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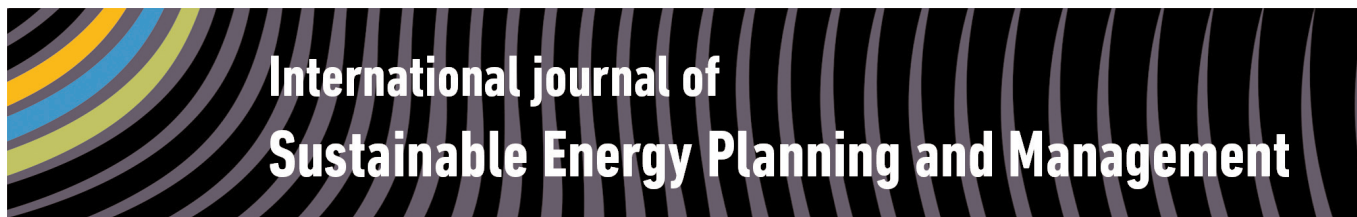
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## Barriers and Potential Solutions for Energy Renovation of Buildings in Denmark

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### ABSTRACT

Buildings account for a substantial part of the total energy consumption. In Denmark this number is about 40 % and this is approximately the same in most industrial countries. On this background there is an urgent need to develop strategies for reducing the energy demand in the building sector. Renovation of existing buildings must have high priority as houses often last for 50 to 100 years, while the time perspective for the desired transformation to low-energy houses is less than 30 years in order to mitigate global warming and avoid irreversible tipping-points.

The only sustainable energy supply in the perspective of centuries is *renewable energy* provided by the sun and exploited in the form of solar heat, solar electricity (PVs), wind power, hydro power, wave power, and some types of biomass etc. A future dominating role of intermittent renewable sources requires new integrated systems thinking on both the supply and demand side for heat, electricity and transport. Implementing such Smart Energy Systems requires integrated strategic energy planning on the national and local level. With the fundamental changes in the energy supply technologies expected during the coming years, it is important to synchronize investments in energy conservation measures with investments in the supply side, in order to avoid overinvestment in supply systems and thus to minimize the total costs of the transformation to Smart Energy Systems.

This paper highlights some of the most important barriers for renovation of existing buildings in Denmark and points to policies for overcoming these barriers. Some of the policies have been presented in the reports of a recent Danish research project (CEESA).

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### Keywords:

Building renovation;  
Energy Savings,  
Renewable Energy Systems,  
Policy Means,  
Synchronization of supply and demand

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### 1. Introduction

The progress of international negotiations on mitigation of climate change due to global warming has been slow, insufficient and hampered by controversies between industrial and developing countries. At the same time, there is an urgent need for fast emission reductions of CO<sub>2</sub> and other greenhouse gases (GHGs) in order to avoid the so-called tipping-points.

The most important contribution to man-made GHGs is due to combustion of fossil fuels. Thus, the energy

sector has a central role for mitigation of climate change. The only long-term sustainable solution involves a transition to an energy supply system based on renewable energy sources (RES) like solar, wind, hydro, waves and some types of biomass - combined with energy conservation. Although research shows that it is technically possible and economically viable to make such a transition [2–4], there are a number of serious barriers for this transition including vested interests and lock-in to traditional energy supply

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systems based on fossil fuels. Thus, it is important to develop professional and realistic scenarios that demonstrate that this transition is both technologically possible and positive for the societal economy. This should be combined with policy scenarios describing efficient policy means for the implementation of the most feasible technological scenarios from a socio-economic and environmental perspective.

Both technical and policy scenarios will differ from region to region, depending on climate, consumption patterns, and present legislation and market conditions. The Danish case below exemplifies a general methodology, underlining the importance of concrete technical scenarios linked to concrete policy scenarios.

The Danish project “Coherent Energy and Environmental System Analysis” (CEESA) [5] is a recent example of an integrated analysis using this general methodology to describe the phasing out all fossil fuels in Denmark before 2050.

