has focused on disseminating and advancing performance-related business models, and it initiates 3–5 public ESPC or energy supply contracting projects annually.

At the federal level, the Ministry of Economic Affairs and Energy and the Ministry of Environment and Construction have set up a Competence Center for Contracting, which is hosted by the German energy-agency Deutsche Energie-Agentur (DENA), and provides a communication platform and specific legislative approaches for all public contracting customers. Federal buildings are owned by the Federal Agency for Real Estate Affairs. In 2011, that agency was tasked with assessing all its buildings with energy costs > 100,000 €/yr to determine their eligibility for improved energy services. A few more than two dozen ESPC projects have been carried out in federal buildings so far.

At the state and municipal levels, three independent or semi-state energy agencies and a few consultancy companies are working as professional facilitators (Bleyl et al. 2014) to develop ESPC projects.

Technical Standards

The German building code (MoC 2013) Energieeinsparverordnung (i.e., Energy Savings Ordinance) calls for specific U-values or primary energy balances according to the Deutsches Institut für Normung (German National Standards Organization) standard DIN-V 18599 1–10 (DIN 2011). The thresholds for new buildings may be exceeded by 40% in refurbishment projects. In 2007, when the project in Pfinztal started, the threshold for heating energy (without hot water and auxiliary energy) was 35–84 kWh/m^{2}a (11.1–26.6 kBtu/ft^{2}yr).

The *Third National Energy Efficiency Action Plan* (MoIT 2014) provides common definitions for different energy services in use. The Energy Service Code provides more specific definitions but does not set up enforceable targets for the usage of energy services. Further definitions are given in DIN 8930-5 and in German Facility Management Association Standard 540.

Description of the Municipality of Pfinztal

One good practice example of where a small public building administration has chosen to proceed in a new and innovative way is the municipality of Pfinztal. This typical southwest German municipality, located close to Karlsruhe, has about 18,000 inhabitants and was founded in 1973 by joining four formerly independent municipalities. The town owns more than 40 public buildings with a total floor area of more than 80,000 m^2 (860,800 ft^2).

Drivers of the Process

In many projects, reduced energy consumption and climate protection are not the primary goals. In this project, for example, the basic intention of the municipal administration was to find a way to refurbish the small public swimming pool. Although the administration was aware of the energy-saving potential, neither energy efficiency nor energy-performance contracting played any role in the discussions in the project's starting phase. First investment costs for the refurbishment of the pool were estimated at roughly 1 M €. It was important for the administration not to exceed the limited budget of about 400,000 € for building refurbishment.

In this project, the head of the municipal environmental office approached KEA to find a solution. Energy service projects are still uncommon in Germany's public sector, whether on the federal, state, or municipal level, so they need key persons to start the process. KEA, along with three other energy agencies and a few engineering companies and energy consultants, provides expertise to support public authorities throughout Germany to initiate the widely unknown process and project structures of energy-service projects. Being the energy agency of a larger state with numerous small- and medium-sized public buildings, KEA specializes in the development of energy-service business models suited to the requirements of these building types.

PREPARATIVE STEPS—DEFINITION OF THE PROJECT SCOPE

Municipal Energy Commissioning Program

As many other smaller municipalities, Pfinztal did not carry out advanced energy planning but decided instead to set up a strategy for energy-saving investment programs in the public buildings by using data collected in the energy management program. The energy management (or commissioning) program was developed by KEA as a noninvesting ESPC business model. KEA and a few trained engineering companies provide monthly on-site visits to the public buildings to assess and commission the existing building's automation and other control systems according to the building's usage and according to energy data that is collected and evaluated at least monthly, in some cases hourly.

In 2005, the administration decided to focus on energy efficiency and climate protection, first on public buildings, and commissioned KEA (KEA 2010) to initiate an energy management program in 15 of the largest municipal buildings that are responsible for 80% of the energy consumption. The energy management encompasses stringent monthly energy monitoring, the restructuring and completion of metering and submetering systems, and the training of building engineers to enable them to manage their buildings and technical installations efficiently. This improved energy management resulted in 20% heating savings, stopped the trend of increasing electricity consumption, and cut water consumption by more than 55% (Figure 1). To lower the threshold, KEA provides energy management as a low-investment energy performance contracting business model, with a small annual fixed sum not related to the savings and a 50% share of all monitored and verified savings. After five years, the average heating consumption in the public buildings is about 6100 MWh/yr (20,812 MBtu/yr) (295,000 €), electricity is 2100 MWh/yr (614,880 Btu/yr) (380,000 €), water and sewage are 14,000 m^3/yr (3,698,420 gal/yr) (84,000 €), and average public building energy costs are 42 € per capita (Annual Energy Monitoring Report Pfinztal 2012, 2013).

One side effect of this energy management program is that data pertaining to technical installations and of thermal building envelopes of the involved buildings is regularly collected and periodically evaluated. The annual energy monitoring report can then use this monthly collected energy data and facility inspection reports to provide suggestions for feasibility studies in buildings with high potential for savings and technical refurbishment backlog.

On this basis, it was decided to focus the ESPC project on the exploitation of energy saving potentials of 30%–40% that would result from the refurbishment of heating plants and HVAC systems and to pursue further cost and energy reduction potential by implementing the use of biomass as an energy source in the largest buildings and compounds.

The refurbishment of the building shell was partly carried out in two buildings when federal economic stimulation grants became available in 2006 and 2008.

Methodology of Project Evolution

The lack of funds forced KEA to identify alternative approaches. To define an overall technical approach, KEA and the administration began to assess the buildings, examining technical weak points, investment costs, and potential savings. To select an appropriate business model, KEA identified ECMs that would generate energy and energy-cost savings. One major part of this was the predesign of a biomass-based utility heating plant and distribution network connecting the buildings of the campus.

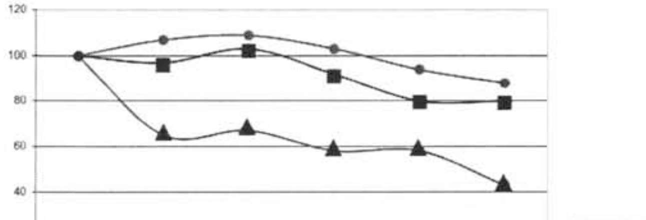

Figure 1 *Municipality buildings energy consumption index during 2007–2012.*

To meet the immediate need for non-energy-related measures (NERMs) in some of the buildings, cost-saving effects of avoided maintenance and repair of existing installations were also considered in the in the cost-benefit balance sheet. The revenue streams of all different ECMs and NERMs bundles were optimized in a cash flow analysis. The cost-optimized bundles and biomass-based utility heating plant were analyzed to determine which revenue stream was needed to fund this project.

Technical Prerenovation Campus Conditions

The Söllingen campus (Figure 2) is located in the municipality of Pfinztal in Baden-Württemberg. The campus consists of six buildings (Table 1) that were built between the 1890s and the 1970s. The facilities were fully occupied and functioning in 2007. In 2008, the swimming pool was closed for safety reasons, but all other buildings were kept in function. The initial energy baseline year for the buildings' energy analysis was 2007.

