Title: Why has the level of household energy consumption stopped increasing in Norway - and how to make it decrease?

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Author: Professor Carlo Aall, Western Norway Research Institute, caa@vestforsk.no, + 47 991 27 222

Abstract

In a research project commissioned by the Norwegian Water Resources and Energy Directorate (NVE), Vestlandsforskning has (1) compiled available knowledge to shed light on changes in stationary energy use among Norwegian households; (2) analyzed possible causes for the levelling out of energy use among Norwegian households since 1990, and (3) developed a mathematical model to (a) generate a historical, utilization based data set on the distribution of energy spent within the households, and (b) to create scenarios regarding the development of energy use in Norwegian households over the next 20 years. The main findings of the project are: (1) Sources of data on the drivers behind energy use in Norwegian households have been found to be unsatisfactory; (2) New insights into plausible causes for changes in energy use among Norwegian households have been gained; (3) New assessments of the distribution of electricity use for different purposes in Norwegian households have been made; and (4) A scenario model has been developed as a reference for debates on future energy use and potential for energy saving in Norwegian households.

Introduction

The study was initiated as a response to an unsuspected development in the use of energy among Norwegian households over the last 20 years (Hille et al 2012). In 1990, it was generally assumed that the increase seen since 1945 would continue. As recently as 1998, in the report 'Energi- og kraftbalansen mot år 2020' ('The power balance toward 2020'; NOU 1998:11), a public committee presented an expected scenario where the increase in electricity use among the households would arrive at 9 TWh (terawatt hours)/year (25%) from 1996 to 2009, compounded by a slight increase in the use of firewood and a fairly level use of heating oil. In reality, the level of energy use among households remained flat from 1996 to 2009, despite the fact that population growth rate and consumer spending had seen a somewhat higher increase than predicted in the scenario 'Stø kurs' ('Unchanged direction'; NOU 1008:11). The hands-on point of departure for the project is represented in the figure below, depicting developments in energy use among Norwegian households. Of particular interest to the NVE was the dip in total energy use (the blue graph) showing up near 1990. The NVE had also requested the development of a mathematical model capable of suggesting future changes in energy use.

