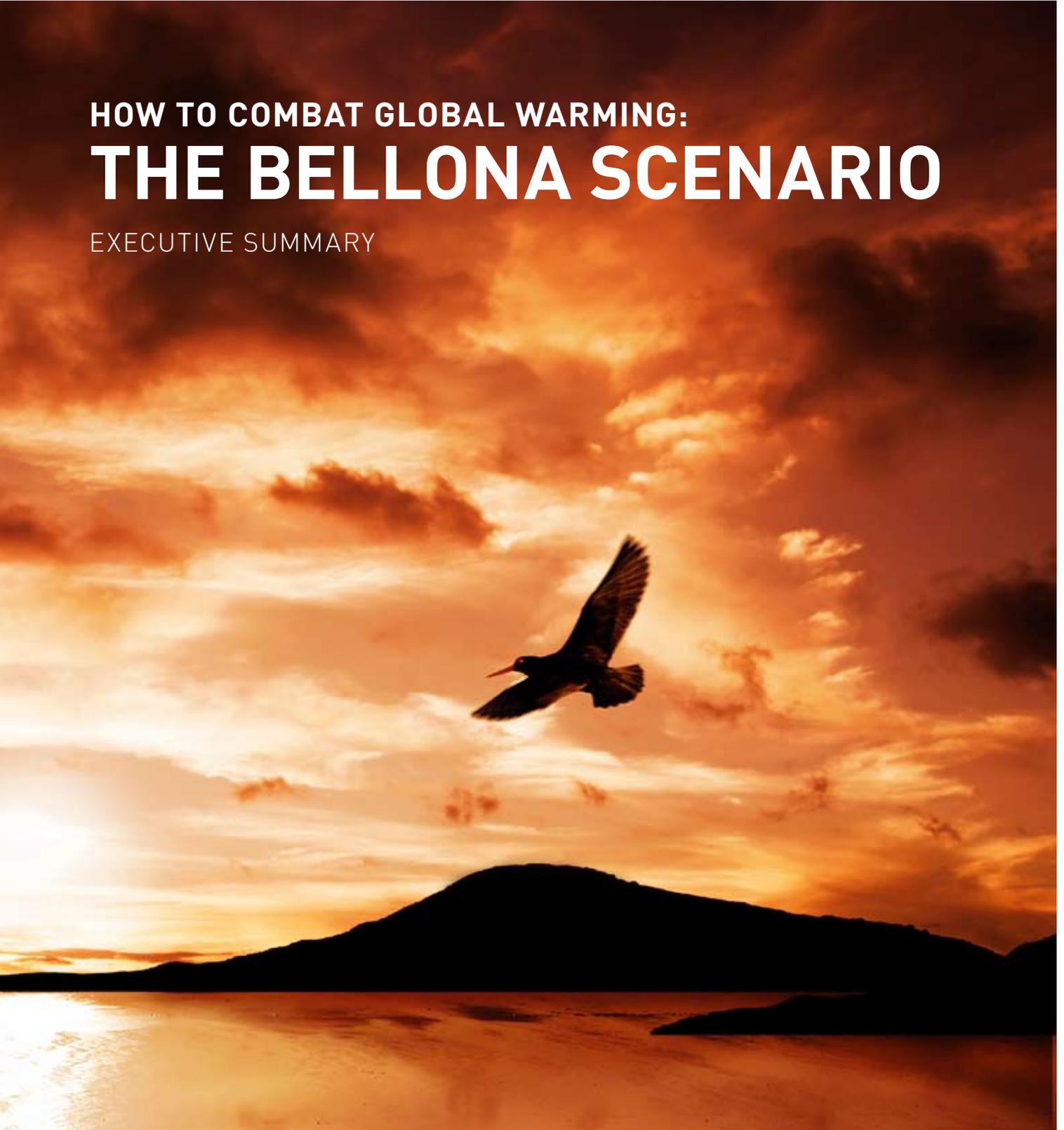


HOW TO COMBAT GLOBAL WARMING:
THE BELLONA SCENARIO

EXECUTIVE SUMMARY



KEY MESSAGE

- *Global warming is a tremendous challenge, but can be tackled*
- *Greenhouse gas emissions can be 85 percent lower in 2050 than they are today*
- *Existing technologies and industrial practices are sufficient to do the job: it is time for political leaders to rise to the challenge*

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TIME TO GET SERIOUS

■ Combating global warming is a tremendous challenge, but it is not insurmountable. The very same human ability and industrial capacity that created the problem can solve it.

