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Paving the way – Concrete measures to tackle climate change

Which are the technical solutions - Can the experience from the Nordic and Arctic Regions be put to global use?

By Kjell Bendiksen, Institute for Energy Technology (IFE), Norway

Good afternoon! And thank you for the invitation and your kind introduction, Chairman. It is an honor and a great pleasure to be here.

I've been challenged to present technical solutions that could tackle climate change – in ten minutes. What can be done to accelerate the development and deployment of such solutions?

These are complex issues, which we are also struggling with at The Norwegian Institute for energy technology. IFE is the largest independent energy research lab in Norway, with about 600 employees from 30 countries, covering a wide part of the energy sector, including oil, gas, renewable energy, carbon capture and sequestration (CCS), energy storage, hydrogen, and nuclear safety. IFE operates the only two nuclear research reactors in Northern Europe, JEEP II at Kjeller and the Halden reactor.

IFE is internationally oriented. We develop technological solutions for customers in 40 countries. More than 40% of our total income of approximately 650 mill.kr (120 mill. US$) comes from abroad. We focus on technological innovation, and create a couple of new spin-off companies every year.

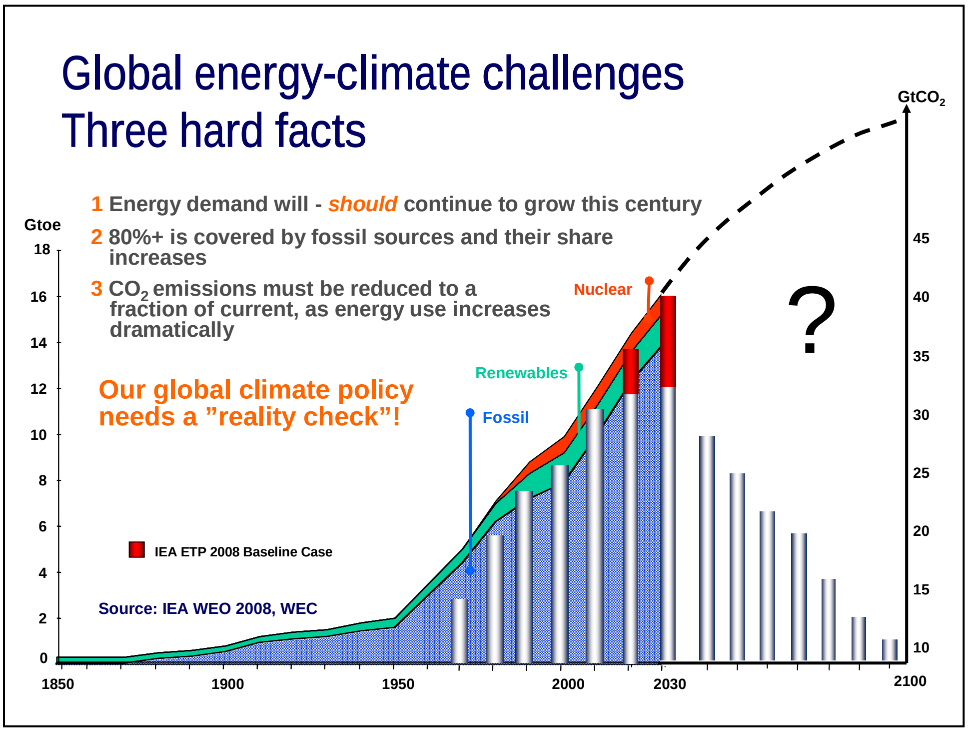
To appreciate the unusual dimensions of the energy-climate challenges, I'd like to start by recalling three hard facts (fig.1).

First, global energy use has increased almost exponentially over the past century, and will *continue* to increase sharply for many decades, due to population growth and basic needs of developing countries.

Second, 80%+ is covered by fossil fuels; oil, coal and natural gas, and their share is *increasing*. This implies a sharp growth in CO_2 emissions over the next decades according to the IEA. These are robust figures, it doesn't really matter if the growth is 30 or 60%, CO_2 emissions and their impact on global climate will be far too high.

