27

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Air Pollution & Climate Secretariat
AirClim

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Content

Foreword, update

The work for this report was mainly done in 2011.

At that time data was available, in various degrees, for 2008 and 2009. It was easy to pick 2008 as a reference year, because it was the last boom year, for the first 8 months, and then slumped for the last 4 months, making it on average a fairly normal year. That was how the economy looked then.

Since then, the economy has moved erratically, and it is hard to pinpoint a "normal year" since then. So let us stick to 2008 as a point of departure.

In the intervening years, a large number of opportunities have been missed, which will make it more difficult to achieve the targets by 2020 and 2030. One of the major missed opportunities is that the EU did not reinforce the 20 per cent target for 2020. This has now led to the near collapse of the emission trading system and prices at 4-5 euro/ton instead of the 20-40 euros expected.

This means that if the Nordic-Baltic countries were to test a radical CO_2 reduction, there will be no support from outside, at least not before 2020.

The failure of emission trading has inflicted considerable collateral damage, because so much hope was pinned on the trading that other, national, instruments have been weakened (national carbon taxes), if they have not banned explicitly by the Trading Directive (national regulation of carbon emissions in the environmental permit for big polluters).

On the other hand, there is now good evidence that things can happen very fast in technology.

Since then, Germany and other countries have proved that the task may be easier than described here, at least as concerns photovoltaic solar power. Germany generated 28 TWh from photovoltaics in 2012, up from only 4.4 TWH in 2008. Much more is to come during 2013. Germany is far from the ideal place for solar. Parts of Scandinavia actually have more insolation than Berlin or Hamburg[1]. Most of the solar electricity in Germany comes from rooftops, but still it is installed on an industrial scale. All costs have fallen dramatically and are projected to fall further, so it is much cheaper to do now what Germany did a few years ago.

Integration of so much new renewables has run relatively smoothly.

The notion that the energy system only changes very slowly has been challenged after the accident in Fukushima. Japan has managed two summers and two winters without almost all of its nuclear power, which supplied some 30 per cent of its electricity before the accident. This was not completely painless, but there were no blackouts or brownouts. The accident led to a policy shift not only in Japan but also in at least China, Canada, Germany, Belgium, Lithuania, Switzerland, Italy and France. In those and probably more countries, plans for new nuclear were stopped or reduced or decisions

1 See EU database at http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php

were taken to phase out existing nuclear earlier than before. The effects were both long and short term. 2012 saw the lowest production of nuclear power in the world since 1998, and it now supplies no more than 10 per cent of global electricity.

In the Nordic-Baltic region, nuclear power has become a less viable alternative. The Olkiluoto 3 reactor, originally scheduled for operation in 2009, has now slipped to 2016. Plans to re-introduce nuclear power in Lithuania have been voted down in a referendum.

The downturn of nuclear power is a sideways movement in the perspective of CO_2 reduction. But it shows that rapid change of policy and technology is possible and it has not been accompanied by a fossil renaissance.

The fossil options have also lost out during the more or less continuous 2008 crisis. Oil is still expensive. Natural gas is expensive in Europe, and is increasingly seen as a security threat in terms of Russian dominance. A large number of coal power plant projects have been scrapped in Germany, the UK and in other countries due either to high cost, low electricity demand or political/legal problems. Old coal power plants have been shut down in many European countries, many of them due to EU legislation.

The credibility of carbon capture and storage, once the principal justification of future coal power, is very much eroded. No full-scale project is operative, under construction or even planned anywhere in the world, 12 years after CCS was launched as "key technology" by the George W. Bush administration in May 2001 and Vattenfall, soon thereafter released its torrent of CCS propaganda.

Not only are fossil and nuclear power receding. Primary energy consumption has fallen over the last 10 years in the OECD. Electricity consumption has fallen over the last five years in the OECD. This is mainly due to increased efficiency. But while fossil fuels and nuclear have moved backwards, renewable energy has increased spectacularly in many countries. Seven per cent of EU electricity came from wind power in 2012 This is nowhere near the limit, as Portugal got 20 per cent of its electricity from wind[2], and Denmark 28 per cent[3]. Except for Denmark, however, our region is however far below the EU average 7 per cent.

By the end of 2008 there was only 1.5 gigawatts of offshore wind power in Europe[4]. By the end of 2012 it was 5 gigawatts, most of it around the UK. A new source of power is now proven on a large scale, ready for fast growth in all our eight nations

2 http://www.ren.pt/media/comunicados/detalhe/ren_publica_dados_tecnicos_de_eletricidade_e_gas_natural_de_2012/

3 http://www.ens.dk/da-dk/info/nyheder/nyhedsarkiv/2013/sider/20130208_elforbrugetfald-ti2012.aspx

4 http://www.ewea.org/fileadmin/images/graphs_statistics_charts/emerging_market_report/Cumulative_and_annual_offshore_wind_installations_1993-2012_by_MW.jpg

Renewable energy is no longer a luxury for rich nations, if it ever was: it is also being developed fast in India, especially in the state of Tamil Nadu[5] which is purchasing 3000 MW of photovoltaics in the three years 2013-2015.

It is also noteworthy that wind power in China overtook nuclear generation in 2012, and that China, already a world leader in wind power and solar heating, is poised to become the world's number 1 for photovoltaics in 2013.

In the few years since the economic crisis of 2008, renewables have moved to centre stage, efficency for electricity, heat and cars has advanced while "conventional" power sources are moving backwards in Europe and much of the world. What has been done so far is nowhere near enough, but it is more clear than ever that there is a real choice.

Executive summary

A 70 per cent cut in CO_2 emissions by 2020 since 1990, and 95 percent by 2030 in the Nordic-Baltic region is feasible, using known technology and not exceeding reasonable costs.

The main elements are

- 100 TWh (upwards 40 GW) of wind power, up from about 10 GW[6] at the end of 2012.
- Far-reaching programme for energy efficiency of buildings.
- Much more solar heating.
- Much more efficient new cars.
- Heavy investments in second-generation biofuels.
- A slow-down in Norwegian oil and gas production.
- A complete phase-out of shale (Estonia) and peat (Finland and Sweden), combined with active job creation schemes in areas concerned.
- Complete phase-out of coal for heat and electricity.
- A significant, but limited investment in solar cells and wave power

A 70 per cent cut by 2020 may sound dramatic, but it is not extreme in relation to what is at stake if global warming is allowed to exceed 1.5 degrees. The world emits about twice as much as is sustainable, and the rich countries to which the Nordic-Baltic region belongs emit about twice as much per capita as the world average.

The main point of unilateral deep carbon cuts in our region is of course that if we can do it here we also make the case that much of what we do can be done all over the world. But to some extent we have an easier task than other regions. We have far more hydro per capita than average. This means that very much wind power can be operated with little need for extra storage. We

5 http://mnre.gov.in/file-manager/UserFiles/presentations-challenges_and_issues_in_solar_RPO_compliance_19122012/Session%20-%202_Tamil%20Nadu%20Solar%20Policy%202012_TEDA.pdf p9

6 EWEA annual statistics for 2012

have a very extensive high-voltage grid, with good possibilities for exporting electricity. We have large a biomass resource. We also have a high level of technical and industrial expertise and are a relatively rich part of the world, though there are large differences between and within our nations.

The investment need is not specified, but is sure to be very big. But some of the investments are profitable in every sense. Systematic energy efficiency in buildings is an obvious example.

More fuel-efficient cars are not any more expensive than other cars. If they are smaller and have smaller engines, they are in fact definitely cheaper.

Wind power is expensive, but nobody can tell if it is more expensive (or less) than the available alternatives for new power: nuclear, coal with CCS or natural gas power combined cycle.

However it is obvious that the world will need wind power, wave power, solar heat, solar cells and second generation biofuels in order to combat climate change, so the "first movers" will have a more competitive industry than nations that try to resist change. This is already the case with the world-leading Danish wind power industry. It has been a boon, not a burden for the Danish economy over the last 20 years.

Doing nothing has other drawbacks. It leaves nations open to the threat of dramatically increasing fossil fuel prices or shortages, and the perspective of political conditions for supply. It can also mean a severely limited level of self-determination, where climate and energy policy is imposed by Brussels or by international agreement.

The instruments to achieve deep carbon cuts are well known. What is needed is to apply many of them, and to show insistence and creativity and demonstrate to citizens and the market that this is for real. The targets, year on year and sector by sector, must be legally binding.

The rationale for such a dirigiste approach is that it takes a very strong sense of direction for entire societies to achieve the necessary transformation. Too much government planning has well-known drawbacks and cannot, and should not be sustained indefinitely. But this is not an optimisation problem to be left to the market. It is more like war. In wars, tight planning – with many targets and timetables – is inevitable.

Market instruments have an important part to play, but must not be allowed to create any uncertainty of what needs to be done and why.

To cut emissions we must call a spade a spade. Coal, peat, shale and oil are to be phased out. Wind power construction must be accelerated. There are no two ways about it, so every avenue must be used to make this happen despite high inertia.

Doing it by doing it rather than waiting for markets to do the work is nothing special here. That is how nuclear power came about, and the French TGV trains. But there is an extra advantage to forcing through renewable energy: it is expensive to build but cheap to run. If enough wind power (and wave power and solar energy for heat and power) is built, it will out-compete fossil and nuclear power, which have higher operational costs.

Nuclear phase-out is one of the conditions set for the scenario, as most environmental NGOs are against nuclear power for a large number of reasons. This does not create great difficulties for the scenario itself. Of course it is possible to live without nuclear, as Lithuania has showed.

CCS is also not allowed in the scenario. There are many reasons for this, but the simplest is that CCS will not deliver CO_2 reductions by 2020, and that we do not need to have any coal power.

A scenario for 2020: the figures

Here is the historical CO_2 emissions data, and the required reductions, in millions of tonnes:

	1990/ base	1995	2000	2005	2007	2008	2020
Denmark	54.142	61.977	54.938	52.204	55.292	52.047	
Estonia	36.136	18.242	15.442	16.687	19.228	17.383	
Finland	56.624	57.859	56.71	56.357	66.102	58.139	
Iceland	2.172	2.326	2.775	2.877	3.301	3.595	
Latvia	19.271	9.119	7.087	7.87	8.722	8.304	
Lithuania	36.091	15.109	12.031	14.288	15.863	15.153	
Norway	34.802	37.801	41.589	42.822	45.087	44.156	
Sweden	56.615	58.521	53.888	53.328	52.291	50.416	
Sum, kton	295.853				265.886	249.193	88.755
Reduction Mtons since 1990					-30	-46	-207
Reduction Mtons since 2008							-160
Reduction % since 1990					-10.1	-16.2	-70

Source: http://unfccc.int/di/DetailedByParty.do

Note: Everywhere in this text the weight measure ton= tonne=1000 kg. G=Giga=thousand millions, M=mega= million k=kilo=thousand.

As can be seen, the three Baltic republics cut their emissions considerably in the period 1990-2000, as a result of restructuring and closure of obsolete industry. Sweden cut its emissions by means of a more active climate policy. Norway and Iceland increased their emissions considerably and not very much happened in Finland and Denmark. Such aggregated figures are however misleading. The picture is in fact much more dynamic.

Sectoral CO_2 emissions are as follows

Summary for all 8 countries, Mtons	1990	2008	2020
1.A.1 Energy industries	110.8	89.9	30
1.A.2 Manufacturing	46.6	33.5	18
1.A.3 Transport	64.7	74.7	30
1.A.4 Other sectors	45.9	21.6	6
(residential, institutional, fisheries			
1.A.5 Other	2.6	1.5	1
1B Fugitive	3.6	4.6	2,5
2 Industrial processes	20.7	22.6	20
3 Solvent use	0.8	0.6	0,5
6. Waste	0.1	0.2	*
Gross emissions	295.9	249.2	
Less export of electricity			-10
Less export of biomass			-10
Net emissions			88

The most important sectors are the energy industries, manufacturing, transport, the first "other" which is mainly heating of homes, offices and other buildings, and industrial processes which is mainly ore-to-steel, cement and lime production.

Energy Industries

All 8 countries, CO_2 in ktons	1990	2008	Target 2020
1,AA,1,A Public electricity and heat production	96117	66740	15000
1,AA,1,B Petroleum refining	7470	8938	6000
1,AA,1,C Manufacture of solid fuels and other energy industries	7190	14269	9000
Total	110778	89947	30000

The biggest part is heat and electricity, which are produced with coal, peat, natural gas, shale and the fossil share of waste incineration. There was an already a sharp drop of emissions from 1990 to 2008. There are good options to produce electricity with wind power, wave power or biomass, and also by more efficient end use. This is discussed further under Electricity balance.

"Heat" here means district heat. The simplest way to cut fossil emissions from heat plants is to switch from fossil fuels to biomass. The downside is that the same biomass will be needed for the transport sector. The best solution is to cut demand by improved insulation, and to add some solar heat and electric heat from wind power. Geothermal heat, direct or using heat pumps, can add to the supply.

Petroleum refining depends mainly on the amount of petroleum processed, but also on the crude oil price. High crude prices give more of an incentive to improve efficiency. As biofuels are phased in, and petroleum use is decreased, emissions should decrease to 6 Mtons by 2020.

The figure of 66.7 Mtons in 2008 could be cut to 15 Mtons in 2020, by the complete phase-out of coal, peat, and shale for heat and electricity with only peak and reserve production from gas and oil. Waste incineration is not a major emitter now, since 85 per cent of the energy content is from biomass[7]. This should become even less of a problem with more waste separation, more recycling, and more waste prevention.

For example in Finland 2009, the 57.8 TWh of fuel supplied for district heating and CHP was overwhelmingly fossil fuel[8]: gas 35%, coal 26%, peat 16% and oil 7%: only 14% was renewable. The Danish figures[9] are similar. But in Sweden about half of the 67 TWh of fuel supplied for district heating and CHP is biofuel, with only 16% fossil fuels, while waste, electricity and heat pumps, and industrial waste heat make up the rest[10].

The category "Manufacture of Solid Fuels and Other Energy Industries" is very much dominated by Norway's, and to some extent Denmark's, oil and gas extraction industry. Norway claims[11] that its "emissions of CO_2 per standard cubic metre of oil equivalent are 47 kg compared to an international average of 120 kg". This figure tells us that the main CO_2 problem with fossil fuels is their use (some 3 tons per cubic metre of oil equivalent during combustion), not their extraction. Norway writes in the national communication that "CO_2 emissions from the petroleum sector are expected to increase until 2019 and then decrease". This is not acceptable. A cap on emissions at for example half of 2008 emissions by 2020 should leave the petroleum industry with a strong incentive to clean up their act or leave more of the oil and gas where it is.

7

8 http://www.energia.fi/en/statistics/districtheatingstatistics/dh_diashow_statistics_2009_pre.ppt#265,10,Fuel consumption in production of district heat and CHP 2009 - fuel consumption 57,8 TWh

9 http://www.fjernvarmen.dk/Faneblade/HentMaterialerFANE4/Aarsstatistik.aspx

10 www.svenskfjarrvarme.se/Global/Rapporter_och_Dokument/Statistik/Fjarrvarmen%20i%20siffror/Branslen%20och%20Produktion/Diagram%20till%20br%c3%a4nslen%20och%20produktion%202008.xls

11 National Communication 5, 2009 p 44 http://unfccc.int/resource/docs/natc/nor_nc5.pdf

	Nuclear	Hydro	Geo-thermal	Wind	Ther-mal	Total Net Genera-tion	Imp-Exp	Con-sump-tion
Denmark	0	0	0	9.8	19	33.715	1.3	
Finland	22	12.4	0	0.5	24.9	70.3	13.9	
Iceland	0	12.4	4.7	0	0	17.1	0	
Norway	0	119.6	0	1.3	4	125.2	-3	
Sweden	57.1	65.6	0	6.1	8.1	148.7	-7.2	
Estonia	0	0	0	0.4	11	12.2	-3.5	
Latvia	0	2.9	0	0.1	2.1	5.6	1.2	
Lithuania	0	1	0	0.5	2.7	4.4	6.7	
	79.1	213.9	4.7	18.7	71.8	417,2	9.4	427

Sources: US DOE EIA, Eurostat

This data is inconsistent, and poorly related to emissions. "Thermal" covers all fossil fuels and some biomass, used either in condensing mode or as CHP.

A 2020 seario for electricity would look something like this, with no use of coal, peat, shale or oil for electricity and no nuclear:

Hy-dro	Geothermal	Wind	gas	bio	PV	wave	Net gen	Imp-exp	Consumption
215	8	100	15	50	12	5	405	-20	385

Manufacturing

Manufacturing is a very broad category. Much of heavy industry's emissions are however in the "Processes" category (below).

Generally, industries use

- electricity, which at the point of use does not emit CO_2
- district heating and cooling, neither of which emits direct CO_2
- fuels for heating of the plant
- fuels for drying, distillation, recovery of chemicals, hot water production (e.g. for washing, or for speeding up chemical reactions) etc.

Much of the industry has very large heated premises that are badly insulated, with primitive and often oversized ventilation which sucks in cold air and blows out warm without heat recovery. The fans were often installed in the first place to address a problem that no longer exists, such as to keep the workers safe from dangerous solvents – either because the solvents have been replaced or because there aren't any workers in the room. Many industries have, or have had, a requirement of two years payback for investments in energy efficiency, and many of the industrial plants in these countries were designed at a time when electricity and oil were very cheap.

The potential to save energy is therefore often breathtaking. Energy Performance Contracting companies, such as Siemens Building Technology, make their money by saving energy for other companies and sharing the profit. In Siemens's reference list[12] of ten industries (in Sweden) the savings achieved in per cent were respectively 39, 42, 43, 50, 66, 66, 70, 78, 80 and 82 per cent, the median thus 66 per cent. This is achieved mainly by improved computer control of ventilation and heating and sometimes a heat pump for heat recovery, not by improved insulation, better windows or solar heating.

Obviously these ten samples are not representative of the whole. But the decrease from 1990 to 2008 gives the clear message that decreased emissions are compatible.

In more detail, the picture is as follows for all the 8 countries, in ktons:

	1990	2008	Target 2020
1.AA.2.A Iron and Steel	5030	6097	5000
1.AA.2.B Non-Ferrous Metals	760	431	400
1.AA.2.C Chemicals	5271	4523	3000
1.AA.2.D Pulp Paper and Print	8523	5988	600
1.AA.2.E Food Processing Beverages and Tobacco	6154	2798	1000
1.AA.2.F Other	20886	13632	8000
Total	46625	33469	18000

The cuts from 1990 to 2008 are 25 per cent.

As for the future, even existing instruments and price relations should induce further aggressive savings through low-temperature heating, and fuel shifts from fossil to renewables.