But we have to act now. We must encourage political and industrial leaders who are ready to commit their countries and companies to take on ambitious emission reductions to move forward. And even more importantly, we must commit to combat global warming at the United Nations Climate Change Conference in Copenhagen in December 2009.

Striking a fair but ambitious global deal on climate change will take great political courage. There are as many political priorities as there are players, and previous negotiations have generally proven very disappointing. This, I believe, has in part been due to a belief that combating global warming is just too big a challenge.

This apathy is not only destructive – it is also unfounded: As the Bellona Scenario shows, the necessary technologies and industrial practices already exist.

Since 1986 Bellona has been working to go from pollution to solution. We acquired our first electric car in 1989, we started looking into carbon capture and storage in 1992 and we have worked on fuel-cell powered ships since 2000. At the time of the Kyoto negotiations in 1997, none of these technologies were thought to be able

to play any role in combating global warming. Now they are showing us that combating global warming really is possible. Imagine what solutions would come to the rescue in the future, once we truly make a global commitment!

One promising opportunity is to combine algae bioenergy with carbon capture and storage to produce *carbon negative* power. Whether you were watching TV, vacuuming the house, or driving your electric car to visit friends and family, you would be *removing* CO₂ from the atmosphere! How exciting is *that*?

Funding for developing and demonstrating more climate solutions must be drastically increased and sustained over time. Market conditions must be changed to reflect the urgency of combating global warming, and investment in climate-friendly technologies must be made financially attractive. But most importantly, we must commit to a schedule for reducing emissions to the necessary level by 2050.

It is time political leaders across the globe step up to the challenge – failure is *not* an option.



Frederic Hauge

FREDERIC HAUGE
President of the Bellona Foundation
30 May 2008



DRASTIC CUTS IN GREENHOUSE GAS EMISSIONS ARE ESSENTIAL

■ The fact that global warming is already taking place and is a problem caused by human activity is firmly established by an increasing number of scientific sources, amongst them the Intergovernmental Panel on Climate Change (IPCC). Failing to tackle global warming could have dramatic consequences. Rising sea levels, retreating glaciers, and increased frequency of droughts, floods and tropical storms would put half of the world's species at the risk of extinction and hundreds of millions of people in desperate need of food and water. To have a reasonable chance of avoiding such dire consequences, the global average temperature must not increase by more than 2 degrees Celsius above the pre-industrial level. According to the IPCC, this necessitates an overall 50 – 85 percent reduction of global greenhouse gas emissions

from 2000 to 2050 with the peak in emissions occurring between 2000 and 2015. There are several reasons to aim for reductions in the higher end of this interval. Firstly, emissions have increased steadily by 3 percent per year since 2000, so a peak by 2015 might be hard to achieve. A delayed peak in emissions means that the reduction target must be set relatively higher. Secondly, as the IPCC points out, the emission reductions necessary to meet a particular stabilisation level may have been underestimated owing to missing carbon cycle feedbacks. We therefore assume, for the purpose of this study, that an 85 percent reduction from the current emission level must be achieved to combat global warming.

HOW TO COMBAT GLOBAL WARMING - THE BELLONA SCENARIO

FINDING SOLUTIONS TO GLOBAL WARMING

■ Bellona has set out to show how to combat global warming. Across the economy, we have searched for solutions that already are available or on the verge of becoming so. We have analyzed findings from both scientific publications and various reports prepared by industry and environmental organizations. Bellona is certainly not the first to undertake such an effort; numerous studies have been published by academics, think-tanks, environmental organizations and governments alike. The problem is that few have shown how the needed 85 percent reduction in greenhouse gas emissions can be achieved by 2050.