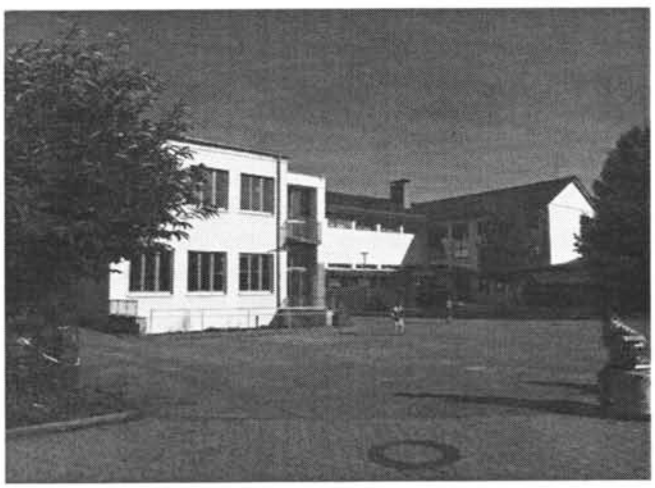

Figure 2 *Söllingen campus view from the southwest toward the school buildings.*

Baseline Energy Analysis

The energy baseline was taken from the monthly utility bills and the monthly monitoring data of the energy management program for the years 2005–2007 (Table 2). These data were time adjusted (365 days) and climate adjusted (on the local weather station of Karlsruhe). The oil data were collected and adjusted from the oil delivery accounts of the years 2002–2007.

The energy analysis during the project preparation was done by calculated estimation. During the tendering, the bidders were required to develop hourly or at least monthly building simulations to calculate the energy demand and different indoor climate situations of the swimming pool/ gymnasium 2. These calculations were required to meet the standards for indoor climate quality in swimming pool halls.

To design the biomass heating plant, bidders were given the hourly gas load data from the utility for the buildings served with gas. Hourly standard profiles monitored for comparable buildings were used to model those buildings serviced with oil. These data had to be adjusted for the effects of the ECMs. The results were collected and an annual-load duration curve had to be calculated by each of the bidders.

Due to the insignificant effects of the building-envelope-related measures, no further building modeling was carried out in the preparation phase. The building's usage timetable was determined from interviews with facility personnel and from hourly-load curves for electricity and gas provided by the utilities.

Technical Flaws Found

The feasibility study identified numerous technical weak points, some of which include the following:

Table 1. Söllingen Campus Building List

Building Name	m^2 (ft^2) (Gross)	Decades Built	Scope of Measures
Räuchle Hall (gymnasium 1)	3200 (34,446)	1960–70	Ventilation, lighting, heating boiler, and distribution systems
Primary school	3000 (32,293)	1960–70	Lighting system, heating boiler, and distribution system
Gymnasium 2 (ground floor) Swimming pool (basement)	1800 (19,376) 150 (1615) (pool surface)	1960–70	Complete refurbishment of pool water technology, pool, hall, locker rooms, cold roof, windows (partly), heating, ventilation system, lighting systems
Rathaus 1 (town hall 1)	3000 (32,293)	1930–40	Heating and lighting systems
Rathaus 2 (town hall 2)	2500 (26,911)	1890–1910	Heating and lighting systems
Rathaus 3 (town hall 3)	600 (6459)	1930–40	(Refurbishment accomplished 2000) Heating system

Table 2. Partition of Consumption and Costs Before Refurbishment

Building	Electricity	Heating	Water/ Sewage
Primary school/ gymnasium 2/ swimming pool	76%	63%	100%
Räuchle Halle (gymnasium 1)	No measures included	18%	No measures
Town Hall 1	10%	6%	No measures
Town Hall 2	6%	8%	No measures
Town Hall 3	8%	5%	No measures

- *HVAC*. The secondary HVAC systems in the swimming hall and in both gymnasium buildings were variable-air-volume (VAV) air-handling units with shut-off-style reheat terminal boxes. The control system for the swimming pool allowed only manual control of the function to dehumidify the circulating air. The heat pump system, which provided insufficient capacity for the buildings, had been installed for use principally in emergencies. In all HVAC systems, the VAV was controlled manually in three stages. The systems were generally in poor working order. In most cases, systems exhibiting little air-tightness were due to broken seals at the air-handling units, with leakage rates >10%. The swimming pool HVAC system shows typical efficiencies, e.g., simultaneous heating and cooling in VAV reheat systems. The air distribution system was found in especially poor hygienic condition, with some parts covered with layers of dust and mold.
- *Pumps*: More than 40 manually controlled efficiency class FG pumps were installed in all heating distribution systems.
- *Heating control and distribution*. Most of the heating circuits were built on the mixing loop principle with a temperature-controlled, three-way valve setting the hot-water temperature following a heating water/outdoor temperature curve. Half of the circuit control systems were allowed to reduce the heating temperature according to the building usage timetable. Thermostatic valves had been installed in the 1970s and 1980s, but no hydraulic adjustments had been done. The temperature of the circulating heating water was high; the temperature spread between the supply and return water was <5 K (9°F).
- *Domestic hot water*. Campus heating and domestic hot-water loads were met using decentralized hot-water boilers. The larger boilers, which were installed in 1960, were in generally poor condition with high exhaust-gas temperatures and surface heat losses >15%. The two smaller gas boilers that had been installed in 1990–2000 were in good condition. One of these smaller boilers was a gas-condensing boiler that had minor quantities of condensate water due to unadjusted low-temperature heating radiators. The other boilers were operated with a maximum hot-water feed temperature of 90°C (194°F) at an outdoor temperature of −12°C (55°F) and a calculated back temperature of 70°C (158°F). Beyond that, the monitored spread was never more than 5 K (9°F). Also, the heating temperature had not been adjusted to the existing heating radiators, allowing for t max = 70°C (158°F).
- *Control system*. Most of the small- and medium-sized buildings were not equipped with building automation systems (BASs). The public BASs are not typically integrated through a network. In this project, the buildings were equipped with decentralized control systems with service panels that allow simple commissioning. They do not include such functions as self-adjusting temperature levels, heating timetables, or separate reduced operation for each individual installation. No integrated building automation had been installed in any of the refurbished buildings. Fully half of the controllers still used analog technology. During the energy management program, most of the settings were optimized, but the decentralized structure still leaves considerable unexploited saving potentials. The project targeted to install new BASs in each building and to integrate them in a network.
- *Lighting system*. Lighting systems consisted of mostly T8 fluorescent bulbs with inefficient white reflectors and analogue ballasts. Typical installations were: in classrooms, between 12 and 16 W/m^2 (3.8 and 5.1 Btu/h·ft^2) (standard level 300 lux [28 fc]); and in the gymnasiums, ~25 W/m^2 (8.0 Btu/h·ft^2) (level 500 lux [46 fc]). Most of the lighting systems have not been refurbished since the year of construction and show a great number of faults, such as work cable insulations and bulb fittings. Most of the reflectors provided a light quality not suitable for information technology (IT) workstations in offices and classrooms.

PREPARATION OF PROJECT IMPLEMENTATION

The preparation phase included the following consecutive steps:

1. Assessment of technical and economic feasibility
2. Decision-making process
3. Preparation of the procurement process

The technical and economic goals of the ESPC concept were to achieve the following:

- Refurbish the swimming pool and reopen it as soon as possible.
- Extend the reach of appropriated funds by leveraging alternative financing to construct the site energy infra-

structure and to refurbish the swimming pool as a main NERMs bundle.

- Provide an eligible energy concept to meet the targets for refurbishment projects of the *German Energy Ordinance* in terms of primary energy targets without altering construction details (MoEE 2010).
- Replace costly fossil fuels with competitive local biomass, and include the cost savings in the revenue scheme.
- Guarantee energy and cost savings and energy systems performance.

