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How can we meet the climate challenge?

Introduction

Vattenfall takes the climate challenge very seriously. Today's emissions must in the long run be significantly reduced at the same time as the global economy and the population of the world are growing.

In the report entitled "Curbing Climate Change – an outline of a framework leading to a low carbon emitting society" that was published in 2006, we discuss developments during the period up until 2100. Unless vigorous measures are taken in global consensus, the emissions will increase dramatically, to levels far above those at which the effects can be handled in a reasonable way.

In co-operation with McKinsey[1], Vattenfall has analysed the possibilities of reducing greenhouse gases globally up until 2030. We have focused on identifying concrete measures. The analysis covers the entire world economy. The results, which are available at www.vattenfall.com/climatemap, are striking. There are major opportunities for real emission restrictions in relation to the development that is likely to take place if no efforts are made.

The purpose of this report is to place the results of "Curbing Climate Change" and the Climate Map in a shared context and to draw conclusions on how the climate challenge can be approached. The report takes up six themes:

- The threat to the climate – We are on the wrong track
- A substantial reduction in emissions is possible by 2030
- Developments beyond 2030 – Predicted trends up until 2070
- How do we put the global economy into motion?
- How much will it cost to reduce emissions?
- The challenge – An outline global agenda

The possibilities exist – it is now a matter of realising them by means of far-sighted and sensible decisions.

Arne Mogren
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[1] The initial data collection was conducted with McKinsey & Company. All the conclusions and recommendations are the work and responsibility of Vattenfall.

Summary

Climate changes, today's major challenge, are already a reality. Can they be slowed down? The answer is as simple as it is challenging: we must come to terms with the current largely uncontrolled emissions of greenhouse gases. The longer it takes, the higher the costs. Unless vigorous measures are taken in global consensus, the emissions will increase dramatically, to levels far above those at which the effects can be handled in a reasonable way.

Dealing with this challenge in a sensible way requires global co-operation on many fronts. No single region, country or sector can handle the challenge on its own. Everyone has a long-term interest in participating because the outcome will affect us all. We need to slow down the rate of increase, stabilise and reverse developments in order subsequently to bring about a significant reduction. Emissions from the currently industrialised countries can only be allowed by the end of the century to be a fraction of today's levels.

If nothing is done, the total annual emissions will increase from 40 billion tonnes of carbon dioxide equivalents in 2002 to 58 billion tonnes in 2030. In 1990, the emission level, calculated in the same way, was approximately 35 billion tonnes. In order for it to be possible with a reasonable degree of certainty for there to be a development that limits the total greenhouse effect to 2 degrees Centigrade, the sustainable concentration of greenhouse gases in the atmosphere should be limited to a level of 450 millionths. The annual emissions in 2030 must be restricted to 31 billion tonnes, or in other words there must be a decrease of 27 billion.

The world economy must be transformed from a situation in which the emissions are unlimited to a situation in which the norm is recognised as being zero or very low emissions.

Our observations indicate that this is fully possible. Over two thirds of the measures can be effected with available solutions. A significant proportion – about twenty-five per cent – appear possible to introduce at costs that are insignificant or negative provided that suitable control measures are applied. No one technique or solution can solve the problem, but the sum of all options makes the necessary changes viable. The measures are largely linked with new building or major investments, which shows that there is no conflict between continued economic growth and increased climate efficiency – quite the opposite in fact.

Beyond 2030, new technology can have significantly greater effects. An estimate of one possible trend from 2030 to 2070 shows that the power sector could in the long term be entirely free from emissions and that the quantity of emissions from other sectors could be substantially limited despite continued vigorous economic development and population growth on a global scale.

How is the transformation to be brought about? We must put prices on emissions and in this way use the power for change that is offered by the market. The total cost of this transformation depends primarily on how it is introduced. Sudden changes that give shock effects in the economy and late measures in the form of emergency braking will prove to be expensive. Sustainable and long-term measures can reduce the total costs to very low levels.

The climate challenge is basically political. The countries of the world must agree on binding emission restrictions. If this is to be possible, the restrictions will have to be designed so that they do not constitute obstacles to development and do not create an economic shock for any one country. At the same time, the effects on the power of international competition must be reasonable and acceptable for all parties concerned. According to the calculations we have made, this is fully possible but of course makes major demands on the ability of the international community to co-operate. Unless the world's leaders manage to handle the challenge in time by steering the markets in the right direction, the cost of the damage caused will increase and significantly more draconian measures will in time become necessary. In the long term, there is a threat that the ultimate instrument of politics, armed conflict, will have to be used.

There must be a clear agenda for the global climate work. If it is to be possible, the agenda must contain as few items as possible at the same time as it addresses the central problems.

First of all, there must be a mutual ambition, a common goal, which in the final instance must be expressed in terms of temperature. Given the knowledge we have today, it is reasonable to try and limit the global warming measured as the increase in mean temperature on the surface of the earth by 2 degrees Centigrade in relation to the pre-industrial level. This means that concentrations of greenhouse gases in the atmosphere must be restricted to 450 +/- 50 ppm.

Those agreements that have been entered into to date have the emission levels in 1990 as a common starting point, and the undertakings are formulated in relation to these. This has been important in the initial phase, but it is now time to be more forward-looking and to set goals for the future for the emission levels that are to be achieved. A forward-looking calculation method must be developed in order to calculate long-term volume trends, and it must be designed so that it can be applied within countries, regions and globally.

Secondly, a common framework must be designed that makes it possible for the reductions that are made to create value. Value generation is possible when the credibility in price formation for emissions reaches a level whereby income and expenditure flows can be capitalised. Mechanisms for trading with emissions must be drawn up and further developed. Market solutions must be structured so that they allow trading between separate parts of the global economy, both geographical and sector-wise. Questions of design, monitoring and clearing must be solved in a sensible way at the same time as experience from the financial sector is made use of. The EU's emission trading system is a good beginning, but it is now important to come to terms with the teething problems that have arisen after the event, to create a higher level of acceptance and to find forms for enlargement.

Thirdly, it is necessary to make joint efforts that lead to the development of increasingly better alternatives and to ensure that they are made available globally. It is a matter of imposing demands on products, systems for marking and the dissemination of information and efforts to spread knowledge and build up competence. It is also a question of efforts that increase and expedite the range of technology by supporting the development of key technologies and measures that serve as driving forces for market introduction.