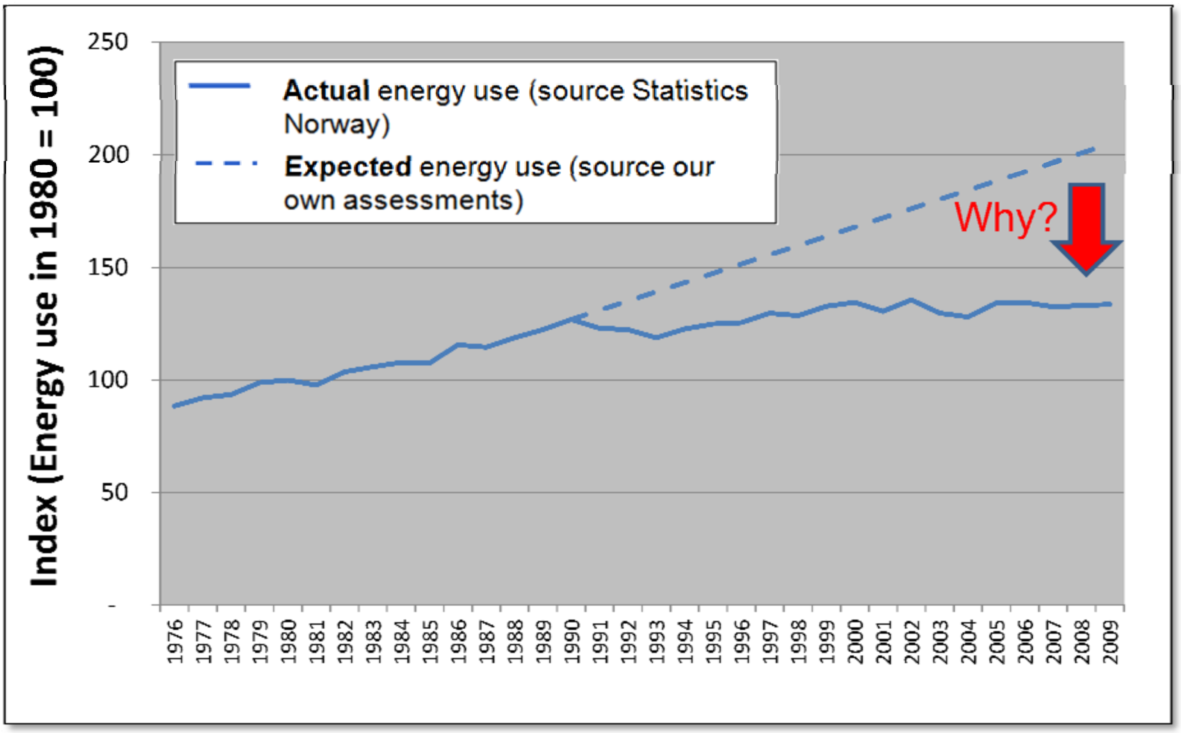

Figure 1 *The relative development of stationary energy use in Norwegian households 1976-2009, indexed by 1980 = 100 (Hille et al 2012)*

Research design in the Norwegian study

The first task in our study was to development of *a causal model* demonstrating how energy use is influenced by physical conditions (direct drivers) and underlying social factors (indirect drivers). The following *direct* drivers were identified and calculated:

- Living area
- The distribution of dwellings and living area according to types of building
- The condition of the building envelope
- Indoor temperature
- Water heating specific energy consumption
- Energy consumption relating to lighting and electrical equipment
- Choice of heating system
- Heat pumps

The following *indirect* drivers were identified, discussed and, to some degree, measured:

- Changes in environmental conditions (mainly outdoor temperature)
- Demographic change
- Economic considerations
- Technological development
- Changes as to knowledge, attitude and preference

The following *response* drivers were identified and the mechanisms in which they could influence on the direct and indirect drivers were discussed and assessed:

- Information
- Taxation
- Regulations
- Economic support

Our second task was to develop a calculation model which should serve two purposes: (1) Interpolate the to some extent sporadic historic data on energy-use available in order to establish a proxy complete historic dataset, and (2) allow for presenting future historic scenarios.

Our calculation model rests on Statistics Norway (SSB) and their prognoses for population change towards 2030. Our model incorporates a range of requirements enabling the user to select development rate (per cent change) and development type (linear, exponential or stepwise change) for a number of factors. The factors apply to area (total area, area by residence type or distribution of area among different residence types) and energy use (kWh/m²). The user can modify requirements for future development relative to the following factors:

- Housing (area, residents, and numbers – overall, and distributed among types of residence)
- Specific energy use, waste heat and technological development of major appliances, lighting, technical operations, electronic devices and water heating
- Ambient heat (distribution between type of residence and technological development)
- Choice of energy carrier for heating
- Gross heat demand (distribution between type of residence and technological development)

It is important to notice that it is possible, in principle, to generate two different projections or scenarios: Single or multiple factor analyses. In the former case, the intention has been to demonstrate how changes to one requirement can affect overall energy use. In the latter case it is possible to demonstrate how changes to several requirements can affect overall energy use. The latter approach can also be utilized to generate what the user would regard as the most likely development, and thus in principle to generate a prognosis, or to depict, for instance, how different political measures may turn out – an approach normally associated with creating scenarios in public political development and planning.