There is for example no reason why the paper & pulp industry should use any fossil fuels at all. They have enormous amounts of biomass already collected within their premises. There are also reasons to believe that paper consumption will fall, as electronic media are already taking up increasingly more of our time than paper media. The many premature predictions of the paperless society are no argument against it happening in the near future. The increased competition for biomass – paper, heating and vehicle biofuels – will push up prices.

With new measures to reduce the problems of paper waste (by taxing commercial print for example), and to recycle more of it, the demand for virgin paper could be cut further. The direct emissions associated with paper and pulp production can for these reasons be cut to zero (or below, by "exporting" biomass to other sectors) by 2020.

Chemicals are dominated by plastics and by Norway, Sweden and Finland. Plastic materials are essential for lightweight applications in transport, for

12 http://www.siemens.se/sbt/BuildingAutomation_HVAC/tjn/tjn_pfc_ref.asp

insulation and other applications, and are used excessively for packaging. To achieve deep emission cuts, plastic production has to be curbed, be produced more in a more energy-efficient wary, and switch from fossil to biomass feedstocks and electricity. Target emissions for 2020 could be 3 Mtons.

The Iron and Steel industry is a major emitter, which has also increased in 1990-2008. This industry also emits the largest share of the "metal industries, processes", below. Better recycling of scrap, minor fuel switches from coke to coal, and exhaust gas recirculation should cut the emissions from constant production. More material-efficient designs, improved strength of steel, and some switching from steel to plastics and wood should target a cut of about about 20 per cent to 5 Mtons by 2020.

Non-ferrous Metals are, to judge from the table, a minor source of emissions. But this is because a large part of the emissions are listed under the Industrial Processes category, below.

Food Processing Beverages and Tobacco halved emissions from 1990 to 2008. The industry should target further reductions, through efficiency improvements and use of its own biomass resources. 1 Mton (at most) remains by 2020.

"Other" cut its emissions 30 per cent from 1990 to 2008 and should target a similar cut by 2020: 8 Mtons.

Transport

CO_2 emissions from the transport sector, excluding international navigation and aviation, in ktons

	1990	2008	2020
1.AA.3.A Civil Aviation	2061	2240	2000
1.AA.3.B Road Transportation	55569	65124	21000
1.AA.3.C Railways	1728	1023	1000
1.AA.3.D Navigation	3790	4024	4000
1.AA.3.E Other Transportation	1571	2252	2000
Total	64719	74664	30000

Transport is by far the most demanding sector. It is even more difficult if international shipping and air flights are included. We will stick, however, to the common reporting format of the National Inventory Reports, which excludes them for the reason that they are not under national jurisdiction. This does not mean that they cannot be cut, but that those cuts must mainly be achieved by international agreements.

There are in principle several ways to cut transport emissions:

- Technical fixes: More efficient engines, more potential for passenger cars, less for trucks and buses. An average improvement of 30 per cent for the whole fleet may be possible, and that includes a substantial market for electric vehicles

- Driver education could cut fuel use by 5 per cent. Empirically an eco-driving lesson achieves more, but newer cars have more of built-in eco-driving features
- Modal shifts from road and air to railway, bus and ship could cut net fuel use by 10 per cent
- Deeper lifestyle and societal changes could cut both goods and transport kilometres by 10 per cent
- Biofuels could cut the remainder by another 30 per cent or in absolute numbers by 10.5 Mtons.

Each reduction factor must be multiplied by the next, or 0.7*0.95*0.9*0.9*0.7=0.38 times the 2008 emissions, rounded to 0.4 or 30 Mton. This would obviously take a lot of policy measures to achieve.

Other sectors (residential, commercial and fisheries)

CO_2 emission in ktons

	1990	2008	2020
commercial	12749	4296	1000
residential	20587	8402	2000
Agriculture/forestry/fisheries	12608	8913	5000
Total	45944	21611	8000

This category is mainly oil for heating. As can be seen, the total was reduced 53 per cent in 1990-2008, or a decrease of 5.1 per cent per year. An extrapolation would give an almost 72 per cent decrease for 1990-2020, so it seems reasonable to target more. This is to be achieved by more district heating, heat pumps, fuel shifts from oil or gas to pellets and by better insulation and more efficient ventilation/heat recovery, much of which is bound to happen anyway.

Other energy industries (not elsewhere specified)

CO_2 emissions in all 8 countries ktons

1.A.5 Other	2616	1528	1000

This is a small residual category, already decreasing, but must be included so as to make data complete.

Fugitives

	1990	2008	Target 2020
1.B.1 Solid Fuels	13	10	
1.B.2 Oil and Natural Gas	3541	4595	
Total	3553	4605	1500

Fugitive emissions are a minor item, except for those from the oil and gas industry in Norway, which emitted 3.1 Mtons, half of which is flaring.

This is not one of the most important aspects of the Norwegian oil and gas industry, but the increase from 1990 is not acceptable. It has to be cut either through reducing production of oil or by using cleaner methods.

Industrial processes

All 8 countries, ktons

	1990	2008	2020
2.A Mineral Products	8123	7197	6000
2.B Chemical Industry	2708	3348	3000
2.C Metal Production	9751	11855	8000
2.D Other Production	82	201	200
2.G Other	50	34	0
Total	20714	22635	17200

The main emitters, nationally, are Norway, Sweden and Finland

Processes CO_2, kton	1990	2008
Denmark	1152	1360
Estonia	1034	907
Finland	3315	4416
Iceland	393	1570
Latvia	577	254
Lithuania	3352	2432
Norway	6024	6504
Sweden	4865	5193

This category includes cement and lime production, in which CO_2 is released when the limestone (calcium carbonate) is heated to calcium oxide. The numbers do not include the combustion fuel (usually coal) used to heat the kilns, as that is listed under Manufacturing, see above.

The rationale for this division is that even if the limestone is heated with perfectly clean energy, the process CO_2 emissions cannot be avoided. This however assumes that there are no alternatives to cement as a construction material, and no alternatives to limestone-based cement and that the cement content of the concrete must be kept constant. New cement processes are being developed[13].

As cement production emits more than 4 per cent of world anthropogenic CO_2, and has increased much faster than total emissions[14] from 1990 to 2007, the present use and production methods for cement are unsustainable. We cannot expect India, China, and Russia to improve their act, unless we do so.

13 Celitecement http://www.kit.edu/visit/pi_2010_1515.php, Novacem http://www.novacem.co.uk/

14 http://cdiac.ornl.gov/ftp/ndp030/global.1751_2007.ems

Emissions from **metal production processes** are in principle the emissions that arise from the reduction of metal oxides to metal. (For every two oxygen atoms in the ore, one carbon atom goes with them, so to speak.) In practical terms, this distinction, between combustion and process emissions, is hard to make, and it is not used in the emissions trading scheme. To complicate things even more, heat or residual gases can be exported to the electricity and heat sector, as for example is the case in the SSAB steel plant in Luleå, north Sweden, where more than 2 Mt of CO_2 is emitted from the chimney of the heat and power plant. The two SSAB ore-based plants together with the Luleå CHP represent an annual 5.8 Mtons, more than 11 per cent of the Swedish CO_2 emissions[15]. The iron mining and ore preparation activities add another 0.6 Mtons of CO_2 . This should in all fairness be compared to emissions from ore-to-steel in other countries, not with other sectors. High quality ore, mined in the vicinity of the plants also offers some rationale. But the absolute numbers are so big as to motivate a political focus.

It should not be taken for granted that technology used in Scandinavia represents the best available technique (BAT) or even close. Both Sweden and Norway have used the dirty, inefficient Soederberg aluminium reduction process much longer than the rest of the world. In Sweden this process became extinct in 2008, but it is still used in Norway. The main energy input for aluminium (unlike iron) is electricity, not coal. As Norway is the biggest CO_2 emitter in this category, the following may give a picture of what is what.

"About 64 per cent of the CO_2 emissions from industry are from metal production. Metal production in Norway includes plants producing iron, steel, ferroalloys, aluminium, nickel, zinc and also magnesium until spring 2006. Production of anodes is also included. Emissions of CO_2 from metal production were 4.8 million tonnes in 2007, of which aluminium production and ferroalloys production accounted for about 2.2 and 2.1 million tonnes respectively. CO_2 emissions from metals manufacturing derive primarily from the use of coal, coke and charcoal as a reducing agent"[16].

Steel, magnesium and aluminium will be essential for a long time ahead of us, and it will not solve any problems to move production elsewhere. In the longer perspective (2030), the use of fossil fuels, especially coal, must be radically cut both by cleaner production (more electricity, more hydrogen, less solid fuels, possibly more natural gas), improved recycling and more materials-efficient design. The environmental costs for metals must be internalised, which means much higher prices on the world market than today. This is likely to happen to some extent. High oil prices will force raw materials prices up as we have seen over the last ten years, and especially in 2008. The European Emission Trading Scheme leaves free allocation of permits to metal production, but still provides an incentive to cut emissions and sell permits. Older, dirtier plants will need new permits under the Large Combustion Plant/Industrial Emissions Directives, and some of them will have to choose between shutdown and investment in new technology.

15 ETS reporting at http://ec.europa.eu/environment/climat/emission/pdf/AL_VE_2009_public_format.xls

16 http://unfccc.int/resource/docs/natc/nor_nc5.pdf National Communication, Dec 2009, p48

A plant-for-plant analysis is not possible here, nor a specific technology options assessment for carbon-efficient technologies. For this reason, the 2020 target is conservative.

Solvent use and waste

These categories are of little importance for the total, and are decreasing anyway.

Ktons CO_2

	1990	2008	2020
waste	91	155	
solvents	814	579	
sum	905	634	500

Both categories are heterogeneous, and the projection for 2020 is not based on anything else than a conservative extrapolation of present trends. The volatile organic emissions, of which solvents are a part, have far more important environmental consequences than CO_2 emissions, as precursors of ozone, and are dealt with mainly through the LRTAP convention, with considerable success[17].

Export of CO_2 -free electricity

For 2020 a considerable export of electricity is possible, mainly through expansion of wind power. This is credited as displacing a mixture of coal, lignite and nuclear power on the Continent – mainly Germany, the Netherlands and Poland – and the UK where coal power and nuclear power are being phased out faster than renewables are being phased in.

There is no undisputed method for quantifying the "marginal electricity emissions", i.e. the CO_2 avoided by the last imported kWh. It looks different on different timescales, and the question "what would have happened otherwise" cannot always be answered even in retrospect.

The worst lignite power stations, such as Jänschwalde, have CO_2 emissions of about 1200 grams/kWh[18].

Older hard-coal power stations have emission in the 900-1000 g/kWh range. There may also be some displacement of natural gas power production from older or newer plants in the 350-500 grams range.

In broader terms, some coal power plants are going to be closed down because they cannot economically be retrofitted to meet demands from the Large Combustion Plants Directive, now superseded by the Industrial Emissions Directive. Also, higher coal prices compared to some years ago and

17 For data 1990-2008, see http://microsites.umweltbundesamt.at/fileadmin/inhalte/emep/xls/2010/Trend_Tables_2010.xls

18 http://assets.panda.org/downloads/european_dirty_thirty_may_2007.pdf

increasing carbon prices will force some of the coal capacity to either shut down definitely or to be downgraded from base load (7000-8000 hours/year) to semi-base load (some 4000 hours per year) or peak/reserve (0-1000 hours per year). The reduced production of electricity is, of course, whatever the reason proportional to the reduced CO_2 emissions.

Once built, wind power is extremely competitive, as operating costs are very low. It will be used as much as the wind and the grid permit, whereas fossil power is run depending on electricity price fuel price and carbon costs.

Nuclear power stations, on the other hand, have near-zero emissions from the power plant (and here is not the place to discuss the full life-cycle emissions from nuclear.) In the UK about 7 of 11 GWe of nuclear power is planned to be phased out[19] before 2020. There are plans for new nuclear power, but only one new plant (Hinkley Point C, 2*1.6 GWe) which (just) might be be operating by 2020[20].

It may be argued that the marginal emission is around 1000 g/kWh, as coal will be worst hit by wind power influx, whereas the operation of nuclear power is mainly decided by other factors.

For the scenario, a conservative value of 500 g/kWh is set, meaning that to avoid 10 million tons of CO_2 , 20 TWh will be exported in an average year.

Over a longer future, it is not so sure that there will be an export market. The UK will build a lot of offshore wind power over the period 2020-2030, and possibly a large amount of wave power. Germany, with strong carbon restrictions, will probably still be a net importer of electricity in 2030, but then solar power from southern Europe and North Africa may become an alternative supplier. The extra capacity for import/export is still valuable to provide a secure supply at reasonable cost: continental Europe will then be able to import from the north, west and south.

Export of biomass/biofuels

Export of biomass is unavoidable under present trade rules and EU legislation which will create a huge demand for biofuels. The Nordic-Baltic region has, on the whole, a huge forested land resource per capita and a good infrastructure for utilising the biomass resource. The paper and pulp industry collects enormous amounts of biomass and can use residue fractions for either simple biomass (wood chips), for somewhat more advanced products such as wood pellets as fuel for heat and electricity or for fully refined products such as synthetic diesel, methanol or DME. One particular resource is black liquor, a by-product in sulphate paper pulp, which can be gasified to make vehicle fuels.

For economy and employment it is much more preferable to have the whole value chain here, i.e. to export vehicle biofuels rather than raw materials. It is

19 A list of expected shutdowns can be found at www.world-nuclear.org/info/inf84.html

20 In 2018 according to the government, see www.decc.gov.uk/en/content/cms/news/letterft/letterft.aspx

also preferable from an ecological point of view, as it opens up the possibility to recycle the ash back to the forest.

This is by no means a foregone conclusion. Co-firing in coal power stations in order to keep the plants running without the high costs for retrofitting flue gas desulphurisation, limiting the carbon costs, or for other reasons, could swallow any amount of biomass. The EU-27 CO_2 emissions from public heat and power, mainly coal power, were 1300 million tons[21] in 2008.

Trade in biomass over long distances is certainly possible. The Gothenburg utility Göteborg Energi actually had wood pellets shipped from western Canada for some years.

The way to make sure that the biomass goes to vehicles and not to coal power plants is to build bio-refineries big and fast.

The extent of biomass export is hard to estimate. The figure given here, 10 million tons of CO_2 worth of exports, may be an under-estimate. There will be strong demand due to the EU mandatory target of 10 per cent of the vehicle fuel[22] . especially if strict sustainability environmental criteria[23] are applied and will limit imports from outside the EU and the use of some biofuels of agricultural origin.

In the longer term, after 2020, biomass export is even harder to quantify. Even with strict environmental criteria, biomass production from sunnier countries should have a competitive advantage, for example from algae. Electric cars and possibly direct solar fuels, derived from hydrogen will open new routes to low-carbon vehicle fuels.

The competition for biomass will anyhow remain strong for a long future.

Our region could be the best. Or the worst.

The Nordic-Baltic region has excellent conditions for deep and fast cuts in its carbon emissions.

This is however in stark contrast to some things that might otherwise happen. In several respects the development in our countries is the least sustainable on Earth. If our worst features were spread to the rest of the world we would be heading for Armageddon, and soon.

Estonia is the world leader in oil shale exploitation, and leads efforts to exploit shale in other part of the world. Shale emits more carbon dioxide per energy unit than coal. Reserves are greater than for oil.

21 EEA data http://dataservice.eea.europa.eu/PivotApp/pivot.aspx?pivotid=475

22 Directive http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0028:EN:NOT

23 http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/10/247&format=HTML&aged=0&language=EN&guiLanguage=fr

	Crude Oil	Shale
Reserves trillion barrels	1.3	4.8 (as oil)[1]
CO_2 content kg/TJ	73.3	106.7

Finland is the world leader in using peat. Peat emits more carbon dioxide per energy unit than coal. Reserves are greater than for oil. The international peat society which claims 1,412 individual and institutional members from 29 countries, has its headquarters in Jyväskylä, Finland. Peat is also used in Sweden, and all the Baltic republics. Finland is the world's leading producer, but as a result of dexterous lobbying for peat (for jobs, energy security etc etc), large amounts of imported peat add to the huge Finnish CO_2 emissions. Much the same is true for Sweden, though figures are smaller.

	Peat, Gton	Hard coal
Reserves	500[2]	411
CO_2 content kg/TJ	106	94.6

Iceland has the world's highest per capita use of electricity.

Norway is one of the richest countries in the world, very much because of oil and gas.

Sweden has the highest per capita capacity of nuclear power. If all the 6.88 billion people on Earth had as much nuclear power as the 9.341 million Swedes (10 reactors), we would have 7365 nuclear reactors instead of the 441 the world actually has. This would soak up all the uranium ore in the world in less than ten years, rather than the 100 years or so that uranium resources are estimated to last.

The Challenge: Deep. Fast. Here.

The requirements set by the Air Pollution & Climate Secretariat when commissioning this scenario study for the Nordic-Baltic region, were

- 70 per cent CO_2 cuts by 2020, counting from 1990
- 95 per cent CO_2 cuts by 2030
- No inclusion of nuclear power
- No inclusion of carbon capture and storage (CCS)
- No crediting for CDM, JI or "hot air" from emission cuts already made in Russia and Ukraine.
- No new hydro
- No crediting for land use, land use change and forestry
- Biomass increase use should be within limits given by biodiversity
- Biomass nutrients must be recycled
- Develop replicable measures for the world

Few regional or national scenarios with this scope and timescale have been produced before, but a global scenario for 100 per renewables by 2030 was published by Mark Z. Jacobson and Mark A. Delucchi in the Scientific American[24].

A 2020 scenario for a 100-per-cent renewable Australia is being developed and the stationary sources part has been published[25]. The gist of it is that coal power (very big there) is phased out and replaced by much more wind (like here), much more concentrating solar thermal (CST) with molten salt storage, a technology which may work well for Australia, but probably not in our region. Biomass and hydro are used as reserves, i.e. when both wind and solar are low during consumption peaks. CST is to supply 60 per cent and wind 40 per cent of annual grid electricity. This part of the plan allows for a 40 per cent increase in electricity consumption so as to allow a shift from oil to electricity for heating. Cost estimates are supplied. How the transformation of the transport sector is to be achieved in such a short time (by early 2011) is only sketched out[26].

A 2007 Greenpeace Nordic (DK, N, SE, SF) scenario[27] for 2030 arrives at similar results as the present study does for 2020, and is more detailed in many aspects, including cost estimates. It is interesting to note that the task looks easier four years later: oil price price projections are now much higher than the $50-$120 (with $90 as central case) assumed for 2030 in that study, and the prospects of photovoltaics look much brighter now, as does wave power. An updated global study[28] with some national versions was published together with EREC in 2011-2012.

A 2009 Danish study[29] targets 100 per cent renewables, but by 2030. It focuses on wind power (but assumes a modest contribution of wave power after 2025), on more district heating, and more efficient transport: 10 per cent less passenger transport in 2030 than in 2007, more rail and more electric cars.