Third, according to the International Panel on Climate Change (IPCC), this development must stop. If global warming is to be limited to 2 ^oC, CO_2 emissions must be reduced by up to 85% of today's level towards the end of the century. The G8 Summit in 2007 agreed to seriously consider a global cut of 50% by 2050.

Fig. 1



According to the IEA Energy Technology Perspectives 2008, if we are to limit the temperature increase to about 3 ^oC, global energy related CO_2 emissions should peak around 2030 and drop to today's level around 2050, as indicated by bars in Fig. 1. If we are to limit the temperature increase to 2-2,5 ^oC, global energy related CO_2 emissions must peak in the next decade, and drop to half of today's level around 2050, according to their BLUE Map scenario.

Consequently, our global climate policy needs a reality check in Copenhagen. This is the development we'd *like* to have (grey), this is the one we're likely to get (red), according to the IEA. CO_2 emissions must be drastically reduced even if energy use increases by 50-100%. The big question is *how*; which technologies can fill this gap?

Our options are renewables, nuclear, coal with CCS, *and* increased energy efficiency and reduced demand (fig. 2).

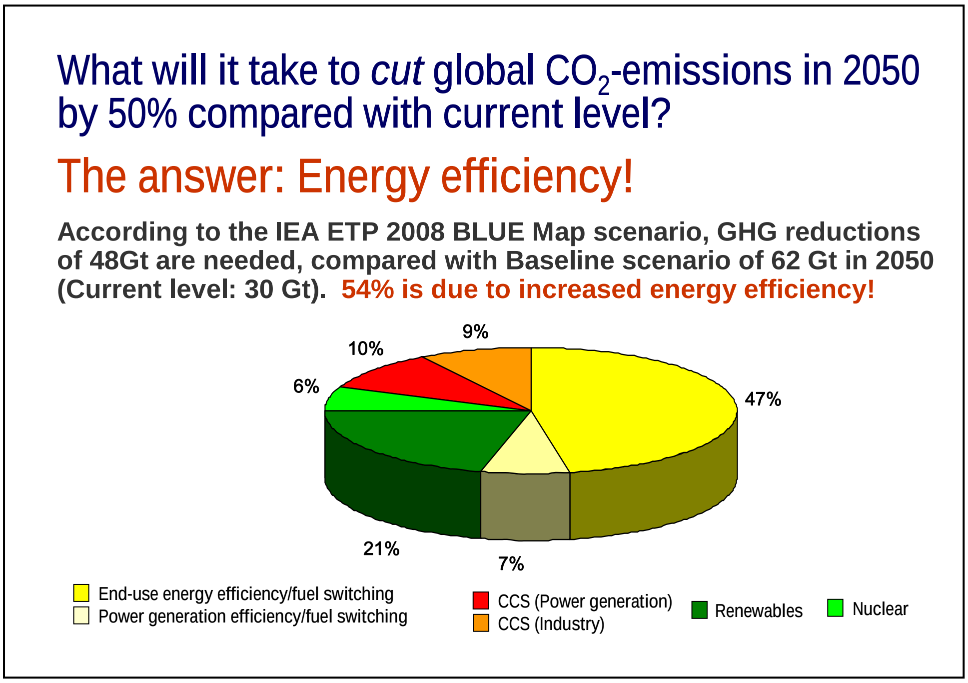
In fact, increased global energy efficiency and reduced energy use in OECD countries is the *only* way to cut Greenhouse Gas (GHG) emissions significantly in the short run. Renewables, in particular hydro, wind, solar and biofuels, represent a long term, sustainable energy supply option, if we can get the costs down.

Fig. 2

The value of the global energy supply system, however, is enormous, and the life spans of large power plants are 30-60 years. Thus, a radical change in our energy system will require completely new technologies, huge investments, and will take time.

To return to one of my previous hard facts: What will it take to *cut* global energy related CO_2 emissions in 2050 by 50% compared with current level (fig. 3)?

Fig. 3



The answer is simple; energy efficiency! According to the IEA ETP 2008 BLUE Map scenario, GHG reductions of 48Gt are needed, compared with the Baseline scenario of 62 Gt in 2050 (Current level: 30 Gt). 54% is due to increased energy efficiency! We would also have to decarbonise power production. This would mean a technology revolution.