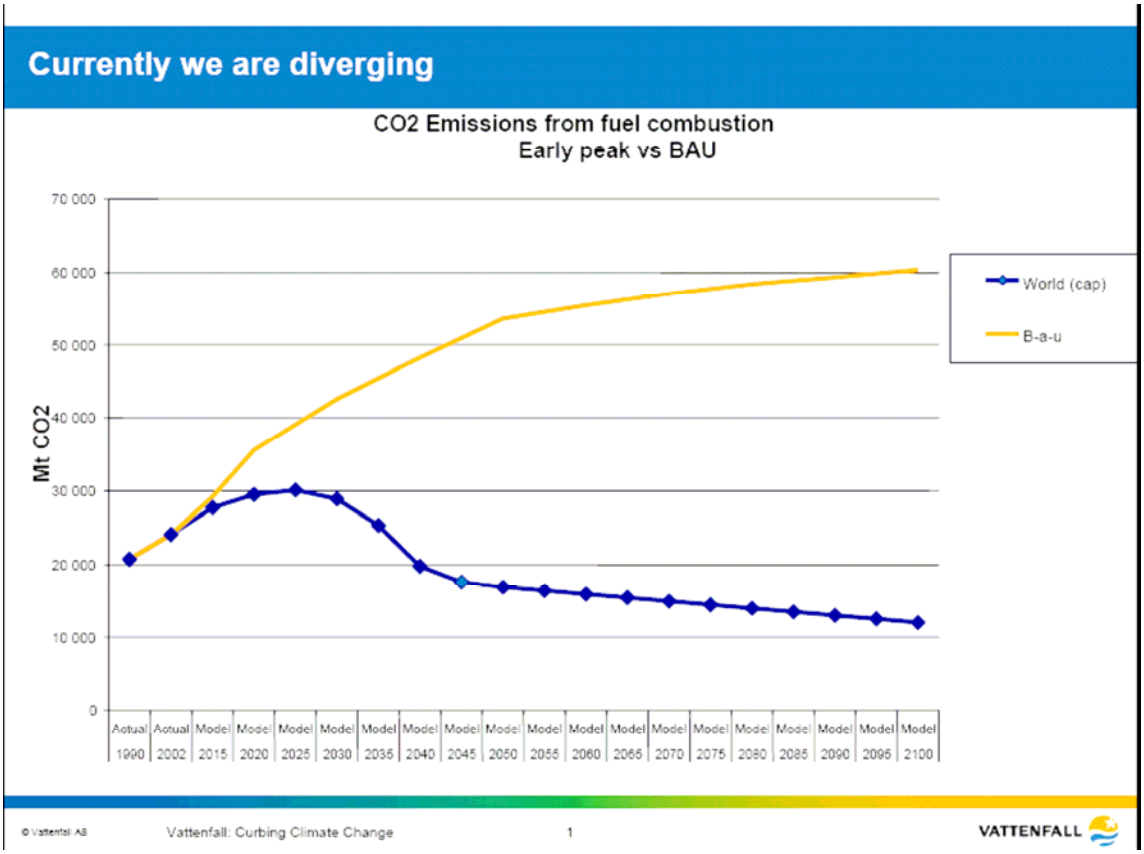
Fourthly, it is a matter of finding forms for a common acceptance of responsibility for necessary adaptations to the consequences of climate change.

The challenge is fundamentally of an economic and security policy nature. It is on this foundation that the give and take to build up global understanding must be based. The foundation must consist of a common acceptance of responsibility and joint commitment. The mapping that has been made of potential measures shows clearly that it is not possible to meet the threats on the climate through measures in certain regions or sectors. The entire global economy must be changed.

The threat to the climate – We are on the wrong track

Ever since industrialisation picked up speed over a hundred years ago, the mean temperature on the surface of the earth has increased by 0.76 degrees Centigrade according to IPCC.[2] The increase is continuing. If we try to review developments during this century, it becomes clear that mankind is facing a major challenge.

With current technology, the activities of human-beings are leading to growing emissions of greenhouse gases which in turn mean that the emissions will be multiplied many times over during the course of this century. At the same time, we know that the trend should be moving in the opposite direction – emissions must be substantially reduced if we are to have the possibility of restricting global warming.



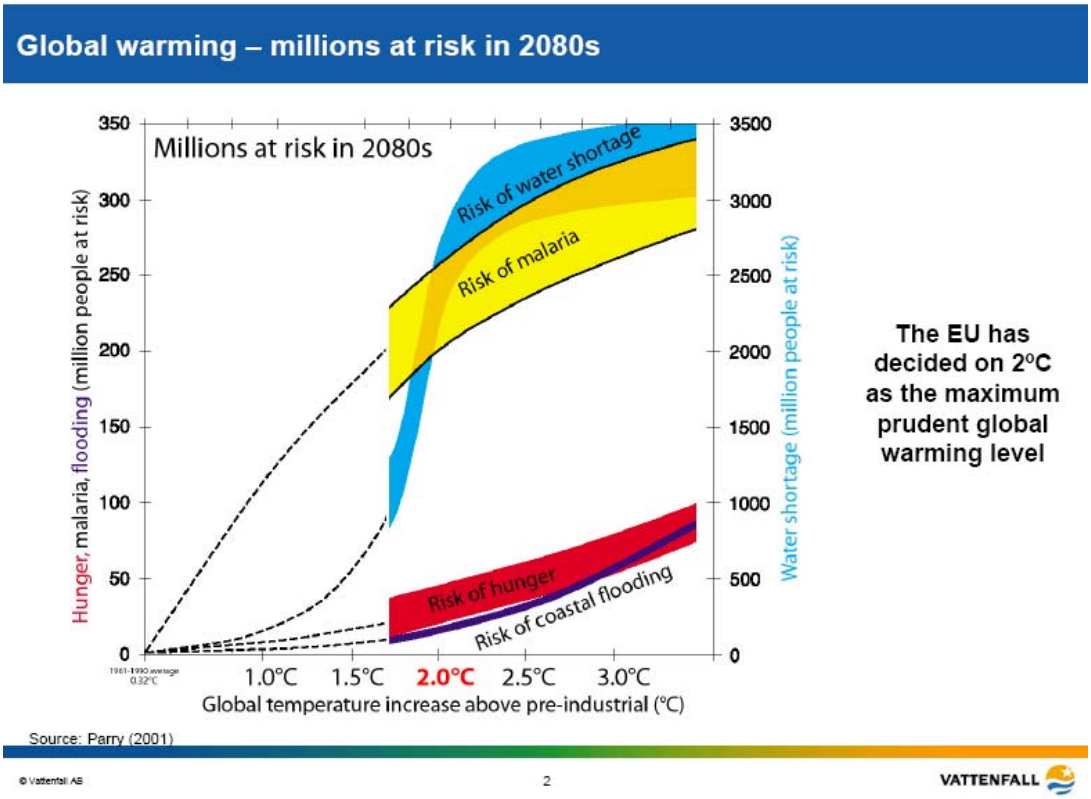
There is admittedly a certain level of uncertainty in terms of knowledge. It is a matter of complicated relationships and gradual changes over a long period of time. A number of different explanation models are possible but the conclusion is unanimous – we are on the

[2] The total temperature increase from 1850 – 1899 to 2001 – 2005 is 0.76 [0.57 to 0.95]ºC.

wrong track. The most reasonable explanation of the information available is that the emissions generated by mankind are giving rise to increasingly high mean temperatures alongside the natural variations in the climate.

The trend today is that emissions connected with human activity will continue to increase significantly during this century.

The greenhouse effect is a threat against humanity, not against the earth as such. The threat is directed against both the individual as well as against a stable and peaceful social order. With an increase of only 2 degrees Centigrade, the effects will be substantial – and particularly so in the case of water supply.



Increasingly high temperatures and their after-effects will reduce the scope for human life and wellbeing. Long periods between cause and effect mean that it is unrealistic to expect that the effects can be dealt with by means of self-regulation. It is a question of reducing risks by as far as possible cutting emissions to the lowest possible level. To the extent that this proves impossible, the adaptation will instead be effected by our learning to live with the consequences, and wherever possible through different types of investments to alleviate the damage that an increasingly high mean temperature will lead to.

The connection between temperature increase and the concentration of greenhouse gases in the atmosphere is not unequivocal. A risk consideration based on the knowledge available indicates that the level 450 ppm[3] gives a 50/50 per cent risk of ending up above or below a two-degree temperature increase. In the analysis work that lies behind this report, 450 ppm has been employed as the principal scenario.

The climate threat is a challenge to the whole of humanity, even though each and every one of us must contribute towards solving it according to his or her own ability. No one person, no individual country, no region can ward off in a sustainable way the threat to the climate on their own. As such, it constitutes a challenge to mankind.

A substantial reduction in emissions is possible by 2030

Is it possible to reduce the emissions of greenhouse gases without jeopardising the continued development of prosperity that can be shared by a growing number of people?

Vattenfall has in co-operation with McKinsey conducted an extensive mapping of the possibilities of significantly reducing the emissions of greenhouse gases during the period up until 2030.

