Trondheim SmartCity

Energy Efficiency

TRONDHEIM KOMMUNE

SIEMENS

BELLONA

Trondheim Smart City

Smartere bruk av energi

Contents

Summary

Norway will not fulfil its climate obligations without the use of new technology. The Energy Efficiency Report of 2007 prepared by the Non Governmental Organisation (NGO) Bellona and Siemens showed that although Norway has the capability to save energy equal to 20 per cent of its electricity consumption, little is being done to achieve this efficiency potential. Perhaps we lack the the good examples of how to achieve our efficiency potential? Trondheim municipality has therefore decided to set one.

By utilising energy efficient technology, Trondheim can reduce its stationary energy consumption by 22 percent. Large quantities of energy can be saved by using existing technology available today, and the energy efficiency improvements can be achieved without affecting citizens' lifestyles or living standards.

This is the overriding conclusion of the report in front of you. It is based on analyses of energy efficiency for residential buildings, commercial buildings, industry, street lighting and distribution grid within Trondheim municipality, making energy efficiency an essential contribution to achieving the municipality's objective of cutting greenhouse gas emissions by 20 percent before 2012.

Perhaps it sounds too good to be true: Energy efficiency can be achieved without affecting citizens' lifestyles or standards of living. Add to this that the majority of the proposed initiatives will save inhabitants, businesses and authorities millions of Norwegian kroner, and it would seem like wishful thinking. These are, however, highly realistic findings, based on facts.

This report focuses on what can be achieved today, using existing, tested and available technology. The report shows that (based on careful assumptions as the foundation for the analysis) energy consumption within the borders of Trondheim municipality can be cut by a fifth, using existing and available technology. It would take Trondheim's hospital and healthcare centres almost ten years to consume the equivalent amount of energy. In other words, it is all about using energy in a smarter way, about thinking smart and acting smart. And although Trondheim's per capita energy consumption is already lower than many other places in the country, Trondheim municipality wants to become even smarter. Trondheim's elected executive committee is united in backing the ambition to become the world's smartest city in terms of energy use. This report shows that it is possible.

Trondheim's potential for energy efficiency

By utilising modern, existing technology, energy corresponding to 22 percent of the city's stationary energy consumption can be released within the following areas:

Homes	387 GWh
Commercial buildings	378 GWh
Industry	52 GWh
Street lights	5 GWh
Upgrade of electricity network	50 GWh
Total	**872 GWh**

Trondheim SmartCity

About the report

This report focus on the amount of energy that can be released in Trondheim municipality using known methods and solutions. Calculations and proposals for energy efficiency are based on tested solutions, i.e. all required technology to make energy use more efficient in the municipality is already currently available on the market. In other words, there is no need to wait for new technology to be developed – existing technology can do the job for us.

The report has chosen to focus on five principal areas: Buildings, industrial activity, the distribution grid, mobility and street lighting.

Trondheim municipality's citizens, politicians, public and private businesses have already made major headway in their work to make the city more climate friendly and energy efficient. Numerous initiatives have been put into action and several have already produced results. Other cities in Norway and abroad will therefore in many cases have an even greater potential for energy efficiency than the potential presented in this report.

At the heart of the findings lies an extensive body of analysis where key sources have been the utility company Trondheim Energi, Trondheim municipality, Enova, Statistics Norway, Siemens and Osram. An analysis agency, Perduco, has assisted in the analysis and preparation of the report.

For the study of industrial activity, street lighting, traffic data, geographical data, energy use etc in Trondheim municipality, the report is based on the most recently available data. The vast majority of calculations are based on data from 2008, however in some cases figures from 2007 have also been used.

Based on the study of energy use, Siemens has carried out calculations for the potential for energy efficiency. The proposed initiatives are based on experiences from Norway and abroad, which means that all the technological solutions have been successfully tested.

The initiatives presented in this report are naturally not exhaustive: far more initiatives can be implemented to further increase Trondheim's energy efficiency. The goal is that this report will provide inspiration for others wishing to work for a more energy efficient Trondheim and – not least – for other cities in Norway and abroad.

Energy terms

1000 kWh (kilowatt hours) = 1 MWh (megawatt hour)
1000 MWh = 1 GWh (gigawatt hour)
1000 GWh = 1 TWh (terawatt hour)

First in the world

Many nations and cities across the world are focusing on environmentally friendly solutions to help reduce the energy load on the environment. Even though a lot is being done, the potential for further savings is substantial. For example, Norway as a nation can save 20 percent of its energy consumption by using existing energy efficient technology, equivalent to the consumption of half the number of Norwegian households. The same applies to Trondheim, and the city's political leadership intends to do something about this.

In 2007, for the first time in history, more people lived in cities than outside. Energy consumption in cities is substantially higher than outside cities, and although the world's cities cover only 0.4 percent of the earth's surface, they generate as much as 80 percent of greenhouse gas emissions and account for 75 percent of the world's energy use. In other words, it is essential that extensive plans are drawn up and implemented to secure smarter use of energy in the cities. A SmartCity is a city that thinks smart in terms of energy use; a city that has calculated the potential for the amount of energy that can be saved in different areas and that aims to harness this potential.