In the spring of 2012 a broad majority in the Danish parliament agreed on short term goals for such a transition towards 2020 focusing on expanding wind power to 50% of the electricity supply, expanding the use of biomass in CHP plants (Combined Heat and Power) as well as increasing the ambitions regarding energy savings in general [6]. This political agreement is an important part of realising the phase-out of fossil fuels by 2050. A special feature of the CEESA project is its focus on policy instruments for realizing the proposed transition including significant changes in principles of market regulation, tax systems, planning methods and priorities, and institutional structures. The transition will hardly be realized in time without such policy changes.

There is an overall need to look at the policy and planning framework in a strategic energy planning context if 100% renewable energy systems are to be implemented locally and nationally [7, 8]. In this paper, however, the focus is on the building sector. The potential for energy savings in this sector have been analysed in recent Danish reports. The report by the Danish building research institution SBI [9] on renovation of existing Danish buildings has provided useful background material for the present paper. Assessment of future heat supply technologies in a renewable energy system context has been presented in [10,11]: The main focus in the present paper is on the barriers and solutions for the technical and economic realisation of the desired changes in the Danish building

sector. The building stock accounts for about 40% of total final energy consumption in Denmark and about 55% of the final heat consumption goes to one-family houses. Similar analyses have been carried out in Germany taking into account the special German conditions [12,13]. Recently, analyses of the European energy system have also shown that there are large benefits from heat savings – also from an energy system perspective [14]. The efficient policy means are, however, dependent on local conditions including climate and political traditions. For this reason, our paper is focusing on the special technical as well as institutional conditions in the Danish building sector. The case study illustrates the general statement that both the technical and institutional solutions are available and may be designed to solve the problems by detailed analyses. It can be learned from the CEESA project that both “god” and the “devil” is in the detail, and that it consequently is necessary to analyse the technical and institutional details at an adequate level of aggregation. Thus, it is not sufficient to rely on a general CO<sub>2</sub> tax, or a CO<sub>2</sub> trading system to secure the needed transformation of the energy system.

Building technologies have now been developed that can reduce the consumption of heat per m<sup>2</sup> by more than a factor of 10 compared to the existing stock of buildings. This is demonstrated by the so-called “passive houses” which have been promoted in recent years especially in Austria and Germany. As most new buildings are supposed to last 50 years or more, one should accelerate strengthening of national building codes for new houses to “passive house standards”. However, this will not solve the urgent problem of reducing energy consumption in buildings due to the long turn-around time in the building sector. Historically there has been no net-decrease of energy consumption in the Danish building sector as the building area has been growing in the last 40 years by about 1% per year. If we assume the same growth in the future we will have a situation with a building stock in Denmark by 2050 that will consist of around 70%–80% of to-day’s buildings, and around 20%–30% new buildings. For this reason, the focus of this paper is on renovation of the existing buildings.

As basic building renovation such as better insulated walls, roofs, floors, windows etc. will last for 40–60 years, one should make sure that renovation standards as well as incentive systems should be strengthened compared to present standard requirements and energy

conservation incentives in 2014. This is also important in order to avoid overinvestments in supply systems and to synchronize house improvements with investments in new supply technologies such as low temperature district heating, individual heat pumps, solar heat collectors and PVs.

## 2. Historical development of energy intensity in Danish buildings

In Denmark the total heat demand per m<sup>2</sup> per year has been decreased by 35% since 1980, see figure 1. The reduction over time has mainly been due to extra insulation in old buildings and less energy intensity in new buildings. The strongest reductions were obtained in the period from 1979 to 1985 promoted by the two jumps in oil price and a systematic Danish heat planning and energy conservation policy. Heat planning was introduced in 1979, and it was mandatory for municipalities to establish a heat plan in accordance with specific rules given by the Ministry of Energy. In addition to this a heat energy conservation policy was introduced based on a “stick and carrot” principle with high taxes on oil, the establishment of a network of registered energy consultants and relatively high (30%–50%) subsidies for investments in energy conservation. The procedure was that a house or flat owner would contact one of the registered energy consultants, who then would examine the house and make an energy report, indicating the most economic

energy conservation measures and the total costs of an economically feasible set of investments. Based on the recommendations in this energy report, the house owner would then, in a non-bureaucratic process apply for a 30%–50% investment subsidy. In order to cope with a potential energy poverty problem, 50% subsidy was reserved for low-income pensioners with high heating bills. This incentive system was a success, and resulted in a fast reduction in energy consumption per m<sup>2</sup>.

