# ENERGY PLANNING AT NATIONAL AND COMMUNITY LEVEL IS THE KEY TO INTEGRATE COST EFFECTIVE RENEWABLE ENERGY

Anders Dyrelund and Thomas Rønn
Ramboll Energy
Hannemanns Alle 53, 2300 Copenhagen S, Denmark
Phone: +45 51 61 87 66 / +45 51 61 55 62
E-Mail: ad@ramboll.com / tsr@ramboll.com

## 1 SUMMARY

Unlike the fossil fuels, renewable energy is of low quality and fluctuating. Almost no efficient and renewable energy source can be used at the building level in a cost effective and environ friendly way to meet the demand. However, at campus, city and national level, there is an opportunity to identify and utilize a wide range of sources benefitting of economy of scale. Careful energy planning is the key to harvest these sources considering the campus, the local community or the state as one profit centre optimizing the energy system including the power, gas, district heating and district cooling system. The integrating energy system opens for an opportunity for storing and utilizing energy, which else would be wasted and it improves the local environment, not least the air quality. We will show three cases on how the energy planning of district heating and cooling (DH&C) which is obvious for any campus owner also is of interest for local communities and governments.

## 2 INTRODUCTION

There are many renewable energy sources as well as free or efficient energy to consider in the energy planning, e.g. biomass, waste, biogas, deep geothermal heat, wind energy, solar heat, solar PV, industrial surplus heat, surplus heat from power generation (CHP), free cooling, surplus heat from cooling processes and surplus cooling from heat pumps. These sources are typically of low quality and fluctuating and can only be utilized and stored in a cost-effective way in large scale, in large hot- and cold-water systems in campuses or in DH&C systems.

For campus owners or district energy utilities it is therefore possible to react fast on the price signals and the national energy policy and plan for integrating the most cost-effective combination of efficient and renewable energy, e.g. CHP plants, electric boilers, large heat pumps for combined heating and cooling, large-scale solar heat, thermal storages and cold storages.

But what if there is no thermal infrastructure? International experience shows that it is very difficult to establish the optimal thermal infrastructure in urban areas unless the city council or the state plan for DH&C as a natural part of the urban infrastructure like water, sewage and electricity. Campus owners and urban developers however, who are responsible for all the buildings and energy infrastructure in their district, can plan and implement least cost solutions. They can even do it better than any utility, as they also own the buildings.

We will show case studies who are implemented already or being implemented, which demonstrate how campuses and developers can plan and implement least cost solutions for their districts. An interesting case is the large-scale heat pumps for combined heating and cooling. Due to economy of scale the integrated solutions save both operating costs and investments and improve the environment as well compared to building level solutions.

## 3 ENERGY PLANNING AT THE NATIONAL LEVEL

According to our EU directives, all national and local communities and cities should plan for heating and cooling in order to pave the way for utilizing surplus heat from power plants and renewable energy. In Denmark it has been a national priority for many years. Since 1976 all power plants have been situated with respect to the heat market and all local communities have had the responsibility for heat supply planning since 1979. Today, there is almost no heat wasted from power generation and all waste, which can-not be recycled efficiently is used for heat and power. The market share of DH has increased from around 30% to 60% and the CO2 emission from heating has been reduced significantly. The graph below shows the historical development of heat supply forms from 1980 to 2015 and a prognosis up to 2050. Thus, we can see that individual boilers have been replaced with district heating. Therefore, the CO2 emission in kg per. MWh heat has been reduced by a factor 3 from 1980 to 2010. This has opened for surplus heat and renewable energy, so far from waste and biomass, but in the years to come more and more solar heat and fluctuating wind energy.