COMBATING GLOBAL WARMING IS WITHIN REACH, BUT REQUIRES COURAGEOUS POLITICAL LEADERSHIP

■ The good news is that it is possible to reduce global emissions by 85 percent by 2050. Energy can be generated from biomass, water, wind, the sun and the sea, and can be used more efficiently. Industrial production, transportation and fossil power can be de-carbonized, and land use can be managed better. Yet, under the prevailing economic and political conditions, the needed technological shift is either happening far too slow or not happening at all. The challenge we face, together as a global community, is more of a political and economic nature than of a technical nature. The solutions exist – what is needed is national, regional and global political leadership to make it happen.

OUR DESIGN PRINCIPLES

■ Several approaches can be taken to decide what climate solutions to include in a global warming mitigation scenario. The most common seems to be a cost-based analysis, which means that only those measures that are expected to cost less than a certain limit are included. For the Bellona Scenario, we have chosen to focus less on cost, since the actual cost of a particular solution is subject to change as market conditions change. Furthermore, if we really must, as scientific evidence suggests, reduce emissions by as much as 85 percent by 2050, then how much it will cost is less relevant. With this as the guiding principle, the Bellona Scenario shows a possible combination of solutions that together reduce emissions by 85 percent by 2050.

The challenge is far-reaching, comprehensive and global: but it is manageable. The activities and technologies necessary to eliminate the bulk of the risks associated with climate change are already available or can be developed through appropriate policies to support innovation.

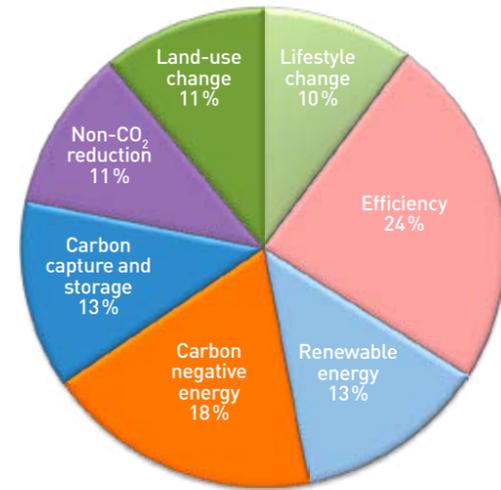
LORD NICHOLAS STERN

THE BELLONA SCENARIO

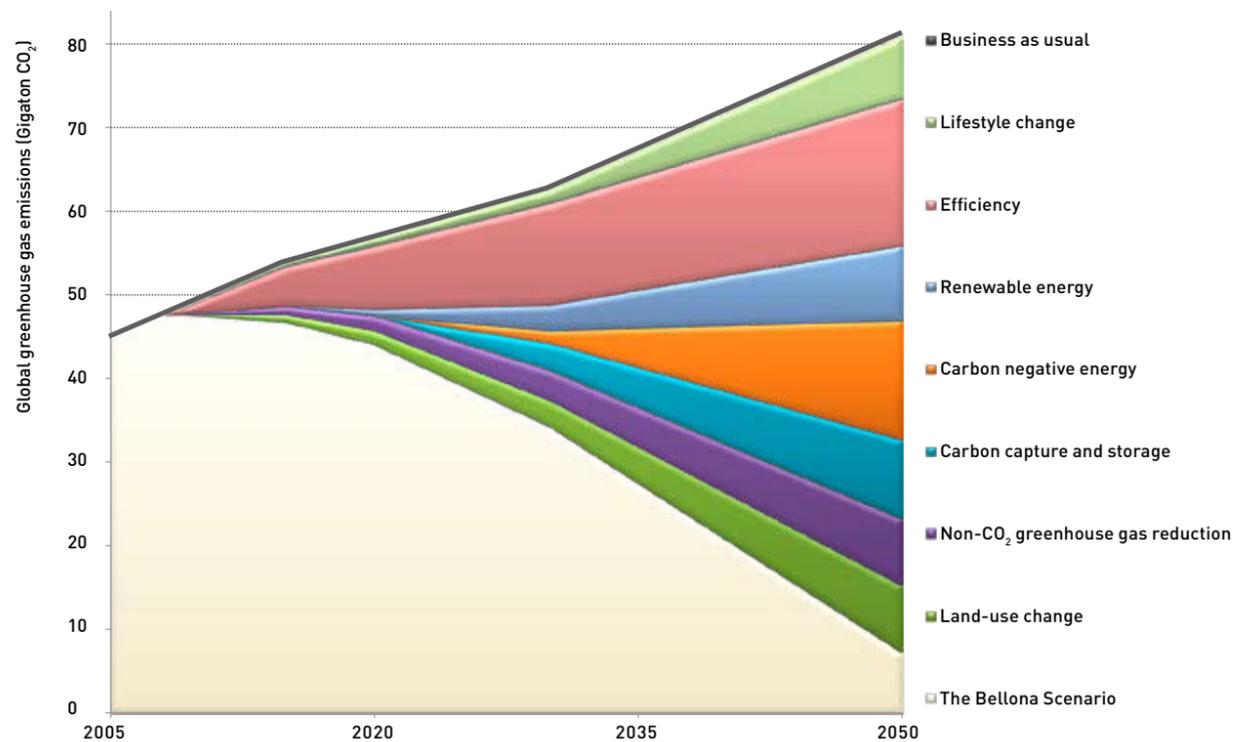
■ To produce the Bellona Scenario, we started with business as usual greenhouse gas emission scenarios published by the Intergovernmental Panel on Climatic Change, the International Energy Agency and the World Resource Institute. The business as usual scenario is represented by the black line in the chart above, and shows that annual emissions are expected to grow to 81 billion tonnes of CO₂-equivalents by 2050.