After 1986 the oil price fell from approx. 70 to 25 US \$ per barrel, and remained at that level until the mid-nineties. The oil price reduction was partly counterbalanced by higher oil tax, and the price reductions proceeded at a slower pace. This high tax policy on oil and electricity was purposely implemented in order to continue the energy savings, as the political system assumed that low oil prices was not a permanent situation and wanted to prepare the energy consumption and costs for future increases in fuel prices. This energy demand reduction has been rather slow in the last ten years. Although the energy conservation efforts still has an effect due to continued larger insulation rates and requirements for new energy buildings energy demand, the total end heat demand has increased and the savings have been found in a higher efficiency reducing local losses by replacing oil boilers with district heating and more efficient natural gas boilers, see details in Fig.1. The supply system has also changed and the amount of primary energy for heating per living area has decreased and the fuel demand has also decreased, mainly due to

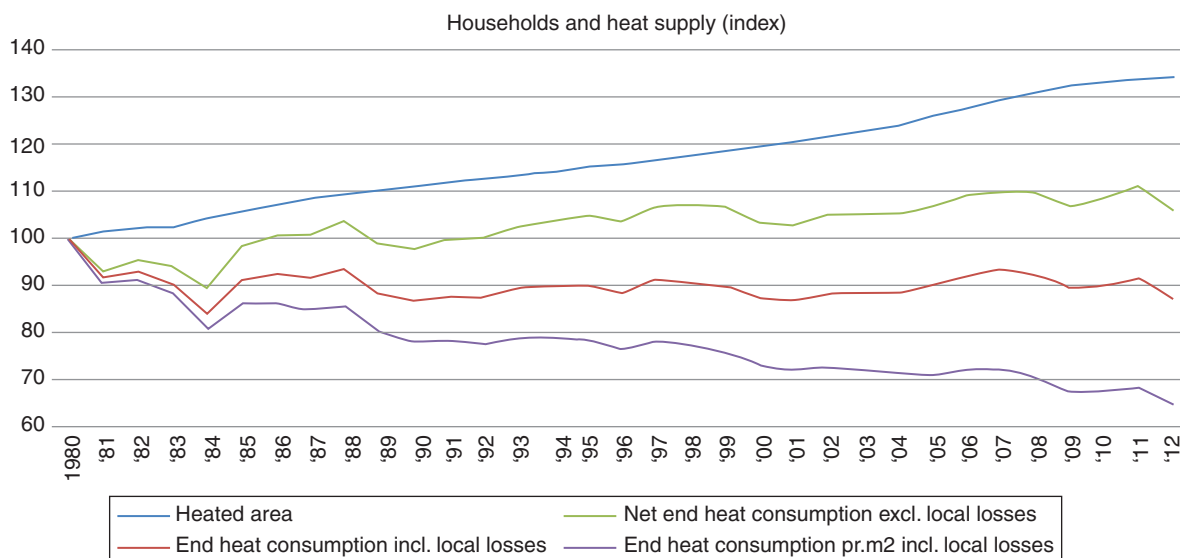


Figure 1: Indexed developments in the end heat demands and local losses in the heating sector [15].

combined heat and power production and the expansion of district heating. However, the total energy consumption in the Danish housing sector has been increasing during the last 20 years due to an increasing living area per person. The relative decrease in intensity can be accredited to initial insulation subsidies and information campaigns and in the later years mostly levies and information campaigns.

### 3. Present Danish policies for energy savings in buildings

The Danish government has proposed a number of policies to reduce the heating demand. The most important in addition to increased levies and energy prices are:

- Maximum U-values for single building elements in connection with renovation (e.g. in relation to windows). The U-values must be consistent with the regulations for new buildings.
- When more than 25 % of a building is renovated, then the total building after renovation must fulfil the regulations for new buildings.
- Demand for energy labelling of houses when sold or rented as well as regularly if the building is above 1.000 m<sup>2</sup>.
- Demand for maintenance of oil boilers and large ventilation units.