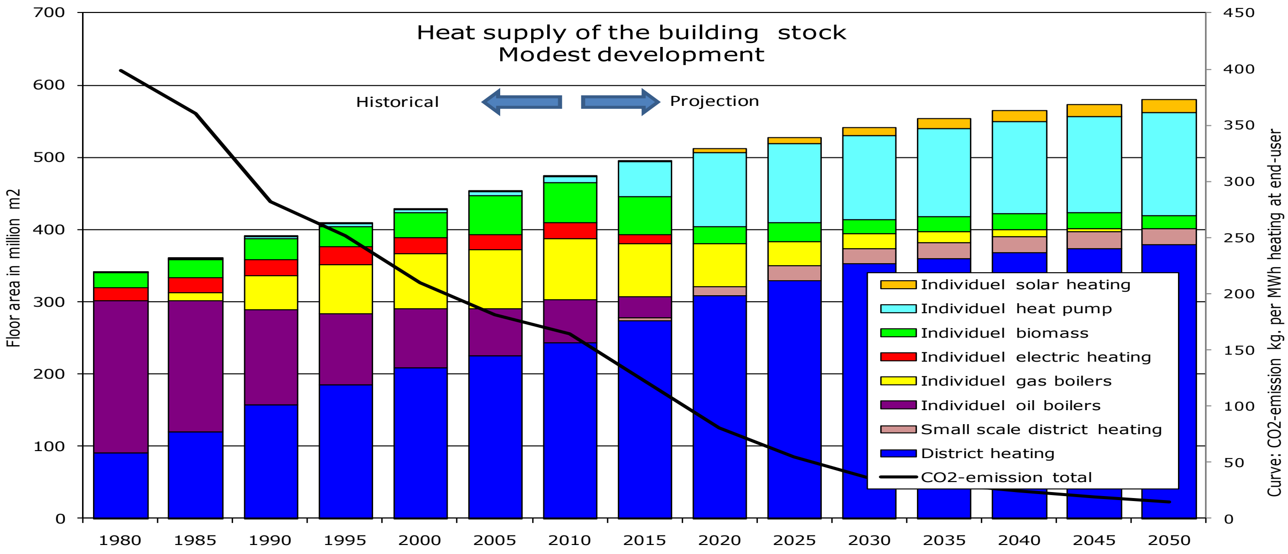


Fig. 1: Heat supply in Denmark, Heat Plan Denmark 2010 [1]

The figure below shows the market share of heat supply forms in Denmark for new buildings since year 2000. Besides, the financial crisis we see that district heating is the dominating heat supply form for new buildings.

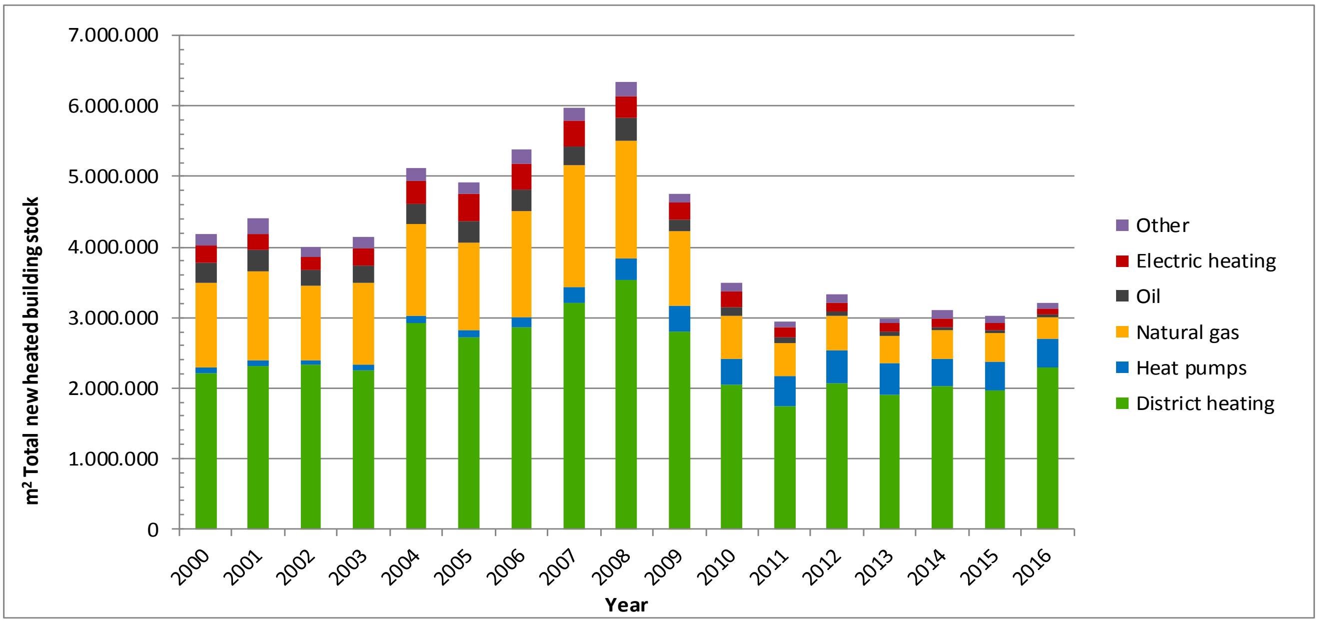


Fig. 2: Heat supply to new buildings in Denmark, Source: BBR register edited by Ramboll

