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NORWEGIAN EXPERIENCES IN THE FIELD OF RENEWABLE ENERGY TECHNOLOGIES

Abstract
The goal of the article is to present experiences of Norway in renewable technologies. For Scandinavian countries are highly experienced in bioenergy and renewable energy sources technologies, Norway was picked up as an example of best practices in the field. After presenting basic assumptions in the topic of renewable energy, the Norwegian examples will be described.

Keywords
energy, bioenergy, biogas, renewable energy sources, Norway energy, Norwegian best practices

Introduction

Modern world is concentrated on searching for balance between technologies and energy, between ecology and energy efficiency. The positive side of this is that there are a lot of technologies applied to ease finding appropriate standard of living and at the same time – use the scarce resources in ecological and economical way. The article is devoted to find such solutions and to promote best practices in the field.

1.Classification of Renewable Energy Sources Technologies

Renewable energy is energy generated from natural resources such as biomass, wind, sun, rain, geothermal and tides. Renewable energy technologies include:

- biomass and biofuels,
- wind power,
- solar power,
- hydro electricity,
- geothermal heat,
- tidal waves.[4]

In 2006, about 18% of global final energy consumption came from renewables, with 13% coming from traditional biomass, such as wood-burning. Hydropower was the second largest renewable source, providing 3%, followed by hot water/heating.

1.1.Biomass as a Source of Heat Energy

Biomass energy is derived from organic matter, which releases energy through digestion, decomposition or combustion. Sources are generally region-specific and may include wood, wood residues, crop wastes and refuse. Combustion of crop wastes produces heat that can be captured to heat buildings, whereas gasification (decomposition) converts solid fuel into combustible gases that can be burned like natural gas to generate electricity.

1.2.Wind Power Engineering

Airflows can be used to run wind turbines. Modern wind turbines range from around 600 kW to 5 MW of rated power, although turbines with rated output of 1.5–3 MW have become the most common for commercial use; the power output of a turbine is a function of the cube of the wind speed, so as wind speed increases, power output increases dramatically. Areas where winds are stronger and more constant, such as offshore and high altitude sites, are preferred locations for wind farms.

[4] *Renewable Energy Sources and Climate Change Migration. Special Report of the Intergovernmental Panel on Climate Change,* IPCC, Cambridge University Press, New York 2012, s. 3-26..

1.3.Solar Power Engineering

Solar energy technologies can provide electrical generation by heat or photovoltaic means,daylighting and and space heating in passive solar and active solar buildings, potable water via distillation and disinfection, hot water, space cooling by absorption or vapor-compression refrigeration, thermal energy for cooking, and high temperature process heat for industrial purposes.

1.4.Geothermal Power Engineering

Geothermal energy is energy obtained by tapping the heat of the earth itself, usually from kilometers deep into the Earth's crust. It is expensive to build a power station but operating costs are low resulting in low energy costs for suitable sites. Ultimately, this energy derives from heat in the earth's core.

1.5.Tidal and Wave Power

Tidal power is the only form of energy which derives directly from the relative motions of the Earth-Moon system, and to a lesser extent from the Earth-Sun system. The tidal forces produced by the Moon and Sun, in combination with Earth's rotation, are responsible for the generation of the tides.

Wave power refers to the energy of ocean surface waves and the capture of that energy to do useful work, electricity generation, desalination, and the pumping of water into reservoirs.
Classification of Renewable Energy Sources Technologies

1.6.The Climate Change Issue

Climate change concerns coupled with high oil prices and increasing government support are driving forces for increasing renewable energy legislation, incentives and commercialization.

European Union leaders reached, in principle, an agreement in March 2007 that 20 percent of their nations' energy should be produced from renewable fuels by 2020, as part of its drive to cut emissions of carbon dioxide. Investment capital flowing into renewable energy climbed from $ 80 billion in 2005 to a record $100 billion in 2006. This level of investment combined with continuing double digit percentage increases each year has moved what once was considered alternative energy to mainstream.