There is a substantial potential for offshore wind power in Nordic countries, off Norway alone it is estimated at 6-7 times our hydropower production (with floaters). This is the 160 MW Horns Reef Wind Park off Esbjerg.

Solar energy has also a huge potential, not only in the sun belt. Passive solar heating already contributes to domestic heating, and solar energy has a significant potential in this context, for instance in smart buildings, also in our part of the world.

There is a strong industrial basis in the Nordic region on hydro, wind, solar PV and bio energy, with leading global companies like Vattenfall, Statkraft, REC and Vestas. There is also a fortunate, complementary national diversification in the Nordic electricity mix, and our efforts on low emission energy technologies (fig. 4). Denmark pioneered the development of commercial wind power, Sweden bio fuels, and Norway established a global solar PV supply industry. Finland, in addition to bio energy, has taken a lead in revitalising nuclear power in Europe.

We don't have and do need efficient large scale energy storage technologies and fuels; batteries, hydrogen and bio, as well as increased energy efficiency!

Fig. 4

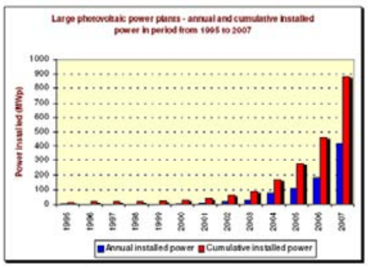
Renewable energy: Nature's response to our energy-climate challenges

Strong Nordic basis in:

- Hydro
- Wind
- Solar
- Bio energy

We need:

- Energy storage & clean fuels: Bio, batteries and hydrogen
- And increased energy efficiency!



Source: The solar server 24/01/2008

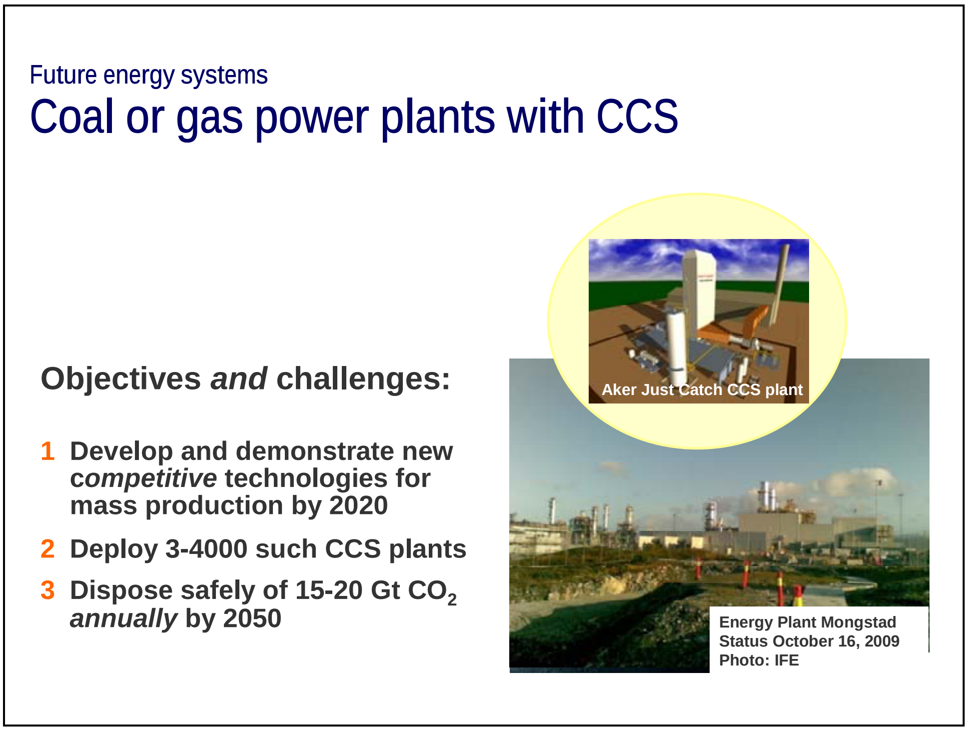
The global wind and solar power markets are growing very fast, 40-60% annually over the past 7-8 years. This also applies to large MW PV-parks, as indicated in this figure. But, as we start from very low annual production volumes, of about 4TWh, globally, it will take time for solar PV to make a significant contribution. Even if the growth rate of 40% continues for another 10 years and then levels out at 10%, global annual solar PV production would reach 2,500TWh, today's annual production from nuclear power, around 2040. Similar long large scale-impact-time horizons apply to other "new" renewables and to CCS, in particular.