Assessment of Technical and Economic Feasibility

The concept for the ESPC project was to construct cost-optimized ECMs and NERMs bundles to reduce the campus energy demand. The next step of the concept was to construct the primary energy infrastructure for the campus. This was to include a central biomass utility plant and a utility distribution system to provide hot water for heating and hot-water storage to the campus. The configuration of ECMs and NERMs influences the site energy demand and the size and cost of the utility plant. KEA pre-modeled the different combinations of ECM and NERMs bundles, the validation of loads, and the differently dimensioned utility plants in the preparation phase of the project. The final optimization and configuration of the bundles was left to the ESCO.

Decision-Making Process in the Municipal Administration

In public buildings, the decision-making process had to be conducted by the municipal administration and KEA. The first step was to find acceptance within the municipal administration. The major issue for the administration was to find an eligible way to refurbish the swimming pool without exceeding the given limits of appropriate, bank-loan-based funding. Secondly, in recent years, the replacement of fossil fuels by local biomass has become an important decision-making criterion in the public sector. Experience has shown that volatility of oil supply costs and continuously rising prices of electricity may lead to a funding shortfall for the public building's energy supply. Local biomass is potentially available at a low price, and the municipality can influence the price of this resource. However, some efforts to set up a working supply chain are needed before biomass can serve as a reliable fuel for energy generation.

To gain general acceptance for the energy concept, the location of the central heating plant, the biomass storage, the supply chain, and the deliverance of the biomass were discussed transparently with all involved parties at a very early stage of the concept. To optimize the investment costs and minimize the impact on the architectural design of the compound, the group considered locating the biomass boiler in the basement of the school and gymnasium hall building and building the biomass storage in the ground as an annex to the school basement. In this preparation phase, KEA had already provided some schematics showing the biomass plant and storage layout and distribution system connection points with all serviced buildings.

The replacement of fossil fuels with biofuels contributes largely to the estimated energy cost savings. ESCOs typically are inexperienced in building efficient structures for a biomass supply chain. Moreover, the individual costs that bidders can spend to price those supply chain structures (MoIT 2010a) are limited in a tendering process and would not lead to technically and economically appropriate solutions. A measure taken at an early stage of the project was to "de-risk" the project by designing the supply chain in concert with the local forest administration, the municipal office for environmental affairs, and local transport and conditioning service providers. In this project, up to 30% of the biomass was to be gathered from the green waste site, and the remaining 70% would be made up of unconditioned wooden biomass such as treetops and roots from municipal and local state forests, which have little market value. The green waste site had to be reorganized to collect the compostable green fraction separately from the ligneous fraction, which would then be prepared for energetic purposes. The ligneous fractions from unconditioned wood and from the green waste site undergo a conditioning process that begins with chaffing, followed by several sieving processes to separate out iron magnetic parts such as rivets or bolts, fines, and compostable parts, and, finally, a drying phase (MoIT 2010b). The transport from the various sites to the biomass storage and the collection and transport of the ashes had to be structured very carefully. Finally, once all responsibilities had been distributed, the costs collected for the price for biomass energy per measure (m^3 [ft^3]) of wood chips or per kWh (Btu) (hot heating water) can be fixed. This price was used for the feasibility study and by ESCOs during the tendering process.

Decision-Making Process in the Municipal Council

The municipal government must involve the council (at least) in the decision-making process to award an ESCO. Experience has shown that, for such complex ESPC projects, the council should be involved from the very early preparative steps. In cases where the council has expressed broad acceptance of the plan, it has been involved in subsequent meetings as well, beginning with the definition of the scope of the measures and including the decision of the business model, the discussion of the ESPC, and finally the decision to award the project to the best bidder.

In this case, the municipal council went beyond the administration's initial criteria to consider several additional criteria:

- *Swimming pool.* Despite the dearth of public funds, all political parties in the council urged the administration to accelerate the refurbishment and reopening of the swimming pool.

- *Reliability of the technical concept.* The council expressed concerns regarding the biomass storage in the schoolyard and the crowded basement. Main concerns were for the security of the schoolchildren and for the feasibility of the general layout of the biomass heating plant.
- *Involvement of local tradesmen and service providers.* The local labor market situation is important for the development of local structures and for the generation of municipal tax revenues. Despite recently started initiatives (Stein and Lohse 2014), smaller tradesmen companies and other subject matter experts (SMEs) still cannot provide risk-related ESPC business models. The involvement of large ESCO enterprises such as Siemens, Wisag, and Cofely, among others, is seen skeptically by many public and SME stakeholders (Standing Committee of Economic Development Baden-Württemberg 2011). The influence of the public sector is limited due to national and EU public procurement legislation. In both owner-directed and ESPC business models, the procurement codes do not allow local preference. An important advantage of the ESPC business model is that the procurement decides on the ESCO, but does not restrict the decision on the subcontractors. In practical experience, ESCOs have learned to improve their standing in the market by awarding specific work packages to local subcontractors.

After discussing and adjusting the technical concept, the administration prepared a decision-making paper for the municipal council. In several sessions, the municipal council received a detailed presentation on the energy concept, the scope of ECMs and NERMs, the supply-chain management concept, the funding concept, and the procurement process structure. The council made some technical and organizational suggestions and decided to proceed.

Scope of Measures to be Carried Out in ESPC

After completion of the preparation phase, the following measures and services were expected to be included within the project:

- Replacement of all major HVAC components in the five serviced buildings and installation of the central utility plant equipment; replacing the five decentralized small heating plants, including peak-load boilers, base-load biomass boilers, hot-water storage, pumps, fans, speed-controlled motors, piping and valves, plant controls, etc.; replacing the heating distribution grid, heat exchanger, and metering system in each building; and installing new lighting systems.
- Construction of a building to house the central utility plant equipment with piping in the school basement and gymnasium hall.
- Refurbishment of swimming pool basin; tiling on floor and walls; overflow water gutter and storage; activated-coal pool water filter; ventilation system with heat-pump-based desiccation for swimming pool and locker rooms; refurbishment of locker rooms with shower cabins; control systems of air humidity; and asbestos abatement of ceiling.
- Installation of distribution system piping/wiring from the central utility plant to supported campus buildings with plastic-jacket steel pipes.
- Installation of advanced metering and submetering for heating and electricity of individual buildings.
- Implementation of an inner-roof insulation on cold-roof 25 cm (10 in.) cellulose fiber flocks with vapor barrier polyurethane sheeting on the roof floor.
- Installation of integrated building and campus management system to include BAS, load management/load shedding hardware and software, and a facility information dashboard. BACnet® was chosen for use in all building and campus management systems for its interoperable metering, control, and management units and access.
- A maintenance and functional guarantee on the replaced installations (except roof insulation) during the complete contract period.
- An energy performance guarantee, in which all savings must be proven in a transparent measurement and verification (M&V) process in comparison with the energy consumption baseline and the timetable of the building's and main component's usage fixed in the procurement documents. Due to the growing IT infrastructure and increasing number of pieces of office equipment, the electricity consumption has been increasing 2%–5% per year in the administrative buildings and in the school complex. Due to this increase, the savings achieved by electrical ECMs will not be verifiable within a couple of years. While the electrical savings of lighting systems are calculated and need not to be verified, all larger electrical ECMs are equipped with separate submeters to allow for M&V.
- The cost savings resulting from the replacement of oil and gas by biomass had to be calculated on the calculated biomass price and the baseline price of oil and gas fixed in the procurement documents.

