DENMARK

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INTRODUCTION AND BACKGROUND

In March 2012, a historic new Energy Agreement was reached in Denmark. The Agreement contains a wide range of initiatives, bringing Denmark closer to the target of 100% renewable energy in the energy and transport sectors by 2050.

No Energy Agreement has ever been reached by a larger and broader majority in the Danish Parliament than this one; and no Danish Energy Agreement has previously covered such a long time horizon.

The Energy Agreement includes large investments up to 2020 in energy efficiency, renewable energy and into the energy system. The expected outcome in 2020 include approximately 50% of electricity consumption supplied by wind power, and more than 35% of the final energy consumption supplied from renewable energy sources.

Energy savings and energy efficiency are key components of Danish energy policy and contribute to limiting energy consumption. The initiatives agreed on in the Energy Agreement will result in a reduction of almost 7.6% in 2020 relative to 2010.

Promotion of electrification will be realised by expanding capacity of transmission lines to neighbouring countries. Smart grids will be enabled by agreement with energy companies for installing intelligent electricity meters. Energy storage options including Power to Gas and hydrogen in the existing natural gas network are investigated.

Biogas is now distributed in the natural gas network in order to benefit the existing energy infrastructure which covers most of the country.

UPDATE ON MEMBER'S ENERGY FRAMEWORK

The intense focus on renewable energy in Denmark during several years has had significant influence on both the share of renewables in the Danish electricity production and on the business opportunities for exports of energy technology and equipment, which is shown on the figures below.

VITAL STATISTICS

(Source: Statistics Denmark 2015)

EU Member since 1973 (Faroe Island and Greenland are not members of EU)

Population

5.66 million

Territory

43,098 km^2

Capital

Copenhagen

GDP/capita

340,500 DKK (2015)

Average Annual GDP Growth

2011:	*1.2 %*
2012:	*-0.7 %*
2013:	*-0.5 %*
2014:	*1.1 %*

Primary Energy Structure

(Source: Danish Energy Agency)

Production (2014)

Total production:

682 PJ

Oil:	*350 PJ (51 %)*
Natural gas:	*173 PJ (25 %)*
Renewables:	*142 PJ (21 %)*
Waste:	*17 PJ (3 %)*

Imports and exports (2013)

	Imports	*Exports*
Crude oil	*201 PJ*	*265 PJ*
Natural gas	*50 PJ*	*83 PJ*
Coal	*121 PJ*	*1 PJ*
Electricity	*11 TWh*	*10TWh*

Degree of self-sufficiency 2013: 93% (2012: 102 %)

Electricity

Production

Total:	*125 PJ (2013)*
Coal:	*41% of total*
Natural gas:	*10% of total*
Waste:	*3% of total*
Renewables:	*46% of total*
- Wind:	*32% of RE*
- Biomass:	*11% of RE*
- Biogas:	*1% of RE*
- Solar PV	*2% of RE*

Total Demand/ Consumption

Total end user consumption 2013: 607 PJ

Oil:	*257 PJ (42%)*
Natural gas:	*65 PJ (11%)*
Coal:	*5 PJ (1%)*
Renewables:	*60 PJ (10%)*
Electricity:	*112 PJ (19%)*
District heating:	*106 PJ (17%)*
Transport:	*34%*
Industry:	*22%*
Commercial:	*14%*
Residential:	*30%*