The ambition is to gain an overview of the capacity of the entire global economy to reduce the emissions of greenhouse gases by quantifying the realistic potential and additional costs of its realisation. The cost of the measures has been calculated as the annual additional operating costs plus the depreciation costs.

The map has been made to be used as a basis for discussing what type of regulations and control measures can support the realisation of the identified potential. The material has therefore as far as possible been cleared of the effects of climate-related control measures. Only commercially available techniques, either existing or possible to develop during the period of time in question, have been included.

The global economy has been divided into six sectors: power, industry, transportation, buildings, agriculture and forestry, and into six regions: the USA and Canada, OECD Europe, Eastern Europe including Russia, other industrialised countries[4], China and the rest of the world[5]. In the study, the potential status is judged at three different junctures: 2010, 2020 and 2030. The study is based on well-reputed material from mainly the IEA and EPA, which has been subsequently supplemented and processed. Assessments from experts from within the sectors and from academics constitute a significant part of the input.

The basic starting point is a description of a probable course of development if no special measures are taken and in this way determines which emission levels are likely in the case of spontaneous development. The base year for the analysis is 2002, at which time the total emission of the six greenhouse gases was 40 billion tonnes of carbon dioxide equivalents ($GtCO_2e$). Of this, 75 per cent was carbon dioxide, 16 per cent methane, 8 per cent laughing gas (nitrous oxide) and the remaining gases accounted for 1 per cent. Up until the year 2030,

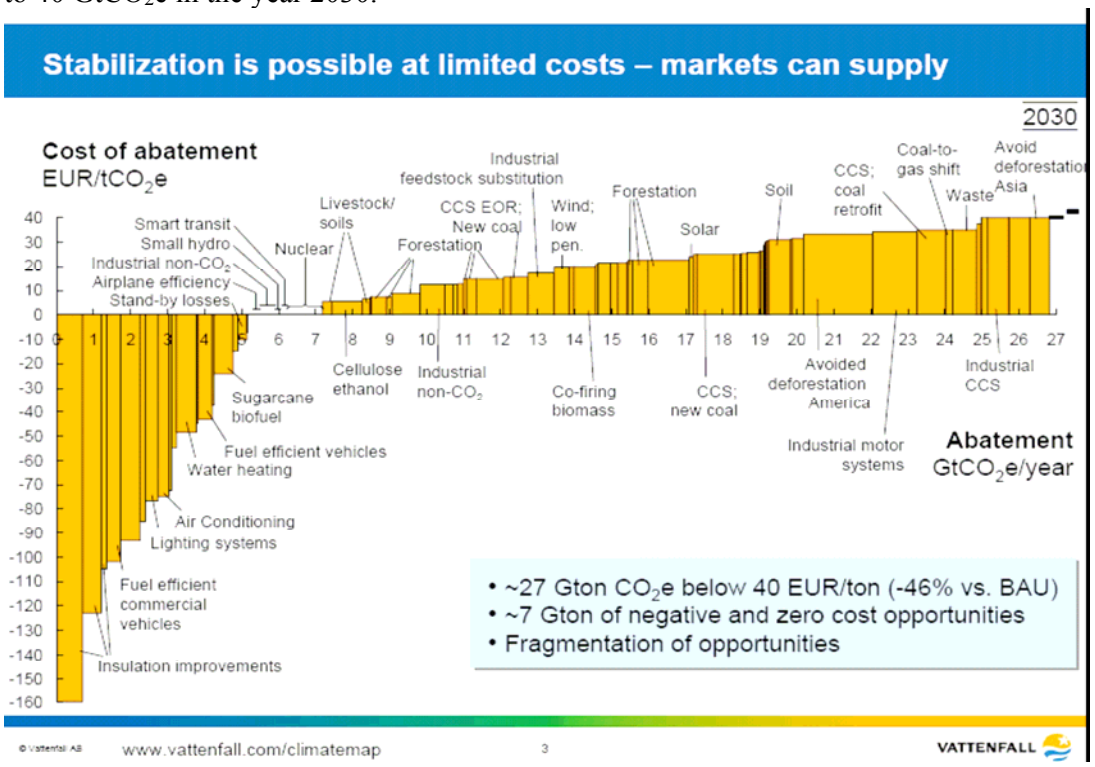
[3] Parts per million, millionths calculated as the number of molecules in dry air
[4] Australia, New Zealand, Japan, Singapore, South Korea, Taiwan, the united Arab Emirates, Saudi-Arabia, Qatar, Oman, Kuwait, Israel, Bahrain, Mexico.
[5] Africa, South and Central excluding Mexico, Asia excluding China and excluding other industrialised countries (see previous footnote).

the overall emissions will increase to 58 $GtCO_2e$ if no measures are taken. In 2010, the overall emissions are calculated to be 45.4 $GtCO_2e$ and in 2020 52.9 $GtCO_2e$. Calculated in the same way and with the same sources, the emissions in the year 1990, based on the climate conditions, were in the order of 35 $GtCO_2e$.

Subsequently, we have investigated the possibilities of lowering the emissions in relation to the spontaneous developments for respective sectors and respective regions.

If it is to be possible to limit global warming to 2 degrees Centigrade with a reasonable level of risk-taking, the long-term concentration of greenhouse gases in the atmosphere must be limited to 450 ppm. In order for this type of future development to continue, we deem that emissions by the year 2030 must be limited to 31 $GtCO_2e$. This means that measures corresponding to 27 $GtCO_2e$ must be taken, a decrease compared to the 46 per cent in relation to the development that is probable if measures are not taken.

In our mapping we have in total identified potential measures ranging in overall size from 35 to 40 $GtCO_2e$ in the year 2030.



The marginal cost, or in other words the cost of the last measure taken, amounts to EUR 40 per tonne of carbon dioxide equivalent, which is a third higher than the highest price so far noted in the European trading with emission rights. A part of the abatement potential, around 7 $GtCO_2e$, has a cost that is zero or negative. The latter means that the operating costs (primarily energy costs) decrease by more that the depreciation costs, so that the total cost is in fact lowered. No single measure predominates – the largest contribution may be given by the separation and storage of carbon dioxide, in total 3.7 $GtCO_2e$, immediately under 14 per cent of the necessary overall reduction. Instead, it is a matter of a large number of measures well distributed over sectors and regions.

The power sector's share of total emissions was 24 per cent in 2002. With no measures taken, the emissions of the sector will have increased by almost 80 per cent by 2030 and constitute 38 per cent of the total emissions that year. Four types of measures can reduce emissions by a total of 5.9 $GtCO_2e$ by the year 2030, corresponding to 22 per cent of the measures that are less than EUR 40 per tonne. Separation and storage is deemed to be a commercially viable technique during the period 2015 to 2020, and the contribution to a reduction in emission levels in the power sector by 2030 could amount to 3.1 Gt. Renewable energy could contribute with approximately 15 to 20 per cent of the power supply by 2030, which would gives 1.5 Gt in 2030. It is considered possible for the global nuclear power capacity to be doubled by the year 2030, which corresponds to 1.1 Gt by 2030. The pricing of carbon dioxide means that natural gas increases faster at the expense of other fossil fuels, which give a lower total emission of 0.4 Gt by 2030. With these measures, the intensity of carbon dioxide in the power sector will be halved from 0.59 to 0.29 kg per generated kilowatt hour.

In addition, more efficient electricity consumption in buildings and industry will reduce the global increase in the demand for power from 2.5 to 1.3 per cent per year during the period 2002 to 2030, which will lead to a further reduction in emissions from the power sector of 3.7 $GtCO_2e$ by the year 2030.

In addition to these measures, all of which are on a level of less than EUR 40 per tonne, there is further potential in the price range EUR 55 to 65 per tonne. A sufficiently high and credible long-term price signal may therefore reduce emissions still further.

