Energy Statistics – Why do modern buildings in Norway consume more energy than expected?

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Abstract/summary
Enova is a state body and uses funding as a policy instrument. Programmes for commercial and public buildings are fundamental for the achievement of specific energy saving goals set by the Government. The paper presents selected analyses of annual energy statistics for the building sector, in the context of a national energy saving programme aimed at market transformation. This programme has been operative since 2002, and in 2005 approximately 1 000 buildings started up, with an annual budget of € 15 million in that year.

The paper focuses on selected data obtained through a Buildings Network established in 1996 and continued pursued by Enova from 2002. The paper also highlights differences in energy consumption for offices and other building types and five categories of energy end use applications. Furthermore the paper presents energy analyses of two modern office buildings in order to compare calculated versus metered energy use in these buildings.

Goals
Enova's mission is to contribute to rational and environmentally sound production and use of energy, relying on financial instruments and incentives to stimulate market players and on mechanisms to achieve national energy policy goals. Enova SF is a state enterprise owned by the Norwegian Ministry of Petroleum and Energy. Enova's objectives, adopted by the Storting (Norway's Parliament) were originally:

- To limit energy use substantially more than if current trends are allowed to continue unchecked (set at 5 TWh/year);
- To increase the annual use of hot-water central heating based on new renewable energy sources, heat pumps and waste heat by 4 TWh/year by the year 2010;
- To install wind power capacity of 3 TWh/year by the year 2010 and to increase the environmentally friendly land-based use of natural gas

From 2007 the above objectives have been replaced by a 30 TWh target for achievement by 2016. Through an ongoing process the Ministry of Petroleum and Energy and Enova is developing and specifying the new and much more ambitious targets. An enlarged energy fund is budgeted and annual funding will be 200 million €.

Background
Key features of Enova's mission are improved energy efficiency, more flexibility in the energy supply and decreased dependence on the direct use of electricity for heating and an increased share of renewables other than large-scale hydropower in the energy supply mix. And as we believe that Enova's method of designing programmes and its focus on energy are of general interest, we would like to let Enova's building programme serve as an example. The design of the programme is general and can be adapted to the needs of other countries. One of its tasks is to manage Enova's funding programme for public and commercial buildings. Based on contracts with numerous building

owners Enova compile annual energy statistics on Norwegian buildings. Last year approximately 2 600 buildings reported to our database, covering 15 million m^2 of floor space and representing 13 % of the total floor area of all such buildings. This makes our statistics to an important instrument for policymakers, design professionals, public authorities and the construction industry.

In Norway commercial buildings, private as well as public, contain 120 million m^2 of floor space. Enova's role is to strengthen the links between the various groups of players, to coordinate project development and to improve the effectiveness of government action in the energy area. Enova's main target group for this specific incentive programme is commercial building owners, public and private enterprises and other decision makers. The commercial building sector has shown considerable interest in the programme, and last two years resulted in 160 new contracts for approximately 1 000 GWh reduction in energy consumption. These new projects cover 9 million m^2 of floor space. The level of financial support is continually evaluated and as a result has been reduced from 60-70 % to 10-30 %. Contractors are invited to propose projects, provided they can guarantee that specific energy targets will be met.

Change of focus from excisting buildings to new future buildings!

Enova's main mission is to create market transformations, and this means that we have to pay full attention to building construction and rehabilitation of housing, public and commercial buildings. As a consequence of a change in policy, a change of focus has been necessary. New steps taken by Enova are related to Norwegian energy policy and to Enova's main mission. Enova co-funds projects, with numerous projects proposed through ten Energy Programmes. 2 500 projects have received co-financing from the Fund, which means that approximately half of all applications are accepted and receive funding. The focus areas of Enova's programmes are industry, wind turbines, district heating, heating plants, bio-fuel production, dwellings and commercial buildings. The contracts between Enova and the building owners are aimed at fostering energy efficiency and more flexibility in energy supply, decreasing dependence on the direct use electricity for heating, and increasing the share of renewables other than large-scale hydropower in the energy supply mix.