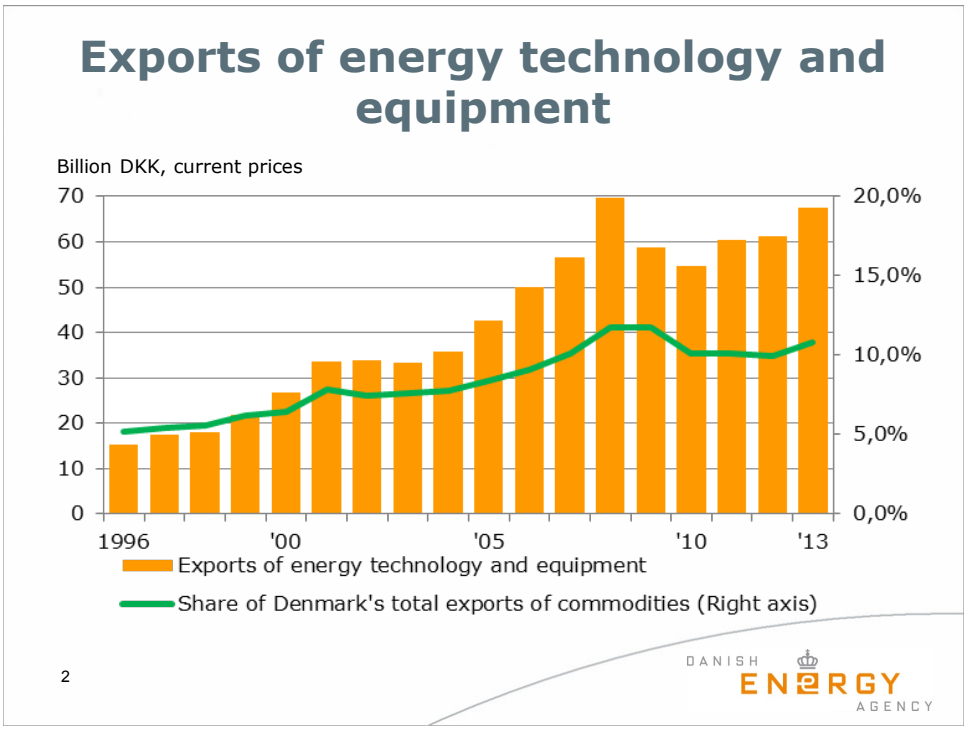

Figure on Exports on energy technology

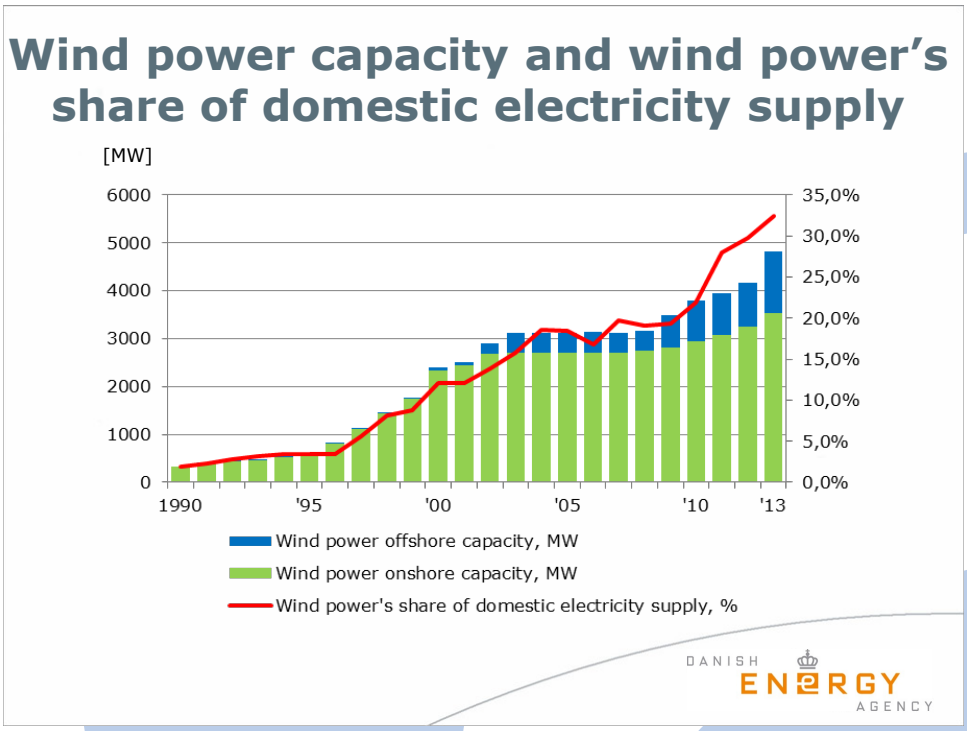

Figure on Share on Electricity generated by wind

The future Danish energy system will be predominantly based on electricity. Electricity, however, cannot currently be stored for later consumption, but has to be used instantly upon production. The electricity production of the future will fluctuate—not only during the day, but also for longer periods of less wind—and it is therefore vitally important that electricity is in store for these times.

To maintain balance in the energy system surplus electricity from the wind turbines must be converted into a storable energy. This is the background of the extensive research in electrolysis apparatuses which has been going on for many years. By using electrolysis hydrogen becomes an energy carrier which stores electricity from surplus production. Hydrogen can then be stored in the existing gas network or used for fuel cell vehicles.

In addition to this, hydrogen may be used for upgrading biogas to methane-quality and thus making it storable in the gas network.

Gases produced by sustainable sources (wind, biomass) are useful for subsequent power and heat production in smaller fuel cell plants or as fuel for different types of transportation—either directly or after further conversion into methane, dimethyl ether (DME) or other synthetic fuels.

PRIORITIES IN THE DANISH ENERGY R&D&D PROGRAMS

In order to fulfil the long term target of 100% renewable energy in the energy and transport sectors by 2050, key priorities in the Danish energy R,D&D programs are: Sources for renewable energy, Energy storage, Energy efficiency and Energy system integration.

Besides R&D activities several Public Private Partnerships have work programs on specific energy technologies in order to benefit of a harmonized strategy and shared knowledge.