Then, is CCS a realistic option (fig. 5)? There are three simple but very demanding objectives *and* challenges here:

1. **To develop and demonstrate *new competitive* technologies for mass production by 2020,**
2. **To deploy 3-4000 full scale CCS plants, and**
3. **To safely take care of 15-20 Giga tons (Gt) of CO_2 *annually*, say within 2050.**

This is the site of the Norwegian CCS "Moon landing" project at Mongstad, on the west coast, near Bergen (fig. 5). A new gas fired energy plant with a net capacity of 280 MW electric power and 350MW process heat for the on-site refinery is under construction, and expected to be on line in a couple of years. The CCS plant, however, with a capacity of some 2 mill. tons of CO_2 annually (including about 0,8 mill. tons from the cracker) is delayed, and may not be in operation before 2020.

Fig. 5



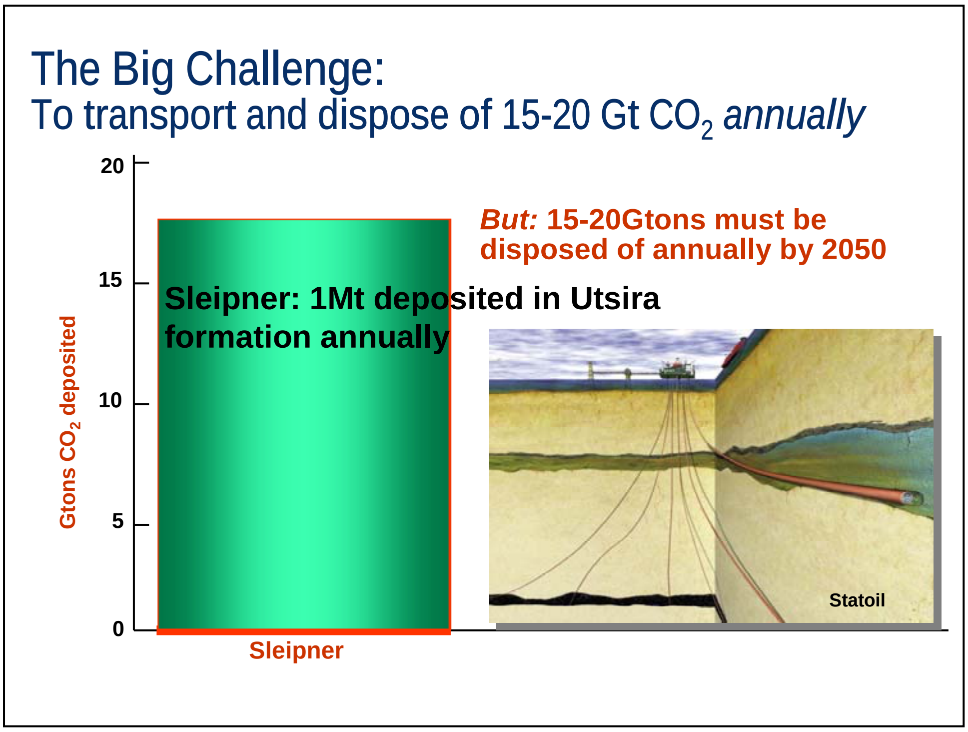
The site will also contain a CCS Test center, also under construction. This is one of the concepts to be realized as demonstration plant of about 50MW in a few years.

There are basically three different types of carbon capture technology concepts: Removal of CO_2 before, during or after combustion. In addition, there are more technologically advanced concepts, but with significantly longer time horizons.

The real challenge, however, if we succeed in reducing costs, is to establish *huge* scale regional transportation systems and storage facilities taking care of 150-200 Gt of CO_2 every decade!

