**Project:**

**„Upgrading the education level at territorial (local) self-governments in the scope of sustainable energy management and Earth climate protection”**

# Some main aspects of

**Energy production and consumption**
**Climate policy**
**Renewable energy**

**in Norway**

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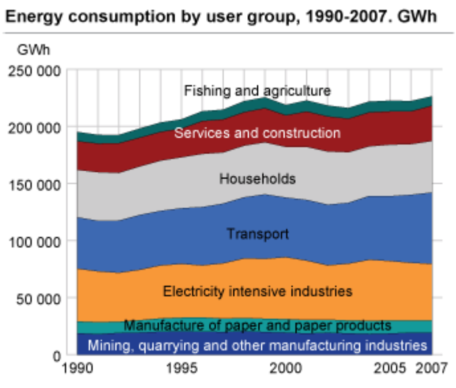
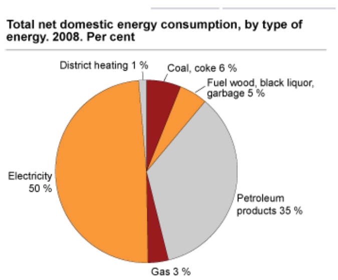
## 1. A little about energy supply and consumption in Norway

Norway is a country relatively rich in resources for energy production. This is particularly reflected in large hydro-based electricity production and oil and gas resources on the Norwegian continental shelf. Moreover, it is a good basis for renewable energy production beyond the hydropower-based electricity production from biomass, wind, waves, etc.

In 2008, Norway was ranked as the sixth largest oil exporter and the eleventh largest oil producer in the world. Norway was in 2008 the world's second largest gas exporter and the world's fifth largest gas producer. The petroleum industry has had a great impact on economic growth in Norway and the financing of the Norwegian welfare state. Through 40 years the industry has created values for about 8,000 billion NOK, measured in monetary value today. In 2009, the petroleum sector accounted for 22 percent of value creation in Norway.

Norway is based entirely on the exploitation of waterfalls for electricity production, and is the world's sixth largest producer of hydropower. The country's hydroelectric resources are a valuable renewable energy resource and water law stipulates that property as a principle to be in public hands.

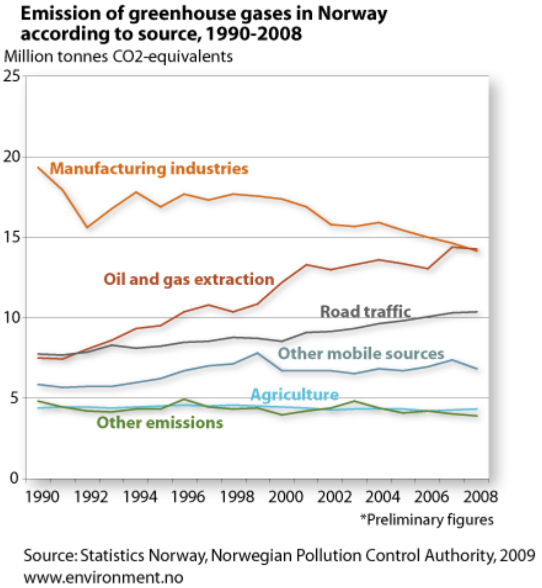


## 2. Green House Gas emissions in Norway

Greenhouse gas emissions to the atmosphere are strongly associated with energy use, in particular the use of fossil energy resources in the transport sector. Other sectors of society also cause greenhouse gas emissions, such as the use of fertilizers in agriculture.

There are mainly three gases at the input to the atmosphere for the greenhouse effect, this is $CO_2$ (carbon dioxide), $N_2O$ (nitrous oxide) and $CH_4$ (methane). The relationship between these is that nitrous oxide provides almost 300 times as much greenhouse effect as carbon dioxide, methane gives approx. 25 times the effect as carbon dioxide. These conditions make it for practical use appropriate to convert everything to the so-called $CO_2$-equivalent and measure the gas emissions to the atmosphere in the number of tons of $CO_2$ equivalents. 1 tonne of nitrous oxide thus has the same effect as 300 tons of $CO_2$.