Trondheim is a SmartCity, and the first of its kind in the world. With the support of the municipality's most senior political management in the municipality, and backed by Bellona and Siemens, Trondheim SmartCity has, in this report, calculated the potential energy savings in the municipality and described where the potential lies. In the next phase, the goal is to harness this potential and implement efficient initiatives over the next two to three years. The project has received support from many key knowledge providers in addition to those behind the initiative, and especially Trondheim Energi and Enova have been key knowledge and information providers.

Population growth in the cities

The last 20 years, the Norwegian population has grown by 13 percent to 4.8 million people, 86 percent of the growth has taken place in and around the cities of Oslo, Bergen, Stavanger, Trondheim, Kristiansand, Tromsø, Moss and Drammen. Whilst the population in these urban areas has grown by 24 percent from 1990 to 2009, growth in the rest of the country has been at 4 percent. If we include an additional 15 cities, the population growth in the rest of the country outside the cities is virtually zero. Domestic migration is principally to the Oslo region: Between 1994 and 2008 the net migration to the capital region numbered more than 48,000 persons, equal to 56 percent of the net migration to the mentioned eight urban areas.

Trondheim

A pioneering city

Why Trondheim?
There are several reasons why Trondheim was chosen to become the first smart city and was assigned the title Trondheim SmartCity. In Norway the city is known as the country's technology capital and is home to key education and research centres within environmentally friendly solutions, such as the Norwegian University of Science and Technology (NTNU) and SINTEF. Enova, a governmental enterprise owned by the Norwegian Ministry of Petroleum and Energy set up to promote an environmentally friendly restructuring of energy use and energy production in Norway, is based in Trondheim. Trondheim also has a high level of urbanisation compared with other cities in Norway, which is pivotal in being able to utilise energy efficient technology. A high level of urbanisation is also considered of high Importance in international reports to reveal how cities can be made sustainable; examples of this are "Megacity Challenges" and "Sustainability Urban Infrastructure" performed by Siemens.

Trondheim was however, principally chosen because its political management has shown the willingness and ability to put energy and the environment on the agenda. Although numerous initiatives have already commenced in Trondheim, instead of resting on their laurels, the municipality's most senior management has set itself ambitions targets to identify and reach further potential for energy efficiency.

Who chooses the city?
Bellona and Siemens have appointed Trondheim as the first energy smart city. Provided the project unfolds as desired, the intention is to carry forward the concept to more of the 190 countries in which Siemens operates. The selection process in other countries may well be carried out by the same parties, or alternatively by Siemens and a local NGO.

A pioneering city in Norway
Choosing Trondheim to become Trondheim SmartCity was a bold choice. The decision was based on the city's good progress in its work to create a greener city. By choosing another city the report could have found even greater potential for energy efficiency. At the same time, Trondheim is a city in which its citizens, politicians, business community and public sector enterprises recognise the fact of climate challenges and are also willing to act.

Trondheim municipality has already set a goal of reducing its CO2 emissions by 20 percent in the period 2008- 2012, compared to 1991. The municipality recently submitted a new Energy and Climate plan where one of the initiatives was to ensure the use of stationary energy not exceeding 4.5 TWh by 2020. Among the going initiatives is a reduction in the energy consumption of municipality buildings. A total of 144 municipality buildings were pinpointed for energy efficiency, where the goal was a 16 percent reduction in energy consumption in a five-year period up to 2008. The project achieved a result of 10.6 GWh, equivalent to an almost 14 percent energy reduction. In the same period, the buildings' operating times and use of floor space in the buildings increased, which means that the original goal was more than likely achieved. Moreover several public sector buildings have been connected to the district heating plant.

Trondheim is Norway's third largest city with around 169,000 inhabitants and the city's per capita energy consumption is 13 percent lower than the national average. Most other cities will therefore be able to achieve greater savings than Trondheim.

The total energy use within the borders of the municipality is around 5.0 TWh, which equals around 2 percent of Norway's overall energy consumption. Energy consumption for purposes other than transport – stationary consumption – is 4.0 TWh. Of this, the consumption of electricity accounts for 2.5 TWh a year. If the stationary energy use for households in Trondheim is distributed between each inhabitant, the consumption is 8.100 kWh a year (2008), compared with the national average of around 9,300 kWh (2007).

Trondheim has a high proportion of district heating as an energy carrier. District heating covers around 30 percent of Trondheim's heating requirements, and currently supplies some 6,000 homes and 600 businesses from Trondheim Energi Fjernvarme. 70-80 percent of the district heating is generated through waste management.

Cities of the future in Norway

"Cities of the future" is a collaboration between the state and the 13 largest cities in Norway to reduce greenhouse gas emissions – and to make the cities better places in which to live.

Cities of the future are organised in four focus areas:
- Land use and transport
- Stationary energy use in buildings
- Consumption pattern and waste
- Adapting to climate changes

The 13 cities participating are Oslo, Bærum, Drammen, Sarpsborg, Fredrikstad, Porsgrunn, Skien, Kristiansand, Sandnes, Stavanger, Bergen, Trondheim and Tromsø.