Compared to the scenarios mentioned above, the task set here is both more and less demanding. It is more demanding because 70 per cent by 2020 is harder than 100 per cent by 2030. It is less demanding because our point of departure in the Nordic-Baltic region is far more advantageous than for the rest of the world with the huge existing hydro power resource already there and the large amount of biomass already being exploited. We also have significant wind power in operation and under construction. And we have more economical and technological resources than the average for the world. If it cannot be done here, it cannot be done.

24 http://www.stanford.edu/group/efmh/jacobson/sad1109Jaco5p.indd.pdf

25 http://www.energy.unimelb.edu.au/uploads/ZCA2020_Stationary_Energy_Synopsis_v1.pdf

26 http://www.beyondzeroemissions.org/sites/beyondzeroemissions.org/files/images/transport%20poster.JPG

27 http://www.greenpeace.org/denmark/Global/denmark/p2/other/report/2006/nordic-energiscenarie.pdf

28 http://www.greenpeace.org/international/Global/international/publications/climate/2012/Energy%20Revolution%202012/ER2012.pdf

29 http://www.ve.dk/images/stories/documents/Vision/02energivisionen_web.pdf

It is still a daunting task, but in no way extreme in relation to what is at stake.

The global context for the need for such radical cuts is that climate change is already here, and more warming will follow from the greenhouse gases that are already in the atmosphere. An alliance of the Least Developed Countries and the Alliance of Small Island States has called for a 1.5 degree limit[30]

"Climate Change is a planetary emergency that threatens the survival of many small island states.

For some low lying states like the Maldives, Kiribati, and some of the Bahamas, the risks from sea level rise threaten their physical existence, as they would very easily be inundated by sea levels in excess of one meter above current levels – levels that can be reached by 2100, if significant action is not taken immediately to reduce and ultimately limit the atmospheric concentration of greenhouse gases to well below 350 parts per million (ppm) in the long run.

For other states, their social-economic viability will be compromised, inter alia:

By the rising seas which will damage their coastal zones, where the majority of their socio-economic infrastructure is located;

- **By the saline intrusion into their coastal aquifers which will negatively impact on their drinking water and agricultural activities;**
- **By the destruction to their coral reefs and their fisheries habitats that result from increases in ocean acidification and rising temperatures; and**
- **By the impact of stronger tropical cyclones that can destroy years of positive development in a matter of hours, as has been demonstrated time and time again, including by the recent experiences of Cook Islands (2005); Cuba (2008); Fiji (2008); Grenada (2004); Haiti (2004; 2008); Niue (2004); and others."**

More need not be said.

To achieve the 1.5 degree limit will be very demanding indeed, as shown by a recent study from the British Met Office, Hadley Centre and The Grantham Research Institute on Climate Change:

"Even if global emissions fall from 47 billion tonnes of carbon-dioxide-equivalent in 2010 to 40 billion tonnes in 2020, and are then reduced to zero immediately afterwards, we estimate that there would be a maximum probability of less than 50 per cent of avoiding global warming of more than 1.5°C above the pre-industrial level."

Time is of the essence. No zero, or even negative, emission target for 2050 can do the job. We have to cut fast and deep.

Fast and deep is something very different from deep and slow. Fast means that we cannot wait for unknown technologies, or wait for unsure cost reductions. What has to be done has to be done with technology that exists on a substantial scale today, and is well documented.

30 http://www.sidsnet.org/aosis/issues.html

As for the other conditions of the scenario, here are some details.

Why here? Look at the table below:

Per capita emissions 2007 for Nordic-Baltic countries and selected other nations

World ranking	Nation	Tonne C per capita
16	Estonia	4.16
21	Finland	3.32
44	Denmark	2.51
45	Norway	2.48
53	Iceland	2.12
76	Sweden	1.47
87	Lithuania	1.23
105	Latvia	0.94
81	China	1.35
200-214	Mainly African nations	<.03

http://cdiac.ornl.gov/trends/emis/top2007.cap Note that emissions in CO_2 are 3.67 times those of carbon as C.

If China is a problem – which it certainly is – we are still more of a problem.

No inclusion of nuclear power

Nuclear power is excluded in this scenario. It is easy to understand why new nuclear is not a sustainable option. You cannot use the same money twice: if it is invested in nuclear, it will not be invested in renewables and efficiency. There is also a leverage effect from setting an example either way and for market creation either way.

Also, whereas some renewables and some efficiency measures have a short lead time, i.e. the time from decision to operation is a few years, the lead time for a single nuclear power station is about a decade, and for a major nuclear programme much more than that. The US new-build programme was initiated in spring 2001 as one of the first and highest priorities of the George W. Bush administration. Construction for two reactors started early 2013. The first unit, Vogtle 3, is scheduled[31] to begin operating late 2018. That is 17 years. During that time very large capacities of wind power have been built and will be built, and even more could have been built.

It is less evident why existing nuclear power should be left out. It is however a misconception that nuclear is cheap and reliable once it has been built. The operating costs for the three plants (with 3 and 4 reactors each) in Sweden were 22, 24 and 47 öre/ kWh (slightly more in euro/MWh) in 2009, with Oskarshamn at the top (close to the cost for new wind power). And it is highly questionable if this figure covers the costs for waste disposal and decommissioning. Investment never stops for a nuclear power station, and major refurbishments and safety upgrades can have very substantial costs. Many of the Canadian reactors were shut down in around 1997 due to safety concerns and are or were being refurbished. The two Bruce reactors cost

31 http://www.world-nuclear-news.org/NN-Georgia_Power_accepts_Vogtle_loan_guarantee-2106107.html

\$5.25 billion to refurbish[32], or \$3500/kWe, or within the range of estimates for building new nuclear. Even after the thorough refurbishment of the Canadian reactors, their performance has been lacklustre. The Oskarshamn 1 reactor was modernised for upwards of SEK 5 billion, and lost 5 years of production[33] during the 1992-2002 modernisation, and has performed miserably since. Keeping old plants running is either dangerous, expensive or both, but has one advantage for the operator: it can keep the costs of decommissioning in the dark, and also keep the waste issue at arm's length. The safety issues of running old plants are of three kinds: outdated design (from the 1960s or 1970s in the case of existing Swedish and Finnish plants), unchecked physical ageing, and decaying safety culture, for example as shown by the Forsmark 1 incident in 2006, when at least 50 safety systems were knocked out by one single faulty piece of equipment in the electric system: the people who run the reactors have no experience of building and designing reactors. This gives a shallower understanding than the pioneering generation had, and even heroic efforts to improve documentation often cannot keep pace with the loss of tacit knowledge. Early, planned, shutdown can be well motivated by risks and costs avoided.

Old nuclear power plants are also, at least in Sweden, increasingly unpredictable in output. In 2009 they produced only 50 TWh, a large drop from the 75 TWh in 2004. On an annual basis, wind power is much more predictable.

The phasing out of nuclear power also makes room for earlier and faster development of renewables.

Is it realistic to expect that nuclear power will be phased out by 2020? Probably not. But it is possible if our elected representatives want to do so and may happen even if they do not want to, as a result of another nuclear accident anywhere in the world.

The Fukushima accident in 2011 had exactly that effect. Several countries either gave up on building new reactors or decided to phase out existing ones faster.

No inclusion of carbon capture and storage (CCS)

CCS is excluded because everything about CCS is unknown except that it cannot give any mentionable reductions before 2020 – unlike renewables and efficiency which are there now. Even if it works alright, it still emits much more CO_2 than renewables over the full life cycle, especially for post-combustion capture. We don't know which of the three major candidates of CCS technologies stands the best chance for development, but we do know that they will all add very substantially to capital costs for the plants; it means adding a chemical plant the size of the power plant itself.

The biggest problem for CCS is however not the capture, which is expensive but technologically feasible. The big problem is licensing and acceptance for transport and storage. The pipelines to a geologically suitable storage site may need to be very long. Sweden and Finland have for example hardly any suit-

32 http://en.wikipedia.org/wiki/Bruce_Nuclear_Generating_Station

33 See the IAEA PRIS data

able sites. Denmark has what Vattenfall considered a suitable site in north Jutland, but Vattenfall had to back away from a storage project due to local resistance[34].

The make or break CCS application is coal power. In our region we have very limited coal resources, and it seems far-fetched to import coal, with a substantial risk for price increases, instead of using indigenous wind.

Natural gas power CCS makes even less economic sense than coal CCS on all counts: smaller plants with more need for long pipelines, more added capital costs, fewer operating hours per year and much less CO_2 avoided. For this reason CCS at combined biomass heat and power plants is even less likely, as such plants are in the order of tens of megawatts, whereas many coal power plants are in the gigawatts range.

A limited use of CCS is conceivable for example at cement factories, oil refineries, biofuel refineries and ore-based steel plants. But unless coal CCS makes it, and makes it big and standardizsed, the technology and infrastructure will not be there for custom-made applications. Besides, a long extra lease of life for oil refineries may not be a sound idea, and there are other ways to address the emissions from steel and cement.

The combination of very high costs, very demanding infrastructure, and difficult licensing makes CCS an uphill task even though it has a lot of political and financial support. The closer it gets to reality, the more problems will surface. High water consumption will make it unviable in some parts of the world. Leakage back into air and pollution of groundwater are other problems to address.

Even if it ever succeeds, it may be too late to become a part of the climate solution. And if it succeeds anywhere in the world, it will hardly be in our region.

There is one exception, though. The CCS that is current practice in Norway is separation of CO_2 from natural gas. It is better to inject the CO_2 into the sea floor than to just vent it. The amounts are not very big anyway (a million tons each year in the Sleipner field, 700,000 tons in Snöhvit). As this CO_2 is not emitted, it is not included in the emission inventory. Such are the rules, and should the Norwegian oil and gas industry increase this specific kind of capture, there is not much to say about it.

In 2005, the IPCC, much encouraged by the George W. Bush administration, claimed in a special report[35] that the economic potential of CCS could be between 10% and 55% of the total carbon mitigation effort until the year 2100.

Few people believe that now. No big project is operating or under construction anywhere in the world.

34 http://www.vattenfall.com/en/news-archive.htm?newsid=7B596DBC3DF644CF91D5FE36F542B6C5

35 *IPCC special report on Carbon Dioxide Capture and Storage*. www.ipcc.ch

No credits for CDM, JI or "hot air"

The first reason for not including other than domestic measures is that it invites cheating or double-counting. If everybody expects somebody else to do parts of the job (for a modest payment), the sums will not add up.

In principle, there may be nothing wrong with trading so as to cut deepest where cheapest, but in practice this cheapskating will lose time rather than save money.

The whole notion that it is cheaper somewhere else is unproven. Cutting emissions is done by the same methods all over the world: slashing the use of fossil fuels by using renewables and making efficiency improvements. It costs about the same everywhere to build wind power. The coal power plants to be replaced have the same range of emissions per kWh in Germany, the US and Denmark as in China or India.

One idea behind the clean development mechanism (CDM) in the Kyoto Protocol is to transfer money to poor nations that cannot afford clean energy investments. This is of some relevance for some nations, especially in Africa. But as China has become the world leader in clean energy, and with India and Brazil following suit, it is no longer a clear-cut North-South issue. The Least Developed Countries have little to gain from CDM, as they have no emissions to cut and sell. They need development assistance alright, but they cannot do the job of saving the planet.

The integrity of the CDM projects, i.e. whether they really achieve emission reductions, is acknowledged as a problem by the EU Commission. It presents a dilemma: either stricter criteria will limit the amounts of CDM emission rights and make them more expensive, or they will not gain political acceptance, which will de-stabilise the whole climate policy effort. Or both.

To get priorities right, the first thing the rich countries should do is to stop supporting coal power and similar projects through financial institutions such as the World Bank, the European Investment Bank and the EBRD. The World Bank is a factor for carbonising, not de-carbonising the world, as shown by the Spring 2010 decision to support the Medupi coal power plant in South Africa with $3,05 billions[36]. The 4800 MW plant is projected to emit about 25 Mtons of CO_2 per year or 10 per cent of all the Nordic-Baltic countries' emissions in 2008 from a single plant. The Swedish government supported the decision of the World Bank, but the UK and the US abstained, which is diplomatic language for "no". Moreover, Eskom, the operator of Medupi, has announced that it will apply for CDM support[37], arguing that the plant somehow emits less CO_2 than another hypothetical plant. EBRD and EIB support for a new lignite power plant in Sostanj, Slovenia[38] in September 2010 is another, closer, example; a stated objective for the project is "to enhance power generation while maintaining the planned consumption of coal".

36 http://www.powergenworldwide.com/index/display/articledisplay/0061455565/articles/powergenworldwide/coal-generation/new-projects/2010/04/world-bank_agrees.html

37 http://www.businessday.co.za/articles/Content.aspx?id=107265

38 www.te-sostanj.si/filelib/ebrd/nts_final_eng.pdf

Hot air, reduction emissions resulting from the collapse of the Soviet empire 20 years ago, is obviously not getting us anywhere in reducing emissions from now on. The hot air space will anyhow be sold for a good price to Japan, Australia, Canada and hopefully the United States all of which have a lot more carbon reduction to do than the EU or the Nordic-Baltic region.

It might be added that the Baltic republics have auctioned superfluous emission rights and used the money for energy efficiency improvements. This was a good thing, but not a model for the future.

No new hydro

New hydro is excluded because it invites conflict with nature conservation interests. The natural values lost after a hydro construction project are irretrievable.

No crediting for land use, land use change and forestry

The amount of carbon stored in soil and forests depends on arbitrary factors such as unsustainable logging in the past and current afforestation of farm land which may be reversed. Crediting for what is already being done is no way to halt climate change.

It is also impractical to decide when a forest should be logged or when and where afforestation, or forest clearing for a possible future expansion of agriculture, should take place from the CO_2 accounting perspective.

An unavoidable formal consequence of keeping land use out of the scenario is that emission categories 4 (Agriculture) and 5 LULUCF are left out, as they are accounted for together.

Biomass increase must kept within limits given by biodiversity, food production and production of fibres

Use of biomass for energy does not exclude use of the same land for other purposes. Agriculture produces food for humans and animals, and fibres for the textile industry (linen, hemp), but also waste products such as straw and other residues which can be put into energy use. The food industries produce more waste (slaughter waste, fruit and vegetable peel) suitable for biogas, and the end consumers add energy content in household waste such as olive stones and potato peel, and through wastewater treatment plants. Forests produce timber and paper pulp, but also a large amount of residual material directly from the forest (bark, twigs, needles, rotten wood) and waste streams (lignin, in the form of black liquor) from the pulping process.

Parks are there for pleasure and leisure, but inevitably they also produce a surplus of biomass.

There is thus no absolute conflict between increased biomass use and other interests. But very strong incentives to use biomass could potentially lead to unsustainable logging, to very large-scale monocultures of energy crops and to infringements of biologically diverse biotopes. This must be checked by increased nature legislation (not specified here), planning and, specifically by not overstating the potential.

With the carbon balance and other social, economic, and ecological impacts of biofuels much in dispute, imports of biofuels from outside the EU should be excluded, at least until a credible certification process is in operation. To stop potentially (or actually) devastating biofuel plantations in Africa, the EU policy needs clarification or reversal. Whatever the finer details of WTO rules, this scenario postulates no imports to our region.

Biomass nutrients must be recycled

When a forest is logged, nutrients such as phosphorous, potassium and selenium are removed, and the soil becomes more acidic. For both these reasons, ashes should be returned to the soil. This is done on a fairly big scale (10,000 hectares, 47,000 tons per year in 2010)[39] in Sweden, though for a very small part of the biomass ash and sewage sludge. Most of the nutrients end up in landfills.

If biomass is exported in the form of wood, chips or pellets (or indeed timber and paper), the nutrients cannot be returned to the forests they came from.

Free trade cannot be limited. But for the above reason we should aim for indigenous production of vehicle fuels, and export them as such rather than as feedstuff. Methanol, DME, ethanol, biogas, and synthetic diesel contain only carbon, hydrogen and oxygen. The nutrients are then left in the residues/ashes and can, in principle, be recycled.

Some of the ash and much of the sludge contain unacceptable levels of contaminants such as heavy metals, some of which are enriched in the process, others such as chromium which results from the wearing of stainless steel during combustion.

The nutrients problem is not acute, at least in Sweden, but in the longer term the present practices are unsustainable and in other nations soil nutrient depletion is already taking place. We cannot go on depleting the soils in one place and heaping millions of tons of contaminated waste in another. Recycling is not a simple problem to solve, but it has to be solved. Coal, oil, and peat ash are much more of a problem than biomass ash, so this scenario is at least a large step in the right direction, together with more ash recirculation.

Develop replicable measures for the world

The main objective is to cut emissions in the region. A second objective is to develop technology and policy measures that can be replicated elsewhere. There is usually no conflict between the two, but the main point of cutting emissions here is to show leadership in how to do it. Over-emphasising short-term cost-effective measures may land us with a lock-in into second-

39 http://www.skogsstyrelsen.se/Myndigheten/Statistik/Amnesomraden/Tradbransle/Tabeller--figurer/ table 11.10 (in Swedish)

best measures and delay development of technologies and policies for deeper and more far-reaching cuts. Very large scale biomass use for electricity is a fast and cheap way to cut emissions, but if the biomass is used that way, it is not available for vehicle fuels; besides which, many other regions do not have as much biomass as we have, and can even less afford to use a more limited resource for just heat and electricity. On the other hand, solar cells are obviously best suited for sunnier countries, but as a relatively rich and technologically advanced region, we have to take our share of research, development and market creation. It is in our enlightened self interest to try to keep one or two steps ahead, because that is the way to create the industries of the future.

Setting the scene: same direction, different speeds

The targets set for our scenarios are a 70 per cent reduction in CO_2 emissions in the Baltic-Nordic region, without CCS and nuclear power, and a 95 per cent reduction by 2030.

These are very demanding targets, but demonstrably technically achievable. As for economics, it will cost something, but implies no unbearable costs. The alternative cost, of just waiting for Peak Oil to come with disruptive economic consequences may be higher. Ignoring climate change, globally, has a still higher cost. The option to wait for somebody else to fix the problem is neither realistic nor self-serving. It is not in our best self-interest.

First, an early and planned phase-out of fossil fuels is cheaper than waiting for external events to force us to do things very fast. Such events may be a sudden quadrupling of fossil fuel prices or a series of EU directives.

Second, the "first mover" for new technology and techniques gains a competitive advantage. Sweden pioneered heat pumps, and in 2008 one of the leading manufacturers exported more than half of their production. Denmark pioneered wind power, and Vestas is the biggest wind power company in the world. Other leading wind power nations have been Germany, India, Spain and China, all of which have created world-leading exporters.