1.7.Energy efficiency - Work Smart and Save Energy

Strong governmental and societal interest in renewable energy have led to comprehensive research and development projects at Norway’s universities, research institutes and industries; ranging from hydrogen, bioenergy, windpower and solar cell technology research at the Centre for Renewable Energy, a cooperative among the Norwegian University of Science and Technology (NTNU), SINTEF and the Institute for Energy Research (IFE), to new offshore wind technology development.

By far, the largest renewable energy related programme in Norway is Enova, which in 2008 had a budget of NOK 1 450 million, an increase of NOK 660 million over 2007 funding levels. This increase in support reflects the Norwegian Government’s determination to establish the country as a leader in the production of environmentally friendly energy resources. And the increased budget will promote efficient energy use, and heating and electricity from renewable energy resources.

Enova’s efficiency projects cover everything from large industries to family-owned businesses. Norske Skog in Skogn, one of the world’s largest producers of newsprint paper, was the beneficiary of an Enova project that began in 2007 and will finish in 2011, with the goal of cutting the company’s energy consumption by 250 GWh. The company has invested NOK 300 million in efficiency upgrades, with Enova’s contribution totalling NOK 50 million.

2.Biomass as Source of Heat Energy

2.1 General Information on Biomass as Source of Heat

Biomass refers to living and recently dead biological material that can be used as fuel or for industrial production. Most commonly, biomass refers to plant matter grown to generat electricity or produce biofuel, but it also includes plant or animal matter used for production of fibers, chemicals or heat. Biomass may also include biodegrable wastes that can be burnt as fuel. It excludes organic material which has been transformed by geological processes into substances such as coal or petroleum.

Historically, before the use of fossil fuels in significant quantities, biomass in the form of wood fuel provided most of humanity's heating, as well as providing our first renewable energy resource.

2.2.The Norwegian Experience

The current energy production based on biomass in Norway is about 50 pJ or 10% of the stationary energy consumption. About 50% is produced and used in forest industries. The main share of bioenergy used by households consists of firewood in stoves. Projections of future bioenergy use in Norway suggest that bioenergy use will increase in some market segments with the current price levels of electricity and oil. However, quite minor improvements of bioenergy competitiveness or increased energy prices may release substantially higher bioenergy use.

Wood stoves and replacement of oil-boilers in central heating systems show highest competitiveness, whereas district heating systems need higher energy prices or more subsidies to be competitive. Biomass for combined heat and power projects or domestically produced liquid biofuels seems to have limited competitiveness in the short term. On the raw material side, wood residues, and roundwood from pine and non-coniferous species represent the main potential, whereas spruce continues to be consumed by the forest industries. Biomass heating systems refers to the various methods used to generate heat from biomass. The systems fall under the categories of direct combustion, gasification, combined heat and power (CHP), anaerobic and aerobic digestion.

Forest renderings, agricultural waste, and crops grown specifically for energy production become competitive as the prices of energy dense fossil fuels rise. Efforts to develop this potential may have the effect of regenerating mismanaged croplands and be a cog in the wheel of a decentralized, multi-dimensional renewable energy industry.

Efforts to promote and advance these methods became common throughout the European Union through the 2000s. In other areas of the world, inefficient and polluting means to generate heat from biomass coupled with poor forest practices have significantly added to environmental degradation.

2.3.Liquid Biofuel

Liquid biofuel is usually either a bioalcohol such as ethannol fuel or a bio-oil such as biodisel and straight vegetable oil. Biodiesel can be used in modern diesel vehicles with little or no modification to the engine and can be made from waste and virgin vegetable and animal oil and fat.

2.4.Biogas

Biogas can easily be produced from current waste streams, such as: paper production, sugar production, sewage, animal waste and so forth. These various waste streams have to be slurried together and allowed to naturally ferment, producing methane gas. This can be done by converting current sewage plants into biogas plants. When a biogas plant has extracted the methane, the remains are sometimes better suitable as fertilizer than the original biomass.