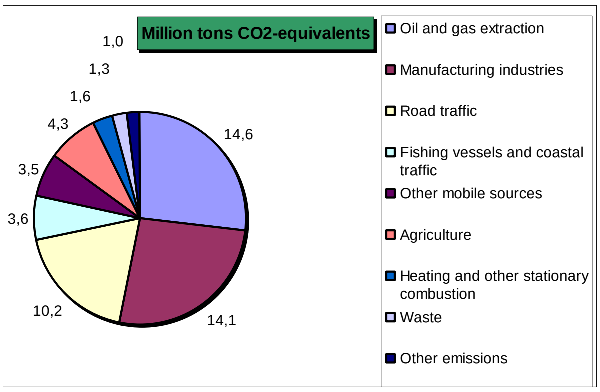



In order to target, prioritize and calibrate a climate policy with the objective of reducing greenhouse gas emissions (reducing the supply to the atmosphere) and/or to engage in carbon capture and storage (extract greenhouse gases from the atmosphere), it is essential to lead a good account of where and how emissions occur, and how this evolves over time. In Norway this is mainly handled by two institutions:

1. Statistics Norway (collection and presentation of data)

2. Climate and Pollution Control Directorate (special preparation of statistics, audits, investigations, etc.).

For planning purposes stasistics on GHG emissions are processed and kept updated by the institutions mentioned above. There is thus suitable statistics for counties and municipalities in Norway as the basis for such preparation of energy and climate actions plans and follow-up of these. Such statistics can be found on [www.klif.no](http://www.klif.no)




Stasistics on GHG emissions are the basis for the climate policy goals in Norway, including the overall Parliamentary Agreement from 2008, and in the many Energy and Climate Action plans that exist for the counties and the municipalities. Examples of such plans for municipalities and counties in Norway can be found on [www.norskeklimakommuner.no](http://www.norskeklimakommuner.no).

Figure: Norway – emissions of GHG by source, 2008.

## 3. Climate policy

Norway is an active partner on the international arena to carry out the most effective and conversely obligations on international climate policy. A lot of different surveys and assessments on different governmental levels have been carried out during the last years to develop the strategies on domestic challenges. The most long term political commitment so far ended up with the Climate Policy Agreement signed by near all parties in the Parliament on 17th of January 2008. This Agreement among other things especially says:

- Norway aims to be carbon neutral by 2030
- 15 – 17 million tons annually reduction of GHG emissions by 2020
- 2/3 of GHG emission reductions shall be realized as domestic reductions
- Norway's financial support to stop deforestation in tropical forests increased by € 400 million on annual basis
- Fossil fuel for heating buildings shall be reduced to zero, partly by governmental support, partly by law.
- Strengthening of different kinds of governmental funding arrangements to boost energy efficiency, implementation of sustainable energy systems etc.

Different NGOs and business and trade organisations have participated with their point of view, everything from position papers to comprehensive surveys and contributions to policy goals and strategies.

In March 2010 the Governmental Climate and Pollution Agency presented a broad assessment on climate policy and the need for new instruments to achieve the goals on reduction on GHG emissions in Norway. This should be looked upon as a step forward from the basis of the above mentioned Climate Agreement of the Parliament. Different expert groups have assessed different agents, the problems to be solved, costs pr. tonn $CO_2$-equivalent reduction of emissions (GHG) or captured and stored (CCS) etc. This will be the basis of the Governmental proposals for the climate Policy to be presented for the Parliament by 2011, to make new decisions.

Both before and after The Climate Policy Agreement in Parliament, it is both by public agencies (ministries and directorates, etc.), business organizations, research institutes, environmental and nature conservation organizations etc., developed a lot of studies and proposed a lot of plans that contribute to the design and implementation of climate policy. It will take too long to display them here.

Here are mentioned only the fact that pr. summer of 2010 has practically all municipalities and counties in Norway developed its Energy and Climate Action plan. These plans are an essential part of the realization of the overall national climate policy, and shows how each of the local authorities have decided to work long term for achieving climate policy objectives within their geography.

# 4. Renewable energy

## 4.1. Introduction

A renewable energy resource is defined as an energy resource that is included in the Earth's natural cycles and thus constantly "renewed". This is the circuit with a very short period compared to the time it takes to create oil, coal and gas. In Norway, hydropower is the most important renewable energy resource.