The greatest potential for action for the power sector is in China, which can contribute with 29 per cent of the 5.9 $GtCO_2e$ in power generation. The USA and Canada can contribute with 22 per cent, the region the rest of the world with 18 per cent, other industrialised countries and OECD Europe with 13 per cent each and Eastern Europe, including Russia, with 5 per cent.

The industrial sector accounted for a third of the global emissions in 2002. The development prior to 2030 will increase its emissions to 22 $GtCO_2e$, despite a strong internal efficiency improvement of 1.5 per cent per year. Measures below the cost limit of EUR 40 per tonne could reduce these emissions by 6 $GtCO_2e$, of which 1.4 Gt is a decrease in demand for electrical power. Of the remaining 4.6 Gt, the field of electric motor operation could contribute with 1.2 Gt, material replacement in above all the cement industry with 0.7 Gt, the separation and storage of carbon dioxide in industrial applications with 0.6 Gt and the combined production of electricity and heat with 0.3 Gt.

It is judged that China will be able to contribute with 26 per cent of the total possible reduction by 2030, the region the rest of the world with 25 per cent, other industrialised countries with 14 per cent, the USA and Canada with 13 per cent, Eastern Europe, including Russia, with 12 per cent and OECD Europe with 10 per cent.

The total emissions of the transport sector amounted to 5.4 $GtCO_2e$ in 2002, of which 75 per cent came from land transportation, 12 per cent from air transport and the remainder from shipping and the railways. Practically all the emissions come from the combustion of petroleum products. Emission volumes are judged to increase to 8.8 Gt per year in 2030 primarily as a result of an upswing in the number of vehicles in the developing countries, although measures could reduce these emissions by 2.9 Gt. Alternative fuels may contribute with 1.5 Gt, greater efficiency in the consumption of fuel could contribute with 1.2 Gt and measures that decrease the demand and result in better capacity utilisation could contribute

with 0.3 Gt. Hybrid vehicles have a major potential, although high costs are holding back development. Hybrid vehicles without the possibility for plug-in only give a marginal reduction in emissions. It is judged that the costs needed for the required measures can be reduced by a considerable extent over the course of time.

It is judged that the region the rest of the world can contribute with 38 per cent of the reduction, USA and Canada with 32 per cent, OECD Europe with 10 per cent, other industrialised countries and China with 8 per cent each and Eastern Europe, including Russia, with 4 per cent.

Buildings. Emissions related to buildings in 2002 amounted to 8.2 $GtCO_2e$, which was equivalent to 21 per cent of the total. By 2030, the emission level is expected to be 14 Gt, but a number of measures could reduce this figure by 3.7 Gt, of which 2.3 Gt by reduced electricity consumption. Measures linked with heating/cooling and ventilation can contribute with 2.3 Gt, more effective lighting with 0.3 Gt and more efficient machinery and equipment and reduced standby-losses with 1.1 Gt. All these measures have a cost that is zero or ?? negative. In addition, approximately 2 Gt of possible measures can be made at a cost of less than EUR 40 per tonne. These are not included in the potential.

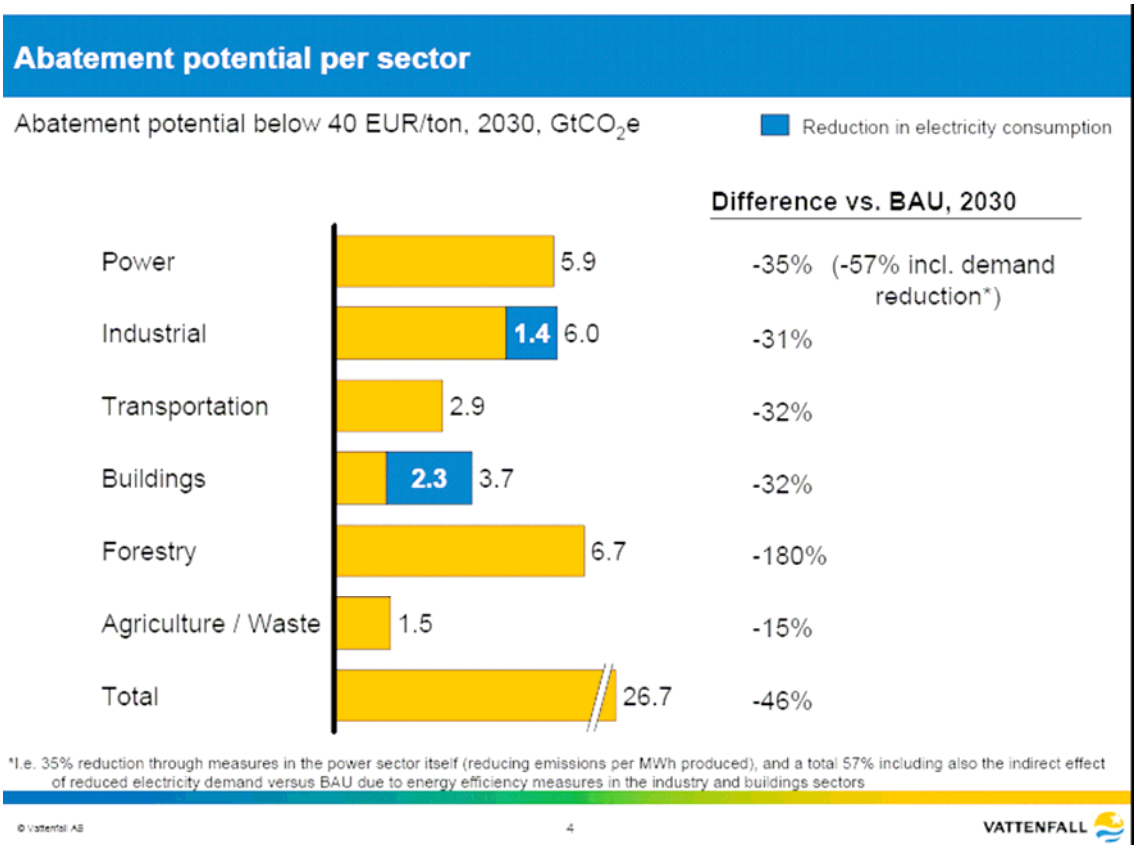
The region the rest of the world is estimated to be able to contribute with 22 per cent of the measures, the USA and Canada with 21 per cent, China with 20, OECD Europe with 14, other industrialised countries with 13 per cent and Eastern Europe, including Russia, with 10 per cent.

The net emission from forestry in 2002 was 5.5 $GtCO_2e$, which was 14 per cent of the total. The gross emission from the deforestation in tropical areas is currently giving rise to 8.2 Gt and amounts to approximately 50 per cent in Asia, primarily Indonesia, 30 per cent in Latin America, primarily Brazil, and to 20 per cent in Africa, primarily the Congo. In the temperate zones, there is at the same time a net uptake of 2.7 Gt. In 2030, the gross deforestation is estimated to have been reduced to 6.4 Gt, which in combination with a constant net uptake gives a net emission from forestry on a global scale of 3.7 $GtCO_2e$. In addition to this improvement, a decrease of 6.7 Gt can be brought about by decreased deforestation and reforestation. Reduced deforestation is judged to be able to contribute with 1.9 Gt in Latin America, 0.8 Gt in Africa and 0.6 Gt within the OECD. Reforestation is judged to be able to give 2.3 Gt in Latin America, 0.9 Gt in Africa and 0.3 Gt within the OECD. With costs for the measures ranging from EUR 40 to 80 /GtCO2e, there is a potential for a further 4 to 5 Gt by 2030.