Direct explanations to the levelling out of energy use from 1990 to 2009

Our analyses show that the total, temperature adjusted energy use in Norwegian year-round residences increased by 3 % during 1990-2009 from 42,2 to 44,9 TWh (terrawatt hours), while the energy use during the previous 20 year period (1970-1990) increased by 55 %. If the development in energy use for the period 1990-2009 had followed the trend of 1970-1990, the energy use in 2009 should have been 73 TWh. Thus, we need to explain the reasons why we have experienced a reduction by 30,8 TWh (42 %) in relation to the expected trend in energy use. The figure below sums up the main findings relating to the explanation of this change; namely: (1) A slower increase in per capita living area relating to 55 % of the total reduction from 73 TWh to 42,2 TWh; (2) reduced energy use per m² (relating to 37 % of this reduction); and (3) a milder climate since 1980 (relating to 9 % of the reduction; a contributing factor comparable to the significant transition to heat pumps occurring in Norwegian households at the same period).

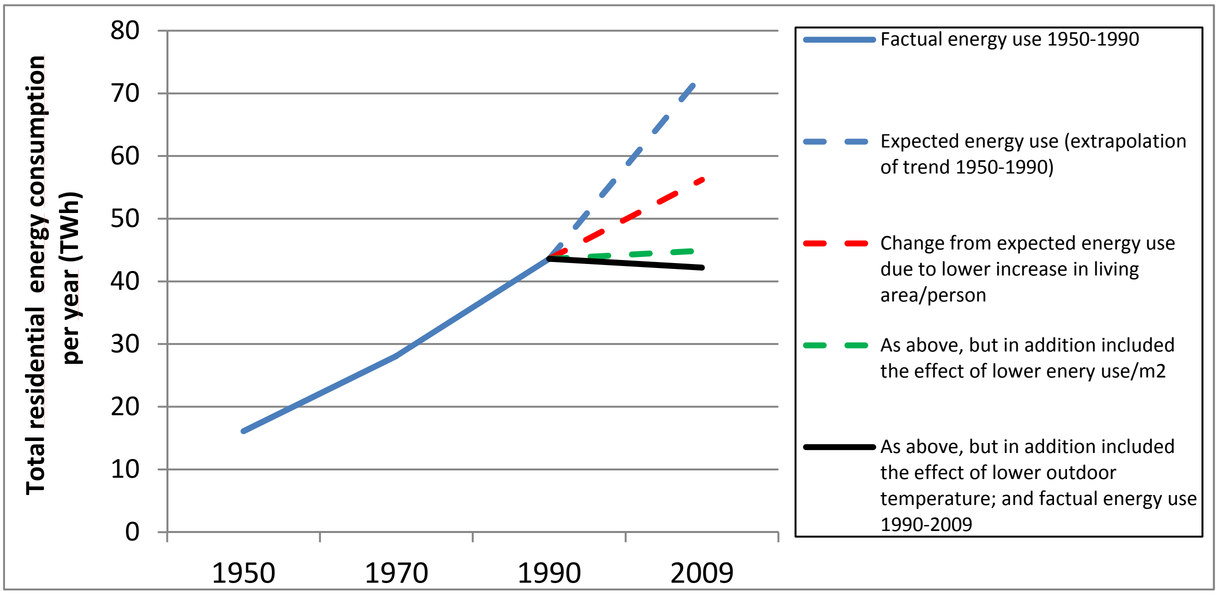

Figure 2 *The main explanations for the difference between observed and trend in total domestic energy-use in Norwegian households in 2009 (Hille et al 2012)*

The *first* explanation involves changes in per capita living area (cf. figure 3). Our analyses document a markedly slower increase in per capita living area in the years following 1990, compared to the previous decade. If per capita living area in 1990-2009 had seen a growth rate similar to 1970-1990, the total living area in 2009 would have ended up at 350 million m², or 36 % larger than it actually is. Even considering the higher energy efficiency of newly built houses, the estimated energy use in the households would have been 25 % higher than de facto 2009 figures. Thus the slower increase in per-capita living area is the most significant of all the factors contributing to the levelling out of the graph representing energy use in the households.