The assumption is then of course that the world moves in the same direction, towards renewables, efficiency and more CO_2 restriction policies.

There is strong evidence that this is the case for a large number of technologies and techniques, such as wind power, solar hot water, biomass boilers, biopellets, solar photovoltaic, solar thermal electric, efficient appliances, and combined cycle turbines.

But this trend, while strong – for example from 6 GW of global wind power in 1996 to 282 GW in 2012 – is very uneven in time and geography. In some countries nothing much has happened at all. For some countries and in some years development has been much, much faster.

This is likely to remain so. We cannot assume that the EU will do nothing at all, but neither that it will work for a 70/95 per cent target. As for our other neighbours, Russia, Belarus and the Ukraine, it now looks likely that it will take time before they catch up, but we all dance to the same music in a globalised economy with an increasingly global convergence of climate policy.

Prime Minister Putin claimed in September 2010 that "You couldn't transfer large electric power stations to wind energy, however much you wanted to. In the next few decades, it will be impossible". He also said that nuclear energy is the only "real and powerful alternative" to oil and gas, and called other approaches to meeting future energy demand "claptrap".[40] But in China, which added the most wind power capacity in the world every year between 2009 and 2012, they see things differently.

Scenarios normally make a lot of assumptions about the future, based on background factors such as GDP growth, population, growth, population age structure, unemployment, and investment intensity, often compared with a baseline.

While such modelling can illustrate different policy aspects, it also has fundamental problems. Some of the underlying factors are so uncertain that modelling is meaningless. Highly aggregated metrics such as energy intensity are abstractions, at best hard to grasp. Worse, they can create a positive barrier to understanding. At worst they are a vehicle for vested interests to that effect.

"Carbon dioxide emissions from fossil fuel are modelled … as a function of the carbon intensity of energy, and the energy intensity of GDP", says the Garnaut Climate Change Report[41] to the Australian government.

Carbon emissions are not the product of carbon intensity, energy intensity and GDP or any such metric. Carbon emissions are the real thing, coming from real coal power stations and real cars. But it is a lot more politically convenient to blame the emissions on "energy intensity" and "carbon intensity" in Australia – the world's biggest coal exporter and one of the world's biggest users of hard coal and lignite for its power production. The fact remains that Australia could do something other than coal-mining, and that the Australians could drive smaller cars fewer miles.

The full "Kaya identity" gives emissions as: Population*GDP/capita*energy/GDP*carbon intensity of the energy. Kaya is named after a Japanese economist. While it does have some value for describing what has happened, especially over a long time, it is most unsatisfactory for describing future options. There is no railway track ahead of us to be shifted and bent to change direction. What the Kaya identity says is only that with business as usual, emissions will rise with population, GDP and energy use, but that this increase will be somewhat dampened by technology such as improved thermal efficiencies of coal power plants.

For policy-driven scenarios, such rules do not apply.

Nevertheless, there are "external factors", which either impede or enhance our chances of achieving deep and fast cuts in the Nordic-Baltic region. One

40 http://www.world-nuclear-news.org/newsarticle.aspx?id=28332

41 http://www.garnautreview.org.au, chapter 4, p 96

such factor is the economic growth, inside and outside the NBR.

Economic growth is an important factor for projecting the future.

Or so they say.

High growth is, at least historically, linked to

1. More CO_2 , because of increased output of carbon-intensive products, transport etc. Examples abound, but China 2000-2009 may be the most noted.
2. Less CO_2 , because of more investment in new industry, power production, efficiency, infrastructure which can be considerably less carbon-intensive. Sweden 1990-2008 is an example, but another was China 1997-2000, with fast-growing GDP and rapidly declining CO_2 emissions. In China the carbon cuts were the unintended result of an effort to close down small coal mines and outdated heavy industry.

Emissions can thus move in either direction with growing GDP. Predictions are even more difficult when GDP change is abrupt rather than gradual, such as following the collapse of the Soviet Union.

As there is no way to know how the world economy or the economy in our region will develop, there is little point in making any assumption at all. High growth or low growth, what has to be done has to be done. This is war.

Some of the policies have to be adjusted to the economic situation. Recession is a good time for green stimulus packages, as actually happened to a considerable extent in the US and Europe in 2009. In good times, it may be a good idea to introduce carbon taxes, and phase out fossil subsidies. It is always a good idea to impose stringent demands on new cars and new houses, and to require improved thermal standards after renovation of existing buildings.

The effects of climate policy on the economy are also pretty meaningless to predict. Nobody can make a good assumption of what the relative costs of wind power and nuclear power will be in 2030.

You win some, you lose some. That is about as exact an answer you can get when optimising based on guesswork. Hedging your bets is not ideal, but it averts risks.

Sweden introduced a substantial CO_2 tax in 1991, but seems no worse off for that in GDP terms. Denmark decided to go for wind power practically alone in the world around 1990, but it proved to be a winning horse, and Denmark gained a big new export industry in one of the most dynamic industries in the world, adding to its GDP growth.

Other very large efforts to develop new energy have failed spectacularly. Coal-to-liquid in the US from the 1970s was a dead loss. Another contemporary (and ongoing) effort, fusion energy, got nowhere. Still another effort, the photovoltaic programme of Jimmy Carter's presidency in the late 1970's produced little tangible results, at least for the following two decades. Many other ill-conceived programs in the wake of the oil price hike in the seventies go nowhere, for good reasons; north-facing solar collectors and leaky heat pumps.

Time and money was lost that way, but solar cells and heat pumps came back with a vengeance.

Here are some specific assumptions:

Peak Oil will happen before 2020, meaning that oil production cannot meet demand at anywhere near present prices. This will mean drastically increased crude prices, much higher than the 2008 peak of July 2008.

What if this does not happen, or happens later? The methods for coping with Peak Oil – stringent efficiency norms for new cars, more alternative fuel production, more fuel taxation and rapid development of electric cars – are a cheap insurance against the worst and have other benefits.

Coal and gas prices will increase as oil prices increase. It has been so historically, and there are reasons to believe it will remain so. Oil is mainly (around 61 per cent globally[42]) used for transport, but the remainder is to a large extent interchangeable with other fuels. Coal and gas are strongly linked to each other as both are used for power production.

What if this is wrong? Even if coal turns out to be cheap, keeping old coal power plants is expensive for the environment and building new coal power plants is expensive. No regret. If gas is cheaper than expected for some time, it also comes with very long term addiction and dependence. This security of supply issue can be avoided with renewables and efficiency.

International climate negotiations will achieve at least one climate treaty, a Kyoto II and some elements of commitments from other major emitters. Whatever the formal structure, we have to assume that there will be strong pressure to cut emissions in the world, in Europe and in our region,

The consequences of this not happening are just too terrifying to consider.

The EU will do something to fix the broken emission trading system and adopt an emission reduction target for 2030 or 2025 which is more demanding than the 20/2020.

If not, we are in very deep trouble.

The EU targets will have to be achieved predominantly by domestic action.

If this is right, there will be strong demand for biomass, renewable electricity and a good market for manufacturers of renewables and efficiency (RE/Eff).

If this is wrong, CDM and hot air will be plentiful and cheap, and there will be little chance of rescuing the climate. If we don't act at home in Europe, there is no way to persuade China or India to do so. Betting on hot air is a self-fulfilling prophecy. Cutting real emissions is a prerequisite for building confidence.

Some nations will go for deeper greenhouse cuts than demanded by the EU, at present for example Germany and the UK, Spain and Portugal. Even a weak binding EU target can be exceeded by such nations.

42 http://www.iea.org/textbase/nppdf/free/2010/key_stats_2010.pdf p33

Other (or the same) nations will invest heavily in renewables and efficiency even if they do not commit to rapid real emission reduction anytime soon. This is clearly happening in China, India, and Brazil.

Against this backdrop the Nordic-Baltic region can both develop and export markets and have the option to import better and cheaper technology. The dynamics are favourable, and some of the renewables/efficiency technologies will be less dependent on political subsidies such as certificates or feed-in tariffs. This depends of course on the competition from conventional fossil and nuclear power.

Nuclear power will not see a great renaissance in most of the world. A large number of new nuclear power plants will be built in China, some in Russia, South Korea and India, but few elsewhere.

If this is shown to be wrong, the consequences could be serious enough. Even one extra nuclear power plant such as the 1600 MW Olkiluoto plant will take a lot of market from renewables/efficiency and also makes claims on some of the storage/grid capacity which they compete for. Even the threat of nuclear new builds will dim the prospects for wind power. The reverse is however also true. If enough wind power is built fast enough, the room for nuclear will shrink. In our region, there is no chance of new nuclear other than in Sweden and Lithuania, and there is no chance of even them being in operation before 2020 if indeed ever. This scenario sets the condition that they will not be built. In the neighbourhood, Poland has plans for new nuclear, which are however shaky and distant in time. Russia is building a plant in Kaliningrad, but that is not enough to upset the Nordic-Baltic electricity market.

New coal power without CCS will not be a major option for new power in the region or in Germany, Poland and the UK after ongoing projects are finished. High capital cost, public resistance, permit issues and price risks for coal and carbon will preclude such investments. If this is wrong, and new coal power will be built, we are again in deep trouble.

Coal with CCS will not be a commercial proposition for plants operable by 2030. A few plants may be built with heavy subsidies, but even if capture technology and economics are improved, there is no chance that the whole infrastructure (plants, very long pipelines and storage) will be in place for large-scale deployment anytime soon, considering the complicated permit issues and local resistance.

If this assumption is wrong,and coal CCS becomes a commercial option for the whole chain, it cannot happen much earlier than 2030, and thus does not change any strategy for the next 10+ years. A CCS "commercial success" must also be measured against simultaneous improved economics for renewables/efficiency.

Some new natural gas power capacity (without CCS) will be added both within the region and in neighbouring countries. There is some competition with renewables/efficiency, but it can also act as a complement: high winds

– low gas power, low winds – more gas power. More gas power capacity in surrounding countries is compatible with more power exports. Gas power is much more flexible than nuclear or coal because capital costs are low and the dominant cost is fuel and carbon emissions. They will be operated according to gas and carbon prices (when low enough) and electricity prices (when high enough). Gas power will not be cheap, because the gas power plants will not produce without making a profit.

Germany and the UK will become net importers of electricity because some coal power and some nuclear power will be phased out, and they cannot build enough renewables/efficiency to compensate by 2020, or import much from anywhere else than the NBR.

This could be wrong for various reasons. Storage technology or demand-side management could make so much progress that it will be much easier to integrate large amounts of wind and solar. Renewables, especially photovoltaics and offshore wind, and perhaps wave power, will make so much progress that the UK and Germany can become independent.

If anything like that happens, it will be more difficult to make the 70 and 95 per cent for our region, but easier to make great global reductions. If it happens, then other opportunities will open up for the surplus electricity, such as exports to the east, hydrogen production or other electricity-intensive industry.

Wind, solar and biomass will be the mainstay of new power in Europe from now on. As follows from above, the now conventional power sources will not be conventional for ordering from now on. This has already been so for years. Major capacity changes in the EU-27 during 2009 in MW are listed in table[43]:

source	Added	Decommissioned	Net change
Wind	10163	115	+10048
Natural gas	6630	404	+6226
Solar photovoltaic	4600	0	+4600
Coal	2406	3200	-794
Nuclear	439	1393	-954
Biomass	581	39	+542

The trend was even stronger in 2012

Wind is still predominantly onshore, but offshore wind is developing fast and is assumed to be a conventional technology by 2015. Photovoltaics are approaching "grid parity" in sunnier countries, but not in the Nordic-Baltic region.

Offshore wind power cannot fail, but there is some risk that it will take more time to achieve favourable costs than now expected. This is however a risk that cannot be avoided.

43 http://www.ewea.org/fileadmin/ewea_documents/documents/statistics/100401_General_Stats_2009.pdf p. 6

Wave power is expected to become a conventional source of power before 2020. Wave power is nearing its moment of truth. If it works, and the economics are acceptable, it is of global importance. The combination of the most advanced testing, best wave conditions and best market conditions are probably in England, Scotland and Ireland. If proven there, it will also work here.

There is a risk that wave power will not be a mature technology by 2020 or even later, but that does not overthrow the scenario, as the energy contribution is small.

Solar power is not expected to give low-cost energy in our region by 2020. If this is wrong and solar proves to be cheaper than expected, it could make the CO_2 cut deeper or cheaper.

Electric cars will be on the market well before 2020, and will win a significant share of the market well before that. The proportion of all-electric against plug-in hybrids is left open. Cars with one engine are obviously cheaper to produced, but hybrids are more versatile. The arrival of electric cars does not mean that the electric car will solve all perceived problems with driving distance, fast battery charging, battery costs etc, just that the politicians will make it a good-enough alternative to very expensive gasoline or no car at all.

The dynamics that will follow mean that if there is an alternative, increasing fossil vehicle fuel prices, by taxes or by Peak Oil, will be less and less of a political problem.

If electric cars prove a disappointment, it will be still more important to cut transport emissions by all means.

Much more efficient internal combustion cars will become standard in Europe. Additional policy for fuel efficiency will be set out from that baseline. Car manufacturers in the region will adapt to new rules. Fuel efficiency is of paramount importance, both because it will cut emissions directly for cars that use diesel and gasoline, and because a given amount of biofuels will fuel more cars.

Second-generation biofuels will be produced on a very large scale by 2020 and eliminate fossil vehicle fuels by 2030. Second-generation diesel from wood or biomass waste can be used in existing vehicles. Biomethane could soon become a very big niche. But there remains a choice to be made on which other biofuels to opt for, and that choice will mainly be imposed on us (in the NB region) from outside. Flexifuel engines are not as efficient as a dedicated engine for methanol or DME or indeed 100% ethanol, and on a life-cycle basis methanol and DME are also best. Unless the EU makes a clear choice of one or possibly two fuels, we will have to make do with diesel, biogas, electric and a mixture of ethanol and synthetic gasoline.

Improved recycling of iron and aluminium, and more efficient use of them will reduce production of primary aluminium and ore-based steel by 2020 and eliminate them by 2030. This has to be done by several methods, including more efficient design, alternative materials, and better organised recirculation. Our region can do some things on its own, but depends on the rest of the world moving in the same direction.

Stricter building codes have to demand much-improved energy efficiency for new buildings well before 2020 in Europe. The technology for passive houses, or even "energy plus" houses is proven, but the construction industry is slow on the uptake and has to be forced to transform to a modern industry with modern quality specifications. We can do a lot in our own countries, but an EU directive will help.

Portland cement production has to stop by 2030. Other less carbon-intensive or non CO_2 -emitting cements, for example based on magnesium rather than calcium carbonate, will have to be developed, tested and evaluated before 2020. Moreover cement is not the only possible material for construction of buildings. To open up other options, governments have to support research and not leave the initiative to the fairly inert (and inept) construction industry. Our region can do quite a lot of things on its own, but depends on supporting development in at least some other parts of the world.

Smart grid applications and techniques will be developed and tested over the next few years. Smart grids, or demand-side management, are of essence for cutting costs and saving time in a scenario with a large wind power component, as they can cut the need for electricity storage, reserve capacity and new power lines. The prospect for smart grids to emerge are anyhow pretty bright, so even if nothing much happens here, smart grid apps will be there to import.

The rapid development of the smart grid in the US and elsewhere is often aimed at different problems than we have here. In much of the world blackouts and brownouts are a great nuisance. In other parts there is little chance for under-invested grids to cope with rapidly changing electricity production and consumption patterns. The interest in smart grids is enormous in the US and in much of the world[44].

The North Sea Supergrid will be partly in operation and under construction by 2020.

Offshore wind power has breathtaking potential, especially outside Norway and around the Britain and Ireland. There is also a good rationale for more power lines between Scandinavia and the UK and between Scandinavia and the Netherlands and/or north Germany and across the Baltic. Connecting the clusters of wind power stations far offshore from Norway and Scotland, for example, has several advantages. It shortens the cable distances. All those wind power stations (not only the Scandinavian) can use Norwegian and Swedish hydro for backup/storage. Wind power stations far apart also act as backup for each other when winds are uneven. And with low winds, fossil power stations in the UK, the Netherlands and Germany can supply reserve power.

Ministers from nine governments: Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Sweden and the United Kingdom made a declaration[45] in favour of the North Sea Supergrid in December

44 See for example www.greentechmedia.com/articles/read/smart-grid-smart-tv-part-of-a-continuum-says-google-japan/ with further links

45 http://www.ewea.org/fileadmin/ewea_documents/documents/policy/Offshore_Wind/Political_declaration_on_the_North_Seas_Countries_Offshore_Grid_Initiative.pdf

2009. Norway joined soon after[46]. There is also a considerable industry lobby behind the effort.

The prospects for something materialising look good. If the plans are thwarted or much delayed, however, it will be very much more difficult to achieve the scenario objects. But it is not mainly an external factor; the crucial player is Norway.

There are now plans for a 1400 MW UK-Norway cable[47], to be operative by 2020.

From stupid grid to smart grid

The future electrical system must, according to ABB, "meet four requirements:

- **Capacity:** the huge demand for electrical energy has to be satisfied
- **Reliability:** high quality electricity must be available whenever it is needed with no interruptions
- **Efficiency:** from production and transport to consumption of electricity, energy has to be saved
- **Sustainability:** Low carbon energy sources must be integrated into the system"[48]

This is, on a global scale, the exact opposite of what we have. In the Nordic-Baltic region, the capacity is certainly adequate, and reliability is fair, but it is neither efficient nor sustainable.

To understand the importance of the smart grid, one has to have a historical background of how the present electricity system was built, how it has worked and how it works now.

The present electric system is not that dumb. Blackouts do not happen very often, and they are very rare on the high-voltage grid (more than 130 kilovolts). Quality is fairly good in the sense that frequency is kept within narrow margins – 50.0±0.1 Hz in the Nordic market.

But the main idea behind the system, unchanged for more than a hundred years, is that demand is the king and that production has to follow on all time scales from seconds to decades.

This has created a very centralised structure, heavy on supply. There has been little incentive to economise on the use of electricity. The cycle goes like this: when the risk of shortage is perceived in the 10-15 years perspective, new power stations are ordered. When demand is less than expected, measures to boost it are introduced. Such measures have included campaigns to switch from gas cooking to electrical stoves, from fuels to electricity in industrial

46 http://www.rechargenews.com/business_area/politics/article205220.ece

47 http://www.statnett.no/en/Interconnectors/Cable-to-the-UK/

48 http://www.abb.com/cawp/db0003db002698/145abc3534b16460c12575b300520d8b.aspx

processes and for more electric heating, all accompanied by more or less temporary rebates. The target for such campaigns is to increase use of energy, but the consequence is more often than not also an increase in peak demand, requiring more power lines and transformers and, once again, added capacity.