Agriculture and waste. The total emission in 2002 was 7.2 $GtCO_2e$.[6] By 2030, the emissions are anticipated to have increased to 9.9 Gt. Theoretically, the potential for reduction is 5.7 Gt, but only 25 per cent of this is judged possible to implement by 2030. The region the rest of the world accounts for 53 per cent of this reduction, China for 18 per cent, the USA and Canada for 10 per cent, OECD Europe for 7 per cent, other industrialised countries for 6 per cent and Eastern Europe, including Russia, for 5 per cent.

If we combine the reduction potentials in all 6 sectors, we gain the following picture of the situation:

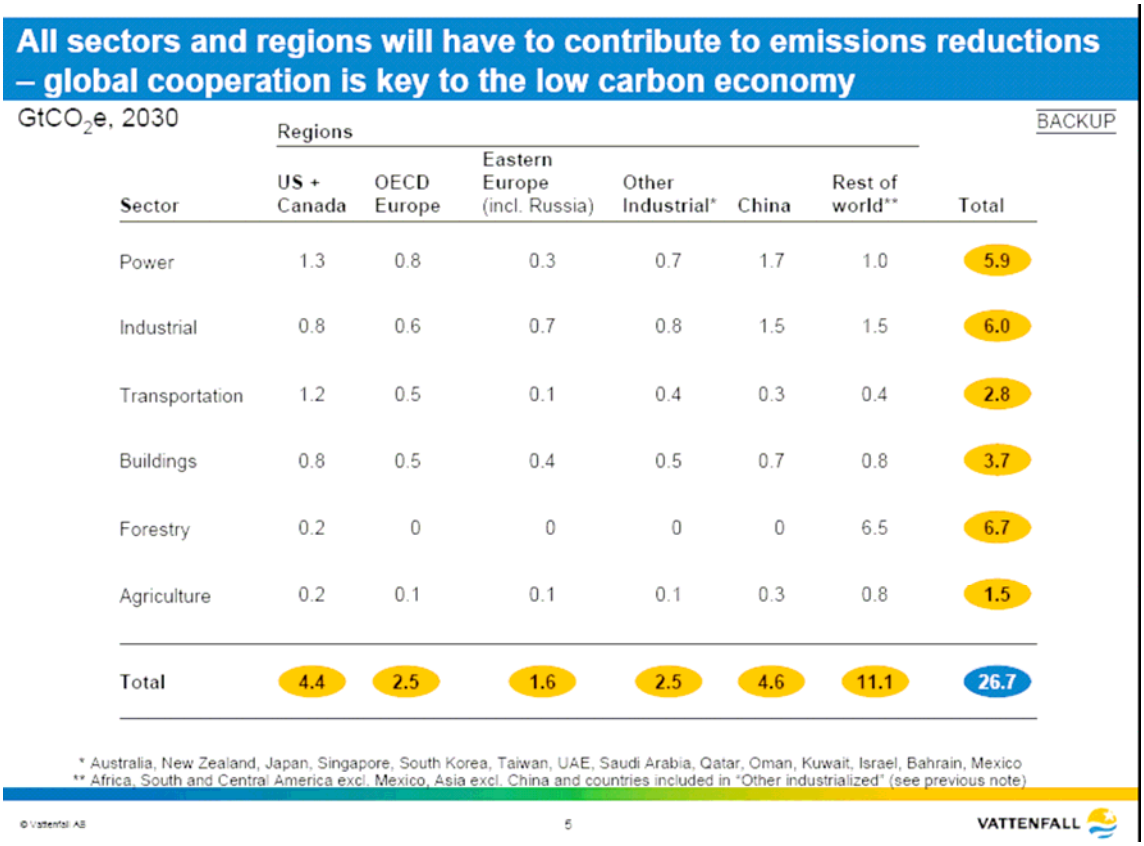
[6] Of which 30 per cent are nitrous oxide from fertilising and 8 per cent from other sources. Methane from cattle contributed with 29 per cent, waste and sewage with 18 per cent, rice growing with 9 per cent and 6 per cent is methane from other sources.



By far the predominant part of this reduction potential, 70 per cent, consists of measures that are based on available solutions with a stable cost scenario. Only 30 per cent are measures in which the learning curves and thereby integrated cost reduction have an important role to play for implementation of the solutions. In the power sector, however, measures of the latter type have a considerably more important role to play in reducing the emissions.

Of the total 26.7 $GtCO_2e$ of possible measures that were identified at a cost of less than EUR 40 per tonne, 4.4 Gt are in the USA and Canada, 2.5 in OECD Europe, 1.6 in Easter Europe, including Russia, 2.5 in other industrialised countries, 4.6 in China and 11.1 Gt in the rest of the world.

The potential measures are well distributed over the global economy irrespective of whether they are divided into sectors or regions.



All sectors and regions will have to contribute to emissions reductions – global cooperation is key to the low carbon economy

$GtCO_2e$, 2030

BACKUP

Sector	Regions: US + Canada	OECD Europe	Eastern Europe (incl. Russia)	Other Industrial*	China	Rest of world**	Total
Power	1.3	0.8	0.3	0.7	1.7	1.0	5.9
Industrial	0.8	0.6	0.7	0.8	1.5	1.5	6.0
Transportation	1.2	0.5	0.1	0.4	0.3	0.4	2.8
Buildings	0.8	0.5	0.4	0.5	0.7	0.8	3.7
Forestry	0.2	0	0	0	0	6.5	6.7
Agriculture	0.2	0.1	0.1	0.1	0.3	0.8	1.5
Total	4.4	2.5	1.6	2.5	4.6	11.1	26.7

* Australia, New Zealand, Japan, Singapore, South Korea, Taiwan, UAE, Saudi Arabia, Qatar, Oman, Kuwait, Israel, Bahrain, Mexico
** Africa, South and Central America excl. Mexico, Asia excl. China and countries included in "Other industrialized" (see previous note)

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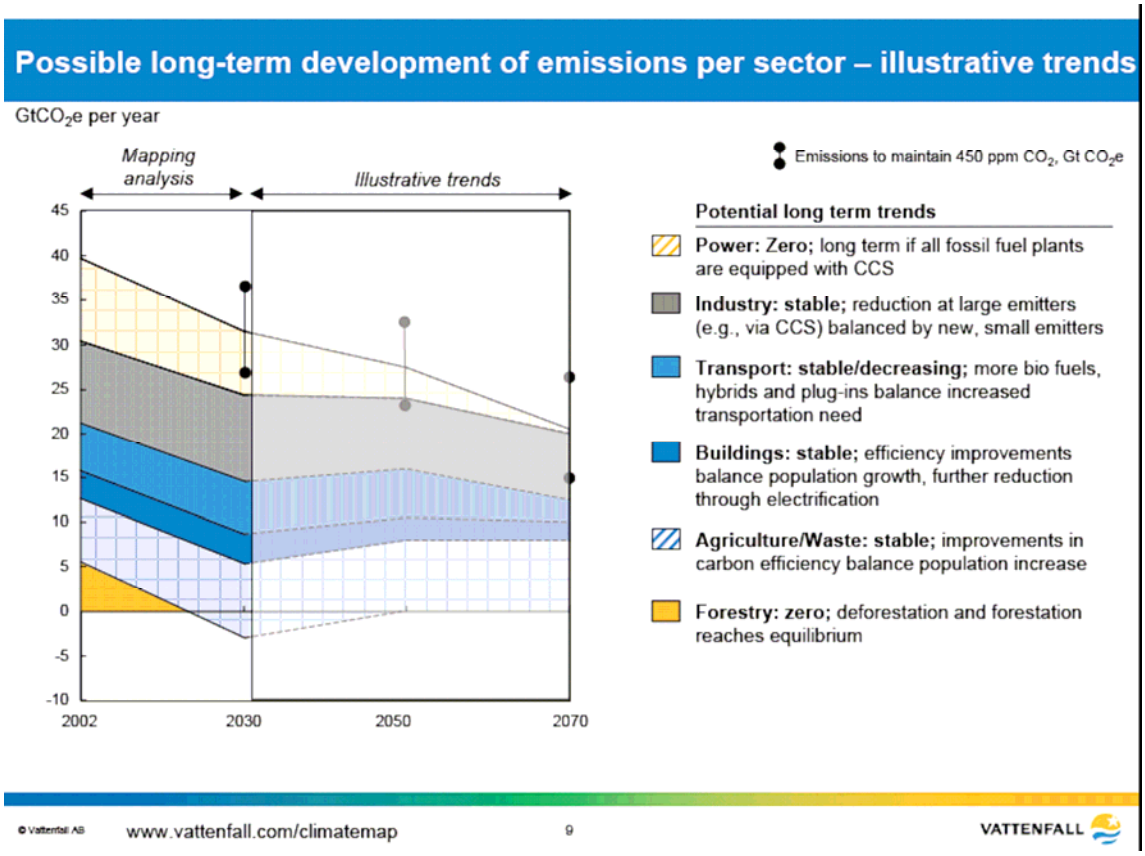
No one sector or region can in other words make more than one contribution to the total reduction that needs to be made. Even paired combinations, for example the USA, Canada and OECD Europe or power and industry cannot make more than a limited contribution to the reduction that needs to be made. One important conclusion of this is that the global economy must be put into motion. Another important conclusion is that it is in fact possible to bring about major reductions in emissions if this can be done. The global economy can supply solutions provided that they are adhered to and we are prepared to pay the costs involved.