In addition, campaigns promoting energy savings have been carried out for decades, e.g. by the Danish Electricity Savings Fund promoting more efficient household appliances and circulation pumps etc. This has resulted in a shift to more energy efficient equipment and less direct electric heating. The Electricity Savings Fund was replaced in 2011 by an Energy Saving Unit in the Danish Energy Agency, but has now been replaced by general information activities from the Agency towards end consumers and the building sector as such. It remains to be seen whether this change will give rise to an overall improved promotion of less energy intensive equipment.

Furthermore a general system has been introduced, where the energy supply companies are obliged to promote energy conservation among their customers. This system has worked with regard to energy conservation in public and private companies, but has not given sufficient incentives to generate the desired heat conservation in private households at this stage.

It can be concluded that the above policies have so far *not* resulted in significant reductions in the energy consumption of the building sector. Small reductions have been observed in the heating sector while the electricity consumption has increased slightly. This is explained by a higher level of comfort, more energy consuming equipment with higher user intensity and more square meters.

### 4. Potential for energy conservation in existing Danish buildings

According to the report “*Policy Means for Promotion of Energy Conservation in Buildings*” [9] from the Danish Building Research Institute, the potential for heat and electricity conservation in existing Danish buildings based on pay-back times in accordance with traditional principles for 20 or 30 year loans is estimated as follows:

Improved insulation: 31 PJ/y in private houses and 6 PJ/y in commercial buildings.

Renovation of installations: 21 PJ/y in private houses and 3 PJ/y in commercial buildings

Total estimated savings are 61 PJ/y corresponding to 30% of the present consumption (203 PJ/y).

It therefore is a problem that the present incentive system does not seem to address the private households in an efficient way.

The report [9] points out that this is a conservative estimate, and that a more detailed analysis leads to higher numbers: 68 PJ/y for heat and 19 PJ/y for electricity.

Investments in renovation of private houses may be based on a number of different considerations other than mitigation of global warming and conservation of energy.

The report also lists a number of investor considerations that are negative in relation to energy renovation [9] e.g.:

- *Too long pay-back times.*
- *Free money is reserved for other purposes, e.g. a modern kitchen, larger panorama windows, a new organisation of rooms etc.*
- *Better wait until a major renovation is necessary.*
- *Private comfort is disturbed during renovations.*
- *Lack of detailed knowledge concerning economic and comfort advantages of energy renovations.*
- *Major renovations may harm the original architecture.*



## 5. Lock-in to old tariff systems

About 60% of the heat demand to Danish households is supplied by co-generation plants and district heating systems. The tariff schemes of these heat suppliers have a significant influence on the promotion of energy conservation in private households. Unfortunately, the present tariff systems are mostly a barrier against the desired energy conservation due to a relatively high fixed part of the heat tariff. This is discussed in the following.

The district heating companies have tariffs with a different but often very high fixed share. This is

illustrated in Figure 2. The figure shows that in some parts of Copenhagen, the fixed share of the total heat bill is between 50% and 62%.

Table 1 shows that in Tårnby, Brøndbyvester and Gentofte, where the fixed tariff is relatively high, it only pays to invest around 12,000 DKK (1,600 €) for a reduction in heat consumption of 25%. 15 years loans on average is realistic with the present situation at the housing market, with low prices, and also reduced possibilities for getting long term loans. If we had calculated with 30 years loans, it would pay to invest up to 17,000 DKK (2,270 €). At the same time empirical data show that on average a 25% reduction will cost