Though sophisticated in its details, this is a structure for over-dimensioning everything.

The organisation of such a system is simple. It takes one decision to build a power station, say a nuclear or coal power station of 1000 MWe.

The economics of such a system were also simple, at least until 1996 when the electricity market was deregulated in Sweden, Denmark, Finland and Norway. Investment in new power was practically sure to produce a return, if not in five years, then at least in 15. Maximum profit was not an issue, as the power producers had no plans to use their money anywhere else.

The government was heavily involved in the entire electricity sector, and the private power producers and grid operators acted as a cartel. In Sweden, for example, the pre-1996 situation was that the government-owned Vattenfall produced half of the electricity, with the remainder mainly coming from Sydkraft, owned mainly by towns in south Sweden; Stockholm Energi, owned by Stockholm town; and Skellefteå Kraft, owned by Skellefteå town. Vattenfall was the acknowledged price-leader, and had very low demands on profitability, as it was seen as a strategic interest to keep prices low. Much of Vattenfall's production was old hydro power, long since written off and with negligible operating costs, so even with low prices it could afford to invest heavily in more hydro, nuclear power and more power lines.

In Norway and Iceland, the hydro resources are even bigger, so nuclear power was never needed.

Hydro and nuclear have a common feature in that both are expensive to build, but cheap to run. Once they are built, it makes best sense to use them as much as possible.

In Denmark, the situation was quite different. Denmark, as a flat country, has no hydro, and plans to build nuclear were defeated by public opinion in the 1970s. Most of the power is produced in thermal power stations, which are cheaper to build, but more expensive to run. For every kWh of electricity, 2.5 kWh of coal has to be imported and paid for.

The consequences for demand are striking. Iceland, Norway and Sweden have a much, much higher demand per capita than Denmark:

Electricity consumption per capita 2008.

		Nordel	Denmark	Finland	Iceland	Norway	Sweden
Population	mill.	25.2	5.5	5.3	0.3	4.8	9.3
Total consumption	TWh	412.7	36.1	87.0	16.6	128.9	144.1
MWh/capita		16.4	6.6	16.4	52.1	26.8	15.6

Source: Nordel statistics[49]

49 https://www.entsoe.eu/fileadmin/user_upload/_library/publications/nordic/annualstatistics/Annual Statistics 2008.xls

The usual justification for high electricity consumption is that a) our countries are cold and b) that the industrial structure is electricity-intensive.

The first is irrelevant. Sweden and Norway are not much colder than Denmark. The difference is that electric heating is very common in Sweden and totally dominant in Norway.

The industrial structure is not the cause, but the effect of low electricity prices. The most important industry in Sweden and Finland is paper & pulp, also of considerable importance in Norway. We have this industry because we have so much forested land, but high electricity consumption is not a necessary consequence. Mechanical pulp requires a lot of electricity to produce, but chemical pulp does not use much electricity and can produce more power than it needs from burning wood residues.

Mining and smelting are major industries in Sweden, Norway and Finland, because we have large deposits of iron, copper and other minerals. But we also have a large production of aluminium, for which the raw material is imported. We do not use electricity because we produce aluminium; we produce aluminium because we have a history of cheap electricity.

Moreover, much of the aluminium has been, or still is, produced by obsolete, wasteful and dirty methods (Soederberg cells in Norway, and until 2008 in Sweden) which are not competitive in the rest of the world.

Indirect subsidies of electricity costs were common up to the mid-1990s. The electricity-intensive industries got extremely cheap electricity on very long term contracts. This practice ceased after Sweden and Finland entered the European Union in 1995 and Norway became part of European competition legislation through the European Economic Area. But the historic subsidies leave us with an industrial structure that is still there.

In effect, the cheap electricity has been subsidised by low return on power investments from the taxpayers: low prices, but high taxes. Hydro power could have generated a large income for the government, but this potential huge income was used to subsidise electricity prices, and for more investment in power and power lines.

The macroeconomic consequences are seen everywhere, as unnecessarily high consumption of electricity, not only in electricity-intensive industry but everywhere.

Researchers from Linköping University compared the Volvo car factories in Gothenburg and Ghent, Belgium: the Swedish factory was found to use twice as much electricity per car produced[50], due to less sophisticated systems for measurement and control of electricity. At the time, the Swedish electricity price was about half of that in Belgium, so the electricity cost per car produced was the same.

Now the price difference between Nordic and continental electricity have essentially been eliminated, but habits die hard. It is a painstaking task to build up effective energy management when everybody is used to seeing energy

50 http://www.energimagasinet.com/em00/nr2_01/02_kyto.asp

costs as small and unavoidable. Many companies do not even have a correct economic theory. A customary requirement is two years pay-back for energy efficiency investments; though much of that investment saves energy for decades or more, for example heat recovery from ventilation, better insulation or presence detection and control of lighting and ventilation.

In offices and homes, the energy wastage is sometimes even worse than in industry, as there is less technical know-how and no clear responsibility.

What is said here about Sweden, Norway and to some degree also Finland is of course even more the case in the ex-Soviet Baltic republics, where energy wastage is rampant, despite a sharp drop in electricity demand.

The 1996 deregulation of the electricity market did not help at all, initially. The prices fell, due to increased competition, good hydro years, and low industrial activity. By the end of the 1990s the Nordpool market price for electricity was just one euro cent/kWh, down from about 2 cents in 1995. But the power producers retaliated, and used the increasing export capacity to increase domestic prices, which are now about 4 cents.

This will eventually lead to big changes in consumption patterns and industrial structure. It will also lead to increased interest in demand-side management. Prices are not only higher, they also tend to become more variable, and that trend will be reinforced for several reasons.

- Wind power is very variable over seconds, days, weeks and months, and with increasing wind power, prices will follow. There have already been cases (in Denmark), where customers are paid for using electricity! As long as the "negative price" is not below the feed-in tariff, the wind turbines earn money for the producer.
- Nuclear power is increasingly unpredictable on all time scales, from seconds to decades. Olkiluoto 3, the biggest reactor in the world, was supposed to start commercial production in 2009, but is is now almost seven years behind schedule. The Swedish reactors produced only 50 TWh in 2009 compared to 75 TWh in 2004, and most capacity uprates are years behind schedule.
- Hydro is variable, as precipitation and evaporation vary from year to year by 100 TWh difference[51] between a dry year and a wet year for the Nordic system, from an average of just below 200 TWh. This is nothing new, and a shortage situation can be predicted months ahead, and is dampened by long-term storage capacity. But the effects of climate change make prediction more difficult.
- Eventual added solar capacity will introduce a new variability.
- Wave power is variable, in a slightly different pattern than wind power.
- Combined heat and power varies with the outdoor temperature. If demand for district heating is low, less electricity will be produced.
- All new projects have uncertain start dates for generation.
- Coal power production depends on coal prices and carbon prices.
- Gas power production depends mainly on gas prices and electricity prices.

51 http://www.svenskenergi.se/upload/Om%20el/Vattenkraft/Bilder/magasin%20stor.gif

- The export/import situation can change fast, because of similar variability in the surrounding countries, and the capacity for import/export increases.

Some of the variabilities tend to cancel out each other, whereas in other cases they reinforce one another.

The present system is supposed to meet demand any time at any cost. This was feasible within the regulated market and with large overcapacity, which we have inherited from that time. But within a deregulated market there is little incentive to keep surplus capacity. For that reason, the Swedish and Finnish grid agencies (Svenska Kraftnät and Fingrid) purchase a capacity reserve, which either comes from keeping old oil power plants ready in case of need or from reduced consumption in some industries.

This is a first step to take demand into the picture, but a small step. The capacity reserve is put into use a few hours per year, if at all.

One of the features of a smart grid is "demand response", the purpose of which is:

- To keep system peak demand low, to avoid investment in new power plants.
- To keep local peak demand low, to avoid investment in distribution.
- To avoid or postpone investment in power transport (400 kV power lines etc).
- To avoid using high-carbon electricity production.
- To use more electricity during wind power production peaks.
- To avoid expensive and inefficient short-term balancing power.

The importance of a smarter grid will be ever more important in the years ahead. With a large wind power component, more power lines and/or more peak power is needed anyway. With better performance from the grid, the need for such investments should be considerably less.

This not only saves money. It also saves time.

How this can be done is illustrated by the British RLTec "smart fridge" concept. A standard fridge turns on the compressor when the temperature exceeds the maximum, say 7 degrees, and turns it off when it gets down to the minimum, say 3 degrees. The smart fridge keeps the temperature within the same range, but sometimes turns the fridge on and off earlier. This "sometimes" depends on the grid frequency; the mains 230 volt supply is synched with the 400 kV frequency, so when demand exceeds production, the frequency drops from 50 to maybe 49.92 Hz, and when production exceeds demand, the frequency may increase to 50.08 Hz. The smart fridge is programmed to cool more when frequency is high and less when it is low. The fridge user will never notice the difference, but if all fridges in Britain were smart, they would act as a virtual power plant of 350 MW capacity[52], ready to start within a second. This could cut CO_2 emissions by 1.74 Mtons per year[53].

52 http://www.rltec.com/sites/default/files/090427%20_environmental_background_3.pdf

53 DECC The Potential for Dynamic Demand 2008 www.supergen-networks.org.uk/filebyid/50/file.pdf

In the UK, some of the spinning reserve comes from pumped hydro storage. In reversed hydro power, water is pumped to a greater height during off-peak hours, and when needed to cover peaks or reserve, the water falls through the turbines and generates power. But of course it takes more power to pump the water up than you get when it runs back. In fact some 30 per cent is lost in the round trip, and if the electricity came from a coal power plant with CO_2 emissions of 1 kg/kWh in the first place, the effective emissions for the energy from the pumped hydro storage would be 1/0.7=1.42 kg/kWh. The fridges are faster (less than three seconds[54] compared to several seconds or a minute for other reserves) and emit nothing at all.

The "technology" is just a piece of programming, with no extra gadgets needed for fridges. It could also be used for air conditioning, heat pumps, electric heating, and drying. And whereas nobody wants this flexibility stretched too far in a fridge, other applications are less demanding. Whether a washing machine runs at 5pm or 5am or even the next day may be of little consequence.

Other demand shift is possible for circulation pumps, ventilation fans, etc., which can slow down a little for seconds or minutes, and for dishwashers and washing machines.

For most of these applications, there are much larger equivalents in industry.

Hot and cool storage can be useful over longer times, even for seasonal storage, shaving peak production (high winds) to be used for shaving peak consumption.

The technology for shifting and shaping peaks is largely available. But there has to be a strong price signal, all the way. For a customer who pays a fixed price, there is no incentive to shift a single watt. "Floating price" often means a monthly average, or at best the hourly average. This does not address the problem of instantaneous balance, which is where the smart fridges and similar applications would mostly come in.

A central issue is to avoid blurring of the price signal through taxes and fixed grid tariffs. They should be multiplicative rather than additive to the price per kWh.

Much hope is pinned on metering. It would however take very big differences in prices to influence behaviour just by providing real-time price information. There must be a two-way communication, and the incentive will be in the contract: cheaper monthly bills if some of the load is controlled automatically.

There is also the growing issue of grid quality. The 230 volt AC supply should be delivered as a pure sinusoidal waveform of voltage and current, but due to digital electronics – for example in compact fluorescent lamps – the sinusoidal waveform is hacked up into small pieces, with distortions in higher frequencies as ripples on the main wave.

These distortions cost a lot of money because equipment malfunctions, or

54 http://www.rltec.com/sites/default/files/090427_product_background_3.pdf

ages and dies faster. Some users are willing to pay a lot extra to have a high quality, uninterruptible supply from batteries.

Batteries are for this reason of increasing importance, and can also be used as to shift and shape the load – in principle even in the ordinary laptop computer, but much more for big data centres: they can "convert your data center into an intelligent, energy-aware asset"[55], according to HP.

If electric cars make it big, the plugged-in car batteries can switch between acting as a source and a sink for electricity loads.

To sum it up, the smart grid will make it possible to save huge amounts of money in deferred or avoided investments while permitting much more variable input, such as from wind power. The technological concepts are developing fast, and a lot of money is being put into this area. But much more policy is needed to make this really happen fast enough.

The main way to make it happen fast enough is by making it necessary and profitable. With rapid construction of wind power and a rapid phase-out of fossil power, the system will be under pressure due to higher and more volatile electricity prices. In the right legal environment, this will create strong incentives for the smart grid. More storage and new power lines will also be needed to make the most of the growing wind power, but demand-side measures are faster and cheaper.

The business opportunity for smart grids is clear, and a newly formed lobby, the Smart Energy Demand Coalition[56] backed by energy giants EDF and ENEL and most major meters and gadget manufacturers. They claim that "active participation by energy users can yield as much as $52 billion worth of consumer benefits annually".

Balancing wind power

In order to cut emissions radically, wind power has to increase radically. This creates three problems, compared to base power from coal, gas, hydro, combined heat and power and to some extent also to nuclear power.

The first problem is that when the winds are weak all over the region, there might be a deficit, which can be handled with a number of measures on the supply and demand side.

The second problem is that when winds are strong all over the region, there is an over-supply, which also can be managed by a number of measures on the supply and demand side.

The third problem is when winds are strong in a part of the region and weak in other parts, creating bottlenecks in the transmission system. A quantitative, detailed analysis of this problem is not possible here, so we just assume

55 http://h20338.www2.hp.com/enterprise/us/en/messaging/feature-servers-datacenter-smartgrid.html

56 http://www.smartmeters.com/the-news/1397-europes-smart-energy-demand-coalition-formed.html

that it is a special case of the two first problems occurring at the same time.

The problems should not be overstated. In general terms, winds are much stronger in winter, when demand is higher.

The first method to deal with imbalances is hydro power.

In the Nordel area there was 50,649 MW of hydro power[57] at the end of 2008. Excluding Iceland (which is not connected to other nations) that is almost 49 GW. The hydro capacity of the Baltic republics was 1624 MW and pumped storage (in Lithuania) was 760 MW.

This represents a formidable existing storage capacity.

This 51 GW or so of hydro power produces electricity roughly half of the time, so a typical situation is that 25 GW is produced. With high winds, this can be cut close to zero. With low winds it can be increased to close to maximum.

Wind power over the whole region can vary from say 10 to 90 per cent around a yearly average of some 25 per cent.

The relationship between capacity and energy is usually described as "full capacity hours per year". This is never the actual number of hours per year, 8760. In 2008 Denmark and Sweden produced about 2000 hours of wind power per year, or 2000 kWh/kW. The Lillgrund offshore plant in Öresund produces about 3000 kWh/kW. Very large wind power turbines in the North Sea should produce upwards of 4000 hours. Newer, bigger plants on land also produce more energy: Stor-Rotliden, commissioned in 2012 in northern Sweden, is projected to produce more than 3000 hours[58].

A conservative assumption is that the capacity to supply 100 TWh translates to 40 GW of maximum capacity, with an average real production of 11 GW.

The "no wind problem" is not a problem. The drop from an average of 11 GW to 0 (which hardly ever happens) is not a lot in relation to the 50.7 GW of installed hydro or 25 GW of average hydro.

What about low winds for weeks on end? Still no worry, other than under extreme dry year conditions, when it is very cold and there is an industrial super boom. Over periods of months, the wind is fairly predictable.

And there are still other options. One is a cut in demand. For winter 2010-2011, the grid operation Svenska Kraftnät purchased additional, more or less emergency, capacity of some 1900 megawatts, 1300 of which was from reserve power stations (older fossil power plants) and 600 from demand cuts in industry, for example 390 MW from three paper and pulp producers. These are the lowest bidders, not the full potential. If incentives are strong enough, the demand reduction could also include some of the steel industry, several large heat pumps etc. As a rough figure for the entire region, there may be a reserve capacity of about 5 GW and a demand reduction of the

57 www.entsoe.eu/fileadmin/user_upload/_library/publications/nordic/annualstatistics/Annual%20Statistics%202008.xls table S1

58 240 GWh and 78 MW, according to Vattenfall, i.e 3077 full capacity hours. www.vattenfall.se/sv/stor-rotliden-vindkraftpark.htm

same size. The demand reduction potential may be even greater if industries start to plan for a slightly reduced output, so they can meet their contracts with customers even if there is some reduced production, though this goes against both the "just-in-time" thinking and the drive to utilise capital and the workforce as much as possible. Such a paradigm shift would however be well rewarded in a situation where electricity prices vary from very high to far below zero, which has happened in Denmark.

Imports of electricity can add to capacity. By 2020 it is assumed that Germany, Russia, Poland and the UK will still have a large fossil power capacity, though it will be used for fewer hours per year.

In short, low winds are not much of a problem.

High winds produce a bigger problem.

If hydro runs at 25 GW and wind increases from the average of 11 to 36 GW (90 per cent of maximum), 25 GW will have to be used somewhere. Even if hydro is cut to zero, this 25 GW is about all of the average hydro power. Some of it can probably not be cut that much. There are legal limits for maximum water levels and minimum flow rates. Also, though the Nordic power system, and increasingly also the Baltic power system, has big capacity, high winds in Denmark and Norway cannot always immediately be compensated for by hydro production cuts in Finland and Sweden. The transport capacity is not infinite.

This problem can partly be reduced by meteorological forecasts. If winds are weak today but strong tomorrow, fuel power stations can produce less while hydro plants can produce more today, and hydro can then be reduced from a higher level, leaving more space for wind power. Hydro regulation is instantaneous and does not need forecasts but fuel power stations need some advance warning (varying, but in the order of hours).

Interconnections across the Baltic are being reinforced so the internal capacity is increasing. The correlation of wind speeds decreases with distance, so the probability of very high or very low winds simultaneously occurring in the seas west of Norway and in southeast Lithuania is much lower than of this happening at a shorter distance.

Exports can take care of another share. The Scandinavian countries presently have an export capacity of almost 4 GW, the Baltic countries even more. The export/import potential has to be increased considerably to put very much wind to good use. The present capacity is (just) sufficient for exports of 10 TWh, if imports are minimal. Statnett has plans for four new cables[59] to the continent which will add 4200 MW of capacity by 2020. With all that capacity there is ample space for exports well in excess of 10 TWh. With the Nordbalt[60] 700 MW cable between Sweden and Lithuania expected to operate by 2016, it should also be possible to export some electricity from Western Scandinavia to Russia and Belarus through Lithuania, now a net importer from the same countries.

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59 http://www.statnett.no/en/Cable-projects/

60 http://www.energinyheter.se/2010/03/svk-tecknar-samarbetsavtal-om-nordbalt

Another option for exporting wind power to Russia would be to upgrade the Russia-Finland connections, now used only for imports to Finland, for bi-directional transmission, though this is presently not under consideration[61].

The North Sea Supergrid, subject to a ministerial agreement in December 2009, will help to achieve the 2020 and especially 2030 targets, for a number of reasons.