In a recent strategic study "Cooling Plan Denmark" [2], we have analyzed the potential for DC in Denmark and found – surprisingly- that there is a huge potential for many cost-effective DC systems in city centers and business districts, mainly in symbiosis with the DH. In fact, the DC market in Denmark is growing significantly, and we have noticed that there is an untapped potential in most EU countries.

## 4 DEVELOPERS AND CAMPUSSES PLAN FOR ENERGY

Campus owners and developers have a natural interest in energy planning. The more cost effective and environmental friendly energy supply, the more value is created for their property. Carlsberg Properties had around 2010 the opportunity to plan for energy to all new buildings at their old industrial 300.000 m2 site of Carlsberg in Valby, Copenhagen. The challenge was to identify the most sustainable supply of energy to 600.000 m2 of floor area, of which around 50% also would have a cooling demand. The criteria for sustainability we used had 3 criteria: economic, environmental and social sustainability. The solutions, which are best for the society taking into account cost of emissions and for the local community should get the largest score. The energy solutions, which got the largest score in our comparison of relevant alternatives were:

- DH being a part of the integrated DH system in Greater Copenhagen
- local DC including chilled water storage, a centralized chiller and in the longer term a heat pump for combined production of heating and cooling
- utilization of electricity from off-shore wind, which is much more cost effective and environmental friendly than local generation of electricity from micro wind turbines or solar PV

The plan has almost been fully implemented:

- The DH has been established by HOFOR as a further development of the network Copenhagen
- A new DC network in PEH pipes, a large underground chilled water concrete tank and a chiller has been established by Frederiksberg Forsyning, and Carlsberg City ensures via commercial contracts that all buildings which have a cooling demand will be connected, thereby reducing the costs for all and improving the local environment.

Fig. 3: Chilled water storage under construction

Due to constrains in the building code, it has however not been possible for the developer to replace solar PV on some of the roof tops with a share of a more sustainable off shore wind turbine.

## 5 LOCAL COMMUNITY PLANS FOR DH&C

Local communities acting on behalf of all residents and land-owners should have the same interest in energy planning as campus-owners. Moreover, according to the EU directives and the Danish Heat Supply Act local authorities have the obligation to plan for energy. Hillerød Municipality have had the opportunity to plan for the energy supply to a new urban development area Favrholm, [3]. The plan is to establish around 600.000 m2 of floor, including a new hospital and a business district close to a new train station. The average building density of the whole area will be around 50%. There will be a mix of districts for business, institutions, apartment buildings and terraced houses - in other words a variety of building density in the districts. In our approach we looked at the planning in two dimensions. The most important was to identify the most cost-effective zoning of DH&C networks against individual heat pumps and chillers. We could rank the districts with respect to profitability of the DH&C. Gas boilers were not an option to new buildings, as the overall energy policy is to reduce the dependency of fossil fuels. The second dimension was to identify the most cost-effective production of heat and cold to the DH&C grids in the long term taking into account the local opportunities. This was an iterative process. Taking into account local conditions for heat storage, peak capacity and ground source cooling lowered the cost of production, which increased the optimal market for the networks, which again lowered the cost of production due to economy of scale.

In the first step in the iteration we assumed that there was no district heating next to the district, and we divided the area in uniform districts with respect to density and use. The best solution for all was to establish DH in most districts, and DC in the business districts and to benefit from the symbiosis between DH and DC. The same heat pump could e.g. generate cooling in summer and heating in winter in combination with ground source cooling (so-called ATES system), and the existing DH system could provide peak capacity and heat storage capacity.

Interesting is, that the key parameter for analyzing the zoning of both DH and DC is economy of scale for investing in heat pumps and chillers. It turned out that the total investment of the integrated DH&C system was almost equal to the total investment in the individual solution. Thus, we proved that the integrated solution with thermal storages and large heat pumps, which compared to individual heat pumps and chillers can integrate fluctuating renewable energy and act like an electric battery - a so-called virtual battery – can be established at no additional cost.