ECON measures and results

Since 1996, a Building Network has been established. Contractors must commit themselves to reducing their energy consumption by supporting a range of activities in a network process and, since 2004, by funding investments and energy conservation measures. The network process lasts for between three and five years, during which time the building owners must commit themselves to cutting energy consumption by at least 10 %. Typical activities include energy management, energy use planning, energy follow-up and analysis, training and consumer information, energy metering, monitoring, HVAC, building envelopes, heating systems and control systems. Every year, about 15 million € has been distributed to projects, which have generated annual savings of about 500 GWh and over the ten years of the project so far have totalled about 1 800 GWh. When the administrative costs of the network are included, funding comes to around NOK 0.20 per kWh of energy saved. The peak in 2005 can mainly be explained by some impressive results from the railway sector. The 400 GWh target for 2006 is based 100 % on the building sector.

Since 2000, all buildings that join the Building Network have had their energy consumption measured before and after the network process. Starting in 2002, incentive agreements have been set up in order to relate the payment of support funding to the achievement of specific targets.

Approximately 2 600 buildings reported to our Building network database last year. Figure 1, 2 and 3 is created from the building statistics which is based on this database. Figure 1 shows that buildings with cooling have significantly larger energy consumption than those without cooling systems. Figure 2 and 3 show that the newest and most modern office buildings in average have larger energy consumption than older ones. Some main reasons for these might be found in higher indoor climate demands and a larger number of technical electric equipments.

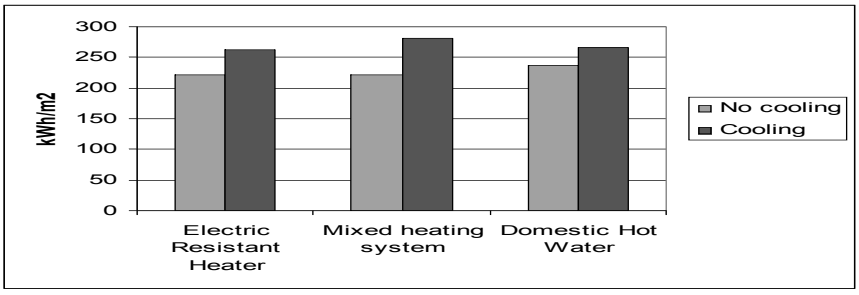

Figure 1. Cooling in buildings has great impact on energy use

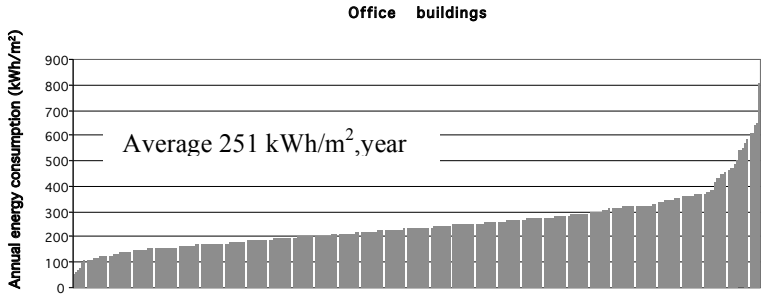

Figure 2. Commercial office buildings and level of annual metered energy use (314 buildings with total floor space 2.4 mill m²)

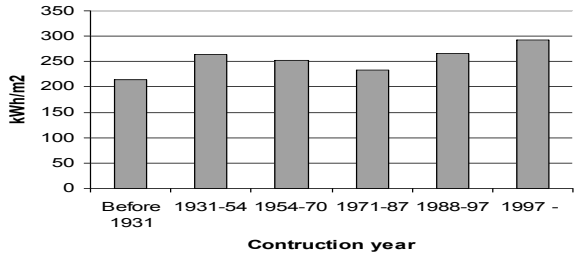

Figure 3. Commercial office buildings and level of annual metered energy use divided into construction year (314 buildings with total floor space 2.4 mill m²)

Holistic Approach and Model Buildings – energy consumption by category of use in 26 buildings

In order to obtain a better understanding of the energy consumption of buildings in terms of category of energy use, such as heating, ventilation, lighting, etc., Enova carried out a project entitled Model Building. Twenty-six buildings in five categories of use were instrumented according to a common plan. The measurement programme lasted for a year, from November 2000 until October 2001.

Seven types of energy use were defined in accordance with Norwegian Committee for Standardization (NS):

Heating, Ventilation, Hot water, Fans/pumps, Lighting, Electrical equipment and Air conditioning.