We then implemented the reductions provided by the identified solutions. The result is a trajectory taking us to 7.1 billion tonnes of CO₂-equivalents in 2050. This corresponds to an 85 percent reduction of current emissions by 2050.

As shown in the pie chart, increased efficiency, renewable energy and carbon capture and storage are all expected to play key roles. Furthermore, no single solution can do the job alone; a whole range of solutions are needed in all sectors of the economy.



SHARE OF REDUCTIONS FROM BUSINESS AS USUAL IN 2050



SOLUTIONS IN THE BELLONA SCENARIO

LIFESTYLE CHANGE

Bring about a change in consumer behaviour by means of emission-based pricing, increased awareness, and public and market based initiatives.

EFFICIENCY

Increase efficiency in the transformation of energy and materials into products and services. This is particularly relevant in industry, buildings, transport and power generation.

RENEWABLE ENERGY

Replace fossil energy in power generation, transport, industry and buildings with renewable energy. Most important sources are solar, bio- and wind energy.

CARBON CAPTURE AND STORAGE (CCS)

Capture CO₂ from power plants and industrial plants and store it permanently in geological formations.

CARBON NEGATIVE ENERGY

Absorb atmospheric CO₂ by growing modern biomass on non-agricultural land and use it in power plants fitted with CCS to achieve net negative emissions.

NON-CO₂ GREENHOUSE GAS REDUCTION

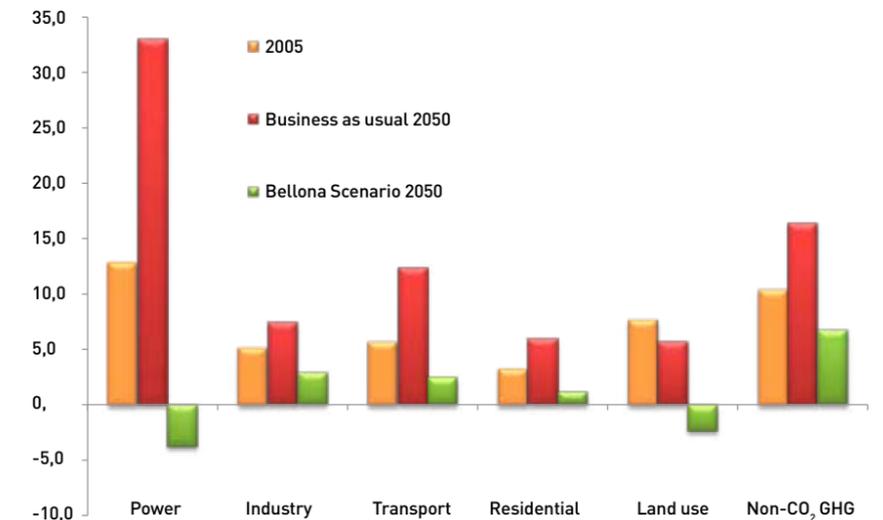
Reduce emissions of other greenhouse gases such as methane (CH₄) and nitrous oxide (N₂O) from waste, industry and agriculture.