To conclude, research in energy storages should not only focus on electric batteries (more suitable for traffic), but also on integrated energy planning.

| **Optimized DH&C to the district** | | **DH** | **DC** |
|---|---|---|---|
| Length og network and branch lines | km | 35 | 10 |
| DH storage tank, rough estimate | m3 | 7000 | |
| DC storage tank | m3 | | 3500 |
| Capacity demand to network | MW | 12,0 | 11,0 |
| Capacity leveling of storage | MW | | 3,0 |
| Ground source cooling | MW | | 3,0 |
| Gas boiler for peak | MW | 5,0 | |
| Total installed heat pump for DH&C | MW | 7,0 | 5,0 |
| **Total installed capacity** | MW | **12,0** | **11,0** |
| Necessary electric capacity | MW | 2 | |
| Total COP for cogen of DH&C | MW/MW | (7+5)/2 = 6 | |

| **Investment in base line** | | **Heating** | **Cooling** | **Total** |
|---|---|---|---|---|
| **Individual heat pumps / schillers** | **mio.Euro** | **20** | **19** | **39** |
| | | | | |
| **Investment in DH&C system** | | **DH** | **DC** | **DH&C** |
| DH&C networks | mio.Euro | 20,0 | 7,9 | 27,9 |
| DH&C storages | mio.Euro | 1,6 | 0,8 | 2,4 |
| DH&C boiler / ground source cooling | mio.Euro | 0,7 | 1,1 | 1,7 |
| DH&C heat pump for DH&C | mio.Euro | 5,5 | | 5,5 |
| **Total DH&C** | **mio.Euro** | | | **37** |

Fig. 4: Optimized DH&C in symbiosis, Total investments base-line and DH&C system

The implementation of the plan is in progress driven by the construction of the new hospital and a new business district.

## 6 FROM GAS BOILERS TO DH

There is a huge untapped potential for saving fossil fuels by shifting from gas boilers to DH, based on renewable and efficient heat sources. As DH is an expensive natural monopoly network careful energy planning and business planning is vital for the success. Even in Denmark there was after year 2000 a huge potential in some local communities in which natural gas so far had got first priority. Vestforbrænding, who is a part of the integrated DH system in Greater Copenhagen operating a waste for energy plant and a local DH network, started a process a decade ago of strategic energy and business planning in co-operation with the local communities, one of them Lyngby-Taarbæk Municipality [4]. We identified how the existing DH grid could be extended from 300 to 900 GWh heat supply in 5 local authorities and besides transmit surplus heat to two other heat transmission systems north of Vestforbrænding. The result of the planning was a zoning and ranking of the districts with respect to the profitability for DH. In 2018 the plan has almost been implemented and DH is supplied to most larger buildings, but not to small buildings (yellow color on the figure below). The successful strategy for connection 90% of all buildings to the network the first year has been a competitive offer including installation of building level substation and no connection fee.