This was the first time in Norway that, through a holistic approach, a systematic set of measurements were made of how energy is used in such a large number of non-domestic buildings. Even though the sample was small (26 buildings) the analyses reveal a number of interesting features. The general impression was that the actual uses of energy are reasonably similar to those used by the most frequently used estimation programs. However, wide variations from one building to another within the same building category were noted. This implies that standard normalised figures for energy consumption by category of use must be used with great caution. This may mean that operating conditions and user behaviour have more influence on energy consumption than we have believed. This is a common finding from many other studies, but still a conclusion to report in this summary.

In certain areas and in certain types of buildings there are clear deviations from the norm:

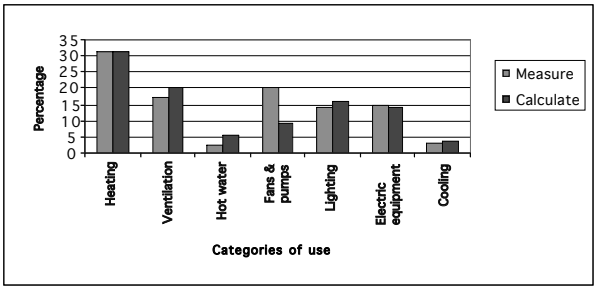

Figure 4. Measured versus calculated energy for office buildings

- In university, college and office buildings fans and pumps are responsible for a larger proportion of energy use than was previously assumed (figure 4)
- In nursing homes more energy is used for lighting than previously assumed
- In most categories of building the proportion of energy that goes to ventilation and heating water is somewhat less than the estimation model suggests
- The portion of energy consumption that is flexible (heating, domestic hot water supply, ventilation heat) varies more widely than expected, but for important categories such as office buildings and schools the average figures aligned closely to expectations (figure 5). However, the more detailed analysis below indicates significant discrepancies in relation to particular aspects of end use within such buildings.

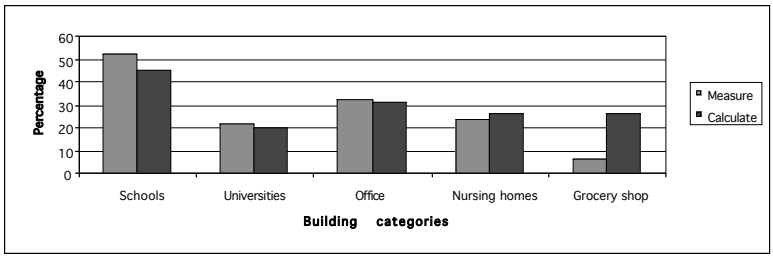

Figure 5. Flexible and specific proportions of energy use for the five building categories represented in the study

Explanation theories for increased energy use in office buildings

Enova has taken an initiative to further study what the reason is for the statistic trend of increasing use of energy consumption in new office buildings (as seen in figure 3 above). We have performed detailed energy analyses of two office buildings in Oslo and Trondheim built after 1997 in order to show what the energy use in the actual buildings originally was designed for, and where the increased use of energy consumption are, based on the definitions in NS 3031.

Parameters considered in the analyses are:

Building design, Technical solutions, Technical infrastructure, Heating systems, Ventilation systems, Control systems, Air-conditioning systems, Operating hours and Persons pr. m2 related to the originally design program

The buildings in the Enova studies are:

Prinsens gate 49, Trondheim, Floor space: 3 950 m^2, Year of construction: 2003

Energy consumption 2006: 293 kWh/m^2, year originally designed for: 239 kWh/m^2, year

Gronland 34, Oslo, Floor space: 6 400 m^2, Year of construction: 1998

Energy consumption 2006: 222 kWh/m^2, year originally designed for: 216 kWh/ m^2, year

What did the analysis show?

Despite the fact that both buildings have participated in an energy saving programme, which have revealed some major faults in adjustments of technical installation, the analyses show that the energy consumption is larger than originally designed. However, the measured energy consumption is significantly lower than the average for office buildings in Enova's Building Network (251 kWh/m^2). This indicates that new buildings might have a larger potential for reduced energy consumption than older buildings due to more technical installations, larger ventilation systems, larger air-condition/cooling systems etc., i.e. correctly adjusted heating system, ventilation systems and air conditioning/cooling systems are even more important in new buildings than older ones. In fact, "more can go wrong in modern buildings". Most of these adjustments takes place during the final stage of the construction period when there is often very limited time left until the building is scheduled finished, thus these adjustments is not always optimally performed. For the same reason, education of operation and maintenance personnel in modern Building Energy Management System is not done well enough. Enova's building statistics indicate that this might often be the case, and therefore this is one of many possible reasons for larger energy consumption than originally calculated.