DGC is active and engaged in Danish Partnerships on

- Hydrogen and fuel cells
- Gasification
- Smart Energy Grid

During the last years a total budget of app. 1 billon DKK have been available for Energy research in Denmark and 15–20% of the funding has been allocated to hydrogen and fuel cell technologies.

HYDROGEN R&D&D CASE STORIES

HYDROGEN FOR ROAD TRANSPORTATION

Transport makes up more than a quarter of the Danish energy consumption and this portion is steadily increasing. In addition to this, almost all transport in Denmark is currently fuelled by oil-based products such as gasoline and diesel.

Several actors are in the process of establishing a nationwide network of hydrogen filling stations covering all the major cities across the country. Today, five hydrogen refuelling stations in operation and six stations more are expected in 2016 as the number of hydrogen vehicles on the roads increases.

As many other cities in Denmark, Copenhagen has established a local climate strategy, which include targets for use of fossil fuels for the city including road transportation.

The city of Copenhagen has 150 electric vehicles. Since 2014, the city also has 15 hydrogen fuelled vehicles and three refuelling stations.

15 hydrogen-fuelled vehicles in Copenhagen

TEST OF POLYMER DISTRIBUTION PIPES FOR HYDROGEN TRANSPORTATION

A field test of 100% hydrogen in polymer (PE) distribution pipes for natural gas is now in its concluding phase. The test began in 2003 in order to investigate possible material deterioration. The tests are carried out in a small grid at Danish Gas Technology Centre. Hydrogen is circulated in the grid under conditions similar to real operation. The test grid is constructed from samples taken from the Danish natural gas grid in order simulate the possible consequences for the Danish natural gas grid if it converted to 100% to hydrogen.

Based on the project results, smaller hydrogen PE grids for demonstration have been put into operation in Denmark.

The final results on the effect of hydrogen at PE pipes for natural gas will be available in 2016.

Test of polymer distribution pipes for hydrogen transportation

THE DANISH MICRO COMBINED HEAT AND POWER PROJECT

Danish Micro Combined Heat and Power is working to develop, test and demonstrate micro combined heat and power units that run on fuel cells. The aim is to have units ready for Danish and foreign consumers after the end of the project, which was initiated in 2006 and finalized in 2014.

Danish Micro Combined Heat and Power combines the competencies of eight leading Danish energy companies in one national consortium with a budget of more than 150 million DKK.

Field test of a large number of micro CHP units, both natural gas and hydrogen fuelled. In total, more than 200,000 operating hours at app. 60 units at two locations: One based on SOFC technology and natural gas and one based on PEM technology and hydrogen supply.

More on test results at: http//www.dmkv.dk/english/index_en.html

The Hydrogen Grid in Vestenskov during Construction Works

THE MEGA-STORE ENERGY PROJECT

The MeGa-stoRE energy project demonstrates the technology that can store wind energy in the natural gas network, by a combination of biogas and electrolysis.

Biogas consists of about 65% methane (natural gas) and 35% CO_2. In first generation upgrading, the CO_2 content is removed and the pure methane is sold as natural gas through the natural gas grid. In the MeGa-stoRE concept, which is the next generation upgrading plants, the CO_2 content in the biogas is also exploited for production of natural gas. It is possible by allowing the CO_2 to react with hydrogen to form methane (natural gas) and water by the Sabatier reaction: $CO_2 + 4H_2 => CH_4 + 2H_2O$.

A group of companies and the Technical University of Denmark have during the last 5–6 years carried out intensive research in converting wind energy into hydrogen via electrolysis. Through this work, electrolysis cells that can utilize over 85% of wind energy have been developed.

The first electrolysis plant that can be expanded to Megawatt size is a reality at the prototype level.

Project info: http//www.methan.dk/index.html

ENDNOTES

Danish Energy R&D projects (database): http//energiforskning.dk/en?language=en

Denmark in figures: http//www.dst.dk/en.aspx

Key energy statistics 2013 (report): http//www.ens.dk/en/info/facts-figures/energy-statistics-indicators-energy-efficiency/annual-energy-statistics

REFERENCES

Danish Gas Technology Centre (www.dgc.dk)

Danish Energy Agency (www.ens.dk/en-us)

Partnership for hydrogen and fuel cells (www.hydrogennet.dk)

Partnership for Smart Energy Networks (www.smartenergynetworks.dk)

Partnership for gasification (http//www.forgasning.dk/partnerskabet)

HYDROGEN IN DENMARK

Hydrogen Refueling Stations in Denmark (http//brintbiler.dk/?page_id=296)

Hydrogen Success Stories (http//www.hydrogennet.dk/384/)

Danish Hydrogen and Fuel Cell Competences (http//www.hydrogennet.dk/445/)

WHEC2020 in Denmark (http//www.iahe.org/whecwhtc.asp)

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