3.Wind Power Engineering

3.1.General Information on Wind Energy

Wind energy is plentiful, renewable, widely distributed, clean, and reduces greenhouse gas emissions when it displaces fossil-fuel-derived electricity. Therefore, it is considered to be more environmentally friendly than many other energy sources. The intermittency of wind seldom creates problems when using wind power to supply a low proportion of total demand. Where wind is to be used for a moderate fraction of demand, additional costs for compensation of intermittency are considered to be modest.

Wind Power is the conversion of wind energy into a useful form, such as electricity, using wind turbines. At the end of 2007, worldwide capacity of wind-powered generators was 94.1 gigawatts. Wind produces about 1% of world-wide electricity use. Globally, wind power generation increased more than fivefold between 2000 and 2007.[5]

[5] S. Fitzgerald, *Wind Power. Energy Today,* Infobase Publishing, New York 2010.

Wind turbines are a highly effective mechanism for generating energy, as wind is in relatively constant supply. Furthermore, modern turbines can generate electricity efficiently at low wind speeds, thereby increasing the return on investment. The efficacy of wind-derived energy depends on wind speed, which is determined by geographic qualities such as proximity to large lakes and oceans, land elevation (e.g., mountains) and landscape features such as tall trees and buildings.

3.2.Large Scale Wind Farms

Large scale wind farms are connected to electrical grids. Individual turbines can provide electricity to isolated locations. In the case of windmills, wind energy is used directly as mechanical energy for pumping water or grinding grain.

3.3.Small Scale Wind Power

Wind turbines have been used for household electricity generation in conjunction with battery storage over many decades in remote areas. Increasingly, U.S. consumers are choosing to purchase grid-connected turbines in the 1 to 10 kilowatt range to power their whole homes. Household generator units of more than 1 kW are now functioning in several countries, and in every state in the U.S.

3.4.Grid Issues

Grid-connected wind turbines may use grid energy storage, displacing purchased energy with local production when available. Off-grid system users either adapt to intermittent power or use batteries, photovoltic or diesel systems to supplement the wind turbine. Isolated communities that otherwise rely on diesel generators may use wind turbines to displace diesel fuel consumption. Individuals purchase these systems to reduce or eliminate their electricity bills, or simply to generate their own clean power.

3.5.The Norwegian Experiences

Norway is already home to key industrial wind power stakeholders, such as ScanWind, which builds large wind turbines; StatoilHydro, which is working on Hywind, a floating wind turbine technology, and SWAY, which has its own floating technology; while Aker Kværner, Nexans, Devold AMT AS, Umoe are all large subcontractors providing a number of key components for wind turbines.

Developing wind turbines that can withstand the strong stresses in the open ocean requires considerable technological expertise. That’s where Norway’s previous experiences working with oil platforms in the North Sea give the country a specific advantage. A key aspect of the project involves the use of Norway’s advanced testing facilities, particularly at SINTEF and NTNU, where researchers can take advantage of everything from the Ocean Basin Laboratory, to a wind tunnel, a materials fatigue testing laboratory and an electronics laboratory. Even the best wind turbines won’t perform optimally if they aren’t located in the right places, and a new 3D-simulator that can be used to find the best locations to site wind farms, has been developed.

4.Solar Power Engineering

4.1.General Information on Solar Energy

Since ancient times solar energy has been harnessed for human use through a range of technologies. Solar energy is the light and radiant heat from the sun.[6] The sun's energy influences on the earths climate and weather, and sustains life. Solar power is the rate of solar energy at a point in time; it is sometimes used as a synonym for solar energy or more specifically to refer to electricity generated from solar radiation.

To day, solar energy is one of the world’s fastest growing industries, and the fastest growing energy technology. The photovoltaic solar energy industry is growing with annual growth rates of 50% and more, by the end of 2007, the cumulative installed capacity of PV systems around the world had exceeded 9 GW. According to EPIA (European Photovoltaic Industry Association), the market value of the solar photovoltaic market reached an annual of Euros 13 billion in 2007. The EU Commission estimates the annual growth to be between 26-32% over the next 20 years. The increased use of solar energy will lead to a reduction in CO2 emissions of about 730 million metric tons. Further more, by the year 2020 the solar power industry will have created 2.25 million new jobs. There are several factors contributing to this long awaited break-through of

[6] S. Jones, *Solar Power of the Future: New Ways of Turning Sunlight Into Energy*, The Rosen Publishing Group, New York 2003.

solar energy. Most important is the tightening of international agreement regarding CO2 emissions to decelerate the effects of global warming and consequent climatic changes.