Developments beyond 2030 – Predicted trends up until 2070

Entirely new solutions and investments in new technology will have limited impact before the year 2030. In a longer perspective, considerably greater potential is given to the fact that sustainable solutions are applied to research and development and to programs in order to take advantage of the opportunities for reduced costs that are indicated by the volume-dependent learning curves that that can be reasonably assumed for key technologies.

At the same time, the global emissions of greenhouse gases will continue to decrease significantly if the 2-degree goal is to be realised.



The annual emissions that are possible if the level of 450 ppm is to be maintained are indicated in the graph by the intervals between the black dots. There must be a successive lowering of the annual emissions throughout the entire period.

Predicted trends based on the technology status in 2030 indicate that this continued reduction in emissions is also fully possible.

It should be possible for the power sector to become emission-free during the period up to 2070 and for developments within the other sectors to be stabilised and reduced to a sufficient extent to create the continued emission reductions that are necessary in order for it to be possible to reduce the total concentration of greenhouse gases in a sustainable way. At the same time, the global economy and the world population continue to grow. The combination of economic growth, population expansion and successively diminishing emissions would therefore appear fully possible to maintain even in the longer term.

How do we put the global economy into motion?

It is unreasonable to believe that the required changes will come into effect spontaneously or simply through behavioural changes on the part of individual players. In the first place, there is a considerable delay between the point in time when the emission takes place and the point at which the dangerous effects become apparent. Secondly, the climate is a public utility. From the point of view of individual players, the measures that lead to reduced emissions are associated with changes and therefore related costs that do not appear meaningful unless they are part of a collective action. Thirdly, most of the potential measures that were identified are

in fact associated with higher costs, which means that these solutions require greater investments and/or higher operating costs. For instance, an electricity generation plant with the separation and storage of carbon dioxide will have both a higher capital cost as well as a higher variable operating cost than a conventional plant.

In certain circumstances, the absence of self-regulation has been described as a market shortfall, whereas the basic problem is in fact the absence of the market mechanisms that are needed for emission restrictions which the market players require – assuming that they act rationally – in order to make use of all the opportunities for reduced emissions that are in fact open to them.

The challenge that lies ahead of us can be described in simple terms as moving the global economy from a state of equilibrium to a different status without causing and disruptions or interference which in an essential way reduces the potential of the global economy to create growth and prosperity.

The global economy can be divided into three distinct groups with significant differences in business logics and a high degree of relevance as to the means of control that can lead to the potentials that have been identified actually being realised at a limited cost.

Three different types of sectors

	2030 abatement potential		
	$GtCO_2e$	EUR/tCO_2e	Key characteristics
Power and industry 	11.9	15–40	• Mainly industrialized countries • Small number of large, rational emitters • High cost • Minor consumer implications • Competitive distortion issues
Transpor-tation and buildings 	6.6	<5 (often negative)	• Mainly industrialized countries • Billions of small emitters • Low/negative cost • High consumer implications
Forestry , agriculture, waste 	8.2	10–40	• 60+% developing countries • Billions of small emitters • Medium/high cost • Big social implications • Hard to measure & monitor
TOTAL	26.7		

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Power and industry consist of a small number of major emission sources which are mostly located in industrialised countries or countries that are in the process of becoming industrialised. The important decisions are made by corporate managements and boards of directors that can be expected to act strictly rationally. The links with consumer behaviour are

limited. The potential for emission reductions is considerable: 44 per cent of 26.7 of the $GtCO_2e$ that are required by 2030. The cost level is in the upper range.

Transportation and buildings consist of a large number of small emission sources, mainly in more developed parts of the global economy. The overall potential is approximately 25 per cent of the total in 2030. The costs are often negative, i.e. at the same time as the emissions can be reduced, the costs can be lowered Realising this potential is to a large extent a matter of encouraging consumers to behave more rationally by looking at the total cost throughout the lifetime of a selected solution and considering the consequences of one's behaviour.

Forestry, agriculture and waste consist of a very large number of small emission sources that are to over 60 per cent situated in developing countries. The potential is just over 30 per cent of the total in 2030 and the costs are distributed over medium to high level. Realising this potential means that new mechanisms will have to be created in order to bring about a desired development at the same time as there are complications with respect to measurement and monitoring, but these challenges are considered as being possible to cope with. The realisation of this potential has strong links with social issues in the developing countries.