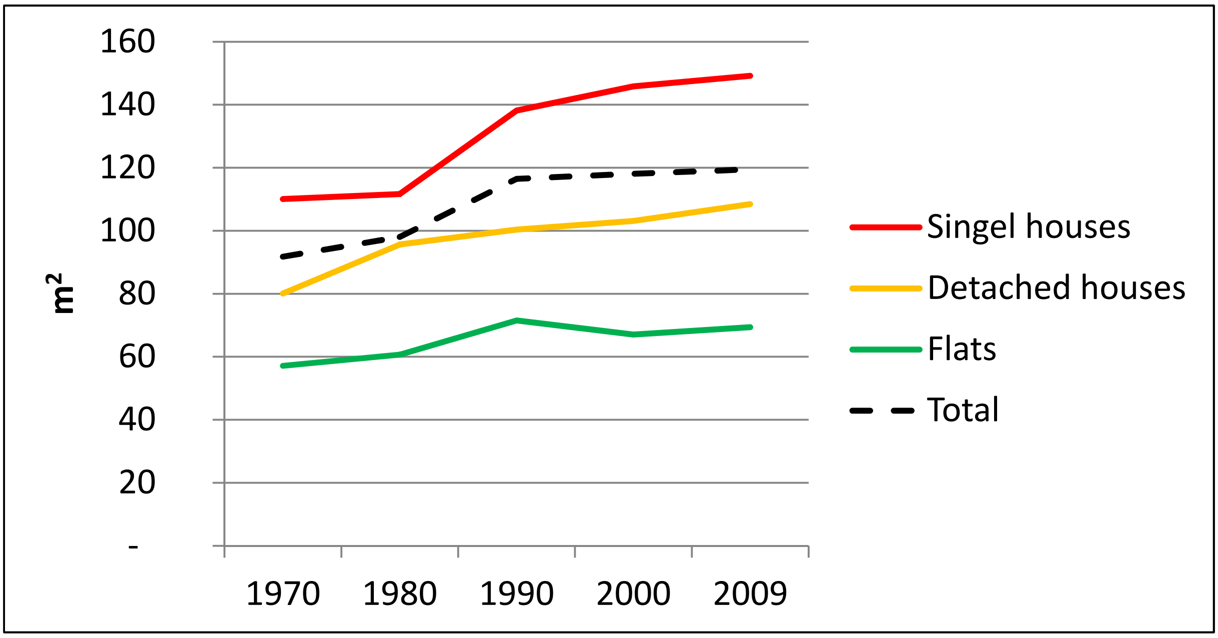

Figure 3 *Changes in average annual size of newly built houses in Norway 1970-2009 (Hille et al 2012)*

The *second* explanation involves changes in energy use per m² (cf. figure 6 and 7). The figures below show how changes within a selection of energy end-use areas have occurred during 1990-2009.