Statoil is a world leader in subsurface disposal of CO_2, and has, as is well known, deposited some 1 mill. tons annually from the Sleipner offshore platform into the Utsira formation since 1996 (fig. 6). The global challenge is to extend this by a factor of 15-20,000. Norwegian authorities are currently investigating several other potential deposition sites.

Fig. 6



To appreciate the magnitudes here, the entire world energy use, in oil equivalents, is roughly 11 Giga tons annually, and that is a high value resource, not a waste product.

How do we achieve competitive CCS technologies - What can we do in the Nordic Region (fig. 7)? To summarize; our main priorities should be:

1. First of all, to reduce the cost gap by technological innovation, increased efficiency and *mass production.* This is more important than the commercial time horizon.
2. We should verifiy new technologies by establishing Demo and Large scale CCS plants (in-line with EU SET Plan, Mongstad projects, and similar global initiatives),
3. Put priority on technologies which may be *mass produced* for a global market, and
4. Continue efforts on large *scale subsea* CO_2 deposition. We need to develop and establish necessary CO_2 infrastructures, with pipelines, boosting and final deposition – and quite fast, and we need to assess the feasibility and safety of large scale global

CO_2 deposition systems, as well as required legal frameworks and regulation regimes (OSPAR and London Conventions).

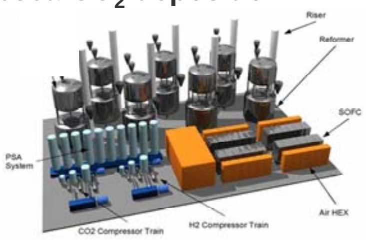
5 **Finally, to succeed, we need completely new technologies! In my opinion, new technology breakthroughs (like the mobile phone) is the only thing that can save CCS.**

Fig. 7

How do we achieve competitive CCS technologies - What can we do in the Nordic Region?

1 Reduce cost gap by technological innovation
2 Verifiy new technologies by establishing Demo and Large scale CCS plants (EU SET Plan, Mongstad projects)
3 Put priority on technologies which my be *mass produced* for a global market
4 Continue efforts on large *scale subsea* CO_2-deposition
5 We need completely new cutting edge technologies!

Objective: Become a major international supplier of CCS-technologies!



IFE/ CMR Zero Emission Gas Power - Hydrogen plant (ZEG)

In my opinion, if CCS is to fly, we need completely new technologies, like The IFE/ CMR Zero Emission Gas Power - Hydrogen plant (ZEG Power Plant). It is based on high temperature fuel cell power production, using the waste heat for hydrogen production, with close to 100% integrated CO_2 capture. If we succeed, it will have competitive costs, and be significantly cheaper and better than post combustion, mainly due to its very high energy efficiency (>80%). It may enable large scale hydrogen production as fuel, and open new markets for Hydrogen in oil production (e.g. heavy oils, tar sands).

For Norway, the main objective must be to become a major international supplier of CCS technologies and solutions, as we do not have a significant home market for CCS.