4.2.Direct Solar Energy

Direct solar energy[7] can be converted to electrical energy through the technology of photovoltaic(PV) panels. These panels, much like the ones found on solar-powered calculator sand watches, consist of solar cells that trap energy from flowing electrons to produce electricity. An inverter converts the DC (direct current) energy to AC (alternating current)energy, which is then used for immediate electrical needs or stored in battery banks. PV panels can be mounted on south-facing rooftops or be integrated into building façades.

4.3.Passive Solar Energy

Passive solar energy is generally considered the easiest and most cost-effective way toprovide heat in new building construction, where factors such as orientation, size, position, glazed area and materials can be controlled to maximize solar absorption. Instead of mechanical equipment, building elements such as walls, windows, floors and roofs control heat generated by solar radiation. The heat gains are then distributed by pumps or fans to regulate temperature.

4.4.Active Solar Energy

Active solar energy is used to heat water and/or air via solar collectors. Unlike PV panels, which generate electricity, active solar energy panels convert sunlight into heat for water and space heating. Active solar energy systems are very efficient for heating hot water for swimming pools or general use, as well as for warming liquid for radiant floor heating.

4.5.The Norwegian Experiences

Norway may be the land of the midnight sun, but it’s not the sunniest place on the planet. That does not deter the Norwegians. R&D related to solar cell technology is big business. REC, the Renewable Energy Corporation, is the world’s largest manufacturer of multi-crystalline silicon wafers for solar cells. Norway’s leading edge in solar cell technology has been bolstered by research efforts at SINTEF and NTNU, with the two research groups working together in the PV-Solar Cell Materials Gemini Centre, which includes a joint laboratory facility called "Heliosi". The facility includes a casting and clean room laboratory; pilot scale equipment for the metallurgical production and refining of silicon feedstock, including a rotary plasma furnace; and an etching and preparation laboratory where ingots can be cut, polished and etched. The group also has started working on a nano-level, with thin films and quantum structures.

Some of the most cutting-edge solar cell research at NTNU is looking at using a greater percentage of the sun’s energy than is currently used. Solar cell technology now only converts visible light into electricity, or just 17% of the sun’s energy. If solar cells could also use the infrared spectrum, cells would be able to use fully 50% of the sun’s energy spectrum.

5.Small Hydro Power Engineering

5.1.General Information on Hydro Power

Energy in water - in the form of kinetic energy - can be harnessed and used. Since water is about 800 times denser than air, even a slow flowing stream of water can yield considerable amounts of energy.

Small hydro is the development of hydroelectric power on a scale serving a small community or industrial plant. The definition of a small hydro project varies but a generating capacity of up to 10 megawatts (MW) is generally accepted as the upper limit of what can be termed small hydro. Small hydro can be further subdivided into mini hydro, usually defined as less than 1,000 kW, and micro hydro which is less than 100 kW. Microhydro is usually the application of hydroelectric power sized for small communities, single families or small enterprise.

5.2.Small Hydro Power Plants

Small hydro is often developed using existing dams or through development of new dams whose primary purpose is river and lake water-level control, or irrigation. Occasionally old, abandoned hydro sites may be

[7] T.P. Hough, *Solar Eneregy. New Research,* Nova Science Publishers, New York 2006.

purchased and re-developed, sometimes salvaging substantial parts of the installation such as penstocks and turbines, or sometimes just re-using the water rights associated with an abandoned site.

Small hydro plants may be connected to conventional electrical distribution networks as a source of low-cost renewable energy. Alternatively, small hydro projects may be built in isolated areas that would be uneconomic to serve from a network, or in areas where there is no national electrical distribution network. Since small hydro projects usually have minimal reservoirs and civil construction work, they are seen as having a relatively low environmental impact compared to large hydro.