LAND-USE CHANGE

Manage forests better to enhance their role as natural sinks of CO₂.

EMISSION REDUCTIONS BY SECTOR

■ The graph shows greenhouse gas emissions in 2005, the 2050 business as usual projection, and the 2050 emissions level if the Bellona Scenario is implemented. Deep cuts in all sectors of the economy are possible; some can even become net negative emitters. On the following pages, we describe the carbon negative energy supply system and how emissions can be reduced in all main sectors of the economy.



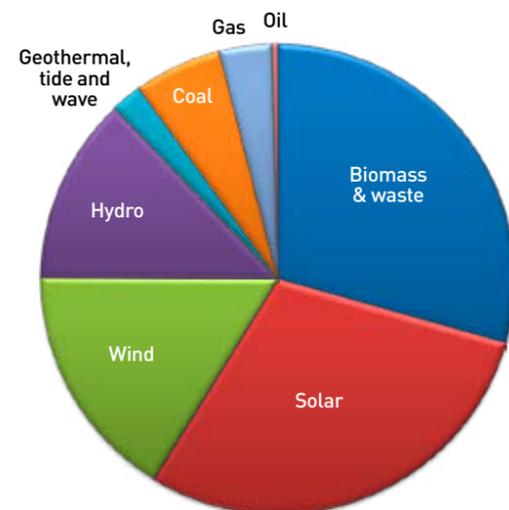
CREATING A SUSTAINABLE ENERGY SUPPLY



■ Fossil energy currently accounts for 80 percent of world energy use, and energy use is responsible for 60 percent of global greenhouse gas emissions. Energy security is a key national policy goal for both rich and poor countries, and the reserves of cheap, fossil energy are both vast and widely distributed. This leads the IEA to predict that fossil fuels will play an even bigger role in 2050 than today. That is, of course, if business is allowed to proceed as usual.

Immediate action to make energy supply more sustainable is needed. This means generating power from renewable instead of fossil energy resources, increasing power generation efficiency, and shifting to clean energy carriers, such as electricity, hydrogen and liquid biofuels.

In the Bellona Scenario, power will in 2050 be supplied as shown in the pie chart.



GLOBAL POWER SUPPLY IN 2050

GENERATE POWER MORE EFFICIENTLY

■ There is a great potential for improving energy efficiency in the power sector. On average, existing coal-fired power plants convert only 37 percent of the energy in its fuels to useful energy – the rest is lost as heat. For gas-fired power plants, the current average is 50 percent. By 2050, a global implementation of state-of-the-art power plants could increase these figures to 50 and 63 percent respectively. For biomass power plants, which play a prominent role in our 2050 scenario, average efficiency is expected to increase from 26 today to 40 percent in 2050.

REPLACE FOSSIL POWER WITH CLEAN, RENEWABLE POWER

■ Renewable energy resources - such as sunlight, wind, water, biomass and geothermal energy - are naturally replenished. While the technical potential for renewable energy is close to limitless, our ability to transform this potential into usable forms of energy has historically been limited. Recent technology development has finally brought a sustainable, renewable energy system within reach, both from a technical and economic perspective. The transition will, however, take time.

In our ambitious scenario, 90 percent of power generation in 2050 will be based on renewable resources, of which bio, wind and solar power will be the most important.

CLEAN UP FOSSIL ENERGY: CARBON CAPTURE AND STORAGE

■ While a renewable energy system is the ultimate goal, we do not expect this is to be fully achievable by 2050. From a climate perspective, however, there is hope: Fossil energy can be made close to climate neutral by means of carbon capture and storage (CCS). Here, fossil CO₂ is captured from power plants and transported through pipelines to safe geological storage sites. CCS can also be implemented at large industrial plants.