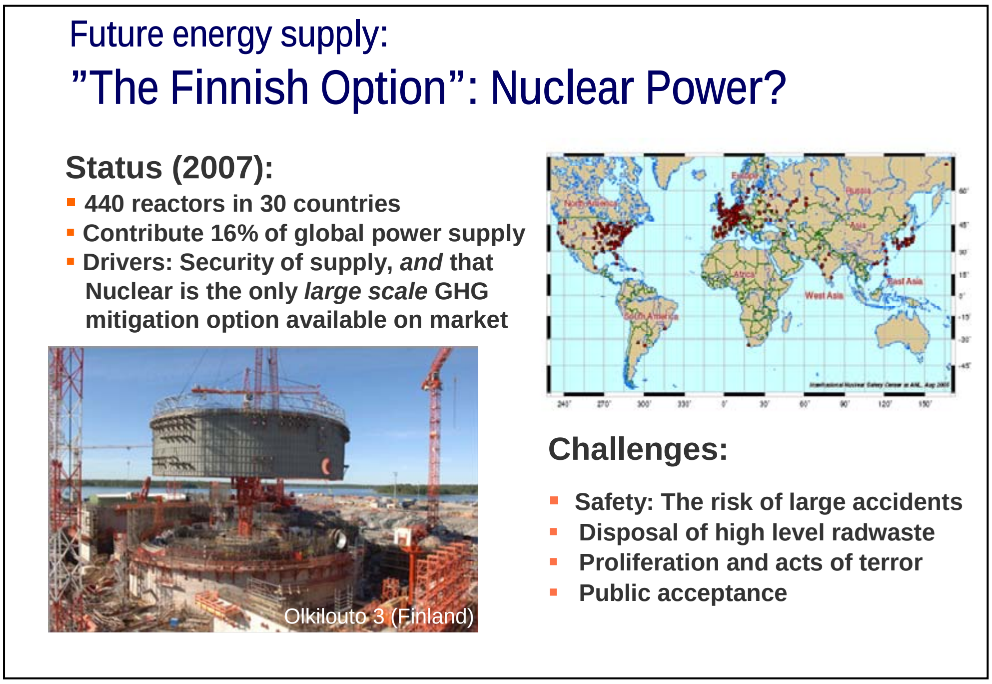
Is nuclear an option (fig. 8)? This is a picture of the new Finnish nuclear power plant in Olkiluoto, under construction. About 440 reactors in 31 countries contribute 16% to global power supply, one third in EU, almost 80% in France, 50% in Sweden.

Many countries are now reassessing the role of nuclear power in their energy supply. The most important drivers are the increasing, serious climate and energy supply concerns in many countries.

Nuclear power is, in fact, the only large scale low emission option available on the market, that you can buy. The question is whether it can play an important role in this context? According to the IPCC Working Group III Report "Mitigation of Climate Change" (pp 13), it can, quote: Nuclear Power may be a major GHG mitigation option.

There is now definitely a more positive attitude to nuclear in the market. According to a recent OECD/NEA-study, nuclear power is already competitive to conventional gas power, and would be more so if CO_2 penalties are imposed on fossil fuels.

Fig. 8



Safety has been significantly improved over the past few years. But there are still challenges. They are many, according to the critics: Safety, the risk of large accidents, in particular, disposal of highly radioactive waste, proliferation and acts of terror. Last but not least, public acceptance remains crucial. Nuclear must be "de-demonized". Nuclear safety and waste disposal must be *felt* to be good enough and nuclear power accepted as an alternative to increased GHG emissions.

So, how do we achieve competitive renewable and CCS technologies - What can we do in the Nordic Region (fig. 9)? In my opinion, main priorities should be to:

1. **Reduce production costs by any means; increased efficiency, innovation and mass production**
2. **Develop, verify and deploy next generation technologies,**
3. **Put priority on cutting edge technologies that strengthen supply industries and clusters,**
4. **Create "Nordic R&D teams" based on national initiatives (FMEs) to support this**
5. **Establish Nordic test markets for new energy technologies**
6. **Establish feed-in tariffs and grid access.**

A main challenge for wind parks offshore Norway is the long distance to markets. We need grid access, new cables to the continent, as well as alternative capacity when there is no wind, ideally instant availability and efficient control. That is basically either hydro power, which, if available, would be ideal because of its extremely short phase-in time, spare base load, or efficient large scale energy storage facilities, which we really don't have today.