Decision-Making Criteria to Choose the Adequate Business Model

It was quickly realized that budget constraints and restricted access to bank loans would significantly limit the ability to achieve the project goals. This forced KEA to research alternative approaches to maintain the scope of the refurbishment program. It was decided to use and advance an ESPC business model in which the savings generated by the energy and non-energy refurbishment measures become a constant in the financing concept. Although energy-supply contracting could also contribute energy cost savings, it does not integrate them into the funding concept.

The research on advanced ESPC business models in Europe led to no adequate findings. Most ESPC projects were limited in their technical scope to HVAC measures. The construction of central utility (heating) plants based on biomass, the integration of the thermal envelope, and other (mostly non-energy-related) measures have not been executed in most of Europe using ESPCs. ESCOs, most of them specialized in the BASs, were, and mostly still are, not prepared to provide the necessary expertise for planning, administering, calculating, and carrying out advanced ESPCs as required in this project. This project was considered to be a pilot project, in which KEA would develop a feasible approach for an advanced ESPC and in which the ESPC would be used to leverage limited public funding sources.

The execution of the project required significant coordination of multiple contractors and contracts. To devise a simple approach for the customer, the customer and KEA decided to integrate the coordination of contracts and contractors into the ESCO's specification sheet. This meant that the ESCO would integrate an external planning team for the refurbishment of the swimming pool and would take the risk for the complete investment costs and the savings guarantee. Nevertheless, it was clear that no such projects have been carried out so far and that the public sector, ESCOs, and facilitators had no experience in projects integrating a larger amount of retrofit with minor or non-energy contributions.

TENDERING AND CONSTRUCTION PHASE

After the positive council decision, KEA started the tendering process. Exceeding the threshold of total investment over the contract period of 220,000 € of EU and German service contract procedures requires an EU-wide procurement process. In this project, the estimated value of construction measures outbalanced the value of the service part (financing, maintenance, M&V, etc.) and the German construction contract (GCC) procedures were chosen for the legal procurement framework. GCC allows up to a total project value of 5 M € for choosing a national tendering process. State and municipal procurement requirements require each administration to conduct a transparent decision-making process, which in ESPC projects usually is based on a decision memo provided by the public administration and approved by the municipal council. The tendering process is simple but uncommon in public administrations. Due to that, most of the municipalities engage a facilitator to conduct the tendering process and to optimize results for the municipality.

Throughout most parts of Europe, energy service projects that include a financing component are considered to be debt, which creates a serious risk for the decision-making and procurement process. To prevent public administrations from debt overload and to ensure that they chose the most cost-effective solution, public administration in some German federal states (DENA 2012) must seek approval by regional offices of the Ministry of Interior. This approval can only be given on the results of an assessment that compares the results of the accomplished tendering process and the estimated virtual results of an appropriations-managed business model with the same scope of work. Since the code of conduct for such an assessment is left imprecise, it creates many imponderables in the procurement process (Lohse 2013). In the worst case, the denial of approval after an accomplished award procedure may lead to a lawsuit for damages from non-performance. This has happened already in a few tenders and has resulted in a kind of negative advertising for energy services in the public sector. One of the first activities to be taken promptly to propel the development of energy services at the European and national levels is to revise the approval for ESPC and other energy services. Here it needs to be established that ESPCs with balanced revenue streams are not to be considered as a debt and are free from approval. For all other cases, transparent rules for the assessment have to be developed in which the assessment must be scheduled before the tendering, thereby creating a transparent threshold for the best bid of the tendering process.

Tendering Process

The tendering process took place subsequently, starting with the EU-wide project tender announcement published on an EU public procurement website, which was followed up within two weeks by a public qualification process. The qualification process provided a brief description of the project's scope of work and the application criteria. Basically, the applicants must prove their legal and economical creditability. KEA usually adds certification of specific expertise needed in the tendered project. In this case, references were required in commissioning and operating woodchip boilers and in the planning of technical swimming pool installations. To enable energy-supply contractors to apply, contracting references, but no specific ESPC experience, were required. These door-opening criteria, which allowed for participation in performance- and risk-related business models, are still to be discussed in Germany. Four large ESCOs and one SME tradesman company applied and were approved to participate in the tendering.

The tender documents handed over to the bidders were developed by KEA as a regional standard to be used in KEA conducted projects:

- *Guideline for the tendering process*. Providing all necessary information on the subsequent process, the time schedule, and the transparent, non-interpretable award criteria.
- *Planning contract*. Most of the ESPC projects are carried out in two steps (described next) so the best bidder will be awarded the planning contract. The planning process and time schedule for the award criteria for the ESPC are described in this contract.
- *Energy performance contract*. This contract includes all necessary stipulation to clarify the allocation of risks

and services; to describe the revenue streams; and to list the monitoring, verification, and accountancy issues.

- *Annexes*. In the annexes, the energy and cost baseline is made transparent, the list of measures is described, and templates to be filled by the bidders are provided. Guidelines for the verification of monitored savings are also explained.

The award criteria of KEA-conducted projects typically focus on the savings but also stipulate a strong impact of the technical measures and solutions. The rating of the bids was finally based on a credit point system in which the bidders can achieve 0–10 credit points for each award criterion. The following award criteria were emphasized:

- Amount of guaranteed and achieved savings in total over the expected technical life of the technical measures (here, estimated 18 years): 25%
- Amount of savings remaining with the building owner in 18 years: 25%
- Technical concept and measures: 40%
- Carbon dioxide savings: 10%.

The list of measures provides individual credit points for single measures and gives an incentive to the bidders to consider the technical concept very carefully. The measures provide sustainable solutions, which are preferred in comparison with those only tackling the low-hanging fruit. Providing a credit-point system is a mechanism to equalize a less-attractive cost/benefit ratio of sustainable technical solutions to some extent. The emphasized credit points are added for each bid and are used as award criteria.

Step 1: Procurement Phase

The bidders are usually offered a time frame of four to six weeks to inspect the tendered buildings and the list of measures and to develop a technical concept to calculate investments, risk margins, and costs for maintenance, operation, and M&V. In the case of Pfinztal, the timeline was six weeks. During the bidding process, it turned out that the ESCOs had no experience in the cost prognosis for the asbestos abatement. To minimize risks, a specialized company calculated those costs, which were used in the procurement phase by all bidders.

After submission of the bids to KEA and a first technical and economical assessment, two rounds of negotiation were held. In the first round, all bidders were invited to present their bids and their technical and economical concepts in detail and to discuss them with the municipal stakeholders and KEA. After the first round, the bidders were requested to optimize their bids. These results were again assessed by KEA, after which a reduced number of bidders was invited to present their adjusted bids. Finally, after a three-week negotiation phase and a last call, the final bids were evaluated and the best bidder was selected. The negotiation of bids is quite uncommon in public procurement codes. To achieve the broadest possible acceptance, a peer committee seated with members from the municipal administration and members of the municipal council was invited to take part in the negotiations. The results of the award process were presented to the municipal council, which decided to award the best bidder with the planning contract. The procurement phase was concluded two weeks after the approval of the contract by the municipal administration and after a time limit had passed for the other bidders to file an appeal.

Step 2: Planning and Final Approval Phase

At this point, the planning contract was to be signed with the best bidder. The contract defines the scope of measure, which results from the negotiation phase and the criteria that had to be fulfilled by the best bidder to be approved for the ESPC:

- The planning has to be carried out in detail. To avoid "black box" solutions, planning must be adjusted and finally approved by the customer.
- All subcontractors have to be defined, and a draft of the final time schedule has to be provided.
- The awarded bid has to be finally adjusted. The spread between the adjusted and the original award credit points has been limited to –10%.