1. In Poland, Belarus, Russia, Ukraine, the UK, Germany and the Netherlands, a substantial amount of fossil power can act as balance for NB power by 2020, and into 2030, though to a lesser extent.
2. The correlation between NB winds and winds in the surrounding countries is weaker than within the NB region.
3. Much of the grid investments are needed anyway to bring the power from far offshore in the North Sea to the population and industrial centres in the NB and non-NB.
4. The same North Sea Supergrid can, in principle be used for wave power, which is not synchronous with wind; waves reach maximum height several hours after the wind peaks.

In the worst case wind power can be "curtailed", i.e. production can be cut. Although a waste from a qualitative point of view, it is no big deal if it means a loss of a few percents of the annual output a few years during an expansion phase.

There are still a number of methods other than exports/imports for balancing wind loads. Much of the district heating, which is of great importance in Sweden, Finland, Denmark and the Baltic republics, is operated as combined heat and power (CHP). In normal mode it produces both heat and power. If power supply is strong, the turbine can be bypassed, so only heat is produced. If there is still oversupply of power, combustion can be reduced or stopped, while the heat is produced by electricity. This was in fact a common practice in Sweden during the 1980s and 1990s when the huge nuclear capacity could be put to no better use, often in combination with running reactors below capacity.

A CHP plant can thus produce power, consume power or be in neutral mode. Some plants have a fourth "condensing" mode of operation, when no heat but more electricity is produced. (The heat of the cooling water is then dumped into the sea or a river.)

There are limits to this flexibility. Not every plant is well suited for very intermittent operation. There may be temperature limits for running in condensing mode, so as not to kill the fish downstream with water that is too warm. Some fuels, notably waste, cannot be stored for extended periods. Other problems are economical, rather than technical. If a plant is designed to produce electricity 4000 hours per year, and it just produces electricity for 1000 hours, because of increasing wind power, a sound investment is turned into a bad investment, and someone will have to pay for it.

61 http://www.fingrid.fi/portal/in_english/news_and_releases/news/?bid=588

Nevertheless the district heating systems can provide a lot of flexibility. They are built to cope with large temperature differences, so they can store large amounts of heat for a shorter interval. The same goes for the district cooling systems, and for smaller heating and cooling systems, even as small as a household fridge (as described in the Smart Grid chapter above).

The limitation of the grid to absorb a large share of wind power is not primarily of a technical nature. There are thousands of smart tricks out there, but the incentives have to be strong.

In Skegness, northeast England, it has been found that existing power lines can sometimes carry more electricity than they are rated for:

"With increasing amounts of wind power being generated, a 'smart' solution – 'Dynamic Line Ratings' – has been applied to the existing circuits to increase the amount of load the lines can accept without physical reinforcement. Traditionally, line ratings would be fixed limits for how much power a line should carry, with a safety margin. However, engineers designed an innovative arrangement whereby the line capacity is varied in accordance with ambient weather conditions and actually increases at times of high wind speed, which is also the time of greater wind power output. This means that additional load is able to be added without physical upgrade. The Dynamic Line Rating system can do this by measuring, in real time, the weather conditions, i.e. wind speed and direction, air temperature, and also the temperature of the line, and uses this information to calculate dynamically the electricity load that the lines can carry. This has resulted in large cost savings from avoiding reinforcement, with no environmental impact."

Under cold and windy conditions the lines will not be overheated so they can carry more electricity. This is simple enough, but it is still unlikely that anybody would have even thought of this possibility unless forced to do so.

A similar project is now being developed by Eon for its offshore wind power plant at Kårehamn, Öland, Sweden, scheduled for operation in summer 2013.

If maximum wind power production grows faster than peak demand, there will be surplus capacity in some parts of the region. The simple way to deal with this is to curtail production. This may be deemed to be acceptable if it does not happen too often. But it is still throwing money into the sea, and there should be a big bonus for shifting demand so as to save that money. (See Smart Grids, above.)

Eon in Germany is now experimenting with an innovative method to handle surplus wind power: by producing hydrogen from electrolysis and feeding it into the natural gas grid, which acts as an enormous energy store and can easily swallow large amounts of hydrogen.

This could also pave the way for other hydrogen usage.

If it works well technically and the costs are acceptable, this method could be used in Finland, Denmark, the Baltic republics, and southern Sweden, possibly also in some locations in Norway.

Balancing solar and wave power

Most of what has been said about windpower above is also valid for solar and wave power. If solar gets cheap enough, battery storage may become more of an option for a number of reasons.

Batteries are projected to become cheaper and better, because of electric and hybrid cars.

With highly variable prices the batteries can pay for themselves through lower average price and lower capacity need in amps. Some customers will also want uninterruptible power supplies and higher quality AC supplies. If they have the batteries they might as well put some photovoltaic panels on the roof, or vice versa.

Photovoltaics make most sense where there is a need for air conditioning or other cooling, such as in offices or hotels with AC, computer server halls, supermarkets, etc., as peak demand electricity coincides with peak PV output. With good policies, a large proportion of installations should come first to such places.

Saving heat and electricity

Saving electricity in a power system dominated by renewables is first and foremost about saving money. Wind power is very nice, but not so nice that more should be built than is needed.

Saving heat in a heat production system dominated by biomass and renewable electricity is a matter both of saving money and of conserving the biomass resource.

Biomass balance

Biomass is controversial in many respects, most related to competing land use. The potential and consequences have much larger uncertainties than for wind and solar. The relationships between targets and policies add more uncertainties. An effort to estimate the biomass contribution should therefore contain a substantial safety margin.

Land not used for houses, buildings and infrastructure is mainly used for three purposes.

1. Food production, such as wheat, meat and milk.
2. Fibre production for clothes, paper, wood as building materials etc.
3. Leisure and biodiversity, ecosystem services.

Energy for electricity, heat and vehicle biofuels is usually a by-product from any of these.

Straw from wheat can be burnt on the field, or be plowed into the field. If so, it is not defined as energy. It can also be used as fibre for making construction material for pallets, or as insulation material, and it is still not defined as energy. But it can also be used for heat and electricity production, and if it is used as insulation material or pallets it will at some time end up as waste, and then be used as energy.

Biomass is a huge resource today, as shown byEurostat statistics[62], (here converted to TWh)

TWh	1997	2008	% increase	2020
Denmark	18.3	29.4	61	
Estonia	6.8	8.6	26	
Finland	66.3	89.3	35	
Iceland	..	..	..	
Latvia	14.8	17.5	18	
Lithuania	6.0	9.7	62	
Norway	13.5	15.2	12	
Sweden	90.9	115.5	27	
Sum	216.7	285.3	32	400

The Eurostat definition of the category is "Primary production: biomass (heat content of the produced biofuels or biogas; heat produced after combustion during incineration of renewable wastes)".

It is no trivial task to sum up categories such as bark in the paper and pulp industry, wood from demolished buildings, straw, biogas from sewage with the products of dedicated bioenergy such as wheat ethanol and pellets from salix plantations. Some are traded commodities, some is waste with a "negative value" and some is hardly even noticed at all.

"Biomass resource base" is actully not primarily a biological concept. It is not just related to available land area for plant growth, frost-free days, water availability etc, but goes deep into the technosphere.

In fact even a nation with no trees and no agriculture would still "produce" large amounts of biomass: used paper, banana peels, wood from building demolition, and sewage, which all have an energy content.

Nevertheless there is of course a biological underpinning, with insolation and photosynthesis efficiency as ultimately limiting factors. The sunshine over the NB region is about 1000 kWh/m2, and with an area of some 1 million km2, this means about a million TWh. At 0.5% efficency that would be 5000 TWh, clearly much more than would be needed. Even allowing for unusable land, natural reserves, agriculture and land used for growing paper and planks, the resource is huge.

Also, some of the limitations mentioned are less severe than it first appears. The main uses of land, except for hard surfaces for buildings, roads etc., are

62 Renewable energy primary production: biomass, hydro, geothermal, wind and solar energy - [ten00082]; Biomass & Wastes (1 000 toe)

http://epp.eurostat.ec.europa.eu/tgm/refreshTableAction.do?tab=table&plugin=0&pcode=ten00082&language=en

food for people and animals, producing fibre (timber, paper, linen, wool), and biodiversity. But competition for land is not absolute. The part of wood that is most valuable for papermaking is the cellulose, which represents about half of the energy content of the wood. The other half is lignin and other substances. In branches, twigs and needles, the cellulose makes up a smaller share and is harder to extract. Papermaking involves extracting the cellulose and either eliminating the non-cellulose component or compensating for its bad properties with large amounts of bulk chemicals, some of which are very carbon-intensive. The lignin is what makes inferior papers yellowish when exposed to light, and is (generally) not wanted in the paper.

Much biomass is left in the fields and in the wood, other parts are landfilled. More biomass is available through better collection, which is the predominant reason for the 32 per cent growth seen in the table above. This resource is huge, as can be seen by biomass development in Germany, which went from 5880 ktoe in 1997 to 23,473 ktoe in 2008, a fourfold increase[63]. The fact that the UK only went from 1652 ktoe to 3620 ktoe in the same period shows that policy is very important; after all the countries have roughly the same size, population, and climate.

A resource of 400 TWh by 2020 can be assumed from just extrapolating the trend and adding a minor part of dedicated bioenergy production (not byproducts), or by switching a small part of the forestry industry to other use. A report by the Swedish Society for Nature Conservation and the farmer lobby organisation LRF estimates the Swedish biomass potential[64] for 2020 at 158 TWh compared to 120 TWh 2008, an increase of 32 per cent, which is a little less than than the projected increase (40 per cent) for the whole region, but it is likely that Sweden has tapped more of its potential than the other nations due to many policy instruments since the 1970s, but most of all the 1991 CO_2 tax.

Dedicated energy growth includes short-rotation forestry (coppice).

With a 400 TWh resource, we can use half for second-generation biofuels and the other half for heat and electricity. With a 60 per cent conversion efficiency for diesel production that would produce 140 TWh of diesel, which would otherwise have produced 37.38 Mtons[65] of CO_2 . On a life-cycle basis it would actually be more because there are also emissions from oil extraction, transport, and refineries. Life-cycle analyses give a multiplication factor of 1.2 from well-to-pump[66]; it takes 1.2 litres of oil to produce one litre of diesel. Some of the energy losses occur also for biofuels, so it may be prudent to use 1.15 instead of 1.2, which would give an avoided emission figure of

63 ibid

64 http://www.naturskyddsforeningen.se/upload/rap-fornybart.pdf p12

65 At 267 g CO_2 per kWh, IPCC default value http://www.carbonmetrics.com/ipcc.html

66 See for example http://www.konsumentverket.se/bilar/Nybilsguiden/Drivmedelochutslapp/Drivmedel/ or http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/24772.pdf

43 Mtons. Those extra 5.62 Mtons are however reduced in oil extraction and refineries, not in the transport sector.

The transport emissions in Nordic-Baltic region were 74.7 Mtons in 2008, and targeted emissions for 2020 are 25 Mtons. Biomass cannot solve the whole problem, but it may solve half the problem. Actually the targeted reduction is 49.3 Mton, so 37.38 Mton is not far off, and the deficit could probably be filled with some reduction in paper production or some more growth of biomass.

But as we live in an open free market, it cannot be taken for granted that all the 140 TWh of diesel or equivalent other biofuels can be used here. Some will be exported to where the willingness to pay is greater, much of it due to the EU renewables directive.

Somewhat arbitrarily, this export is estimated as a credit of 10 Mtons, or 37.45 TWh of diesel equivalent. With this in mind, biofuels can save 27.38 of the required 49.3, solving a little more than half the problem.

The other half will have to be achieved by improved fuel efficency, electric cars, modal shift, better driving, more efficient transport of goods, lower speeds or fewer kilometres of goods and passenger transport.

This is technically achievable, but politically demanding.

Another urgent problem is to stop a lock-in situation where more and more biomass goes to heating and electricity, leaving too little space for vehicle biofuels.

Good coherent data on what biomass is used for in all out countries is not easy to find, but evidently most of the 285.3 TWh of biomass in 2008 was used for heat and electricity. Call it 240 TWh, assuming the remainder is for vehicle biofuels and use for heating other than district heating. Reducing this to 200 TWh is very demanding, because

1. Present incentives strongly encourage more biomass-fuelled heat, electricity or both (CHP)
2. Increased carbon tax (whether higher or wider in scope) and/or higher carbon prices will give even stronger incentives for fuel shifts from fossil fuels, especially coal, peat and shale, to biomass. In some cases old condensing coal power stations with efficiencies of about 30 percent will cofire biomass – a really wasteful use of the resource even if it does reduce some CO_2 emissions.
3. Wind power or solar heat is no alternative for the owner of a district heating plant or a power plant, unless the plant is going to be scrapped anyway or can only use a fuel (usually oil) that makes it uneconomic to run. The owner of a combustion plant will want to continue burning something or other.
4. There is a tendency to increase district heating.

For these reasons it is imperative to cut heat demand, by improved insulation, windows, and ventilation for all district heating customers. Experience shows that radical reductions are possible and affordable in all categories: apartments, houses, industries, hospitals, and offices. With a big enough effort, demand could be cut by 30-40 per cent. This could leave some room for district heating expansion into new buildings with some reduced use of biomass and a very radical reduction in fossil fuels. One consequence of reduced annual heat demand is that the peak demand will be even lower.

A minor, but important part of reduction of biomass for heat is more solar heating.

The other side of the coin is to improve the competitive advantage of vehicle biofuels over heat and electricity by heavy investment in biofuel production. Ethanol has a part to play, especially when vehicles for 100 per cent ethanol are on the roads and can use the ethanol more efficiently than blended ethanol/gasoline. Biogas has an important part to play, and maybe DME. But to make sure that there are vehicles that can use large amounts of biofuels soon, biomass diesel production must be stepped up soon, and be given strong enough incentives to compete with both fossil fuels and other uses of biomass.

New plants in Sweden and Finland are now producing diesel from talloil, a by-product from the pulp industry that is very promising and can be replicated all over the world. But much more must be done to assure a broader feedstock base for vehicle fuels.

Biomass balance 2020

	2008	2020
Into transport	10	200
Losses3	5	80
Energy content of trpt fuels	5	120
Into heat and electricity	275	200
Losses	55	4
Total	285	400
Export of transport biofuel	0	40
Available domestic trpt biofuel	5	80

CO_2 avoided from 80 TWh of bio-syndiesel or equivalent. Only direct emissions (as other life cycle emissions may occur in another country, or be accounted for in another sector) IPCC default value[67] is 74.1 t CO_2 /TJ, or 267 kton/TWh. Thus the avoided emissions are 21 Mton, twice what is needed (10.5 Mtons) in the scenario.

This safety margin may seem big. But the object of this exercise is not to find the cheapest way to have a 50 per cent probability of meeting the target. The object is to be sure of meeting the 2020 target in a way that keeps the road open for the 2030 target.

To meet the total target, at least some of the sub-targets have to be overshot. Some instruments may deliver less or later than expected. The transport

67 http://air-climate.eionet.europa.eu/docs/ETCACC_TechnPaper_2003_10_CO_2 _EF_fuels.pdf

target is the most difficult of the subtargets, and the hardest part of it is biofuels. It would take a Herculean effort to make it happen. If, however, we miss the target by two or three years, we are still in the black. If we meet the target on time, we are in a good position to meet the 2030 target. It is a safe prediction that all the vehicle biofuels that can be produced will be needed for a very long time.

What must not be allowed to happen is that the potential is eaten up by more biofuelled power stations or heating, but if that happens to some extent, there is still a margin.

Instruments: What we can do and can't do here

The way to achieve a deep CO_2 cut is to make it a legal commitment for governments, as in the UK, and to use as many instruments as possible and fine-tune the many knobs as real data and forecasts come in.

The simplest way to achieve deep carbon cuts is to put a high enough price on carbon. "Simple" is then understood as the method which needs fewest decisions. If you slap a €200/ton tax on carbon emissions, through taxes or by emission trading, emissions will indeed be radically reduced. But that cannot be done unless it is done with good international harmonisation.

If a mad government were to try, it would soon see all its heavy industry and much of the transport system collapsing, and people would rush to the nearest border to buy their petrol and diesel. And then, if the government survived the immediate outrage, it would lose the next election.

Simple is good, but not at any price. CO_2 taxes have been discussed for more than 20 years but so far with little results except in the Nordic countries, where there are big loopholes. For example in Sweden, there is no CO_2 tax on power production, nor on peat for any purpose; manufacturing industry has reduced CO_2 tax, and industrial processes are fully exempt. There are some arguments for the latter, but the full exemption has delayed development of very low-cost CO_2 reduction measures.

Still, an imperfect CO_2 tax has delivered some results, such as a fuel shift from fossils to wood in both district heating and heating of individual houses and buildings. Fewer loopholes would lead to still less emissions.

The energy tax is a blunter instrument than a carbon tax, but still leads to a more efficient use of energy. But industry is essentially exempt from energy tax in countries such as Sweden.

The industrial lobby against any increases in carbon and energy taxes is always strong but can, and should, be resisted. There are nevertheless limits on what is feasible, especially for some industries with what they see as inevitably high carbon emissions per value produced and which have to compete on the international market with companies that do not have to pay such taxes.

Some of these problems can be dealt with through international sectoral agreements.

If the EU goes for a 30 per cent reduction, the carbon prices will rise, and lead to a faster transformation of the power industry. Manufacturing industries with high carbon emissions will be less affected, as they receive most of their allowances for free.

We now have many climate policy options that were not there 25 years ago: wind power, solar cells, efficient windows, and hybrid cars, to name a few. 25 years ago they were either too small-scale to matter or were unreliable or did not exist at all. Now they are each able to save many millions of tons of CO_2 per year.

These options are there not because of energy and carbon taxation, but because of direct subsidies. The whole world has, to varying extents, subsidised wind and solar, and often biomass. Economists usually do not like subsidies, as it is easy to prove in theory that they are not the least-cost way to do things. There are other objections. National subsidies often do not benefit the national economy or employment, as foreign competitors cannot be kept out. The consequences of subsidies are often hard to predict: they may achieve far below expectations and they may over-achieve with dire financial consequences. There is an inherent instability: a political decision to subsidise can just as quickly be reversed, creating disruptive boom and bust cycles that erode long-term commitment among private investors.

For these reasons, nations have sometimes tried creative solutions to avoid direct subsidies, such as green certificates for renewables in Sweden and Norway. Then you know in advance how much renewables will be produced, but not which renewables and not at which price. That may be less attractive for investors than feed-in tariffs.

But there is no doubt that a) they are politically possible and b) that they deliver. Moreover, they are possible in one country at a time without waiting for an internationally harmonised effort, a common EU policy or even a federal harmonised effort within one nation such as the US.