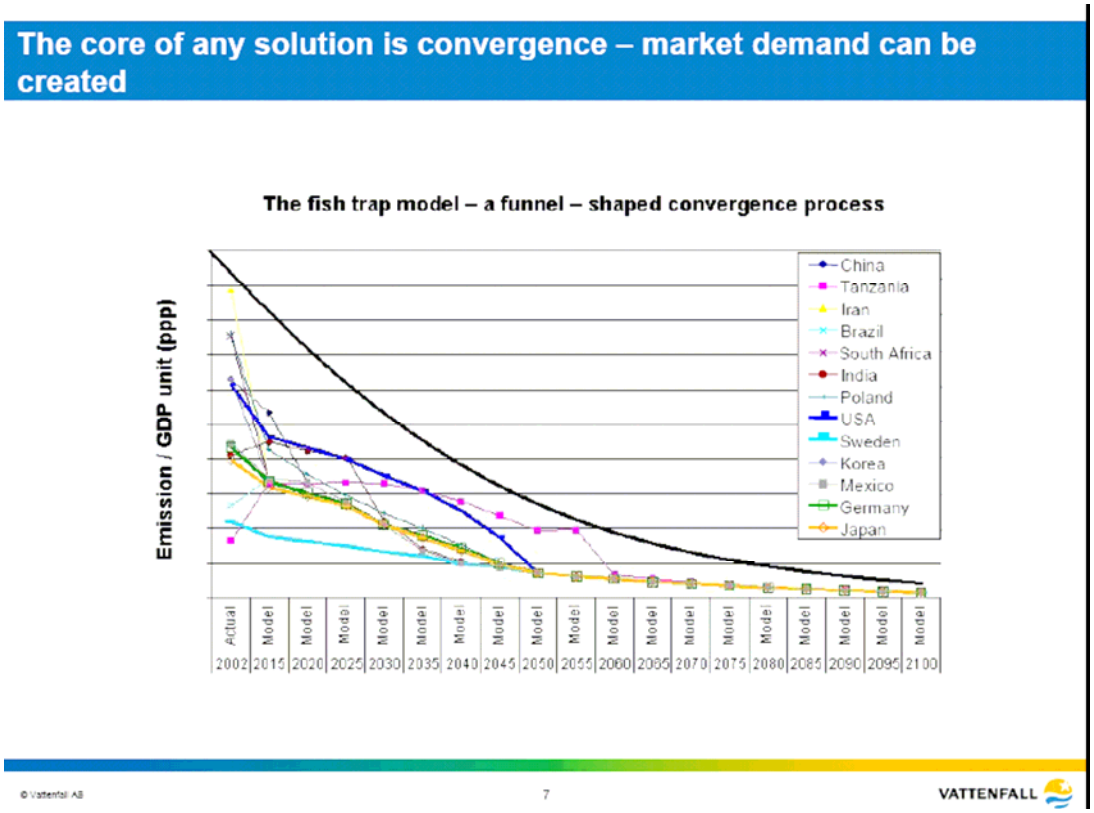
Setting the global economy in motion means that a system of regulations and means of control must be created to send signals to the market players to incorporate the effects on the climate into their decision-making. Alternatively, the measures must be effected by means of public financing, but the overall extent means that that this alternative does not appear to be realistic. It is difficult to see that it would be possible to mobilise the necessary financial resources, and even if it were to be the case, it would be difficult to create the necessary decision and implementation capacity in the public sector to successfully realise the detailed regulation that would then be necessary. On the other hand, public funding can of course play an important role as "a lubricant" and for financing initial input. But in order to achieve the required shift in the entire global economy from one position to another, it is basically the many small decisions that are constantly being made on different markets that have to be influenced.

The basic mechanism must be that reduced emissions create value from both a corporate economic as well as a private economic point of view. Only then is it possible to adopt a behaviour that leads to the potential measures being realised.

Mechanisms for value creation can be designed in different ways – through taxes, by trading with emission rights or direct administrative measures with "shadow prices" as a result. A common factor of all solutions is that there must be some type of long-standing agreement to the effect that the possibilities for discharging greenhouse gases will be limited and that there is a credibility in the fact that these limitations can and will be maintained. Otherwise, the value creation that the emission-reducing measures can generate will not be considered as being sufficiently credible in order to serve as a basis for the necessary investments to be financed by the decisions of market players.

In January 2006, Vattenfall published the report entitled "Curbing Climate Change - An outline of a framework leading to a low carbon emitting society" which takes up how a global model for emission reductions that results in value creation could be structured.

A solution of this type must initially have a scope that is wide enough for a majority of the world's nations to consider taking part, at the same time as it must contain mechanisms which will in the long term create the extensive measures that will successively lead to the necessary reductions in emissions.

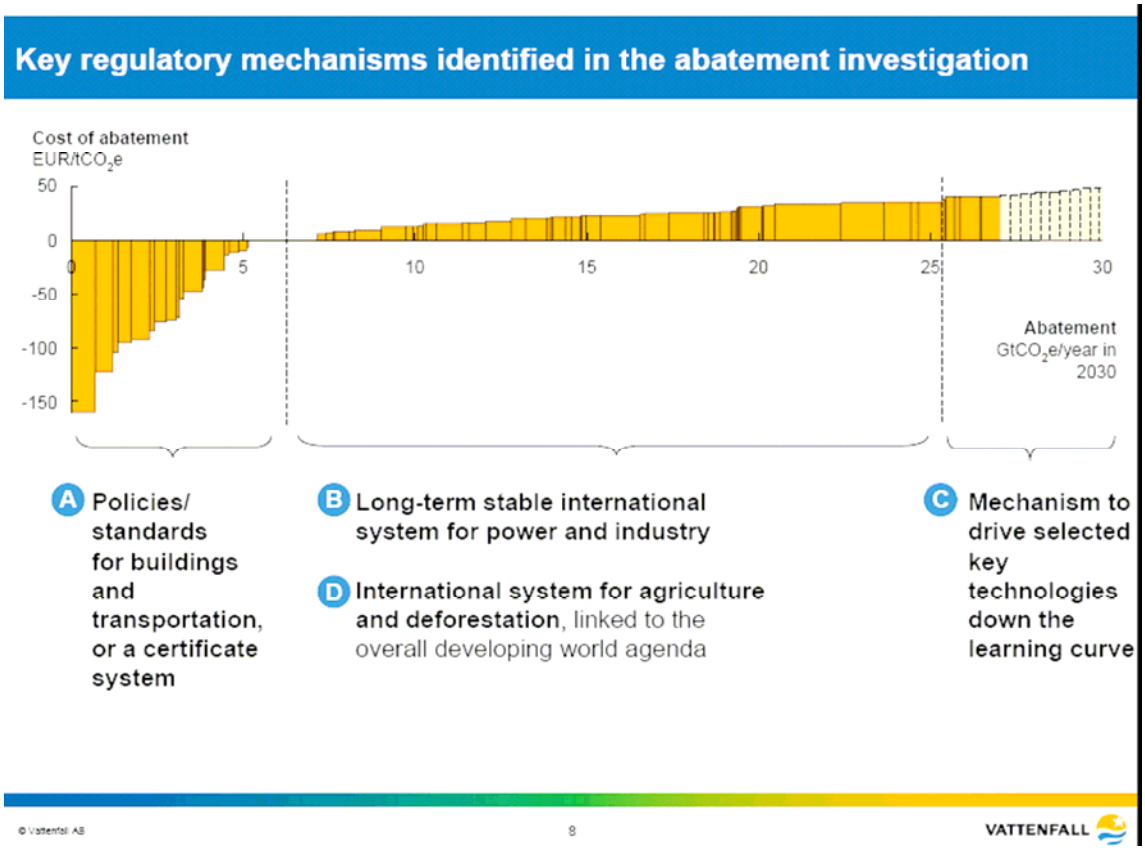


The model runs on which this report is based started from the level 550 ppm and are only founded on data relating to fossil fuel consumption. However, the same basic argument can be applied for a level of 450 ppm, even though the challenge in that case would be far greater in the form of quicker reductions. Similarly, the argument can be expanded to include other emission sources and greenhouse gases.

How then is it possible to establish a model of this type? It must be based on agreements that are experienced as binding by the participating countries, and the solution must be regarded as reasonable and fair from the point of view of each country. The countries must in the long run have more to gain from taking part than from remaining outside. In the longer term there are links with international trade and a common acceptance of responsibility as a move towards globalisation. The first critical stage is to create a model of this type with a sufficiently large level of participation. Analyses show that it is fully possible to adopt a funnel-shaped model that allows the major differences in emission levels per GNP-unit which will be necessary to start with in order to encourage the vast majority of the world nations to participate, and that it is then fully possible over the course of time to force these into a common framework to a mutually sustainable level given that the distribution model applied is sufficiently long term in nature. In this way it will be possible create a mutual development without it posing a threat to the continued development and growth in prosperity of any one country.

These emission restrictions must then be transformed into some type of pricing. According to the analysis performed by Vattenfall, trading with emission rights is to be preferred because it gives a sustainable and credible distribution of work between politics and market. But the decision on the structure of the means of control to be adopted will in the final instance be made by each individual country. The advantages of international trading in emission reductions are, however, so great that it is reasonable to assume that trading will be developed over the course of time regardless of its initial extent. The important thing is for common regulations to be developed so that they as far as possible facilitate development on these lines.