5.3.Micro-Hydro

Micro-hydro systems, also referred to as run-of-river systems, can readily supply AC electrical andspace heating demands. Systems consist of turbines powered by pressurized water acquired viagravity-operated pipelines. The energy produced can be used immediately or stored in batteries, depending on flow rates and energy output. Micro-hydro systems are site-specific and generallysmall in scale, thereby mitigating environmental impacts.

5.4.The Norwegian Experience

Building and management of small hydro power plants have long tradition in Norway. Approx. 2000 plants were built from 1900 to 1940. In 1980 approx 250 of these were still in operation. Today the small power stations counts for an output of 8-900 MW with a total production in a year of 3 TWh.

The Energy statute from 1991 has been deregulated and is now based on free competition. This has led into an increased interest for developing small waterfalls. New technique make also small waterfalls easier to exploit. Small Hydro plants do not deteriorate the nature in the same scale as some big size hydro plants. Furthermore are the small hydro plants often situated within the local power net and such reduce the transportation losses.

6.Geothermal Power Engineering

6.1.General Information on Geothermal Heat

Geothermal generally refers to any heat contained in the ground, but geothermal power is energy generated by heat stored in the earth, or the collection of absorbed heat derived from underground, in the atmosphere and oceans. Iceland produced 170 MW geothermal power and heated 86% of all households in the year 2000.

6.2 Geothermal Engineering

Ground-source heat pump systems employ heat from the ground (geothermal energy) or water and operate with a heat exchanger and heat pumps within either open- or closed-loop designs. This type of system is most often used for space heating and cooling requirements, and can also supply hot water for commercial or domestic use and radiant floor heating. It has been estimated that geothermal energy can meet 67 percent of total commercial energy demand.[8] Although capital costs are generally higher than for conventional systems, geothermal systems have the lowest lifecycle costs, and payback is accomplished within a relatively short period of time.

6.3.The Norwegian Experience

In Nydalen, Oslo, 180 hard rock wells will be a key factor in providing heating and cooling to a building area of close to 200,000 m2. The project is the largest of its kind in Europe. An energy station will supply the emerging building stock in Nydalen with heating and cooling. By using heat pumps and geothermal wells, heat can both be collected fromand stored in the ground. In the summer, when there's a need for cooling, heat is pumped into the ground. Annual energy purchase is to be reduced by an anticipated 60-70 percent, compared to heating by electricity, oil or gas. The combined heating and cooling secures a high utilization of the energy station. The most unique aspect of the project is the geothermal energy storage. Each of the 180 wells has a depth of 200 metres, providing 4 - 10 kW. The total bedrock area of thermal storage has a volume of 1.8 million m3, located below the building area. Plastic tubes in closed circuits are used for transferring the heat.

[8] M.A. Grant, P.F. Bixley, *Geothermal Reservoir Engineering*, Academic Press, Oxford 2011.

Total cost of the project is NOK 60 million (7.5 million Euro). This is about NOK 17 million more than the cost of a conventional solution. However, with an anticipated reduction in annual energy purchases of close to NOK 4 million, the project will be profitable. The project has received a total financial support of NOK 11 million from the government owned entity Enova and the Energy fund of the Municipality of Oslo.

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NORWESKIE DOŚWIADCZENIA W ZAKRESIE TECHNOLOGII ENERGETYKI ODNAWIALNEJ

Abstrakt

Celem artykułu jest przedstawienie doświadczeń Norwegii w zakresie technologii energetyki odnawialnej. Spośród państw skandynawskich doświadczonych w bioenergii i technologiach OZE, Norwegia została wybrana jako przykład najlepszych praktyk w tym zakresie. Po przedstawieniu ogólnych informacji na temat OZE, opisano norweskie doświadczenia w różnych typach instalacji ekologicznego pozyskiwania energii.

Słowa kluczowe

energia, bioenergia, biogas, odnawialne źródła energii, energia w Norwegii, norweskie najlepsze praktyki