The programme runs from 2008 to 2014 and will help the urban municipalities to exchange ideas with each other – and to develop new collaboration forums with the business community, regionally and the state.

Trondheim and energy

Total energy consumption	5.0 TWh
Stationary energy consumption	4.0 TWh
Consumption of electricity	2.5 TWh

The estimate is slightly higher than the figure with which Statistics Norway operates, primarily because Statistics Norway does not fully allow for the use of district heating and wood.

87,000 homes	1.4 TWh
4,500 commercial buildings	1.7 TWh
300 industrial companies	1.0 TWh

Method and sources

Trondheim is known as the country's technology capital and is home to key education and research centres within environmentally friendly solutions. SINTEF and NTNU probably have the largest number of researchers, laboratories and students in Scandinavia working on renewable energy. They work within education, pure research and applied research and development in close collaboration with the industry. Their industrial partners comprise both national and international energy providers, producers and energy companies.

Trondheim municipality was one of the first municipalities in Norway to start working actively with climate and energy issues. A local climate action plan was composed in 2001. In the autumn of 2008, Trondheim municipality was awarded the State's City Environment Prize, by the Ministry of Environment, for its initiatives within climate and city environment. And as mentioned above, an extensive energy and climate plan for the municipality was recently submitted.

Trondheim is one of three European city-areas in the EU-financed ECO-City, looking at energy use in buildings. The two other cities are Helsingborg Helsingør in Scandinavia and Tudela in Spain. The object is to develop and utilise new technology to improve the urban community's energy system. By fulfilling the ECO-City goals, Trondheim will achieve an annual saving in its electricity consumption of 3.5 GWh, increase its production of renewable energy by 52.2 GWh, as well as reducing its greenhouse gas emissions by approximately 12,000 tonnes. The project runs from 2005 to 2010.

In its energy and climate politics, Trondheim emphasises sweeping before its own doors. When it comes to driving within the municipal services, the CO2 emissions are to be reduced by 40 percent from 2007 to 2011. Several initiatives have been started, like classes in economic driving, use of bio-fuel and increasing the use of electric cars. The project includes an overall package of measures which will lower emissions of components affecting local air quality.

Trondheim is a green energy municipality

Norway's Ministry of Local Government and Regional Development has designated 21 municipalities and one county authority to green energy municipalities. Trondheim is one of them.

The green energy programme runs until the end of 2010, and the Ministry of Local Government and Regional Development will spend a total of NOK 30 million on it. The goal of green energy municipalities is to get the municipalities to focus on energy efficiency, renewable energy, such as bio-energy, and to reduce greenhouse gas emissions. The experiences gained from the networks will provide inspiration and be a source for learning for other municipalities throughout Norway. The green energy municipalities are: Central Norway: Trondheim, Rennebu, Sunndal and Tingvoll. Northern Norway: Sørreisa, Lenvik, Bardu, Målselv and Narvik. Oppland: Gran, Lunner, Jevnaker, Oppland county authority. Hedmark: Åmot, Trysil, Engerdal, Stor-Elvdal and Elverum. Southern Norway: Ås, Re, Lier and Ringerike.

SOURCE: ENOVA AND KRD

The government designated Trondheim a Green Energy Municipality in June 2007. The Green Energy Municipalities will be leaders and set good examples for other municipalities in Norway in the area of energy and climate. The project Green Energy Municipalities will run until the end of 2010.

The calculations of the potential for energy efficiency in this report are based on the fact that Trondheim's total energy use relates to land use and applications. Figures from Trondheim Energi Nett, Statistics Norway (SSB) and the Norwegian Petroleum Industry Association form the basis for analysing total energy use.

Figures for the use of floor space in buildings are largely based on figures from Urban Zoning in Trondheim and the property department of Trondheim municipality, however they are also coordinated with figures from Statistics Norway. Information about industrial companies in Trondheim has been retrieved by SSB and Dun & Bradstreet. Figures for traffic censuses and the number of street lights is sourced from Trondheim municipality. Data concerning Trondheim municipality's electricity network comes from Trondheim Energi Nett.

Unless otherwise specified, other data has been provided by SSB. All the figures used are the latest available figures and are largely from 2008.

Trondheim municipality and Trondheim Energi have provided information about energy use, land use and application. Siemens and Osram have conducted analyses and calculations of the potential for energy efficiency and the figures have been verified by Bellona. These types of calculations are always reliant on simplifications of reality. Each individual initiative and percentage for energy efficiency is however based on concrete experiences made in Norway and abroad.

The analysis agency Perduco has helped to gather and collate information regarding the potential for energy efficiency in the different areas covered by the report.

Buildings

Buildings account for 40 percent of Norway's and the rest of the world's energy consumption. A greater use of electronic products and higher comfort requirements, mean that energy consumption is constantly increasing. Unless effective action is taken, the International Energy Agency (IEA) estimates that buildings will account for around half of the demand for energy investment up to 2030.

Buildings are the largest energy consumer of Norwegian sectors and represent a long-term challenge unless addressed with stringent energy requirements. Buildings have a long lifetime, and are often inherited from one generation to the next. Adapting existing buildings with energy-efficient technological solutions is an extremely sound investment in reducing future energy consumption. Siemens' experience of energy efficiency spans over 6,500 buildings across the world, and the majority of the energy efficiency initiatives are extremely profitable.