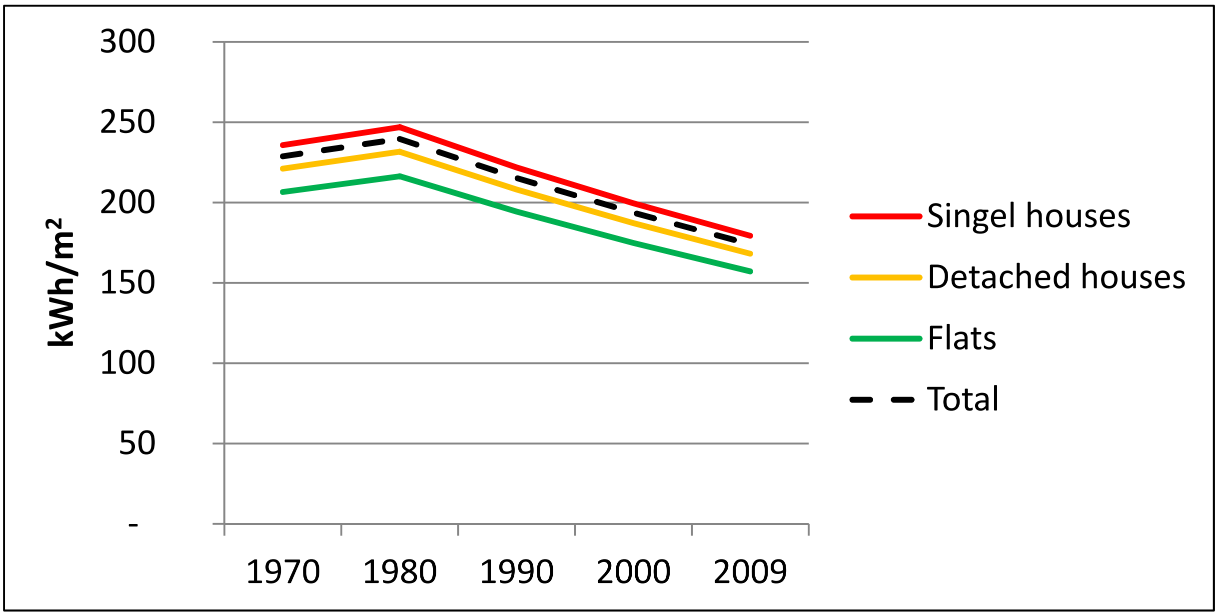

Figure 4 *Changes in energy-use per m² for energy-use in Norwegian households 1970.2009 (Hille et al 2012)*

Figure 5 illustrates more specific how energy-use per m² has changed from 1990 to 2009. These areas of changes in energy-use, when added up, constitute a total reduction equivalent to 41 kWh/m²/year. The gray section of the graphs represents the margin of uncertainty in our estimates, indicating the possibility that data may be combined in several ways to reach an accurate explanation.