The following provides a brief description of the renewable energy sources that could be the basis for increased energy production in Norway. It contains for some parts a descriptions of the development potential that exists, and the constraints arising from environmental considerations and environmental protection, then restrictions as a result of profitability demands that ultimately provide technical / economic expansion potential. Descriptions are given as an example of how a review of the renewable energy sources can quantify the goals one might have for renewable energy production and how this may contribute to the total energy supply. In turn, this could provide a basis for evaluating the use of renewable energy contribution to achieving climate policy goals for a nation, region or other geographical area.

Most of the information in this chapter is taken from the website of the Norwegian governmental body ENOVA, the company with the main responsibility to put the official policy on renewable energy into action. A lot more can be found on www.enova.no , a version in English as well.

## 4.2. Sources of renewable energy production

### 4.2.1 Hydropower

The technology to utilize waterfalls for different works is old. More than 2000 years ago, water wheels were used by the ancient Greeks to grind grain. But it was not until the Middle Ages that the technology was spread to large parts of Europe. Hydroelectric power was important during the industrial revolution at the beginning of the 1800s and provided mechanical power for textile and machine industry. In 1870 hydro power was for the first time utilized to generate electricity. During the first half of the 1900s, hydropower was the most important source of electricity. Hydropower is considered a mature technology, and contributes still to a significant share of world electricity production (approx. 16% - IEA, 2006). In Norway hydropower dominates the total electricity production by a ratio of up to 99%. In many countries, the driving force behind the watercourse regulation just as much is to curb the damaging effects of flood and irrigation and water supply.

The total theoretical resource base for the exploitation of hydropower in Norway is estimated at approx. 600 TWh / year. Because of economics and environmental concerns, it is not possible to exploit all this potential. The total technical/economic hydropower potential possible to establish was in 2008 estimated at 205.7 TWh/year, assuming an upper limit investment for new production of 3 NOK per kWh. Of the total hydropower potential 45.7 TWh/year is in protected areas. This potential is therefore not available for development. It remains today a potential of 37.3 TWh / year which is not protected against hydropower development.

The technical/economic potential for the establishing of new hydropower electricity production changes, along with more efficient means of mapping methods by geographic information systems, technological development, changing of the investment limits and the time periods for the hydrological basis. The potential has increased from 156 TWh/year in 1980 to 205.7 TWh/year in 2008. In the same period, the production capability (development capacity) increased 95.9 TWh/year to the current 122.7 TWh/year. In 2004, NVE (Norwegian Water Resources and Energy Directorate) published a resource mapping related to small power plants (plants <10 MW). Assuming an upper investment limit of 3 NOK per kWh, a potential of 25 TWh/year was found.

### 4.2.2 Bioenergy

Bioenergy is a collective term for energy production bases on the utilization of biomass. The most common application for bioenergy is the production of heat. It is also possible to produce electricity, liquid biofuels, biogas and hydrogen from biomass. Bioenergy is the most important energy source for at least half of the world's population.

Biomass occur in many different forms with different properties. All the biomass is originated in photosynthesis, which uses the energy of sunlight to release electrons from water molecules. The free-electrons are used in cellular metabolism to build organic molecules in the plant by binding carbon from the air. The net reaction can be described by the following chemical reaction equation: $6CO_2$ + $6H_20$ + (energy from sunlight) → $C_6H_{12}O_6$ + $6O_2$. The end products are sugar, which plants use as building blocks and energy storage, and oxygen is released into the atmosphere. Plants (and algae) production of biomass depends on temperature and the supply of growth factors such as sunlight, nutrients and water. Green plants convert usually between one to four percent of solar radiation into energy bound in the biomass.

Combustion of biomass is the opposite of photosynthesis: $C_6H_{12}O_6$ + $6O_2$ → $6CO_2$ +$6H_20$+ (free energy). The use of biomass for energy purposes is $CO_2$-neutral in the sense that the $CO_2$ released by combustion of a tree equal to the amount of $CO_2$ the tree has taken from the surroundings and tied up in the growth phase. Environmental benefit of bio-energy is contingent upon the harvest of biomass does not exceed growth. Commercial bio-energy resources come mainly from forestry, agriculture and waste. It is possible to harvest biomass from the aquaculture, such as biofuels can be produced from fish waste and algae.