As shown below, the overall potential for energy efficiency in homes and other private and public sector buildings in Trondheim municipality totals 764 GWh, which is the equivalent of the amount of energy used by Trondheim's hotels and restaurants over 14 years – or Trondheim's nurseries, schools and universities combined energy use for the next two and a half years.

First we present the scope and the energy consumption of commercial buildings (public sector offices and private commercial buildings), before we look at other public sector buildings. Private homes are described on page 18.

Commercial buildings in Trondheim

Trondheim is a regional centre in Trøndelag, with more workers commuting to the municipality than travelling out of it to work.

There are roughly 107,000 workplaces in the city and 27,000 people travel from other places to Trondheim to work, whilst 11,000 travel out of the municipality.

Waste becomes heat

Trondheim has a high proportion of district heat as energy carrier. District heating covers around 30 percent of Trondheim's heating requirements. The table shows the deliveries of district heat:

	kWh	Number of customers
Homes (detached homes, terraces and apartments) individually measured	24 238 353	2400
Housing cooperatives and co-ownership jointly measured	87 114 398	140
Private business (property companies etc)	105 993 947	255
Private hotels and restaurants	5 624 206	12
Private production	18 960 494	29
Private trade	26 825 416	60
Public sector service and administration	35 264 718	82
Public sector healthcare centres	71 196 951	35
Schools and nurseries (mostly public sector)	65 591 405	73
Total	440 809 888	3086

A workplace is usually in connection with an office, shop premises, warehouse or other works building. Trondheim has some 3,500 commercial buildings totalling 4.1 million square metres under roof, which means that the commercial land use is equal in size to 540 football pitches – bigger than the land used for apartments.

The energy efficiency initiatives proposed will give a total potential for energy efficiency of 387 GWh. The majority of the initiatives are also economically viable: Assuming a calculation interest rate of 6 percent and energy price of NOK 1/kWh, the proposed initiatives have a combined repayment period of 8 years.

Private commercial buildings

These buildings accommodate some 5,300 private employers and house 70 percent of the county's private sector workplaces. Commercial properties make up around 25 percent of all buildings in Trondheim and account for an equivalent proportion of the municipality's energy consumption, not allowing for energy for production processes. As a regional centre, energy efficiency in commercial buildings will make an impact both regionally and nationally. For example: If all office premises in Trondheim installed control systems for lights, heating and ventilation, the savings would correspond to the electricity consumption of almost 4,000 households in Trondheim.

Commercial buildings have different potentials for energy efficiency. Whilst offices, shops, hotels and restaurants are close to 20 percent, areas used for industry and warehousing have a lower potential. This type of commercial building have a combined potential for energy efficiency of 180 GWh.

Public sector buildings

Trondheim has 1.8 million square metres of buildings classified as schools, healthcare centres/hospitals, leisure centres and cultural centres. In addition are areas associated with public sector offices, which are dealt with under private commercial buildings in the previous paragraph. These buildings accommodate 34,000 public sector workers.

Trondheim municipality has at its disposal municipal buildings covering 636,000 square metres in owned premises. Trondheim's 55 primary and secondary schools are the largest group of municipality buildings, covering 330,000 square metres. Adding municipality nurseries brings the total to 390,000 square metres. Healthcare centres, which include nursing homes, Is another large group, covering 122,000 square metres. The remaining public sector buildings relate to county authority and state activities, such as NTNU and St. Olav's Hospital.

The public sector buildings use 526 GWh energy in total annually. The project has calculated that school buildings and healthcare centres/hospitals have an energy efficiency potential of 15 percent, whilst cultural and leisure centres have a potential of 8 percent. Their overall potential for energy efficiency is 74 GWh, which is marginally less than the combined

Schools in Trondheim	Heated area in m2	Energy consumption in MWh	Number
Primary schools	189 949	29 461	37
Combined primary and lower secondary schools	41 460	5 653	7
Lower secondary schools	74 733	10 497	11
Total	306 142	45 611	55

Buildings (cont.)

energy consumption of all primary and lower secondary schools in Trondheim.

Lighting

The lighting in Norwegian commercial buildings is a mixture of energy inefficient fittings of up to 30 years old and new modern fittings with advanced light control. Modern light sources with electronic connection equipment, motion sensors and daylight control can save over 80 percent of the electricity consumption compared with older types. A number of upgrades have already been carried out, and possible savings in commercial buildings are therefore estimated to 45 percent.

Trondheim's commercial buildings consist of office buildings, warehouse buildings, workshops, workshops premises, factories, healthcare centres/hospitals, cultural and leisure centres and other types of buildings. These buildings have different types of lighting and therefore a proportionally different energy use. Osram and Lyskultur estimate that lighting accounts for on average 20 percent of the energy consumption in Norwegian commercial buildings. As Trondheim has a broad mix of businesses, we have opted to use 20 percent as a prerequisite for calculating the potential for energy efficiency in lighting.