In this second step, the bidder has the opportunity to reassess the measures and to model and optimize the measures. Important challenges for the bidder are to select the subcontractors and integrate them into the technical and maintenance concept, to align their bids with the calculation, to allocate responsibilities and risks, and to achieve binding time schedules. In this case, an hourly modeling was only carried out for the swimming pool and for the design of the heating grid; other measures were estimated or modeled on monthly data.

An important step was the integration of an external planning company specialized in the design and refurbishment of swimming pool construction and installation. Here the target for the ESCO was to get an external partner to provide sufficient reliability in the predicted measures and investment costs and to synchronize the time schedules for both ECM and NERMs measures.

After the four-month planning phase, the bidder submitted all adjusted planning results, calculations, and schemes to KEA for final approval. Since the award credit point spread was only 6%, KEA proposed the approval and signing of the ESPC to the municipal administration.

Step 3: Construction Phase

The bundle of measures described previously, in step 2, had been slightly adjusted by the bidders during the bidding phase:

- *Uncertain cost structure for asbestos replacement*. During the bidding process, it turned out that the ESCOs had a large spread on the cost prognosis for the asbestos replacement. To minimize risks, a specialized company calculated costs for the asbestos replacement, and this cost was used in the procurement phase by all bidders.

- *Photovoltaic (PV) systems.* Originally intended to be included as a part of the ESPC, the installation of PV systems was deferred. It was determined that a cooperative of citizens would construct the PV systems by investing private money and collecting the revenue streams from renewable energy code payments.

The projected heating load for the campus after the demand-side measures was predicted by KEA on a hourly simulation of the load curve to be approximately 1.5 MW (5.1182 MBtu/h). Finally, after modeling the hourly load curve in the detailed planning phase, the ESCO decided to reduce the total heating load to 1.3 MW (4.435 MBtu/h). The installed load includes redundancy of capacity. As a result, the heating system was designed to use a 0.6 MW (2047 MBtu/h) heating-load biomass boiler and 1.2 MW (4094 MBtu/h) oil boilers to meet the required (n+1) redundancy for the system. In addition, 15 m^3 (3963 gal) of storage was to be installed to buffer peak heat loads for 0.5–0.6 h, mainly for the optimized operation of the biomass boiler.

All construction, especially the underground construction for the biomass storage (Figure 3) and the microheating grid, was strictly scheduled to take place in the summer holidays in August 2009. At the same time, the basement of the swimming pool had to be opened to bring in the biomass and oil boilers (Figure 4). All larger technical equipment like pool water filters and stainless steel parts of the swimming pool basin had to be brought into the building. To avoid disturbing classes during the school year, most parts of the heating distribution, the lighting systems, the building automation, the ancillary units, and the related duct and cabling work were done during the summer holidays.

Figure 3 *Wood-chip bunker on the school campus.*

Phase II of the project involved the renovation of the swimming pool (Figure 5). The swimming hall was to receive a core and partly shell renovation converting the battered ventilation and sanitation facilities; installations, tile, duct and cable constructions; and the leaking pool basin into a modern pool with high user comfort, a high-efficiency ventilation unit with an air humidity control system, and modern sanitation facilities. Specific issues involved the abatement of ceiling asbestos, which had to be done by a specialized company, and the unscheduled need to strengthen the base of the pool. This additional work contributed several delays (an additional six months) to the construction phase. The construction phase was completed in 13 months.

ADVANCED ESPC BUSINESS MODEL

The business model used in this project is an advanced ESPC. Advanced features include the integration of a bundle of NERMs planned and carried out with support from an external planner and specialized subcontractors. For comparison, Table 3 lists the features of this advanced ESPC along with those of a typical ESPC in use in Germany.

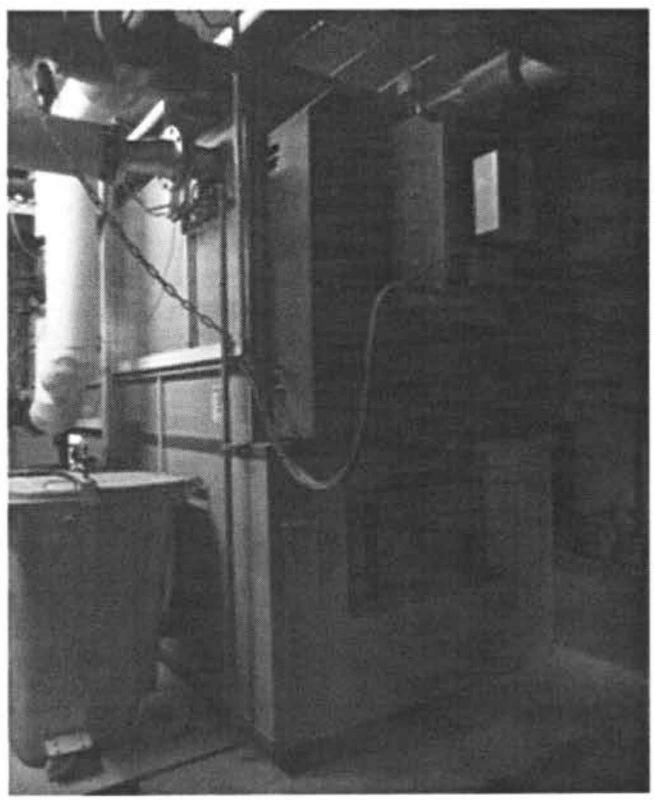

Figure 4 *Front view of wood-chip boiler integrated in the basement and fine-dust bin connected to the combustion chamber.*

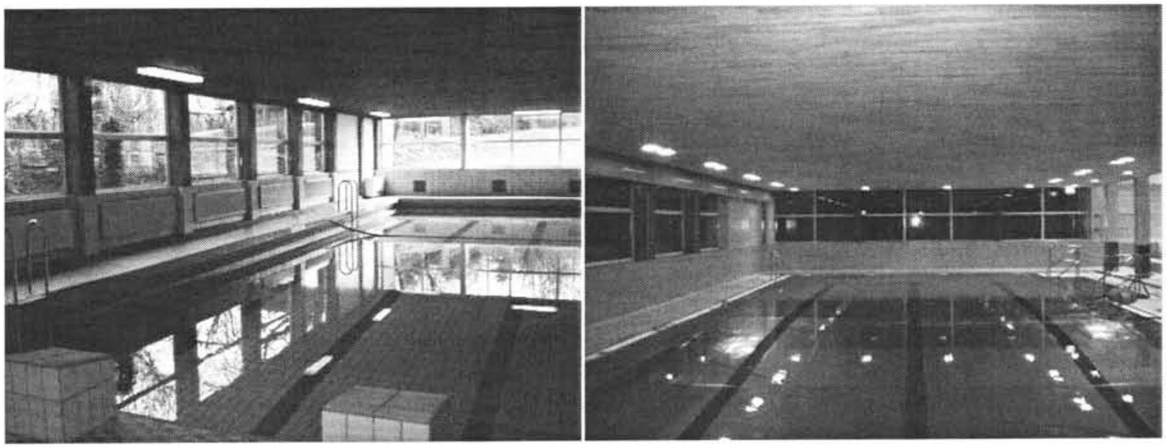

Figure 5 *Swimming pool before (left) and with refurbishment accomplished (right).*

Table 3. Structure of ESPC and Advanced ESPC Business Models in the Pfinztal Case