Biomass is usually processed into a refined good before it is used for energy production. The simplest form of processing is cutting, splitting and drying of plain wood. For the more refined goods, processing can be very sophisticated and complicated. There are many routes from biomass to energy supply. All is not as relevant, and it is important to have a good understanding of bio-energy to select the most advantageous solutions in a given situation.

The most common use for bio-energy is for heat production. Heat production can take place in a local supply center of a single building, or a small area (district heating). In towns with block buildings and industrial areas it may be profitable to establish a district heating network which distributes the heat over a larger area. The heat basis, that is the annual requirement for energy and power, makes up the guidelines for what kind of fuels and combustion technologies which are suitable.

As an example some of the permanent bio-energy products that have commercial interests in Norway are mentioned. Raw material source is most often waste from the processing of pulpwood, lumber in sawmills, trees, and parts of trees that can be used for products and chips recycled wood products. Even from this limited portion of the biomass resource, it is a wide range of commercial products:

- firewood
- bark
- wood chips from forests
- Wood chips from recycled wood
- Pellet

On the basis of the bio-energy resources in Norway a national bio-energy strategy has been developed by the Ministry of Agriculture. This has as its long term goal that biomass shall contribute to a national energy production of 14 TWh by 2020

### 4.2.3 Wind energy

Researchers at Stanford University have made calculations of wind speeds 80 meters above the ground in the world. They have reached a global potential for wind power of 72 TW, corresponding to an energy production of 144 000 TWh/year. Although only a fifth of this potential is exploited, it will cover the entire world's energy consumption and seven times the electricity consumption. It is also carried through calculations for Europe. For the EU-25 it is estimated a potential of 600 TWh/year on land and 3000 TWh/year offshore.

Norway has very large wind resources. Average wind speed through the year 50 meters above the ground on a well-exposed coastal area in Norway, may be 7-9 m/s. In areas where local acceleration occurs (hills), wind speeds over 9 m/s can be found, but many places complex coastal terrain slowes down the wind speed and creates turbulence. Kjeller Vindteknikk have on behalf of NVE prepared complete wind maps showing which areas are most suitable for the exploitation of wind energy both on land and at sea. In addition to considering wind speeds, they also mapped the risk of icing and assessed the complexity of the terrain. In Norway, we find the highest wind speed just outside Stad (western "corner" of Norway) with the annual mean winds in excess of 10.5 meters per second in 80-meter height, the height of the wind turbines. But analysis shows that storm frequency is great here and therefore, with today's technology, it will be required to stop production often. The seas southwest of Stavanger offers according to analysis highest energy production even with lower annual mean wind because the area is less vulnerable to storms. Surveys show that the waters off parts of Rogaland and Finnmark has particularly good wind resources for wind power development, but also Eastern forests of Norway may be suitable for wind power development.

### 4.2.4 Solar energy

The Sun emits enormous amounts of energy. The small proportion which annually hits the Earth's surface is equivalent to more than 10,000 times the world energy consumption. Outside Earth's atmosphere, solar radiation intensity is almost constant, 1367 $W/m^2 \pm 3\%$. The variation is due to the distance between the Earth and the sun varies over the year. Radiation varies from year to year (typically ± 5 percent). Sun's radiation varies due to fluctuations in the internal, physical processes. This phenomenon is of so little importance that one can ignore it in the context of utilization of solar energy. On average, about 30 percent of solar radiation is reflected before it reaches the ground. The radiation from the sun is modified by the atmosphere, which scatters light and reduces certain wavelengths. The reduction varies, depending on the atmospheric content of gases. The amount of radiation that are available for energy-related exploitation, therefore depend on:

- where you are on the planet; far north and south, the sun passes lower above horizon than at the equator, and the sun's rays must pass through a larger portion of the atmosphere to reach the ground. The sunniest places receive annually about 2500 $kWh/m^2$ towards a horizontal surface.