This means that almost 276 GWh is consumed in lighting up Trondheim's more than 4,500 commercial buildings. This is almost equivalent to the total amount of energy used by Trondheim's kindergartens, schools and universities in one year. A 45 percent cutback would save 124 GWh, equal to the total electricity consumption of 8,000 homes.

Calculations from Osram show that by switching an older light fitting (e.g. 2x36W fixture with a magnetic reactor and lighter) to a new, modern fitting (e.g. 2x28W fixture with electronic connection) the investment would be repaid within one to three years. By integrating the latter with automatic daylight and motion detectors, the investment's repayment time is slightly longer, however this will lead to greater energy efficiency in the course of the equipment's lifetime.

More energy efficient lighting produces less heat as a larger proportion of the effect is used to produce light – whilst a lower proportion is heat production. The problem in today's commercial buildings is that because so many appliances used, buildings need to be cooled down in the winter too. Light fittings that produce less heat reduce the need for cooling.

Energy efficient schools

Between 2006 and 2008, Trondheim's 54 lower secondary schools cut their combined energy consumption by almost 10 percent.

Participating in major EU project

Trondheim is one of three European city areas in the EU-financed ECO-City, a project focusing on use of energy in buildings. The main goal is to develop and utilise new technology to improve the urban community's energy system. If the objectives of ECO-City are achieved in Trondheim, this means an annual saving in electricity consumption of 3.5 GWh, increased renewable energy production of 52.2 GWh, as well as reduced greenhouse gas emissions of approximately 12,000 tonnes. The project runs from 2005 to 2010.

	Efficiency potential (MWh)	Investment excl. VAT (MNOK)	Investment in NOK per kWh saved
Building-related initiatives	**17 900**	**210**	**15**
Insulation roof and/or walls	2 500	32	16
Beading for windows and doors	10 700	43	5
Replacement of windows and exterior doors	4 700	135	36
Sanitary installations	**800**	**0**	**0**
Economy showers/fittings	800	0,2	0
Heating	**73 900**	**303**	**5**
Insulation of pipes and vents	4 800	5	1
Shunting and outdoor temperature compensation	3 700	20	7
Transition to quantity-regulated central heating with rpm-regulated pump	4 500	20	6
Adjustment of central heating combined with water purification	3 200	16	6
Heat pump	56 400	232	5
Thermostatic radiator valves	1 300	10	10
Refrigeration unit and sun protection	**10 700**	**215**	**25**
Automatic exterior sunscreen	7 500	172	29
Transition to refrigeration unit with thermostat with rpm-regulated pump	3 200	43	17
Ventilation unit	**44 800**	**527**	**15**
Better heat recycling for ventilation	19 300	150	10
Switch to directly operated fans	10 000	81	10
Frequency converter for fans	8 000	40	6
Variable air volume ventilation (VAV)	7 500	256	43
Electrical units/Lights	**124 000**	**790**	**8**
Switch to modern fittings with advanced light control	124 000	790	8
Control initiatives	**105 400**	**227**	**3**
Central operation control (CO unit) with upgrade of gauges	9 700	58	7
Energy optimisation system (EOS)	13 400	54	5
Time control ventilation	30 600	26	1
Precipitation control of snow melting unit	21 500	35	2
Thermostat and heating timer	13 000	54	5
Reduce indoor temperature to 21 C	17 200	0	
Total	377 500	2 272	8

EXPLANATION OF THE RIGHT-HAND TABLE: The efficiency potential and investments are shown combined for Trondheim municipality. The efficiency potential and investment costs have been estimated by Siemens and Osram. Investment in NOK per kWh saved gives an indication of how quickly the investment in the specific energy efficiency initiative is repaid. The lower the investment the quicker the repayment. Assuming a calculation interest rate of 6 percent and energy price of NOK 1/kWh, the initiatives have a combined repayment period of eight years.

Industry

Trondheim has several hundred industrial companies, which account for almost half of the energy consumption of the city's jobs, but for less than every tenth job. In other words, this is a sector where there is a lot to gain on modern solutions for energy efficiency. An estimation shows that the potential in energy efficiency could result in savings equal to the electricity consumption of Øya-Singsaker (well-known district in Trondheim).

A common feature of all industrial activity is the machine-processing of raw materials and semi-finished goods. In Norway such machines are usually operated by electric motors, but also gas and other fuels are used to produce energy for the motors. Both the machines themselves and the organisation of the production processes influence the amount of energy used.

Mounting pressure

The pressure towards the industry sector is mounting when it comes to reducing the use of energy: As the international competition increases in the product markets, lower energy costs play a key role in industrial firms' competitive power. Authorities impose more stringent requirements to – and often a price on – emissions of greenhouse gases from energy consumption. Furthermore, eco-conscious consumers demand products that leave the lowest possible "carbon footprint".

Energy Optimization

Siemens has analysed the potential for energy saving in some 2,000 industrial companies across the world, and on the basis of this the Energy Optimization concept is developed. Experience shows that, irrespective of industry, the potential for saving is between 10-15 percent. According to an analysis of a food producer in Oslo, the potential for energy efficiency was nearly twice as high, around 27 percent. The largest companies in Trondheim are precisely in the food industry, but to allow for possible variations, a conservative average potential of 15 percent has been used. See the textbox "The energy efficient industrial company" for examples of initiatives leading to such energy efficiency.