	ESPC	Advanced ESPC (+ ; additional, – : reduced
Key partners	ESCO, facilitator, public building owner	+ Experts in the planning and construction phase to carry out specific measures
Key activities of ESCO	Planning, financing, implementation, operation, maintenance, commissioning, integration, and coordination of subcontractors for ECMs	+ Integration and coordination of subcontractors for NERMs – Maintenance is, in this case, not provided for NERMs
Key activities of customer/facilitator	Tendering, supervision, stipulation	
Key resources needed (ESCO)	Experience-based knowledge on key activities, project management, ECMs provided from own manufacturing or purchased, installation capacities, funding sources	+ Integrated external expertise on the specific topic (swimming pool technology, asbestos abatements)
Value proposition	Guaranteed investment costs, energy savings, turnkey solution, high efficiency, revenues from savings balance annual costs	+ Integration of NERMs into the value proposition, guaranteed investment costs and NERMs-related savings; + integration of NERMs revenue streams into the cost balance to minimize bank loans
Risks	Risks for investment costs and energy-saving guarantee	+ Risk for reliability of externally provided cost and savings + No experience-based knowledge + No adequate tools for calculation
Cost structure	ECM investment → ECM annuities, maintenance, operation, commissioning, M&V	+ NERMs investment, external costs for NERMs planners and construction companies → + NERMs annuities, maintenance, operation and M&V as options
Revenue streams	Savings plus optional upfront payments ≥ annual ECM costs	Savings plus optional upfront payments ≥ annual ECM + NERMs costs

Funding Structures for ECMs and NERMs

Both investment streams were integrated into the ESPC. Although the municipal council decided for a nine-year contract period, the revenues coming from ECMs could be partly integrated in the payments for the NERMs part of the ESPC project. The annual costs are cumulated for an assumed life cycle of ECMs and NERMs of 20 years. The annual cost and the cumulated cost balances are displayed for the nine-year ESPC contract period. The effects of long-term, advanced ESPCs are described for a 15-year-ESPC-contract period.

Investment Cost for ECMs

The total investment for ECMs calculated by the ESCO was 1,367,000 €. This included taxes, planning, demolition, construction site equipment, delivery and installation of components, and a margin for risks.

The municipality provided a 415,000 € down payment to the ESCO after the termination of the construction phase. This amount was the investment cost for the biomass heating plant, including ancillaries. The European grant program Europäischer Fonds für Regionale Entwicklung provided a grant of 87,000 € for the municipality under the condition that the municipality pay the investment cost of the biomass heating plant in an upfront payment. The grant was received by the municipality and directly enhanced into the ESPC project funding. In the annual cost structure, the interest rate for assets is set at 0.25%. Therefore, the calculation assumes that the municipal upfront payment does not induce any capital costs.

The ECM investment costs remaining with the ESCO are calculated as follows:

$$(1{,}367{,}000 - 415{,}000 - 87{,}000)\text{ €} = 865{,}000\text{ €}$$

Investment Cost for NERMs

The total investment for NERMs, mostly in the swimming pool, calculated and adjusted during the construction phase, was 870,000 €. This also included taxes, planning, demolition, construction site equipment, delivery and installation of components, and a margin for risks. Assuming that the average lifetime of all NERMs is 20 years and the ESPC contract period is nine years, the residual value has to be taken into account. The residual value of the NERMs after nine years is calculated as follows:

$$870{,}000\text{ €} \times (20 - 9) / 20 = 478{,}500\text{ €}$$

Annual Costs and Savings Within 9 and 15 Years—Advanced ESPC Contract Period

The annual costs calculated by the ESCO were elicited during the detailed planning phase:

- Annuity costs (including payback and interest rate in annual net present value) for 865,000 € ECM investment are 110,000 €/yr (interest rate ~2.8%, nine years contract period). The annuity costs are borne by the ESCO.
- The annual costs for maintenance, technical support, and energy commissioning of the ECMs amount to 17,000 €/yr. The maintenance costs are borne by the ESCO.
- The ESCO is providing an ECM savings guarantee for energy costs (i.e., verified energy savings and verified transition of primary energy priced with defined energy prices) of 116,400 €/yr. During the advanced ESPC contract period, the ESCO is receiving 100% of the verified energy savings.
- The savings of maintenance costs from the perspective of the customer, resulting from the replacement of equipment at the end of its life cycle and the maintenance of the newly installed ECM equipment by the ESCO is 23,600 €/yr. During the advanced ESPC contract period, the ESCO is receiving 100% of the verified maintenance savings.
- The ECM cost balance shows an overlap savings: annual ECM savings of 140,000 € and annual ECM costs of 127,000 € leaves an overlap of savings of 13,000 € to be used to co-fund the NERMs annual cost balance.
- The annuity and maintenance costs for the NERMs are 110,000 €/yr.
- The replacement of equipment at the end of its life cycle and the maintenance of the newly installed NERMs equipment by the ESCO saves avoided maintenance costs of 26,000 €/yr.
- The extra annual costs to be paid by the building owner for the NERMs in an advanced ESPC contract period of nine years is calculated as:

  $$(110{,}000 - 26{,}000 - 13{,}000)\text{ €/yr} = -71{,}000\text{ €/yr}$$

  which, accumulated over nine years = 640,000 €.

The amount that must be paid by the building owner to implement NERMs is influenced by the contract period of the ESPC: a calculation of a 15-year contract period decreases the annuities for ECM and NERMs while the savings are kept stable. This leads to the following annual costs to be paid by the building owner for the NERMs in a 15-year contract period:

- ECM cost/savings balance for 15-year ESPC: (140,000 – 71,400 – 17,000) = 51,600 €/yr of savings
- NERMs cost/savings balance for 15-year ESPC: (71,200 – 26,000) = 45,200 €/yr of savings

In a 15-year ESPC, the building owner need not pay extra annual costs to set up the NERMs investments and saves 6400 €/yr. The breakeven, where costs and savings are in balance, is a contract period of approximately 14.3 years.

Cumulated Annual Costs and Savings within a 20-Year Life Cycle

The cumulated costs for the advanced ESPC contract period of nine years has been described previously; the cumulated costs and savings are –640.000 €. After the termination of the ESPC, the costs and savings that have to be borne by the building owner are the following:

- Annuity costs for ECMs and NERMs: the annuities will be paid off within nine years.
- Maintenance costs for ECMs: the building owner will have to bear the maintenance costs of 17,000 €/yr.

- Maintenance costs for NERMs: the owner will bear annual costs of 0.5% of the initial investment costs (4350 €/yr).
- The ESCO's energy savings attributed to ECMs are reduced by 10% under the assumption that the building owner will not be able to operate the ECMs as efficiently as the ESCO.
- The maintenance savings of ECMs and NERMs are assumed to remain at the same level as during the ESPC contract period.
- The annual cost and savings balance for ECMs and NERMs for years 10–20 is the following:

  128,360 + 26,000 – 4,350 – 17,000 = 133.010 €/yr of savings

  Cumulated for years 10–20, this is 1,463,110 €
- The total cost balance from years 1–20 is

  1,463,110 € – 640,000 € = 823,110 €

- If the same assumptions are made for a 15-year advanced ESPC, the total cost balance from year 1 to year 20 will be 763,000 €.