Fig. 9

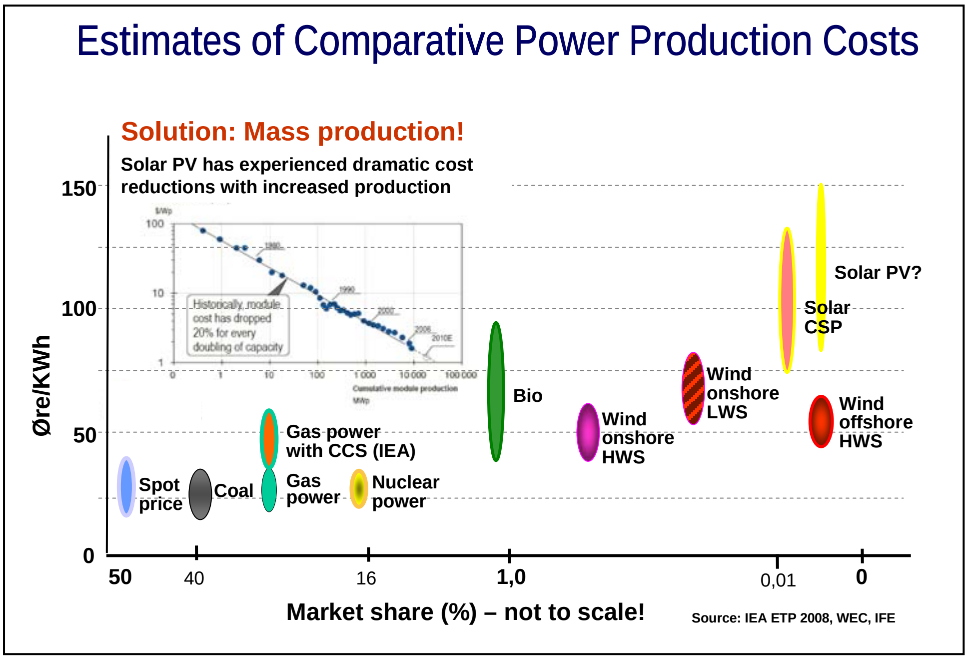
The objective must be to become a major European growth region – "A Green Valley" for development, use and export of renewable energy *and* energy technologies!

This is absolutely not an exact science, but if we compare production costs (in øre/kWh) from different sources, it is, despite uncertainties, possible to draw a couple of clear conclusions (fig. 10):

First of all, it is clear that solar PV, wave, wind power and CCS all have some way to go before being competitive, and will be dependent on subsidies (in addition to quota benefits) for years to come. The Gas power with CCS price range is based on IEA ETP 2008, which I think is far too optimistic. If we include Kårstø or Mongstad cost estimates, CCS extra costs would be in the range 30-80 øre.

Finally, it is seen that nuclear power is competitive with natural gas without CCS, and definitely cheaper than natural gas (or coal) with CCS.

Fig. 10



A main challenge is to make renewable energy competitive. Mass production is a very efficient way to bring costs down. Solar PV has experienced a fantastic, exponential 20% cost reduction with each doubling of production volumes over a 30 year period, as shown here. In fact, production has increased a factor 10,000 and costs have been reduced by a factor of a hundred since 1975.

The module price forecast last year (June 2008) was from 4,2 to 2,8 US$/$W_p$ in 2012. However, the finance crisis has led to a cost drop this year of 50%, to 2,0-2,5 US$/$W_p$!

Solar PV, has in fact already become competitive in some niche markets, in California, Hawaii and Italy at midday due to air conditioning, with spot prices up to 30-40 cents/kWh.

To conclude, I think the Nordic countries could and should agree on common objectives on energy efficiency, renewable energy and CCS. The ambition must be to create new billion dollar industries and clusters, and become major exporters of renewable and CCS technologies *and* competence.

We should develop and verify next generation renewable and CCS technologies that may be mass produced and establish the Nordic region as a test market for these technologies; establish common rules and standards to harmonize innovative markets, identify and establish Nordic clusters within renewable energy, transport, smart buildings and CCS.

And we should promote more efficient energy production and use *now.*

Finally, our global climate policy needs a ”reality check” in Copenhagen. The gap between our climate objectives and the real development widens. Energy demand will continue to rise sharply for many decades due to population growth and basic needs in developing countries. The global energy mix will be dominated by fossil fuels for a long time. Robust policies must incorporate the fact that Global GHG emissions must be reduced, even if energy use increases.

Fig. 11

Conclusions

The Nordic countries should:

1. Agree on common objectives
2. Create new billion dollar industries and clusters and become major exporters of renewable and CCS technologies
3. Develop and verify next generation technologies that can be mass produced
4. Establish the Nordic region as a test market in energy and environmental technologies
5. Promote more efficient energy production and use *now*

Thank you for your attention!

This is a satellite photo of the Arctic from 2007, showing a huge reduction in minimum ice extension, which occurs in September, compared with the 30 year average. The reduction in ice area, in fact, is the size of Texas and California in just two years, from 2005. To me, it gives an early warning of what we may expect, and of the urgency.

Thank you for your attention!