In short: subsidies work and direct subsidies such as feed-in tariffs work better than indirect subsidies such as green certificates, which tend to address low-hanging fruits.

Command and control instruments also have their place. Unfortunately the EU gave in to neoclassical dogmatic thinking in the Industrial Pollution and Control Directive, now the Industrial Emissions Directive. "In order to avoid duplication of regulation" the directives specifically leave out CO_2 regulation; this is to be achieved by the ETS and ETS alone.

This was soon proven to be extremely stupid. The first phase of the ETS in 2005-2007 was crashed by too generous allocations, so the carbon price fell to near zero. The second ETS phase in 2008-12 also led to prices that were too low for it to become a very effective instrument. Much time has been lost and many unnecessary millions of tons of CO_2 have been emitted. Now we are seeing it happening all over again for the third period, 2013-2020. Most EU coal power plants are still with us, even the least efficient, and some more coal power plants are under construction.

"Duplication of regulation" is in fact what the situation calls for. It is true that regulatory cuts in CO_2 will not cut the total immediately, as other emitters will buy these cuts and emit somewhere else. But this line of argument misses the dynamics. If emissions demonstrably can be cut, there is less resistance to a stricter target, notably to go from -20 per cent to -30 per cent for the EU.

Even under the assumption that the Industrial Emissions Directive will not be changed, there are still uses for it. Many of the worst CO_2 emitters are very far from BAT in other respects, such as emissions of particles, SO2, NOx, mercury, PAH, methane, CO etc. There is also a general requirement for energy efficiency in the directive, though this is not compulsory.

So if there is a will, there is a way to force the most polluting industries to clean up their act or shut down. This is now happening on a grand scale in the UK, and some other EU countries.

Closing down a dirty plant is not easy, politically speaking. There are always overblown claims of local and regional disaster as the result of any kind of change, but there is also some justification for such worries. People do not want to lose their jobs in times of high unemployment when their skills are not in demand. They do not want to give up their houses for nothing. They do not want to move from a socially tight-knitted community. The politicians do not want to see the tax base eroded and have to choose between deteriorating societal services or tax increases which will drive away still more people.

Simply closing down obsolete and dirty industries and letting regions slip into desolation can have nasty political consequences, as the rising tide of right-wing extremism over most of Europe is showing.

The arguably worst industry in our region for CO_2 is the Narva district in Estonia, where the shale industry and power stations are extremely polluting, but also important for jobs. Most of the jobs are Russian. To just shut down the shale industry carries a risk not only of exacerbating the ethnic tensions within Estonia, but also relations with Russia.

This does not mean that Estonia is stuck with shale forever. But new jobs will have to be created more or less on the same spot.

A strong climate and environmental policy sheds some jobs, but it also creates new jobs. The governments' part is to direct the new jobs to where the old jobs are lost, for example by prioritising energy efficiency in such areas, but also by many other means. There does not need to be an exact match between old and new job profiles. Even if a mine is closed and a research centre employing 100 PhDs is established in its place, the researchers will still need car mechanics, cooks, fitters and cleaners. And some of the PhDs will be sons or daughters of the miners. Factories making parts for renewables industries and retrofit insulation of buildings have a better match. On the whole, the new jobs will require somewhat more skills and education. This is both in line with the way things are moving anyway and what most people want.

Taxation

Present taxation of fossil fuels is generally seen as insufficient. IEA director Nabuo Tanaka has[68] claimed that a carbon tax of $175 is needed to halve world CO_2 emissions by 2050. If this were true, one may ask, what is then needed to achieve a 70 per cent cut by 2020 with the same kind of modelling?

The question is foolish.

The observation that it takes a high, or very high, carbon price to cut emissions radically is both facile and misleading, unless several factors are weighed in, such as:

- A uniform carbon tax does not produce anyway near uniform results for various sectors of the economy. An extra cost of €10/ton is enough to kill steel and cement industries. At the same time it is almost insignificant when applied to gasoline or diesel, adding just €0.03/litre[69] on a price of €1.4-1.5 per litre.
- The response to carbon prices is non-linear and time-dependent. If people do not believe that the tax is there to stay, even a very high tax does not achieve much change in behaviour. Some response is seen only after a long time, when the message has sunk in enough to bring credible new products to the market. The Swedish CO_2 tax of 1991 is still a major force behind the shift from oil-fired heating to heat pumps. Exceptions and exemptions may be just as important as the tax. Sweden has a high CO_2 tax at about €110/ton, but it excludes electricity, cement, steel, refineries and all use of peat. Industry and much district heating pay lower taxes. What counts is of course the actual tax paid, not the non-applied tax.
- Carbon tax interacts with implicit taxes, such as energy tax and VAT. In Sweden, much of the carbon tax on vehicle fuels was increased while energy taxes were lowered. Obviously a high nominal carbon tax which does not increase the actual price does not influence driving habits or choice of car.
- All energy taxes are implicit carbon taxes. What counts is not the name but the numbers when it comes to the effect on prices. In Sweden a very high CO_2 tax on gasoline was introduced as the same time as the energy tax was cut, resulting in no net price change.
- Carbon/energy taxes are less effective higher up the value chain. A tax on crude oil is a stronger instrument than a tax on gasoline, and a tax on coal is much more effective than a tax on electricity.
- The willingness to pay for carbon is extremely uneven. For a big new car, fuel costs are small compared to the depreciation per kilometre – even if the driver actually pays for the fuel. For this reason, a carbon tax will not affect the fuel consumption of new cars very much.

68 http://www.bloomberg.com/news/2010-11-01/carbon-price-must-rise-to-175-a-ton-to-halve-emissions-iea-s-tanaka-says.html

69 1 litre of gasoline gives emissions of 2.77 kg CO_2 or at €10/ton a tax of €0.0277/litre

- Subsidies on fossil fuels can counteract the carbon tax. Direct and indirect coal subsidies still exist in many EU countries. In Sweden, electricity from peat is subsidised. Mining legislation favours explorers. Unenforced speeding limits are a subsidy on fossil transport fuels. The list is long.
- Tax deductions can seriously disturb the carbon price signal, for example for company cars.
- Brave politicians achieve little if they lose elections. Taxes are obviously of enormous importance, and simplicity is always a virtue. But if complexity cannot be avoided, a complex scheme is better than nothing.
- International harmonisation of carbon taxes is much more preferable, but it will not come anytime soon. EU harmonisation is also much better than national taxes, but in the real world some member states, or "coalitions of the willing" have to take the first steps, and can in fact achieve a lot.

Carbon trading is just another form of taxation which is evident from 2013 when all the allowances for the power industry will be auctioned.

Subsidies

Subsidies should ideally be used for technologies that almost, but not quite, can compete on the market. That is why wind power is so big in the world, and why solar cells are just a few steps behind.

The feed-in tariffs have produced the best results. "Technology-neutral" instruments such as the Elcertifikat green certificates in Sweden have also resulted in more renewable electricity, but do less to transform markets. In the early years, Elcertifikat mainly promoted conventional biomass CHP and little wind power. In later years, however, wind (which is now a conventional technology) has caught up.

Some of the subsidies are paid for by the tax-payer and others by electricity consumers, for example through a stipulated percentage of new renewable electricity. The difference is not very important.

A different kind of subsidy is demonstration projects, for technology that is still not mature. For new technology such as second-generation biofuels, wave power, etc., much or all of the capital costs, and sometimes the operating costs, has to be carried by the taxpayer.

Offshore wind power may just be leaving the demonstration phase to become a regular but subsidised alternative. But considering what is at stake, it may not be so smart to "leave it to the market" to define its future. More demonstration projects may still be needed to really make sure that performance is close to optimal and that costs come down to an acceptable level.

Still another kind of subsidy is lifting taxes. Ethanol and bio-diesel are subsidised in Sweden both by lifting of energy tax (part of the gasoline tax) and for low-blending by a stipulated quota. This has created a market for ethanol, and helped to develop the technology and economies of scale to a certain extent. The more recent, and much more preferable, biogas is developed by other subsidy schemes.

Subsidies are expensive , but go down with the electorate much easier. Germany subsidised the first 40-50 TWh per year of wind power, in a not very windy country. It subsidised solar cells even more (to 31 GW [70] by the end of 2012), in a not very sunny country. And this is on top of enormous subsidies for coal. With somewhat different quantities and timing, exactly the same could be said of Spain, which though sunnier and windier is also less rich than Germany.

"White certificates"[71] that demand a certain level of energy saving by power utilities for their customers have been used in the UK in the form of the Energy Efficiency Commitment EEC, an obligation for electricity and gas retailers with more than 50,000 customers to achieve energy-saving targets by promoting energy efficiency improvements in households. The EEC is now integrated into the Carbon Emission Reduction Target (CERT). Measures include insulation (biggest share), fuel switching, lighting, heat pumps, solar heating, and behaviour changes by installing real-time displays. The programme has a social component in alleviating what in the UK is called "energy poverty", as poor insulation is a health issue especially for low-income old-age pensioners.

Other kinds of subsidies for energy efficiency have been in place in many countries, often on and off. Ill-designed and short-lived schemes can produce very disappointing results, with booms letting incompetent or not very serious installers in, and subsequent busts ruining the competent and serious firms. On the other hand, there are many good examples of subsidies. Some products which did not even exist on the market have been subsidised first, and then completely transformed the market. Energy-efficient fridges, windows, and occupancy-controlled lighting are examples from Sweden, with consequences far beyond its borders.

Information

Simple schemes such as energy efficiency labelling of washing machines are proven to be effective in first influencing consumer choice and then manufacturers' output. Energy performance certificates for buildings aim to make energy efficiency bankable and low efficiency a liability, as the buyer can see the energy status of a building, and if the audit is done well, also what to do about it.

Eco-driving, a Finnish concept for reducing fuel consumption by 10-15 per cent, has so far been used as an information instrument, through short courses. (If such courses were made compulsory, it would become a legal instrument, and eventually become standard behaviour.)

70 Nature November 4 p 11, original source Bloomsberg New Energy Finance

71 An analysis can be found at www.ea-energianalyse.dk/reports/710_White_certificates_report_19_Nov_07.pdf

Another example of information is courses in life-cycle cost calculation for purchasers in industry and administration, essentially teaching people to purchase products with higher capital costs if lower energy costs at least offset them; this should be evident, but is not so.

Free energy auditing is an information instrument, with mixed results. Sometimes the information is not enough without a more formal commitment from the CEO to put it into practice.

Information instruments are not very expensive for a government, but need a lot of ingenuity and devotion.

Information and subsidies can also be combined by coordinated procurement contests[72] where the winner – for example the most efficient heat pump – will win both the honour and a big order.

Legal instruments

Some legislative options are limited by EU legislation for better or for worse.

With the EU Industrial Emissions Directive in operation, some of the worst emitting power and least efficient stations and industries will have to shut down, as some have already done

The Emission Trading Directive makes it very difficult to put legal limits on CO_2 emissions even if they are very unnecessary, and cheap to mitigate.

The Eco-design directive means bans for inefficient product such as incandescent lamps.

Traffic legislation is mainly up to member states.

Legal instruments are of special importance for the transport sector, and for end-use efficiency, see below.

Instruments for cutting CO_2 from heat and electricity

The present carbon trading is insufficient to do the job. A CO_2 tax on fossil fuels, imported or produced, for heating and electricity is nevertheless needed to achieve a phase-out of coal, shale and peat.

All subsidies on fossil fuels must stop, and no exemptions should be allowed for fossil CHP.

Subsidies on wind, wave, photovoltaics and solar heat are also needed, much of it already in place. The rapid phase-in of wind power will stop the option of importing dirty electricity from neighbouring nations. Once the wind power is there, it will always be cheaper to run it than to import coal power.

Taxes and subsidies should add up so as to make renewables the only option for new power, and to make continued use of fossils for base load electricity

72 Energimyndighetens teknikupphandlingar http://webbshop.cm.se/System/ViewResource.aspx?p=Energimyndigheten&rl=default:/Resources/Permanent/Static/32f73b4c526b4bd2a6a334ee22eb40b1/ET2006_08w.pdf

increasingly loss-making. Electricity from gas, to cover semi-baseload, peak and reserve power, should still be viable by 2020, but not by 2030.

Reduction of electricity consumption will to some extent happen due to price increases that have already taken place, though organisations and habits take time to act on this. To enhance this process, governments should be active in promoting efficiency. A good example is the PFE program for energy efficiency in electricity-intensive industries in Sweden. Electricity costs are important for these industries, so they claim to use it almost as efficiently as possible. When the EU introduced a tax of about €5/MWh, electricity-intensive companies were offered rebates if they signed an agreement with the government energy agency to improve energy efficiency. Almost all joined the programme. They profitably saved 1.4 TWh (from about 41 TWh) during the first programme period[73]. Another good example is the BELOK programme[74] for landlords of private and public premises, which targets an average of 50 per cent savings from offices, jails, hospitals, schools, etc., about half on electricity and half on heat. BELOK is supported by the Energy Agency, but the projects are now profitable. Just like commercial energy Performance Contracting projects, such as from Siemens Building Technology and TAC, the idea is to let the most profitable savings pay for the more long-term elements in a package with an economically acceptable payback/rate of return. Just like them, BELOK uses a standardised methodology and has come a long way from a game for enthusiasts to a commercial product.

There is also extensive, if anecdotal, evidence for a circa 50 per cent savings potential for existing industries and residential building during renovation.

A green tax shift – with more tax on electricity production or consumption, less on work – would also help.

The EU Energy Declaration for buildings is (at least in Sweden) not a very efficient instrument as yet, because of the generally low ambitions of the recommendations. The idea that a well insulated and well managed building will be valued by the market has not really caught on yet. With some reform it may still produce substantial results.

Nuclear windfall and counter-measures

Nuclear power can benefit from a high CO_2 tax, which is a problem in a scenario that postulates the phase-out of nuclear.

It should however be noted that instruments to promote efficiency and renewables may sometimes hit nuclear power harder than they will hit fossil fuels.

The problem of an unintended boost to nuclear power may not be very big

73 http://www.energimyndigheten.se/sv/Press/Pressmeddelanden/Pressmeddelanden-2009/Slutrapportering-av-programmet-for-energieffektivisering-i-energiintensiv-industri-Foretagen-har-effektiviserat-mer-an-forvantat/

74 www.belok.se

at that. The fate of nuclear power depends on many other factors than CO_2 price/tax. The foremost of these factors are rising costs for construction (as shown by Olkiluoto 3 in Finland), rising costs for operation and maintenance (at least in Sweden), and volatile public acceptance.

Instruments to phase out nuclear could include more tax on nuclear energy, more stringent demands on safety and security, more enforcement of existing legislation (such as fewer years to comply and heavier sanctions for non-compliance), a halt on capacity uprates and limitation of life extensions. Nuclear power should also be less attractive if it carried its costs for accidents and waste. Unlimited liability in combination with a requirement to insure, or at least have money set aside, against a big accident would affect some plants more than others. This would economically hit the the least safe plants hardest.

With EU legislation to declare the origin of electricity, it might also be possible to levy a tax on imported nuclear power for nations that have no nuclear power.

Whether such measures will be enough to phase out nuclear power by 2020, or if more direct governmental action, such as in Germany after Fukushima, will not be further discussed here.

Instruments for cutting CO_2 from transport

The carbon-cutting methods that can be applied to transport are efficiency, biofuels, electric cars, and modal shift from air and road to rail and water.

Efficiency is best achieved by EU legislation. The 130 grams/km fleet average limit[75] for 2012 and 95 grams for 2020 could well be surpassed. They can be reinforced by car sales tax, which is done in some countries but not in others[76], and by annual car tax. Stopping subsidies on company cars would save €54 bn/year[77] and lead to smaller cars with lower emissions. The long-term consequences are in all likelihood enormous: the new car market is dominated by company cars and fairly rich people, where the users either do not pay for the fuel or do not care about the fuel cost. This has a certain logic, because the value loss of a large new car (€28000) is about €400/month compared to the fuel cost of €157. A 20 per cent fuel saving will only reduce driving costs by about 4 per cent[78].

Most people drive second-hand cars, and for them the fuel cost is of greater importance, but they have to choose from the cars on offer, where heavier and thirstier cars are over-represented.

75 Regulation (EC) No 443/2009

76 For a quick view on the unbelievable inconsistency of car taxation, look at http://www.acea.be/images/uploads/files/20100921_TaxGuide2010Highlights_update.pdf

77 http://ec.europa.eu/taxation_customs/resources/documents/taxation/gen_info/economic_analysis/tax_papers/taxation_paper_22_en.pdf

78 After http://www.swedbank.se/idc/groups/public/@i/@sc/@all/@kp/documents/article/fm_601660.pdf

Every method must be used to transform the new car market: sales tax, annual car tax and procurement policies that prescribe which taxis and lease-cars should be used by government agencies and eco-profiled companies.

Later on, say by 2018, when new cars are much better than old cars, a scrap premium should be introduced, together with an increased tax on (fossil) petrol and diesel.

As for biofuels, the main challenge is to accelerate second-generation and biogas and put the brakes on foodstuff ethanol and rapeseed. There are enough incentives to use biofuels, but investment has to be speeded up. For new fuels such as liquid biomethane, DME and methanol, production output has to be linked to fleet trials on a big scale, starting with buses, city-owned vehicles etc. For F-T-diesel from biofuels, there is no such chicken and egg problem.

Biofuels, if produced under strict rules, are carbon neutral, but not without environmental and social costs, so in the longer run (after 2020) they should carry some tax.

Electric vehicles (EV) are certainly getting enough publicity and moral support from the political leaders. Indeed the present EU regulation will give so much support to electric vehicles so as to risk undermining efficiency gains. Every EV counts as 3.5 cars, meaning that a manufacturer who sells even 10 per cent EVs can go on selling vehicles with high emissions.EVs are also not necessarily zero-emitting.. Charging stations could possibly be obliged to sell only green electricity (but that is not a fact). If the cars are also charged at home, or any place it is difficult to see how to force home-owners to buy specified electricity.

It still remains much in the open whether even heavily subsidised EVs will make it big.

Electricity is so much cheaper than liquid fuels that the difference may also cover battery costs when batteries become cheaper and have longer lives.

The infrastructure for charging is challenging: EVs are not going to make it big unless it is quick and easy to recharge them, at least not as long as there is any other option.

A small number of electric cars can be heavily subsidised, and they should be, in order to identify real problems for real people. For the longer term, EVs have to pay their way. At present, car and fuel taxes are an important tax base. It is unsustainable to make cars a source of cost instead of income.

Modal shifts from air and road to rail and water take time to achieve, if they mean new rail lines and harbours. But some railways can either take more trains immediately or after modest upgrades of signalling systems. More buses can be put on the roads without delay.