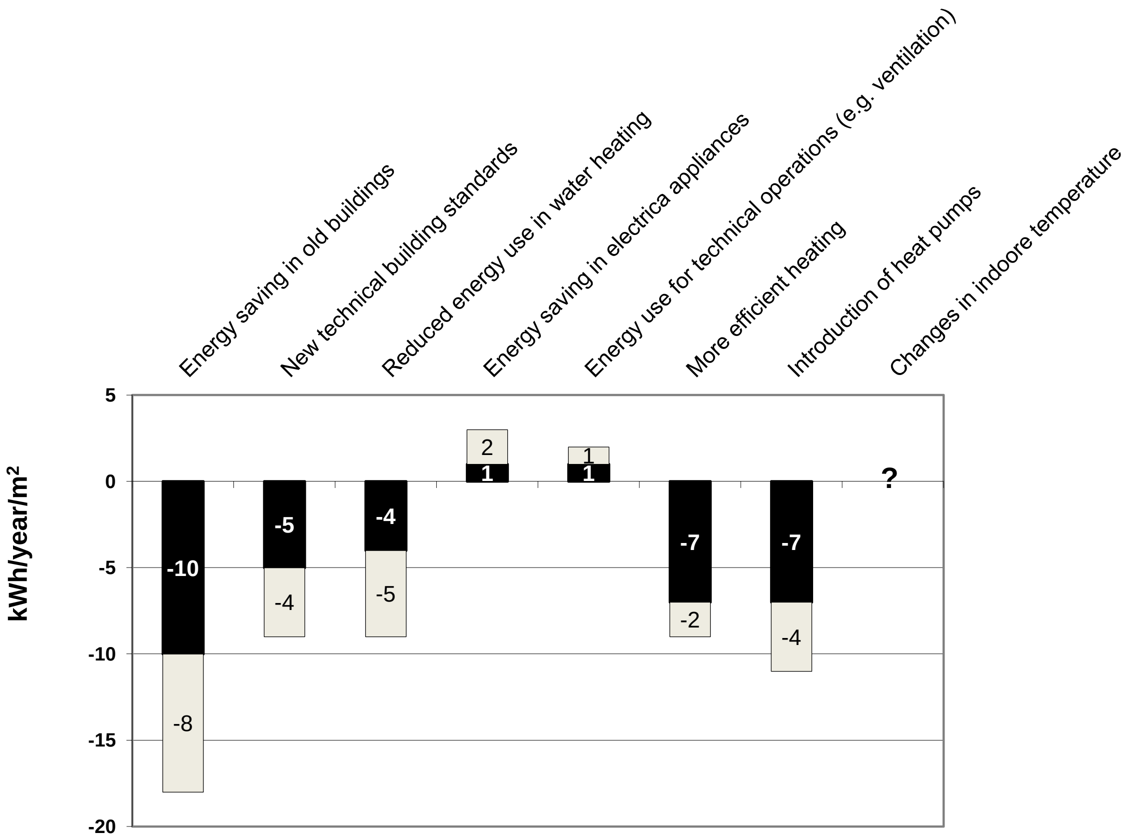

Figure 5 *Upper (gray) and lower (black) range for estimated contributions in total reduction of energy use of 41 kWh/year/ m² from 1990 to 2009 in Norwegian households (Hille et al 2012)*

The most critical factor is incremental energy saving measures (as opposed to complete renovation) relating to improvements in the building envelope of older residences (façade, windows, roof and insulation). This is of particular interest as they are measures which have received limited attention of authorities, whose focus in recent years has been on public and commercial buildings. Moreover, to the degree attention has been directed towards private residential housing for this type of energy saving measures, it has been to the benefit of newer houses, through amendments to building regulations. As indicated in the figure, this has contributed to approximately half as much as incremental measures in older houses. On a shared second place are contributions from the implementation of heat pumps and a reduction in heat loss as a result of increased heating efficiency (mainly due to the phasing out of household furnaces). These are followed by the amended building regulations mentioned earlier, affecting new building projects and changes in water heating such as the introduction of water saving shower heads and a transition from manual dish-washing to the use of dishwashers (which heat water more efficiently). As for factors contributing to an increase in specific energy use, there is the issue of the growing number of electrical appliances, and an increased amount of energy-demanding technical operations in blocks of flats (elevators and ventilation systems).

We do not have sufficient data to determine whether indoor temperature has changed over time. Surveys abroad suggest an increase; if this turns out to be the case, several of the entries in the figure above would need somewhat higher values in order to compensate for the increased energy use that higher indoor temperatures would generate

Furthermore, our analyses show that there has been a decrease in specific energy use of 6-7 % compared to temperature adjusted energy use for the 1980's through 2000's period. This does not apply when considering the reduction between the specific years 1990 and 2009, as 1990 was an exceptionally mild year. It is important to note, however, when the starting point is a graph representing 30 years of actual energy use in households, that part of the levelling out is a result of increased outdoor temperatures. Six per cent of the specific energy use in Norwegian year-round residences corresponds to 10 kWh/m², an effect proportional to what heat pump implementation and changes in heating habits have had respectively since 1990.

When it comes to energy use in cottages, our analyses show that we have scant knowledge of the development. To the extent that anything specific can be said, our figures show that, contrary to what is the case with year-round housing, a marked increase has occurred in both overall and specific energy use. While in year-round residences the overall energy use not adjusted for temperature increased by 5 % from 1990 to 2009, the corresponding increase for cottages was 70 % (we did not have the data needed to provide numbers for the temperature adjusted energy use in cottages). The difference in electricity use was even greater; + 17 % for year-round residences, compared to + 142 % in the case of cottages. In 2009, energy use per year and m² was as high as 107 kWh for cottages, while it was 178 kWh for year-round residences within all categories; that is, merely 40 % lower, which is remarkable considering the comparably short amount of time one spends in cottages (somewhere in the range of 20-40 days per year). In 2009 energy use in cottages still only amounted to 6 % of the energy use of households; however, with the much higher growth rate for the energy use in cottages, this may become a substantial component in the energy balance of the future.