Varying potential

Trondheim has several major industrial companies where we have investigated the energy consumption in the production processes: Nidar, Tine, Nortura, Ringnes (E.C. Dahls Bryggerier), Peterson (Emballasje og Linerboard) and Felleskjøpet Agri. These companies have to different degrees worked on energy efficiency, and the potential for savings therefore varies. However, a review shows that a 15 percent overall reduction in energy used for production is completely realistic.

Over 300 industrial companies

According to Statistics Norway's register of business enterprises, there are well over 300 industrial companies located in Trondheim municipality, employing some 8,000 workers. Some 100 of the municipality's industrial businesses have more than 10 employees, which we take to be the minimum size for industrial production of a certain scale.

Considerable potential

In 2008, Trondheim's industrial businesses used 345 GWh electricity and a total of 1005 GWh energy in their production processes. Their electricity consumption corresponds to approximately 20 percent of the total energy consumption, and approximately 40 percent of the stationary consumption relating to jobs in the private and public sector. In comparison, the industry accounts for well over 8 percent of Trondheim municipality's total employment. By making industrial companies more energy efficient, the municipality will see relatively large gains in its overall energy use.

For the sake of simplicity, this report is based on an estimate of the savings potential linked to the consumption of electricity. This is based on the inclusion of district heating production in the industry's total energy consumption of 1005 GWh, where waste and gas are significant input factors. This report has not considered the potential for energy efficiency in the district heating production. A 15 percent reduction will correspond to nearly 52 GWh, the equivalent amount of electricity used by 2,700 detached homes or 6,500 apartments in the course of the year, and roughly the same as that used by the entire district of Øya-Singsaker.

The energy efficient industrial company

The pressure towards the industry sector is mounting when it comes to reducing the use of energy. Competition in the product markets means focus on costs - and energy costs money. Furthermore, consumers and authorities demand production that leaved the lowest possible "carbon footprint".

An energy efficiency project today concerns far more than machines and automation. A number of aspects need to be considered when implementing an energy efficiency project in an industrial company. This is precisely what the Energy Optimization concept does.

Focus areas are:

- Cooling/heating
- Heat recycling – utilisation e.g. of waste heat
- Compressed air
- Electronics
- Process
- Automation
- Water
- Energy efficient attitudes amongst all staff
- Support schemes available

Street lighting

In Trondheim municipality, the roads and streets are lit by 22,000 street lights, burning 4,000 hours a year, with an annual electricity consumption of 10.7 GWh. In 2008, the cost was NOK 11 million.

Quantum leaps have been made in the last few decades when it comes to energy efficiency and street lights. In addition, new rules have emerged regarding the content of toxins in the lamps. The vast majority of light sources in Trondheim use the most efficient light source available, NAV Super 4Y, which means that the potential for energy efficiency by using newer and better lamps is insignificant. However there is a vast potential for energy efficiency by dimming the light by 50 percent, without this affecting safety on the roads. Such a saving have no investment cost, and gives a saving of 5.4 GWh a year, which equals just as many millions of kroner. Dimming the street lighting will not affect the lamps' lifetime negatively.

Distribution network

En route from production to plugs in homes and businesses, roughly 10 percent of the power is lost, amounting to a total of 12 TWh annually. In Trondheim the losses in the network are estimated to be in excess of 5 percent.

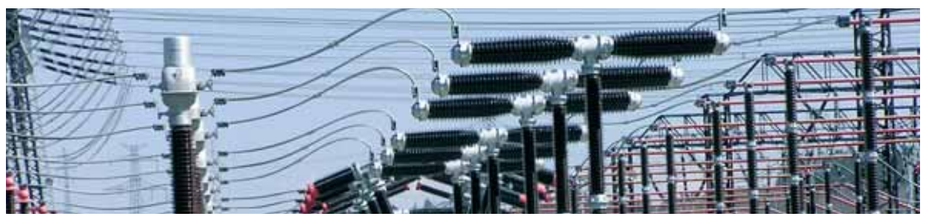
The main reason for the losses is the low voltage level in the part of the electricity network that leads from the transforming stations to the end users. 50-60 percent of the losses occur here. This part of the electricity network is referred to as the distribution network, whilst the overlying networks are called regional network and central network.

In Trondheim, the distribution network measures 1030 kilometres – a good 100 Norwegian miles, distributed between cables and air lines. The total electrical consumption in Trondheim amounts to approximately 2500 GWh per annum. Trondheim Energi estimates that the losses in the network are just over 5 percent, giving a loss of 130 GWh. Assuming a cost price of 0,5 NOK per kWh, the total loss will amount to NOK 65 million. The network in Trondheim municipality principally is a distribution network. Based on distribution of low voltage and distribution network, we can assume that 60 per cent of these losses are caused in the low voltage distribution network, which equals approximately 80 GWh per annum.

An upward adjustment of the voltage level in the distribution network will reduce the losses. In addition, a higher voltage level will reduce the fire risk and increase personal safety. The energy efficiency may amount to 50 GWh, giving a saving of NOK 25 million in a normal year.