For both buildings the analysis showed that the categories heating, ventilation heating and fans/pumps uses less energy than originally calculated at the design stage. However, the other 4 categories of use (hot water, lighting, electrical equipment and air conditioning/cooling) uses more energy than originally calculated. In the case of air conditioning/ cooling, electrical equipment and lighting, this increase in energy usage is most dramatic.

Gronland 34:

Based on metered energy consumption compared to designed energy consumption there are significant differences in all categories of use, but total consumption is only 4 % larger than designed. Main reasons for the differences in categories of use can be:

1. The building hosts more persons than originally designed for (increased from 190 persons to approx. 230 persons). In addition operating hours for the building have been increased to a certain extent. As a result:
   - Increased demand for ventilation, air conditioning and cooling, and less demand for heating (heat energy from more persons, more computers and other electrical office equipment, more lighting etc).
   - Longer hours of usage causes more lighting hours and cooling energy consumption(demand for comfort temperature more hours/day than originally calculated)[
   - Increased demand for lighting and hot water
2. The operating hours of ventilation and heating systems have been optimally adjusted to "opening hours". Furthermore temperatures and airflow have been optimally adjusted. This has impact on categories heating, ventilation heating and fans/pumps.

There has been a 20 % reduction in total energy consumption in the period 2002 – 2006 as seen in figure 6. The energy saving programme that has been ongoing is the main reason for this.

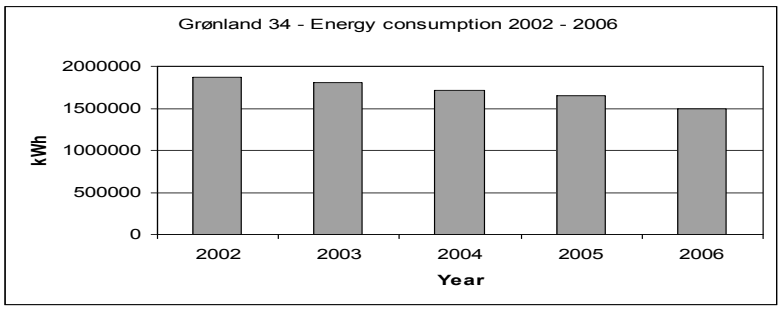

Figure 6. Gronland 34 - Reduction in energy consumption in the period 2002 - 2006

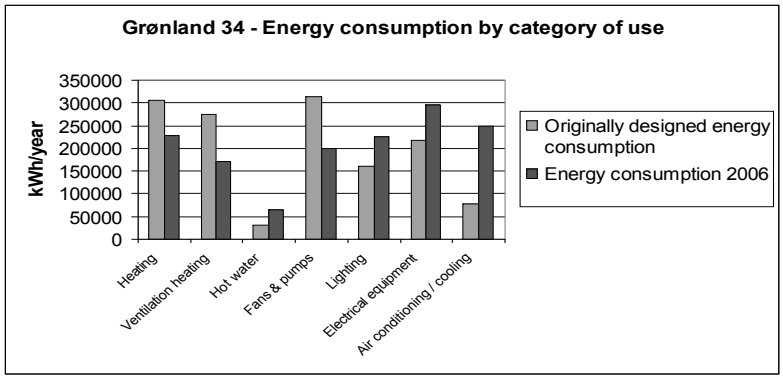

Figure 7. Gronland 34 - Comparison of originally designed and metered Energy consumption by category of use

Table 1. Gronland 34 - Energy consumption by category of use

	Energy consumption			
	Originally designed		2006	
Category of use	kWh	kWh/m2	kWh	kWh/m2
Heating	307200	48	227333	35,5
Ventilation heating	275200	43	170000	26,6
Hot water	32000	5	64000	10,0
Fans & pumps	313600	49	200000	31,3
Lighting	160000	25	225000	33,5
Electrical equipment	217600	34	296167	46,3
Air conditioning / cooling	76800	12	250000	39,1
Total energy consumption	1 382 400	216	1 432 500	222