The underlying explanations to the levelling out of domestic energy use in Norwegian households from 1990 to 2009

As pointed out earlier, the most significant reason for the levelling out of energy use since 1990 is a slower increase in building size. Population growth has been substantial, particularly in the 2000's, and would, all other factors alike, have produced a higher increase in living area compared to the state of affairs from 1970 to 1990. The decrease in household size, however, is slower; i.e. the number of households does not increase at a significantly higher rate than the population. In 2001, the 'non-Western' immigrant population had access to a per capita living area which was

1/3 smaller than that of other Norwegians. The number of individuals belonging to immigrant groups from what used to be defined as non-Western countries increased from 99.000 by the end of 1990 to 415.000 by the end of 2009, constituting 52 % of population growth from 1990-2009, and as much as 61 % from 2001-2009. Consequently, this may be an essential partial explanation as to why per capita living area has had a markedly slower increase since 1990, and particularly since 2001, compared to earlier periods.

Also, the considerable increase in real estate prices and real interest rates contribute strongly as an explanation. Opting for that extra m^2 now comes at a much higher price than it did previously. In 2009 we inhabited an area per capita that was 2/3 larger than in 1973, but had to pay 7 times more for it (in constant currency). There is not much doubt that the expenses attached to residences has slowed down the increase in living area since 1990, although the importance of this influence, compared to demographic factors pointing in the same direction, and possible preference changes, can hardly be decided with certainty.

What then is the reason behind the decrease in specific energy use? The focus of previous studies is on the importance of prices as determining factors of energy use. The prices of electricity and oil were fairly stable throughout most of the 1990's, but have increased in the 2000's to a degree that will have taken many by surprise, including the committee behind NOU 2008:11, who in 'Stø kurs' ('Unchanged direction') conjectured that the price of electricity would remain unchanged until 2020. Increasing real prices on both oil and electricity will have been of some importance – stimulating energy efficient buildings, the phasing out of household furnaces, and the implementation of heat pumps. The increase in real prices is largely due to market forces and legislation priorities, rather than consumer taxes on energy goods. Financial support has barely had an effect – with one possible exception: While energy saving measures aimed at Norwegian households has been modest, a 2003 support initiative for air source heat pumps may have played an important role.

Access to improved technology has been of some importance. The relevant technologies in 1990 included energy saving light bulbs, water saving shower heads, heat pumps, solar water heating, and refrigeration devices which would have been eligible to receive a class A energy efficiency classification when the labelling system was introduced later in the 1990's. What became of these technologies in the subsequent 20 years speaks of the difficulties in making general statements regarding what we know are possible versus what will be implemented:

- In 2008, refrigerators and freezers of energy efficiency class A and higher had a market share of 84 %
- In 2009, there were water saving shower heads in 50 % of residences
- Heat pumps – the technology probably contributing the most to reducing energy use – had a negligible distribution up to 2001, but had been installed in 18,5 % of residences by 2009
- In 2006/2007, energy saving light bulbs still constituted a modest 13 % of light sources in Norwegian residences
- Solar water heating still has a negligible distribution

Regulations have contributed in some measure. New building requirements could explain 10-15 % of the reduction in specific energy use for all residences since 1990. Regulations to do with equipment inside the building have so far been of less importance, but are likely to contribute more following 2009.

We know rather little about the effect of changes in behaviour, in the sense that we do not know the extent to which behaviour has influenced development as a whole. What we do know, is that behavioural differences may have a great impact on an individual level. Energy use for certain categories of electrical equipment may see differences by a factor of 20 among otherwise equal households, and there may be differences in energy use for heating by a factor of 3. In the former case, the differences are explained primarily as extent of use; in the latter, primarily as a choice of room temperature.