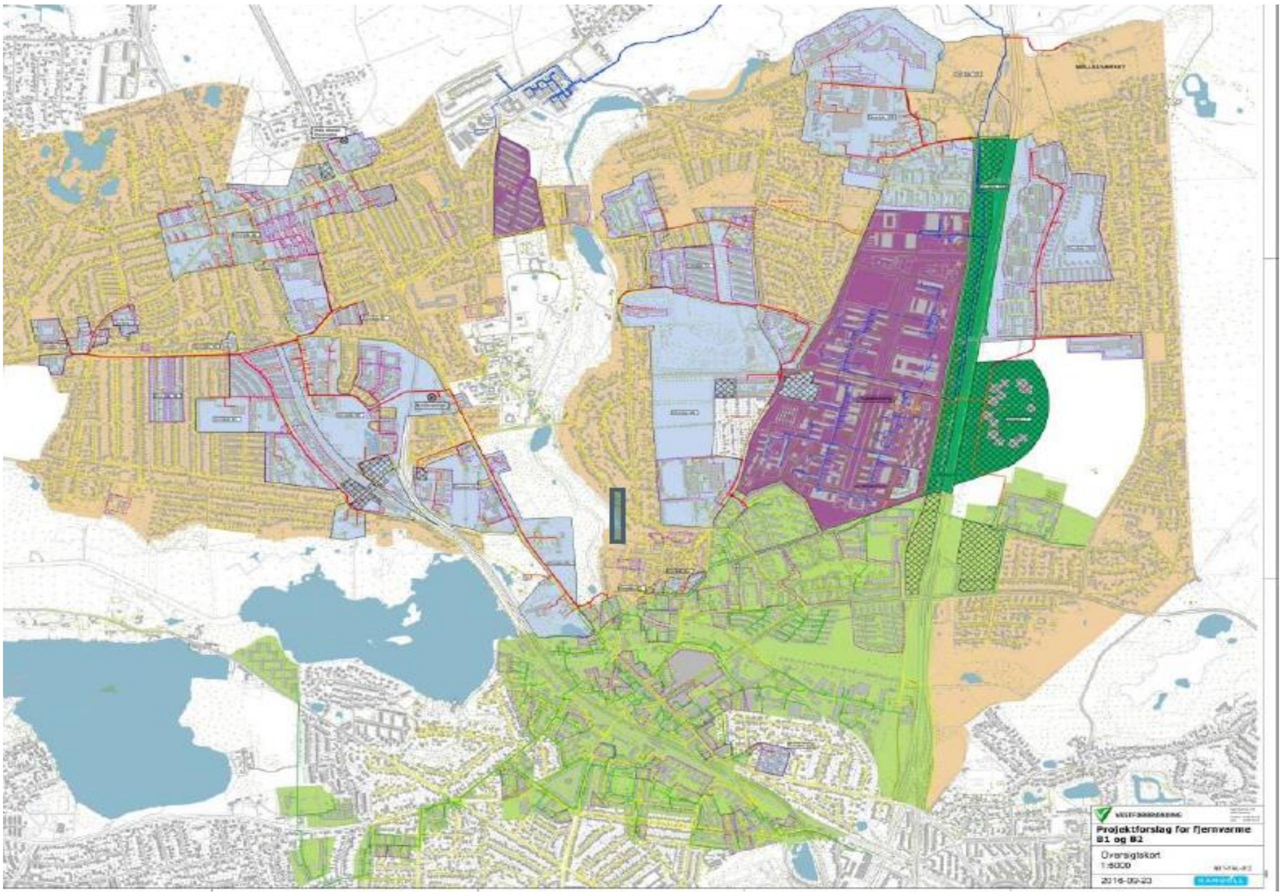


Fig. 5: From gas boilers to DH from Vestforbrænding in Lyngby-Taarbæk Municipality

In a recent study from EU, JRC [5], the district heating system in Greater Copenhagen, including Vestforbrænding is described as an interesting case to replicate.

## 7 REFERENCES

[1] Varmeplan Danmark 2010
http://www.danskfjernvarme.dk/viden-om/f-u-konto-subsection/rapporter/2010-02-varmeplan-danmark-2010

[2] Køleplan Danmark, April 2016
http://www.ramboll.dk/projects/rdk/koleplan-afslorer-10-mia-kroners-besparelse

[3] Strategisk energiplan for Favrholm, Hillerød Municipality, December 2016
http://www.favrholm.dk/nyheder/nyheder/strategisk-energiplan/

[4] Strategisk energiplan for Lyngby-Taarbæk Kommune, June 2013
http://www.ltk.dk/sites/default/files/uploads/public/user_uploads/CMP/Byggesag/strategisk_energiplan_2013.pdf

[5] Efficient district heating and cooling systems in the EU, JRC, December 2016
https://ec.europa.eu/jrc/en/publication/efficient-district-heating-and-cooling-markets-eu-case-studies-analysis-replicable-key-success

## 8 CONCLUSION

Campus owners and local authorities, who serve the interest of the land-owners and residents can benefit from energy planning, in which we can identify the most cost-effective and sustainable energy solutions for low carbon communities. Due to economy of scale and the ability to store the fluctuating renewable energy as if it was a battery, DH&C often turns out to be the most cost-effective solution compared to individual building level solutions. The implementation is not a problem for the campus owner, who owns all buildings or controls the land-use. For the local community, serving the interest of many stakeholders, it is possible to demonstrate the total benefit for all and how it could be divided on all stakeholders, but often a challenge to implement, as the major stakeholders have to agree on how to share the benefit.

Name: Anders
Surname: Dyrelund
Institute, company, organisation: Ramboll
Key activities: Energy planning
Miscellaneous: Has been working with energy planning since 1979

Name: Thomas
Surname: Rønn
Institute, company, organisation: Ramboll
Key activities: Energy planning