Another tool to reduce the network losses is the introduction of so-called two-way communication. Two-way communication enables the network companies to reduce the load with each end user in peak load situations and thus achieve a more even load profile throughout the day, week and year.

The initiatives are profitable within the same time period as assumed by Enova for such infrastructure, 30 years.



Households

Although Trondheim's homes use less energy than elsewhere in the country, there is still plenty of scope for further cuts to energy consumption. Existing technology can be harnessed to save an energy amount large enough to cover the electricity consumption of 11,000 households in Trondheim.

Buildings account for around 40 per cent of the world's energy consumption, with 67 per cent of this deriving from private homes. Put differently, private homes account for 29 per cent of the world's overall energy consumption, and 21 per cent of greenhouse gas emissions.

The percentage is approximately the same in Norway, where households account for 30 per cent of Norway's stationary energy consumption. Although household energy consumption has been stable in recent years, there is substantial potential for reducing this energy consumption.

In a densely populated city, the figures are slightly different: In Trondheim municipality, buildings account for 79 per cent of energy consumption. Of the buildings' energy consumption, homes make up roughly half, 49 percent, against 30 percent on a national level.

The average urban residence is initially more energy efficient than homes in more rural areas. Nearly every other home in Trondheim is an apartment. The average energy consumption of 12,600 kWh per annum for an apartment building is under half of detached homes, which in 2006 on average used 26,700 kWh.

In 2007, households in Trondheim had an energy consumption of 1.4 TWh. Of this, electricity amounted to 900 GWh. While each household in Norway on average uses at least 21,000 kWh per annum, the average household in Trondheim has an energy consumption of around 15,500 kWh. The degree of urbanisation in Trondheim probably explains why the energy consumption is also below the county level of nearly 22,500 kWh.

In the report we have reviewed the potential for energy efficiency in Trondheim, where we have based ourselves on what is normal for Norwegian households and made adjustments for special features relating to urbanisation. By utilising existing products for energy efficiency, households in Trondheim can save 15 percent of their current energy consumption. This equals 210 GWh. Add the potential deriving from lighting and household appliances, and the total potential for energy efficiency is 387 GWh. See table for specific initiatives.

Lighting

Osram and Lyskultur estimate that 15 percent of the energy consumption in Norwegian homes is used for lighting, which means that nearly 170 GWh is expended to light up Trondheim's nearly 90,000 homes, which is the equivalent of the total amount of energy used by Trondheim's 55 primary and secondary schools for almost four years.

Lighting in Norwegian homes is a mixture of traditional, energy inefficient incandescent lamps, more efficient halogen lamps (both with and without dimming) together with even more efficient LED lamps and economy bulbs. A class A economy bulb uses 80 per cent less energy than a traditional incandescent bulb. A modest assumption that a little over half of the light bulbs in Trondheim are of the inefficient, old incandescent sort, gives an energy efficiency potential of 50 percent for lighting.

Under these conditions, 83 GWh can be saved if all older types of light bulbs are replaced with economy bulbs. The savings equate to the total electricity consumption of 6,600 homes. A better location of light sources, more correct use of fittings, motion sensors and other controls can yield an energy efficiency of a further 15-20 percent, however this was not included in the calculation.

As shown in the overview of initiatives for energy efficiency, the replacement of traditional incandescent lamps to economy bulbs (70 percent of the replacement), halogen (29 percent of the replacement) and LED lamps (1 percent of the replacement) is among the initiatives with the very lowest

This table does not include potentials relating to lighting and household potentials as these represent a combined potential saving of an additional 300 GWh.

	Electricity	District Heating	Oil, firewoods, gas, kerrosine etc	Total energy consumption	Heated area	Efficiency potential	Efficiency potential
	[GWh]	[GWh]	[GWh]	[GWh]	[kvm]	[GWh]	%
Household	910	111	347	1369	8 913 000	210	15 %
Health and social services	69	71	11	151	426 000	23	15 %
Offices and businesses	499	163	53	715	2 078 000	133	19 %
School buildings and university including nurseries	193	66	28	286	1 100 000	44	15 %
Hotels and restaurants	44	6	5	54	178 000	9	17 %
Leisure and cultural centres	75	5	8	89	314 000	7	8 %
Warehouse and logistics	165	2	18	185	718 000	12	7 %
Light industry	**149**	**15**	**18**	**182**	**783 000**	**25**	**14 %**
Total service sector	1192	328	141	1661	5 597 000	254	15 %

Households (cont.)