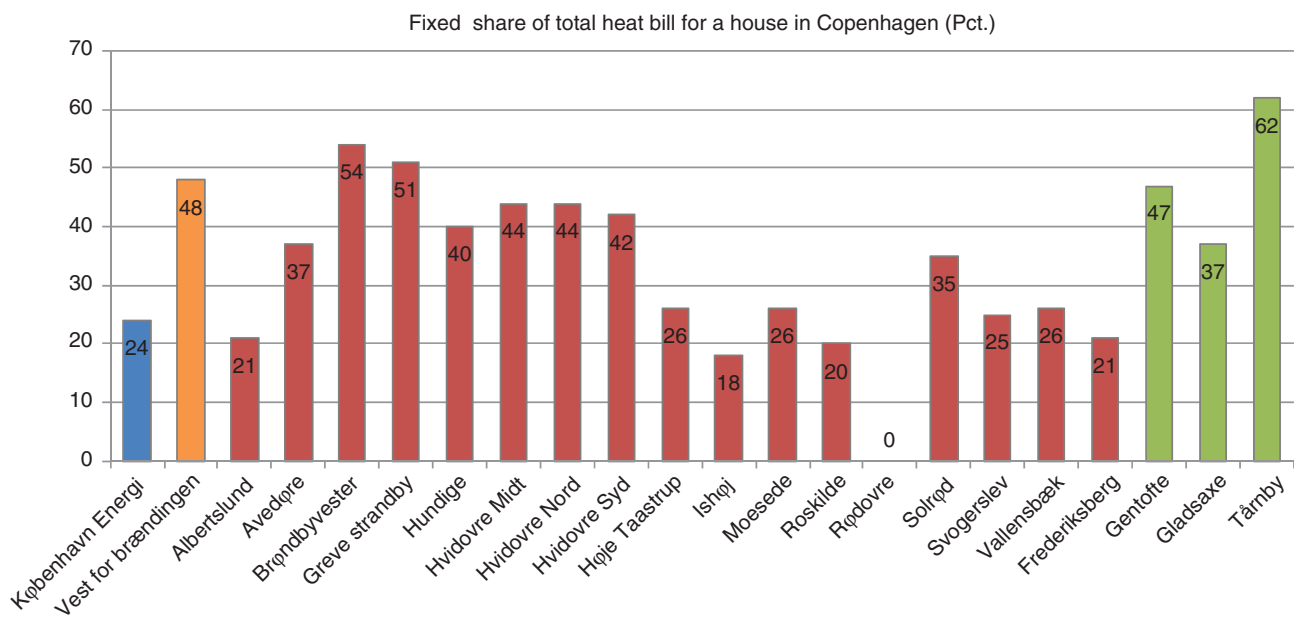


Figure 2: Fixed share of total heat bill for a house in Copenhagen [16].

Table 1: Break even investment for 25% reduction in heat consumption per m<sup>2</sup> in parts of Copenhagen with 15 years loans (1 € equals 7.45 DKK) [17].

	Annual heat payment DKK	Annual variable payment DKK	Annual saving in case of 25% house improvements DKK	Break even investment (6% discount rate/15 year lifetime-25% house improvement.
Tårnby	13.000	<b>4.949</b> (38%)	1.235	<b>11.994</b>
Gentofte	10.000	<b>5.300</b> (53%)	1.325	<b>12.868</b>
Albertslund	13.800	<b>10.902</b> (79%)	2.725	<b>26.465</b>
København Energi	13.500	<b>10.260</b> (76%)	2.565	<b>24.911</b>
Brøndby Vester	10.000	<b>4.600</b> (46%)	1.150	<b>11.169</b>
Frederiksberg	10.000	<b>7.900</b> (79%)	1.975	<b>19.181</b>

around 30,000 DKK. (4,000 €), when implemented as a part of house renovation. And more than the double, if 50% reduction of heat demand per m<sup>2</sup> is required. In this case only Albertslund is close to have tariffs, where it pays to invest in 25% heat reductions. The tariff situation in other district heating cities is very similar to the average situation in Copenhagen.

Although it pays, from a societal point of view, to reduce heat consumption per m<sup>2</sup> up to 50%, this will not happen if people react economically on the present tariff conditions. As a consequence, it is proposed in the CEESA project to abolish the fixed part of the heat tariffs.

## 6. Policy recommendations

It is important to underline that according to the calculations in the CEESA project it is necessary to implement efficient energy conservation measures. And to make sure that these are implemented in time, both in order to avoid overinvestment in the supply side of the energy system, and in order to synchronize the conservation measures with the design of the supply side energy system.

This balance between investment in the supply side and the conservation side is essential for the whole transition towards a lower demand and better supply system. It is also very difficult to achieve, as it requires the introduction of a set of coordinated and concrete policy measures. The list below are examples from the Danish case, giving the general message that concrete policies are necessary, but that they should be designed to the concrete institutional setting of a specific region. One cannot expect that a general CO<sub>2</sub> trading system will give sufficient energy conservation incentives. It should always be supplemented by policy measures that give incentives in the concrete setting of the concrete region to be dealt with.