Results from the Analysis of the Funding Structure of Advanced ESPCs

- An analysis of the funding structures was done on a pilot case study where the typical scope of measures carried out in an ESPC were increased from typical HVAC measures to biomass district heating and NERMs (refurbishment of a swimming pool). ECMs with a total investment of 1.367 M € were combined with NERMs investments of 0.87 M €. The pilot case study was analyzed to determine how the ECMs energy could contribute to the funding of the NERMs. The relationship between the ESPC contract period and the building owner's annual payments was also assessed in a cash flow analysis.
- In this case study, the funding structure integrated public funding with upfront and annual payments and private funding by an ESCO under an umbrella of a performance-related business model. The ESPC business model provides a guarantee for energy and maintenance cost savings and for both NERMs and ECMs investment costs. In most cases, German ESCOs engage banks to provide funding for their investments, which is then paid back by monitored savings. Therefore, the guaranteed saving and investment costs are necessary requirements for third-party funding.
- In ESPC projects, measures are selected to balance savings and costs. This allows the ESPC to be declared a debt-free business model. However, it is a challenge to maintain the economic balance of the ESPC when the projects integrate measures with low-cost-saving effects, such as the thermal envelope or NERMs. These investments increase while the energy savings remain on the same level. In this case, two approaches have been successfully carried out to extend the scope of the measures:
  - *Integrate additional savings into the calculation.* This advanced ESPC business model integrates the avoided maintenance costs for the replaced old installations (23,000 €/yr for ECMs and 26,000 €/yr for NERMs) into the revenue scheme. These values were collected from the municipal accounts and became a part of the cost baseline of the project. However, the ESCO has to take over the maintenance and refurbishment of the newly implemented installations. There has been some discussion regarding increasing these values annually according to the increasing age of the replaced installations.
  - *Use energy savings to contribute to funding the NERMs.* The annual savings achieved by the ECMs will first be used to achieve the ECMs' payback. If the contract period of an advanced ESPC is longer than the ECMs' payback period, the energy savings may contribute to fund the NERMs' annuity as well. In this case, the municipal council opted for a nine-year ESPC contract period, which restricted the effect to 13,000 € of the total NERMs annual costs of 84,000 €/yr and which leaves annuities to be paid by the building owner of 71,000 €/yr. If the contract period had been 14.3 years, the annual NERMs costs would have equaled the NERMs and ECMs savings. In that case, the building owner would have been required to make any additional payments.

The scope of measures and the investment of ESPC projects can be extended significantly without any additional payments by the building owner by adjusting the contract period and integrating the maintenance cost savings with the revenue streams in the cash flow analysis. The results (shown in Table 4) could be further optimized if increasing rates are considered for the energy and maintenance cost savings.

VERIFICATION AND MONITORING PHASE

In most European ESPC models, the performance achieved by the ESCO plays a crucial role to the revenue streams between the ESCO and the public customer. From the perspective of the customer, the saving guarantee and the transparent monitoring and verification are strong arguments to describe the advantages of ESPCs in comparison to other business models. Experience also shows that the clearing of the savings in ESPC projects is very sensitive and is an indicator for the reliability of the ESPC model in general.

Most ESPC projects in German public buildings include, among other services, a guarantee for energy savings and a revenue stream from the customer to the ESCO that is usually based on the resulting cost savings. In the Pfinztal ESPC, it is stipulated, as in most German ESPC projects, that the annual savings are monitored and verified by annual consumption

Table 4. Annual and Cumulated Costs and Savings in 20 Years for a 9-Year Advanced ESPC

	Years 1–9 (ESPC Contract Period)		Years 10–20 (Operation by Building Owner [b.o.])		Total Years 1–20
	Annual (€/yr)	Cumulated (€)	Annual(€/yr)	Cumulated (€)	
1. Costs					
Annuities, ECMs	110,000				
Maintenance, ECMs	17,000		17,000		
Annuities + maintenance, NERMs	110,000		4350		
Costs, ECMs	127,000	1,143,000	17,000	187,000	1,330,000
Costs, NERMs	110,000	990,000	4350	47,850	1,037,850
2. Savings					
Energy savings, ECMs	116,400		104,760**		
Maintenance, ECMs *	23,600		23,600		
Savings, ECMs	140,000	1,260,000	128,360	1,411,960	2,671,960
Maintenance, NERMs	26,000	233,000	26,000	286,000	519,000
3. Overlap = (2–1)	–71,000 (building owner)	–640,000 € (to be paid in nine years by building owner)	133,010 (building owner savings)	1,463,110 (building owner)	+ 823,110

*Maintenance, ECMs/NERMs: avoided maintenance of replaced installations.
** Energy savings, ECMs: it is assumed that the municipality will achieve 10% less than that guaranteed by the ESCO during the contract period.

metered at the energy meters, compared to the energy and cost baseline. To avoid any noteworthy advantage or disadvantage to both contract parties and to make sure that efforts initiated by one of the contract parties may be fairly awarded, the measured values are adjusted to climate and building-use factors. These aspects of the project can influence the performance of the ESCO positively or negatively. The ESPC developed and used by KEA provides some standard adjustments for climate, changes in the building's usage timetable, ECMs to be carried out by the customer, increasing or decreasing floor areas, repurposing of the building, etc.

KEA supports more than ten municipal administrations to control and revise the annual bids and tendering processes.

One of those is Pfinztal, which is now in the third of nine contract years. The results of two years, which have already been revised, show that the ESCO fails to achieve the savings guarantee by about 3% (Table 5). Due to inherited risks, the contract does not include a penalty for the ESCO if the guarantee is not met. The payments from the Pfinztal municipality, however, will not exceed the M&V savings of 112,700 €/yr in the first two contract periods. The change of nearly 3700 €/yr will be borne by the ESCO.

The following discussions identify the reasons for missing the targets:

- *Modified usage of the swimming pool.* The number of visitors increased more than 100%. This may also be seen as a positive measure of the attractiveness of the newly designed swimming hall. As a direct consequence of this, the energy consumption increased: to run swimming courses, the pool water has to be heated to 29°C (84°F) (instead of 28°C [82°F] fixed in the baseline). The ambient temperature of the swimming hall then had to follow and was adjusted to 31°C (88°F). An hourly modeling of the swimming hall (two zones, the swimming hall/shower rooms and the locker rooms) has shown that approximately 60% of the increased heating demand resulted from the higher pool water and swimming hall temperatures. It is believed that the impact may be even larger, as the modeling may prove.
- *Ineffective monitoring.* During the first two years, the new building monitoring and control system will have to be adapted to the building usages and optimized carefully to achieve the performance targets. The revision of the performance measures was carried out the first time after the first contract period and showed that the energy management was not done accurately enough to achieve the targets; monitoring took place only once a month instead of daily. These lapses in monitoring made it impossible to calculate building energy use for certain short time periods.

Table 5. Energy Consumption and Costs, Before and After the ESPC Refurbishment

	Before ESPC		ECMs Guaranteed Savings			M&V Results After Two Years, €
	Consumption, kWh (Mbtu)	Load, kW (Btu/min)	Consumption, kWh (MBtu)	Load, kW (Btu/min)	Cost Savings, €	
Electricity	335,600 (1,145,403)	805 (45,821)	87,900 (300,003)	210 (11,953)	10,910	10,910
Heating gas/oil	1,730,000 (5,904,490)	1440 (81,965)	588,500 (2,008,551)	490 (27,891)	47,000	43,000
Heating biomass	0	0	–958,000 (–2,008,551)	–450 (–25,614)	45,800	45,800
Water/sewage	6579 m^3 (232,335 ft^2)	—	3190 m^3 (112,654 ft^3)	—	12,760 €	13,000 €
					116,470 €	112,700 €
Avoided maintenance	—	—	—	—	23,620 €	23,620 €
Annual savings-related performance	—	—	—	—	140,090 €	136,320 €

Some of the building engineer's interventions in the heating curves and timetables had not been reviewed by the ESCO in time. Meanwhile, the ESCO has increased its efforts to optimize the energy management program that already has begun to show the first positive results in the third contract year.