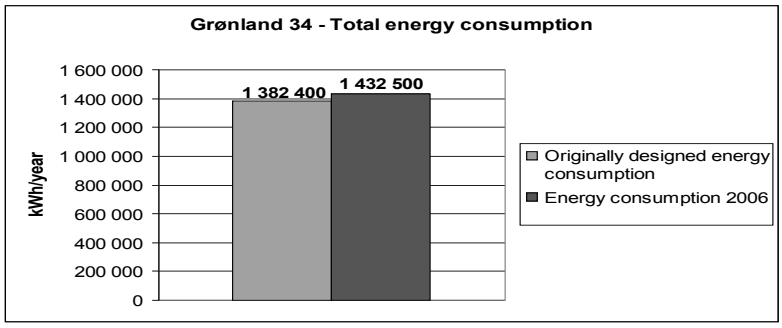

Figure 8. Gronland 34 - Comparison of originally designed and metered total energy consumption

Table 2. Gronland 34 - Energy consumption by category of use

	Energy consumption			
	Originally designed		2006	
Category of use	kWh	kWh/m2	kWh	kWh/m2
Heating	203 940	51,5	113000	28,5
Ventilation heating	198 660	50,2	140000	35,4
Hot water	23 100	5,8	35000	8,8
Fans & pumps	230 340	58,2	180000	45,5
Lighting	119 460	30,2	205000	51,8
Electrical equipment	114 840	29,0	319000	80,6
Air conditioning / cooling	57 420	14,5	170000	42,9
Total energy consumption	947 760	239	1 162 000	293

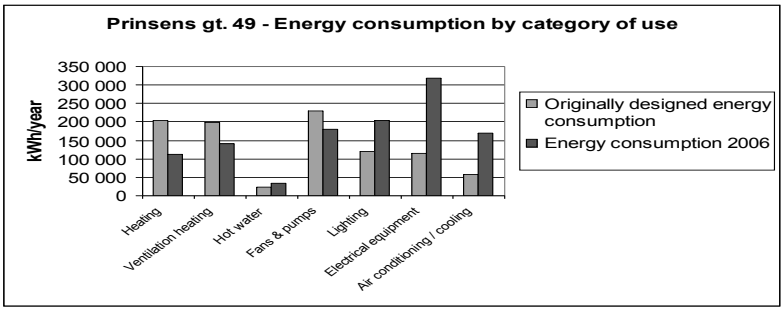

Figure 9. Prinsensgt. 49 - Comparison of originally designed and metered Energy use by category of use

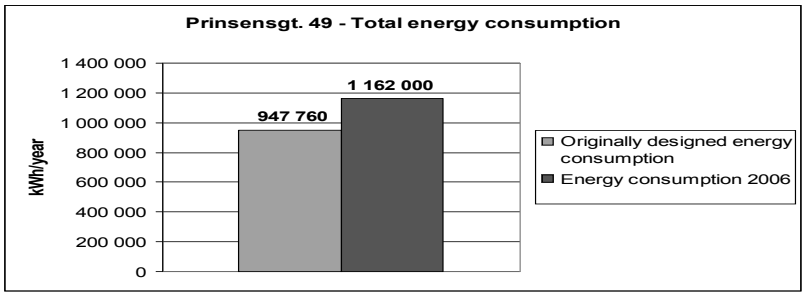

Figure 10. Prinsensgt. 49 - Comparison of originally designed and metered total energy consumption

Prinsensgt 49:

Based on metered energy consumption compared to designed energy consumption there are significant differences in all categories of use. Total consumption is 23 % larger than designed. Main reasons for these differences can be:

The grocery store involves a larger part of the total building area than originally designed. This explains some of the differences in the categories of use (more lightning, electrical equipment and air conditioning/cooling).

The ventilation and heating systems have as much as possible been adjusted to operating hours. Furthermore temperatures and airflow have been optimally adjusted. This influences on categories heating, ventilation heating and fans/pumps.

There has not been a significant change in total energy consumption in the period 2003 – 2006 as seen for Grønland 34. The main reason for this is probably that the ongoing energy saving programme is not yet completed. An analysis that has been worked out as an activity in the energy saving program, shows that there is a potential for energy savings by adjustments on technical installations.

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