- time of year; as the sun rises higher above horizon in summer than in winter, except from the tropics. Thus, the sun's rays pass a shorter path through the atmosphere, the loss is less and available radiation is greater.

- local circumstances; for example, the local formation of clouds and shadows from the surrounding scenery and buildings can prevent solar radiation reaching the ground.

In Norway, annual solar radiation on a horizontal surface varies between 600-1 000 kWh/m$^2$. There are huge differences between the various regions, and between summer and winter.

### 4.2.5 Ocean energy

The ocean is an enormous energy storage that is supplied with energy from sunlight, geothermal sources, the earth's rotation and gravity, in concert with mechanical and hydrothermal processes. There have been many ideas to try to extract some of the energy potential from the ocean through the years. The oldest ones are several hundred years old, and on a global basis there are more than 1 000 patents on different constructions to harness this potential.

According to the International Energy Agency, the potential for total global resources from ocean related energy sources lie at up to 100 000 TWh/year. In comparison, the earth's total energy consumption lies at over 13 000 TWh/year. However, factors like immature technology, large technological challenges and high costs mean that no commercial ocean based power plant can compete with conventional power production without strong support. Other important shortcomings are value chain functions, infrastructure, legislation and standardization.

### 4.2.6 Geothermal energy

Geothermal energy is heat energy from the earth's interior. This is a substantial energy resource. It originates from heat energy stored in the earth's core and mantle, coming from a continuous supply of heat energy from the splitting of radioactive elements in the earth's crust. The temperature difference leads to a continuous heat flow from the earth's interior to the surface.

The most obvious application of geothermal energy and background heating with heat pumps is for heating and cooling purposes. On a global scale, the total installed output is 27 825 MW thermal output and the total production in 2005 was 261 400 TJ (or 73 TWh).

Geothermal energy, background heating and waste heat are ecologically sound energy sources. Utilization of background heating and waste heat in most countries is a non-emission alternative to use of fossil fuels.

The life cycle of geothermal projects can be determined through a pre-study with a survey of energy needs and consumer profile, choice of solutions, localization and dimensioning of wells, dimensioning of the energy central, installation and start-up, operation and maintenance

## 4.3 Frameworks for renewable energy in Norway

When one talks about the framework for renewable energy, this is most often about the authorities' measures to improve competitiveness for such energy production.

Renewable energy generally has high establishing costs and low operating costs. They compete primarily with energy production based on coal, oil and gas and nuclear power. Of these, coal, oil and gas have low establishment costs, which is an advantage in a short-term market.

The reasons why renewable energy is supported are more:

- Environmental and climate considerations
- Supply and reduction of import dependence
- Industrial and commercial development

Basically, all forms of energy have to compete on a free basis in the Norwegian energy market. Developers of projects on renewable energy still have the opportunity to apply for financial support, primarily through the state enterprise ENOVA which manages the governmental Energy Fund, but also other public contributors exists. This is primarily for grants to investments in various types of facilities such as wind power and bio-energy.

In the White Paper from the Parliament No.11 (2006-2007) "About the subsidy scheme for electricity production from renewable energy sources (renewable energy)", it was proposed a different levels production support on hydropower, wind power and biopower, plus immature technologies. The proposal was primarily aimed to trigger increased production based on mature technology, but took in some extent also into consideration immature technologies. In addition to this, the national authorities signalled in September 2009, that they will introduce a Swedish-Norwegian market for electricity certificates from 2012. This system allows producers of new renewable electricity a own kind of feed-in tariff.

Beyond this includes The Planning and Building Act requirements relevant to the development of renewable energy production. The Technical Regulations - TEK07, according to this says: "Paragraph 8-22 of TEK, with associated guidance, sets the requirement that buildings shall be arranged so that about half, and at least 40 percent of the energy demand for hot water and space heating (including heating ventilation air) may be covered by any other energy than electricity and/or fossil fuels at retail."

In April 2009, the EU adopted the so-called renewable directive, which, in brief, is that 20% of EU energy consumption (electricity, heating, cooling, transport) must be based on renewable energy by 2020. The directive includes binding targets for increasing renewable energy share of each member country. Norwegian authorities have confirmed that this renewable directive also is EØS-relevant, and that it therefore must be implemented in Norway. Thus, it has been developed a large number of support schemes for renewable energy technologies. The objectives of support schemes vary, and thus also the design of them.