As for instruments, the same instruments that encourage modal shift are also the ones that encourage less travel and less transport of goods.

This is without any doubt necessary. The present level of global transport, let alone the projected increase, cannot be sustained, wherever the energy comes from. A small annual decrease in the number of person-km and ton-km is much preferable to a sudden shock, as occurred in 1974.

A kilometre-tax for trucks, etc., makes rail transport more competitive, and also decelerates the trend towards ever more road transport. If large enough it will reverse this trend. The practice of transporting bread and milk, etc., thousands of kilometres may be greatly diminished, but people will still want bread and milk even if it is produced nearer.

Though infrastructure is inert in the short run, it does change with every major decision, and so far usually in the wrong direction: a new airstrip here, a broader road there, a postponement of a railway, insufficient investment budgets for harbours, inadequate maintenance budgets for railways, etc., etc.

It takes a lot of resolve just to brake this process, and even more to stop and reverse it. The more important part is to stop carbon lock-ins, such as more roads. It is not possible to cut emissions by just investing more in railways, even if there are good reasons for such investments.

Congestion charges are not of very great importance for cutting CO_2 , but are important for another reason: to send the clear message that we do not have the "right" to drive anywhere, anyhow, for free. More effective enforcement of speed limits and higher, income-related fines send the same message, take some cars off the road, and save a number of people from being killed or maimed.

Insurance companies in Sweden are considering 30 per cent lower policies for customers who conform to speed limits, and can prove it with GPS tachograph[79]. This should be encouraged by governments all over Europe. After a few years it could become the legal standard for all professional drivers, for rental cars, etc.

"Free parking" is just as illusory as a free lunch. Somebody pays, though not the motorist. Free parking paid by the employer is common, but means that the employer subsidises employees who travel by car, at the expense of those that travel by bicycle, public transport or on foot. It is also illegal for example in Sweden; it should be taxed as a benefit – but the law is not enforced.

Tax deductions for car travel to work should be neutral, so that someone who uses a form of transport other than a car should have the same deduction, which for fiscal reasons should in any case not be over-generous. If people want to travel long distances in a big thirsty car, it is no business of the taxpayer to compensate them.

The politics of fuel taxation is admittedly difficult. The differences between countries within the EU (see below) show, however, that there is some room for increases in most countries, and that there is good reason for an increased

79 http://www.dn.se/motor/kor-lagligt-och-spar-tusenlappar-pa-bilforsakringen-1.1204632

EU-harmonised minimum tax.

Gasoline prices in €/litre, week 17, 2010

Netherlands	€ 1.53
Greece	€ 1.52
Denmark	€ 1.48
Belgium	€ 1.46
Finland	€ 1.46
Germany	€ 1.42
United Kingdom	€ 1.41
Portugal	€ 1.40
Italy	€ 1.39
France	€ 1.37
Sweden	€ 1.37
Ireland	€ 1.32
Slovakia	€ 1.28
Czech Republic	€ 1.27
Hungary	€ 1.24
Austria	€ 1.22
Malta	€ 1.22
Slovenia	€ 1.22
Lithuania	€ 1.21
Luxembourg	€ 1.19
Spain	€ 1.18
Poland	€ 1.17
Estonia	€ 1.14
Latvia	€ 1.12
Romania	€ 1.07
Bulgaria	€ 1.04
Cyprus	€ 1.04

Source: www.energy.eu/#prices

One of the difficulties for a government that increases the fuel tax is that it will not be believed when it says that the increased tax will bring other taxes down. One way to prove this would be to divide the dividend by the number of taxpayers and specify the same sum for everybody and then add this to the tax refund or subtract it from the back tax.

The motorists who lobby against fuel price increases always cite the relatively few people that live far off and are dependent on long-distance car travel, and use them as pawns in their argument for low prices for well-off suburban dwellers with big cars. If new cars that use much less fuel flood the second-hand market, such scare stories will become less and less credible. Also, the fuel costs, though very visible, will become a small share of total cost per kilometre.

New car efficiency is imperative for this reason, too.

Instruments for cutting CO_2 from industry

Industries use fossil fuels in different ways and to a different extent. General instruments such as carbon taxes are problematic. But what most industries have in common is that they have large heated premises. Oil and coal heating continues in some places, because the industries pay less or no CO_2 tax. In Sweden they can deduct the CO_2 tax for the fossil element (if there is a fossil element) of their district heating. This should stop. They should have the same incentives as the home-owner for both efficiency and fuel shifts.

All light industry could well pay full CO_2 tax.

For the production of cement, lime, aluminium, copper, ore-base iron and similar industries this is more of a problem. If their competitors anywhere on the globe do not have to pay anything for their carbon emissions, it will not work to impose large costs on such industries here.

The Emission Trading Scheme could be reformed when (if) the EU 2020 target is increased from 20 per cent to 30 per cent. The carbon-intensive industries cannot pay the full carbon cost, but they could well pay a little more, and be handed down free allowances based on the BAT level for that year.

National carbon taxes, such as in Sweden, Finland, Norway and Denmark, are a very effective instrument to use on industry, as they can be refunded on condition of a voluntary agreement with the government to do what is reasonable to cut emissions and save energy.

The industrial structure, including very big CO_2 emitters, is often the result of historical subsidies. Keeping old, dirty, unfit industries going is expensive. Letting them just fall is politically dangerous. An active policy that aims not at saving the existing jobs but saving the number of jobs is, again, a necessity.

Further reductions 2030

The target set for 2030 is a 95 per cent reduction in CO_2 emissions. This cannot rely on exports of renewable electricity. Such exports may or may not occur, but it cannot be taken for granted that large amounts of electricity from coal power are still used in neighbouring countries, so that exports can be credited for anything near 0.5 Mton/TWh. It would be absurd to assume anything other than deep cuts throughout Europe, because it would mean that the 2 degree target will be overshot, never mind 1.5 degrees.

For the same reason, biomass exports, though likely to continue, cannot be credited, as oil must be well on the way out everywhere.

The heat and electricity sector are already virtually carbon-free in the 2020 scenario, so the sectors where further reductions can take place are the oil and gas sector (under Energy), manufacturing industry, industrial processes and transport.

In the **energy industries, electricity and heat** will have to shed the remaining fossil part. This may mean more need for storage, either as in-built at wind power stations or as compressed air storage, depending on how much demand response can make this unnecessary. **Oil refineries** will have to shrink and convert to biomass feedstock.

Manufacturing industry will have to be more efficient and switch to biomass and electricity.

The **transport sector** will have to make do with electricity and biomass, with only a marginal use of fossil fuels for the oldest vehicles. In the 2030 perspective there are many more decarbonised options than for 2020, as the lead time for many infrastructure projects is long. Railroads can be built and be better integrated so as to take transport of people and goods off the roads. Public transit in towns can certainly be improved very much by 2020. But better planning that shrinks the distance between workplaces and homes takes more time. It is not an easy task anyway; we cannot go back to the 1950s situation with workers living within walking distance of the factory, because the typical household consists of two people who have different jobs in different locations and often move from one job to another without wanting to uproot themselves and the children. But the present paradigm of creating ever-larger labour markets through increased commuting must be reversed. The trend towards more shopping centres outside town centres must also be reversed.

Industrial processes for producing steel, lime, cement, etc., will have to be dealt with both by technology and international policy. An example of the former is substituting Portland cement for other cements and/or other building materials. International policy means that there is either a global full-scope agreement or an international sectoral agreement for curbing emissions from cement and steel.

What will it cost?

There are very diverging views on the costs of different energy sources even in the short perspective, though most people agree on at least some things, such as that solar power is right now more expensive than wind, nuclear or fossil energy. For any longer term there is no common ground. Just look at the "abatement curves" i.e. the cost to cut emissions per ton of CO_2 -equivalent using a variety of options (from insulation to CCS) by 2030 by McKinsey[80] and Bloombergs[81], though both are fairly middle of the road.

Nevertheless there are good reasons to believe that the scenario lies in the same cost range as any realistic alternative, with a strong stress on "realistic", because some of the cheapest options are just not credible. The "oil forever" option, for example, does not exist.

For supply of **electricity**, the scenario adds a huge capacity of wind power onshore and offshore, and minor contributions of wave power and solar photovoltaics.

The alternatives for **new-build** are natural gas combined cycle, nuclear power, coal CCS, and biomass, some of them also in cogen/CHP. Hydro is also an option, though hardly a big one. Non-options are for example oil power and

80 www.mckinsey.com/mgi/publications/Carbon_Productivity/slideshow/slideshow_4.asp

81 http://bnef.com/Download/UserFiles_File_WhitePapers/NEF_RN_Carbon_Markets_NAmerica_2010_01_USMACC.pdf

coal power without CCS. For reasons given elsewhere, bio-CCS is also excluded. Waste power may be cheap, but is not viable as a large-scale alternative to wind. Bio-power may also be relatively low cost, but should not be a very large-scale option, because then less biomass will be available for vehicle fuels.

So the main contenders are natural gas combined cycle, nuclear and coal CCS.

Natural gas combined cycle has low capital costs, low maintenance costs but high and very unpredictable fuel costs, as well as some carbon costs. Assuming that the expected mean value of gas power costs is lower than for wind power, the choice is asymmetric. How do you choose between "probably slightly cheaper, but with a significant risk of being much more expensive" and "probably more expensive but with no significant risk of big cost hikes"?

It may still make sense for a power company to order gas power rather than wind power, because of an in-built hedge. Higher gas prices usually mean higher electricity prices, and if they don't, then stop production; as fixed costs are low, it does not cost a lot to sit idle. Also, assuming a 30-year life of an investment, the first 10 years of operation are much more important than years 20-30 – for the power company, that is. Natural gas power may be a default alternative, but in the real power "market", politics matter, and politics should, and often does, take a longer view and also weighs in geopolitical considerations. The Swedish green certificate system – which Norway has signed an agreement to join by 2012 – has quotas up to the year 2035. Many countries support renewable electricity, but few if any, natural gas power. If there were to be a "dash for gas" in our countries, it would in all probability meet political resistance.

The costs for new nuclear power are extremely uncertain. A few years ago figures of $2000/kWe were often quoted. For US nuclear power projects, more recent estimates are sometimes more $7000[82] or more. But in China and South Korea nuclear construction seems to go just fine. Nuclear cannot in any case be used as a benchmark for 2020, as a decision now will not result in any new nuclear by that date. In the 2030 perspective, nuclear is an option, but the cost relationship then between wind, nuclear, solar and wave power is anybody's guess – and also the result of what we do in the meantime.

The IEA **Projected Costs of Generating Electricity 2010** gives a lot of data, much of it the result of national wishful thinking in various directions and compiled by the IEA. Though the study was published in spring 2010, the actual development of nuclear power costs in the US and Finland is poorly reflected.

At the moment there is no consensus on why nuclear power construction costs have risen in most countries but not in others (China, Korea). If the US development is anything to go by, nuclear power will not be a serious

82 Moody's estimate in June 2008. http://en.wikipedia.org/wiki/Economics_of_new_nuclear_power_plants

contender in our countries. If, on the other hand, the Chinese development could be duplicated, it would probably be much cheaper than any renewable. The order of things is important, however. If a lot of wind power is up and running, nuclear will have to compete on very awkward terms. Nuclear power that runs 4000 hours a year (when the wind does not blow) instead of 8000 hours will have nearly the same cost (capital costs, staff) but only half the revenue from electricity sales.

Coal is somewhere in between. Some data from the IEA study, mentioned above, may be illuminating in this respect.

- "Overnight costs for OECD area coal plants consuming black coal range from 807 USD/kWe in Korea to 2719 USD/kWe in Japan."
- "Overnight costs of the 8 coal-fired plants fitted with carbon capture range from 3223 USD/kWe to 5811 USD/kWe."

Before a single coal CCS plant is even under construction, the cost estimates say that CCS will at least double the capital cost. On top of that, they will also have higher running costs: more coal, more staff, more machinery per kWh electricity.

As coal power plant projects without CCS are in trouble almost everywhere in Europe and the USA, with many projects stopped, things certainly do not look bright for coal with CCS.

Again, just as for nuclear vs. wind, the order of things is important. In all probability, CCS will not be a commercial option in 2020, assuming the same level of support as for renewables.

To sum it up: as for new-build power, wind power is the safest bet, except for efficiency and other demand-side measures, which is almost always cheaper than building new power stations and power lines.

It is conceivable that new technology will make solar cells cheaper than wind power by 2020, but it can certainly not happen (in the region) before 2015, and sitting on the fence until after 2015 is credible climate and energy policy.

The real competition to new wind is not anything else new. It is existing fossil and nuclear power. "Existing" is in itself a rather misleading term, because it takes a lot of re-investment to keep a plant running and to upgrade it to comply with current environmental, safety and environmental legislation. Nevertheless it is, or can at least be presented as, inexpensive to keep a plant running for another five years.

The real cost of keeping a plant running may in fact be high, but if so, this is not known in advance even by the insiders. Long stops and expensive repairs are often unexpected, and it does not lie in the interest of management and staff to take a dimmer view, at least not in public.

Whatever the real prospects are, there are strong vested interests against what is invariably called a premature shutdown by the power companies, the local trade unions and local politicians. They will try to get national and EU support, first to stop the plant from being shut down, and second to get compensation if they are shut down.

Noted examples are the Swedish Barsebäck reactors and the Lithuanian Ignalina reactors.

But power plants are not very different from old cars. It makes good economic sense to repair a car up to a certain point, after which it costs more to keep repairing it than to buy another car. But when this point is reached is often not known in advance, and wishful thinking is common.

The economic damage of a "premature" shutdown depends on how premature it is. Of course it is cheaper to run the Danish coal power plants from the 1980s than to build new wind power to replace them, but their advantage is much reduced when CO_2 , NOx, mercury, etc., are included in the cost.

As for **heat and cooling** the scenario stresses better insulation, better windows and smarter ventilation and heat pumps, and not a lot of new supply. Most of this is profitable by any count, and it is more economic to do everything at once rather than one measure at a time.

Low-carbon transport is dirt cheap as long as it concerns efficiency. A Hummer costs much more than a Toyota Prius. The extra costs for second-generation biofuels compared to diesel and gasoline depend on assumptions of future oil prices.

Electricity for electric vehicles is much cheaper than gasoline. Batteries are expensive, though, and it remains to be seen if EVs will go from frenzied hype to a real mass market. The main barriers are technical/behavioural/organizational rather than economic: range, charging time, longevity of batteries, infrastructure for rapid charging or battery swapping. Money is not the issue.

The economics of **industrial emissions** other than from the above are especially hard to judge. CO_2 from lime and cement production is an inevitable result of using CaCO3 as feedstuff, so either alternative feedstuff or alternative materials have to be found, which is not much credited for 2020, but needed for 2030. In this respect, the extra cost for the 2020 scenario – other than carbon trading – is just some research, development and demonstration.

CO_2 from reduction of iron ore and other metal oxides depends on efficiency and choice of reductants. Better thermal efficiency is economic anyway, and more efficient recycling of steel is not expensive. Switching fuel from coal to natural gas in ore-based iron production probably is. If the reducing agent is hydrogen from renewable electricity the cost will be still higher. That is not a problem in the sense that we could not afford to use steel. Even if steel prices were to increase by 50 per cent over 10 years, due to higher carbon costs, it would by no means be disruptive. The problem is that in a global market, cleaner steel cannot compete with coal-based steel, as it looks now. If it remains that way, the 2020 scenario poses no problem. For 2030 a global solution is probably needed to reach the required emission cuts.

To sum it up, we do not know a lot about the costs for a 70 per cent cut, but it does not look likely that there is a credible much cheaper alternative. A bet on cheap fossil fuels and no international climate agreement or a very big investment in nuclear can conceivably save money, but also carries unacceptable risks for the economy.

Energy, or climate, economy is not a one-dimensional optimization of least cost. There are other aspects that have to be weighed in, such as security of supply, biodiversity, health, international relations, and food security. In addition, while the 2020 scenario is heavy on investments in wind power, grid infrastructure and other things, it can be seen as a cost now, but a benefit to be reaped 10-15 years later. There is nothing new, or wrong, or uneconomical, about that.

Other ways to do it

The reason for presenting just one scenario is of course not that there is only one way to achieve the 70 per cent cut, or any pretence that we have found the best way.

As for **power**, it is quite possible to shift some wind to more photovoltaics, possibly also to more wave power, if their technology and economics develop faster than implied. Really cheap photovoltaics could be a game-changer.

Even if photovoltaics makes a global breakthrough, and beats wind power in lower latitudes, it will still have a more limited part to play in our region, because lower insolation means that each kWh will cost 2-3 times as much as in the best locations in the far south, and because peak capacity (in June) is very far off peak demand (in December-January). Wind and wave power, on the other hand, produce much more energy in winter months. Thermochemical storage of solar energy can stretch the amount of solar energy that can be fitted into the energy system, but there are still much better places to do it than here. More solar is possible but not very much more solar.

It is equally possible to increase wind power still more, either for more export or for more heat production, so as to alleviate pressure on biomass resources.

Even more demand-side efficiency is also possible, with a very clear focus and perhaps some luck with technical development. Will for example LED lighting live up to the hype?

The fine-tuning of policies should of course be based on the latest data on technology and economics – unless the market moves on its own in the desired direction.

There are many ways to clean up the power system. **Heat** is more limited, because of biomass restrictions. Biomass resources could possibly be stretched somewhat by using other forestry and agricultural practices or more land use for energy crops. More solar heat could be used with seasonal storage on an enormous scale. If this is possible, it will not come anytime soon.

A faster option is geothermal heat with heat pumps, for example in the biggest city of the region, Copenhagen.

There is no way the 70 per cent target could be reached without very substantial heat saving in existing buildings. But the mix of saving, solar heat and biomass can of course be varied to some extent.

Transport could achieve its share through less transport, modal shifts (to ship, train and bus) or more electric vehicles. Less transport could either be a result of crises (Peak Oil, Middle East wars, trade wars, and general economic depression) or policy. A more radical town planning policy could cut total transport substantially, with acceptable social costs (or gains, depending on what you count.) New railroads have long leads, and cannot deliver much by 2020, but investing in rails and trains could increase the capacity of existing and planned tracks. Better bus systems could be running soon. Increased harbour capacities for a shift of goods from truck to ship could be in place within a few years.

Hydrogen as a fuel is an option, but hardly on a substantial scale by 2020.

Algae fuels or solar thermochemical fuel production is not an option right now, but might become so within a few years. If that happens, it will make it easier to reach targets, mainly through imports of such renewable vehicle fuels.

Industrial emissions can be cut more than in the scenario if more radical structural change is assumed. This can either be the result of relocation of carbon-intensive industries from our region, new production technology or changed uses of materials such as steel and cement. The extent and speed of such developments depend a lot on the general development of climate policy.

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