LESSONS LEARNED

After the third year of the contract period of this advanced ESPC project, the accumulated experience shows large market potentials for the advanced ESPC. To continue this success with increasingly complex projects (in terms of funding and business models) more effort will be required in the preparation phase.

- The introduction of new funding models requires the integration of diverse interests of a number of different stakeholders. This project has provided a good example of how to establish an interdisciplinary project working group in the early stages of the project.
- It is essential to carefully prepare for the ESPC (especially for an advanced ESPC), including early calibration with all stakeholders and upfront planning to minimize technical and organizational issues. Increasing investment costs that are commissioned in an advanced ESPC should be avoided. Good project preparation minimizes potential problems and is an important part of the de-risking strategy. It is a greater risk to exceed the investment cost than to not meet the savings guarantee. Clarifying and minimizing these risks will positively impact the interest rate levels for the project funding.
- Experience shows that bundling ECMs and NERMs in one ESPC is feasible as long as the NERMs investment does not significantly exceed the ECMs investment costs. In this case, the investment for NERMs could be funded by triggering the contract period of the ESPC and by integrating avoided costs for maintenance into the revenue stream of the ESPC business model.
- Bundling in one contract sets the ESCO in a position to gain maximum influence over the project management, on-time scheduling, and appropriate design of technical interfaces.
- Public procurement has not been an issue under the circumstances found in this project. ESCOs provided competitive bids as long as they found enough preparatory information that they would not be able to collect in a tendering process. In this project, this was the case in the discussion of the heating plant site and in the preparation of the biomass supply structures and of a consistent energy and cost baseline. It can be assumed that, in the case of the integration of a thermal building envelope, good preparation is a necessary requirement to receive competitive bids.
- If all effects had been appropriately accounted for, the advanced ESPC model would have contributed even more to minimize the customer's payments.

SUMMARY AND DISCUSSION

The advancing age of the building inventory and increasing requirements governing governmental refurbishment projects (the number and pace of which are also increasing) are stressing the budgets and resources planning of public building owners. As the number of projects increases, the availability of current funding and bank loans will decrease, as will the already limited sustainment, restoration, and modernization funds, and other public funding required to provide the capital to initiate deep refurbishment projects. Addressing this challenge will require administrators to think in new ways, to assess the methodology (business models) used to implement deep refurbishment projects, to determine new ways to increase the impact on energy efficiency per unit of investment cost, and to make cost savings a dependable part of the funding.

The project described in this paper illustrates a first step in that direction by using a business model that resolves both challenges:

- The business model structure of the ESPC provides, in comparison with the owner-directed business model, a high incentive for the ESCO to reach for higher-than-average energy efficiency.
- The ESPC allows the ESCO to provide investment cost funding and to assume maintenance, M&V, and other costs. Revenue streams, however, are based on the savings that have been monitored and verified. If both costs and revenues are in balance, the ESPC provides a non-debt-based funding model.

Deep refurbishment is not often initiated to satisfy energy concerns but to achieve specific, non-energy-related targets. In the described project, the ESPC business model was advanced to merge a bundle of non-energy-related measures into an energy conservation measure bundle in one project. This innovative approach blended ECMs and their savings with NERMs to generate additional accountable values:

- Guaranteed ECMs savings provided the complete funding for the setup of considerable end energy savings and a biomass heat plant with a heating microgrid.
- ECMs savings contributed more than 10% to the annual costs of a comprehensive refurbishment of a swimming pool.
- The advanced ESPC business model also assumed the risks to meet the calculated investment cost frame for both ECMs and NERMs bundles.

In this project, additional saving potentials have been assessed but not accounted for. In addition, the increased residual value of the building could play an important role in the financing model of such projects. In upcoming pilot projects in IEA-EBC Annex 61, the financing model will account for both potential contributions.

A side effect of increasing investment costs and longer payback periods, which are to be expected with the integration of the building envelope and NERMs, is increasing interest rates. In recent years, long-term funding models require higher (20%–30%) interest rates than short- and medium-term (<15 years) funding. This effect leads to inefficient spending of money. Instead of using the money for investment and mission-related annual costs, larger amounts are dedicated to interest rates. The impact of inefficiency is further increased by ESCOs (partly by their lack of expertise in the collection of funding). This project reviewed interest rates and found a spread of nearly 1% among the bidders for more or less the same scope of work and total investment. In relation to a total investment of 1.3 M € and a funding period of nine years, the annual additional costs add up to nearly 20,000 €/yr. Over nine years, this is equivalent to 180,000 € of investment, which could be spent on additional ECMs or NERMs. To alleviate this problem, governments that intend to advance ESPCs into the business model by providing mid- and long-term payback for NERMs or building envelopes should consider providing a specific funding source for ESCOs. This fund, in combination with a low interest rate, would enable high-performing ESCOs to minimize capital costs and focus on investment cost. This, and many related issues, will further refine the IEA-EBC Annex 61 in the coming months.

REFERENCES

BEA. 2013. *Berliner Energiesparpartnerschaften*. Berlin Energy Agency.

Bleyl et al. 2014. R*ole of Facilitators in Energy Service,* IEA-DSM Task 16.

DENA. 2012. Contracting Competence Center, 2012 (in German). Deutsche Energie-Agentur. www.kompetenzzentrum-contracting.de/contracting-infos/laenderregelungen-haushaltsrecht/.

DIN. 2011. *Energy-efficiency of buildings—Calculation of the net, final, and primary energy demand for heating, cooling, ventilation, domestic hot water, and lighting.* Standard DIN-V 18599 1–10. Deutsches Institut für Normung. www.din.de/cmd?level=tpl-art-detailansicht&artid=142651278&languageid=en&bcrumblevel=1.

DOECC. 2013. *Factors influencing energy behaviors and decision-making in the non-domestic sector.* Department of Energy and Climate Change, UK.

JRC. 2014. European Commission Joint Research Center. https://ec.europa.eu/jrc/.

KEA. 2010. Climate Protection and Energy Agency of Baden-Württemberg. www.kea-bw.de/contracting.

Lohse, R., et al. 2010. *Assessment of accomplished deep renovation projects*. KEA project report (in German). KEA Baden-Württemberg, GmbH.

Lohse, R. 2013. Assessment of the approval structures for public energy service tenders in Germany. *KEA Newsletter* (in German).

MoC. 2013. *German Energy Ordinance*. Berlin: German Federal Ministry of Construction.

MoEE. 2010. *Financing instruments to implement building refurbishments* (in German). Stuttgart: Ministry of Environment and Energy.

MoIT. 2010a. *QM wood heating systems, guidebook for operators* (in German). Stuttgart: Ministry of Industry and Trade.

MoIT. 2010b. *QM wood heating systems, planning guideline* (in German). Stuttgart: Ministry of Industry and Trade.

MoIT. 2014. *Third national energy efficiency action plan*. Berlin: Federal Government, Ministry of Industry and Trade.

Pfinztal Environmental Department. 2013. *Annual energy monitoring report Pfinztal 2012*.

Standing Committee of Economic Development Baden-Württemberg. 2011. Rehearsal Protocol 1452-2.

Stein, W., and R. Lohse. 2014. *ESPC business models for small and medium sized buildings, Karlsruhe*.