Some schemes will primarily trigger new energy production on relatively short term. Support for wind power, which now must be regarded as mature technology, is an example of this. By introducing support for mature technology, the first new projects to come after the system is initiated, are most often the economically most profitable. Later projects will often be less profitable because the natural conditions are such that it requires higher investments, or lower (annual) energy production, or that they lead to greater risk of the project owner. In order to maintain profitability for the investor, this suggests a support regime that is strengthened over time.

Other support may have objectives to form the basis for new technology and industrial development, which in turn can provide new energy production. When the technology is immature and production costs are way over the estimated fair market value, it requires significant support to trigger activity. The level of support must aim to stimulate technology and product development, and also to the development of industrial production capacity in the long term. In such cases it is appropriate to have relatively high support to begin with. As technologies evolve and more players start to compete, the prices (unit costs) fall and support needs will be reduced.

When a country's government sets out the terms of the new arrangements or adjust existing ones, (the determination of funding level, time horizon, etc.), it is a challenge to identify the levels that trigger the activity, but also not too costly or generous. Renewable energy production can be supported/given special conditions in many different ways, here are some of the most common:

- Subsidization of investment (investment grants) to the plant for production of renewable energy. This is a widely used tool in Norway.
- Arrangements to ensure a fixed price for renewable energy.
- Order that a fixed proportion of energy consumption has to be covered by renewable energy.
- Measures for technological development (R & D support, technology competitions, strategic public procurement).
- Taxes and fees that increase the price of conventional energy. An example is the $CO_2$ tax on petroleum products.
- Tax exemption schemes.
- Imposition of standards and labeling, for example on energy products (building regulations, demands for energy production of the equipment). The new technical regulations to the Planning and Building Act (TEK 07) is an important example.
- Laws concerning the use of renewable energy, such as for heating water systems in new buildings, such as in Spain. In Norway, new construction in areas with district heating facilities is required to facilitate the use of district heating, but they are not required to use the energy from the plant. The assumption is that district heating provider has a license from the authorities. In practice, this is about larger district heating plant.
- Banning the use of conventional technologies, an example is the prohibition on the use of electric boilers in new buildings in Australia, so that options such as solar or bio-energy can strengthen its position.
- Voluntary agreements between government and enterprises on the development of technology or energy efficiency.
- Public information campaigns.

Energy technologies and -carriers compete in free markets, in Norway as well as in most other European countries. National authorities should in principle not affect the markets with measures that favor individual technologies. If some believe regulatory action cuts across the principles of free competition, can you, as a citizen of an EØS country appeal to the EFTA Surveillance Authority. When a national authority wants to introduce a new type of stipend , ESA must first approve it. ESA can accept intervention in markets when the measures are of less importance to the market conditions overall. There is also accepted funding for renewable energy because the concern for the environment is considered more important than free competition alone.

## 5. Energy savings and energy efficiency

A consistent energy - and climate policy has its justification in the fact that people and businesses need to secure energy supply to safeguard production and welfare while long-term requirements for sustainability is also addressed.

This means that we ensure an energy supply with both the lowest and as correct as possible energy consumption to achieve long-term climate policy objectives. We must therefore focus on both the right and lowest possible energy consumption – all at the same time.

An important part of all Energy and Climate Action Plans are thus the sum of measures leading to lower and more efficient energy consumption rates per $m^2$ heated/cooled buildings, per production unit, per transported km etc.

In particular, it is energy efficiency measures in buildings which are most often first implemented. It has its justification in that it is possible to achieve relatively good results quickly, it is often very profitable and it seems inspiring for further work. In order to make the measures, in the right order, to provide energy efficient buildings, a number of factors that affect energy use have to be analysed. On the basis of such analysis, building by building, plans can be made for the implementation of the measures and the financing.

The measures will span wide, from the management of energy consumption through the day, week and season to physical measures such as better insulation and replacement of windows, heat recovery from ventilation, etc.

The money saved over time on energy savings, on can invest in new initiatives and thus have a fund to continuously improve results.