Tiltak	Efficiency potential (MWh)	Investment incl. VAT (MNOK)	Investment in NOK pr saved kWh
Building-related initiatives	**81 900**	**1 970**	**24**
Insulation roof and/or walls	25 700	422	16
Beading for windows and doors	15 800	79	5
Replacement of windows	30 300	1100	36
Replacement of exterior doors	10 100	369	37
Sanitary installations	**17 700**	**20**	**1**
Economy showers/fittings	15 900	6	0
New boiler	1 800	14	8
Heating	**39 000**	**200**	**5**
Heat pump	39 000	200	5
Ventilation unit	**7 800**	**76**	**10**
Better heat recycling for ventilation	7 800	76	10
Electrical units/Light	**176 200**		
Lights	83 300	658	8
Electrical appliances	92 900		
Control initiatives	**64 300**	**176**	**3**
Thermostat and timer of electric heat	21 000	105	5
Automatic timer of water-borne heat	9 500	53	6
Individual measurement of heat and hot water	2 200	18	8
Reduce indoor temperature to 21 degrees C	31 600	0	0
Total	386 600	3 100	11

Explanation for the table
The efficiency potential and investments are shown combined for the whole of Trondheim municipality. Investment in NOK per kWh saved gives an indication of how quickly the investment in the specific energy efficiency initiative is repaid. The lower the investment, the faster the repayment. The potential for energy efficiency and investment costs are estimated by Siemens.

investment cost in relation to savings potential. Such investments are repaid in less than one year. If investments in modern light sources are integrated with daylight and presence control, the repayment period increases, although the energy efficiency in the equipment's lifetime will be higher.

Replacing older, inefficient household appliances with new ones with a high energy class benefits the environment hugely. Energy use in production is minimal – only 5-10 percent of the energy that is used in the lifetime of the household appliance.

The technological development of household apparatus in recent years has been significant. Refrigerator produced by Bosch Siemens, for example, use 79 percent less energy today than in 1990. Compared with normal energy efficiency in household appliances produced in 1994, today's washing machines, tumble driers, ovens, fridges, freezers and vacuum cleaners use 30-70 per cent less electricity. The average is around 50 percent.

Enova has estimated that an average household uses 4,200 kWh on electrical appliances in the course of a year. If we assume that the electrical appliances in Trondheim's homes consist of a combination of older and newer models, we can estimate that the energy consumption for electrical appliances can be cut by 25 percent or 1,050 kWh per household. For the entire city, this equals roughly 93 GWh – the equivalent of the overall energy consumption of 6,000 homes.

Earth Hour

On 28 March 2009, Trondheim was one of 15 Norwegian municipalities that turned off its lights from 20.30 hrs in the evening. The previous year the municipality was the first and only one in Norway to do the same in connection with Earth Hour, which is an international event supported by WWF (World Wide Fund for Nature). The event highlights the climate issue by getting private individuals, businesses, authorities and organisations to turn off their electric lights for one hour.

Mobility

Have you ever noticed how buses have to queue in the same line as cars where most of the people are travelling alone? This is an ineffective use of the transportation system in a city like Trondheim. Travelling time is significant when choosing means of transportation. Hence, initiatives to reduce the travelling time for public transportation will contribute In making public transport more popular, and thereby reducing the total emission of greenhouse gasses as well as the energy consumption.

The last 20 years has seen a 40 percent growth in the number of private cars and vans registered in Trondheim, from 57,000 in 1990 to 80,000 cars in 2008. There are also more mopeds and motorbikes on the roads: Up from 3,300 to 11,700 in the same period. The number of vehicles has grown faster than the number of inhabitants, which in the same period rose by just over 20 percent.

Estimated greenhouse gas emissions in 2006 for the road traffic in Trondheim was 195,000 tonnes CO2-equivalents, which represents 41 percent of the total emissions. 58 percent of daily journeys are made by car.

Trondheim's Environment Package for transportation aims at reducing the emission of greenhouse gases from transportation by 20 percent within 2018. To ensure this reduction, several initiatives are planned: land planning, parking politics, systems for toll collection, investing in a relieving main road network, as well as adaptation for public, walking and bicycle transportation. In addition, improvements in technology of vehicles, change-over to bio-fuel and electric cars, as well as a more environmental friendly pool of buses (for example hybrid buses that use electrical engines in the city centre). New recharging stations for electric cars have been prepared for, and these should be using the technology for boost charging as soon as this is on the market.

Average travelling speed by bus in Trondheim has decreased year by year till 2007. This trend changed by establishing lanes for public transport in the central areas of the city in 2008. Investments in intelligent traffic control systems, through establishing green waves and give priority to public transport, will increase the travelling speed by bus further, and thereby contribute to increasing the use of public transport and subsequently reducing greenhouse gas emissions. Trondheim is planning for prioritised signalling in all traffic lights by 2010. This will give priority to public transportation; depending on how belated they are and/or how many passengers they carry. At the same time, information can be sent to the bus stops, indicating how far away the next bus is (real time information).

By paving the way for parking on the outskirts of cities with the transition to collective traffic, a reduction of the car traffic in the city's centre will also be achieved. Modern systems for directing cars to multi-storey car parks may make their use simpler and more accessible.

Efficiency of the cargo industry may also contribute to reducing emissions, and systems to managing the cargo transport are being developed. In this way, the vehicles can choose the shortest route, and find room at a point of loading/unloading without unnecessary waiting and detours.

> In the course of the next two to three years the objective is to harness a substantial part of the energy efficiency potential we have identified in the Energy Efficiency Report for Trondheim SmartCity.
>
> This relies on the municipality, inhabitants and the business community doing their part. Therefore this project is also about encouraging the city's inhabitants and businesses to participate and to do their best to reduce energy consumption.
>
> **Rita Ottervik,**
> **Mayor of Trondheim**

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