Our analysis of the development in the 1990-2009 period indicated a probability that political decisions aiming to reduce energy use – i.e. the sum of revised building regulations in 1987 and 1997, other regulations, taxes, subsidies and information campaigns – provide an explanation only to a smaller part of the reduction in specific energy use occurring in the period. A great deal has been accomplished as a result of private initiatives, independent of regulations and without financial support. This includes the rather extensive number of renovations of older building envelopes - particularly those of detached houses; the replacing of hot water tanks; the installation of water saving shower heads, and a majority of changes involving a choice of energy carriers and heating solutions. Political decisions, too, may have had an effect on the greatly reduced increase rate for per capita living area since 1990. If this is the case, it would largely be as a non-intended consequence of decisions relating to topics other than changes in energy use (e.g. immigration politics and interest rate policy).

Which are the more important contributors ahead?

It is clear that the growth rate for living area will remain a significant factor when determining the energy-use of households in the next couple of decades. If the population is to increase as much towards 2030 as the SSB (Statistics Norway) estimates in its current, average projection (+27 % in the 2009-2030 period), and if the increase in per capita living area remains at 0,5 % per year, as it was in 1990-2009, it would entail an increase in living area by 40 %. Assuming a demolition rate of 0,1 % per year, and a strict adherence for new housing to existing building regulations as well as any future tightening of the same, total energy use could increase by 10 TWh. With an increase in per capita living area twice as high (1, 0 %), the total increase in energy use will be approximately 50 % higher. If we can avoid an increase in per capita living area altogether following 2009, total energy use will be approximately 30 % less. Freezing the average per capita living area so that it remains on a 2009 level would have an effect equal to introducing, as defined by Norsk Standard (Standards Norway), a passive house level energy efficiency (68 kWh/m²) for all new buildings after 2009, according to the calculations above.

As we have seen, specific energy use in year-round residences was reduced by 19 % from 1990 to 2009, a rather small part of which came as a result of new houses being built in the period. Is another one-quarter reduction of energy use towards 2030 viable for existing buildings, and if so, how? The ongoing transition to energy saving light bulbs will only contribute in a small way (1-2 %), and the potential for heat loss reductions is probably minimal as there is almost no remaining use of heating oil – and a reduction in the use of firewood is unlikely. The changes that may still contribute substantially are:

- Changes to water heating (transition to foam insulated hot water tanks, implementation of water saving shower heads among the remaining half of the population, installation of solar water heating, and heat recovery from drain water). - 10 %
- Continued transition to heat pumps: - 25 % (In which case much wood burning and adjacent heat loss would be replaced by heat pumps.)
- A continued upgrading of building envelopes: - 12-20 %
- Transition to more energy efficient electrical equipment (the largest potential probably lies with refrigeration devices and electronics). - 3 %

Throughout the last 20 years, owners of existing residences have carried out several efforts, voluntarily and without any support, to minimize energy use. One could infer from this that the positive development has its own momentum, with no need to implement particularly strong measures. On the other hand one could argue that as long as there is an interest among the public, supportive measures – economical, advisory, a combination of both of these, and possibly others – have great potential. In any case there is a probability that moving from the simple and inexpensive to the costly and more complex – from water saving shower heads to solar water heaters (to use an extreme example), from air source heat pumps to alternatives requiring a water based heating system, from economically viable efforts aimed at the building envelope to the rather more expensive; both advisory assistance and financial support could play a more decisive role in maintaining a heightened energy efficiency. This would require more comprehensive arrangements than the limited support available today for heat pumps and solar water heaters, which at least up to 2010 mainly seem to have found resonance with a group of people who are already interested enough to make the investment without any support.

References

Aall, C., Hille, J., Simonsen, M. (2012). *Houshold energy consumption in Norway 1990-2009 and beyond. Final report*. VF-report 13/2012. (in Norwegian) Accessible at http://www.vestforsk.no/filearchive/vf-rapport-13-2011-nve-energibruk-i-norske-husholdninger.pdf