A number of proposals for policy means in the Danish institutional setting are listed in [6 and 9] and additional proposals based on the CEESA project are included in the following:

1. In the district heating systems, tariff systems with a high fixed share should be changed to 100% variable tariffs or close to 100%. This will on the average increase the annual savings of a given energy conservation investment by around 40%, which in district heating systems is more than 10 times the effect of a CO<sub>2</sub> price per ton of 20 €.

2. An incentive system consisting of energy consultants, energy reports and investment subsidies should be introduced. This is necessary as the present system with an annual supply company conservation obligation does not work sufficiently efficient on 80% of the heat conservation potential located at the household level. The current tax deductions for house renovation should have a stronger focus on energy savings and should be combined with other incentives.
3. A financial reform could consist of:
  - a. Long term low interest loans should be made possible for house renovation according to the recommendations in the energy report from the energy consultant.
  - b. Public guaranties should be supplied for loans in energy conservations that have been recommended in the energy report.
  - c. Heat consumers should have incentives to shift to low temperature district heating networks where possible, in order to be able to integrate the intermittent Renewable Energy Sources or where district heating is not an option to invest in geothermal heat pumps.
  - d. A system of investment subsidies should be established. For instance with 15% in subsidies the next 3 years. After that 10% in 3 years, and then no subsidy.
  - e. Expenses linked to the points a, b, c, d, should be paid by the heat supply utilities and should not be paid by the state through taxes.
  - f. Green building tax graduated in accordance with the energy intensity of the house.
  - g. Labelling of energy intensity of all houses could be the basis for green building taxes.
  - h. Introduction of a new scheme where old houses unsuited for an efficient total renovation are demolished.

*Graduated green building tax (cf. f above):* This scheme could be combined with the proposed labelling of energy intensity (cf. g. above). A

short-cut may be to register the total consumption of heat and electricity in the house and divide it with the area of the house to obtain a measure of energy intensity. A strong tax graduation could have a substantial positive influence on new investments for energy efficiency in old buildings. A social problem is related to “energy poverty” where low income households live in apartments and houses with relatively high energy intensity. This may be compensated by other policy means, but could complicate the scheme.

*Labelling of energy intensity (cf. g. above):* This scheme should include proposals for relevant reductions in energy intensity as a support for new investments. Such a scheme has now been introduced by the Danish Government.

*Investment subsidies (cf. d. above):* This scheme will need a precise description of the requirements to obtain the investment subsidy. This is made by the energy consultants. This may include a condition that the renovation must move the house a specified number of places up on the scale of energy efficient houses. This scheme has partly been introduced by the Danish Government, as tax deductions can be obtained for costs of labour in energy renovations of buildings.

*Replacement by a passive house (cf. h. above):* This scheme needs further investigation in order to evaluate the potential for replacement of old houses by passive houses and to evaluate the investment subsidy necessary to activate the house owners. Other practical questions include housing of the owner during the building period. It should be pointed out, that even these policy measures may turn out to result in too low energy reductions. In that case, the Danish government may consider to introduce stronger policy means such as e.g. the so-called Personal Carbon Allowance scheme [18] or other means.

## 7. Conclusions

In most industrial countries heating and electricity of buildings account for about 40 % of the total energy consumption. Especially the heating part can be drastically reduced in new low energy buildings. The main problem is that existing buildings have a lifetime

of 50 to 100 years while mitigation of global warming implies much shorter reduction times for the consumption of fossil fuels. As a consequence, renovation of existing buildings is an important part of the mitigation strategy.

Experience from Denmark and other industrial countries have shown that present policies for renovation of buildings are too slow and inefficient in comparison to the potential for energy savings in existing buildings. The Danish CEESA project and other Danish analyses have pointed to a number of barriers in the existing tax and tariff systems and have proposed new policy means.

It is estimated that the proposed policy means in this paper should be able to reduce energy consumption in existing Danish buildings by more than 40%.

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