Based on the mapping that has been made of emission reductions and the arguments put forward above by different types of market players, the following general conclusions can be reached on the need for means of control.



Basically, a price signal is needed that gives emission reductions a sustainable value.

The power and industry sectors will act in a financially rational way provided that a credible form of value creation is established in emission reductions.

In the case of forestry and agriculture, a trading mechanism must be established that transfers resources from the developed countries to action plans for less well-developed economies. The structure of these measures must be based on the fact that they are in the interests of both parties. The alternative is more expensive solutions to create the same effect.

In the case of transportation and buildings, price signals are important because they create preconditions, but we know at the same time that they are insufficient. The price signals must be combined with clear minimum requirements for solutions and with measures that facilitate the options open to consumers. This can be brought about in various ways and the solutions do not need to be global in nature. It is a matter of clear specifications of requirements, support and/or certificate systems that allow commercial players to realise the major potential that evidently exists.

The development of new technical solutions needs to be supported. If it is possible to create value by reducing emissions, the market forces will drive this development, but public efforts are also required in the initial stages and carefully considered support for central technical areas that can encourage development. This includes, for example, renewable energy sources and the separation and storage of carbon dioxide. In this context, there is also a need for efforts to make new solutions available more quickly on a global scale.

How much will it cost to reduce emissions?

Reducing emissions is a question of investing in low-emission solutions. As can be seen from Figure 3, some of these have a significant negative cost. If the negative and positive parts in Figure 3 are summated, the average cost per tonne will be very low, but important components are lacking in the compilation. There are no transaction or information costs included because they are largely dependent on regulatory systems and means of control. For example, discussions are currently under way in several countries on forbidding conventional light bulbs after a certain date, which would drastically reduce the transaction and information costs. Nor is there any indication as to how much consumers appreciate the value of a certain solution, and above all there is no estimate as to the value of future damages that can be avoided.

These kinds of estimates were made in the Stern Report, which was published in autumn 2006. Stern's point is that a relatively low cost that is taken out in "near-time" means that the future prosperity will be greater. This approach has been criticised and it has been pointed out that Stern gives no consideration as to when costs and income respectively occur by discounting them.

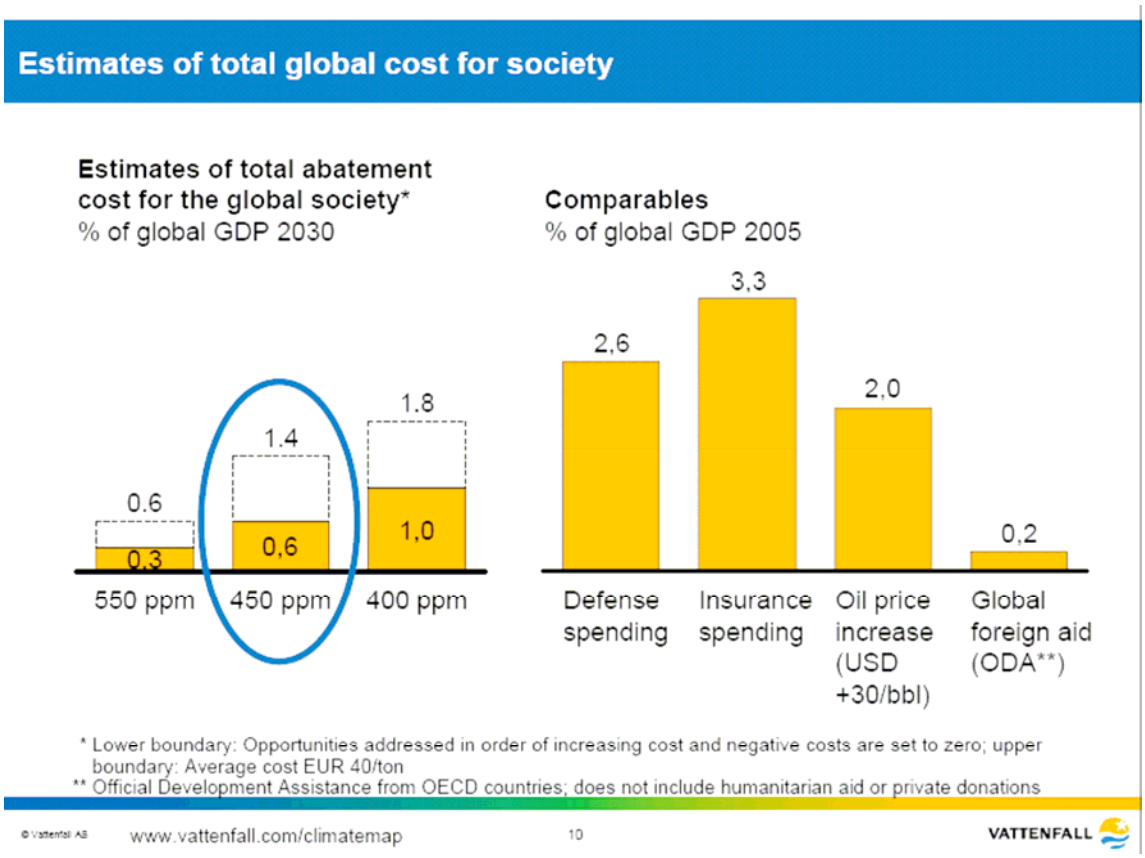
It is, however, highly motivated to question the justification for discounting in this case when two completely different futures are being compared and where significant parts are difficult to measure. Discounting means that income today has a greater value in relation to future income, and that the costs today will be greater in comparison with later measures. This kind of approach is applicable when it is a question of a problem of optimisation, i.e. within a certain framework distributing income and expenditure in such a way that the value is maximised.

The threat to the climate means a choice of alternatives, and the actual basis for this is the risk of future uncontrolled consequences in the form of damages and decreased return as a result of problems in connection with water supply, etc. To refrain from taking measures today, given that there is a real threat to the climate, means that we will be forced either to incur significantly higher costs for measures in the future or quite simply to accept the consequences. A substantial part of the problem is that we do not know and cannot know in advance how extensive the damage will be and at what point in time the damage can be

expected to take place. Handling this question as an optimisation problem is therefore not a reasonable approach.

A more relevant approach is therefore to try to measure the consumption of resources for a global economy with significantly lower emissions. With the mapping that has been carried out as a basis, it is possible to make indicative estimates.

Such calculations indicate that the consumption of resources is very low and considerably lower than the cost of handling other types of changes and risks. The mapping indicates that the cost of the main alternative of 450 ppm ends on a very low level of 0.6 per cent of the global GNP in 2030. In absolute figures, the cost is on a level of EUR 450 billion for the year 2030. This calculation is based on the potential measures being executed after rising cost. The negative costs have been set at zero. If certain types of measures are discounted or cannot be implemented, the cost will of course rise.



An alternative point of departure is to take the marginal cost, i.e. EUR 40 per tonne, and multiply it by the volume, which gives a cost of EUR 1 050 billion for the year 2030, corresponding to 1.4 per cent of the global GNP for this year. This calculation gives an indication of the total impact on prices that is necessary in order to bring about the desired changes, rather than an indication of the consumption of resources.

At the same time, it should be pointed out that these calculations show that it is possible to make changes in the global economy with a very limited consumption of resources as a consequence, not that it is necessarily the case. Poorly considered political decisions, irregularity, preferences for the most expensive alternatives, etc. may mean that the

consumption of resources will be many times higher with considerably greater consequences for how the available scope for consumption can be disposed of as a result.

Even though these calculations may be approximate, they still provide a basis for an indicative conclusion: a change in the global economy under controlled forms, and provided that time is set aside for adaptation, will lead to a very limited cost for society. The cost to society will probably be so low that it is quite simply too small to measure. There is in fact no reference point, since this will be shifted as part of the change.