In the Bellona Scenario, carbon capture and storage is implemented at all remaining fossil energy power plants by 2050.

GENERATE CARBON NEGATIVE POWER

■ Carbon capture and storage can also be used to generate power with a net negative climate impact. In such a carbon negative process, CO₂ is first absorbed from the atmosphere through the production of modern biomass, such as algae. This production will be limited to non-agricultural land so as to not compete with food and feed production. The resulting biomass is then used to generate power in modern power plants fitted with carbon capture and storage, hence achieving a net negative emission.

Carbon negative power is already being implemented at some locations, and given an adequate development and demonstration effort, a large emission reduction from carbon negative power is feasible by 2050. In the Bellona Scenario, carbon negative power makes power generation a net negative emitter.

PHASE OUT NUCLEAR ENERGY

■ Nuclear power production does not lead to any direct greenhouse gas emissions, and substituting fossil fuelled power plants with nuclear power has been suggested as a solution to global warming. However, serious problems with nuclear power exist, such as nuclear waste handling, the risk of nuclear accidents, and proliferation of nuclear weapons.

Until these significant problems are solved, using nuclear power as a solution to combat global warming would be to fight one problem by creating another. In our scenario, nuclear energy is therefore phased out completely by 2050.

CUTTING EMISSIONS IN ALL SECTORS



START USING CLEAN CARS, TRUCKS, PLANES, SHIPS AND TRAINS

- Transportation currently accounts for about 13 percent of greenhouse gas emissions, and most business as usual scenarios project a doubling of transport emissions towards 2050. This need not be; a transport system with near-to-zero emissions is technically possible. Key components are improved energy efficiency and switching to climate neutral energy carriers. Hence, in our 2050 scenario,
 - 75 percent of road transport is carried out by electric vehicles, the remainder runs on biofuels and fossil fuels,
 - all aircraft run on biofuels, and
 - 1/4 of all ships run on hydrogen fuel cells, 1/4 on biofuels and 1/2 on fossil fuels.

INCREASE INDUSTRIAL EFFICIENCY

- Industry currently accounts for about 12 percent of global greenhouse gas emissions and uses about half of the electricity generated. Most important in terms of greenhouse gas emissions are the chemicals, cement, and steel industries. Increased energy efficiency is an important measure to reduce industrial greenhouse gas emissions. For example, state-of-the-art motor systems could reduce industrial electricity demand by 12 percent. Large emission reductions can also be achieved by improving manufacturing processes and increasing recycling.
 - In our scenario, industry emissions are reduced by almost 40 percent compared to the 2050 business as usual projection.

USE ENERGY SMARTER IN BUILDINGS

- The dominant greenhouse gas emission from residential and commercial buildings is energy-related CO₂. The most important ways to reduce emissions are to reduce primary energy demand by improving energy efficiency and to replace fossil heating with renewable heating. In the Bellona Scenario, renewable energy and a range of energy-efficient technologies cut greenhouse gas emissions from buildings by about half.

PRODUCE FOOD WITH LESS CLIMATE IMPACT

- Agriculture currently accounts for 13.5 percent of greenhouse gas emissions, of which methane from livestock and manure and nitrous oxide from agricultural soils make up the lion's share. While there are no technical 'quick fixes' to reduce agricultural emissions, improved agricultural practices, such as restoring cultivated organic soils and improving cropland management, can enable a 30 percent emission reduction compared to business as usual in 2050.

PRESERVE FORESTS AS NATURAL SINKS OF CO₂

- As growing vegetation binds large amounts of CO₂, cutting down forests and letting grasslands turn into deserts (commonly co-termed 'land-use change') has a negative climate effect. While land-use change currently leads to a higher atmospheric concentration of CO₂, intelligent land management, reforestation, and measures to stop the deforestation of rainforests can make land-use change a net absorber of CO₂ by 2050.

DISPOSE OF WASTE WITHOUT WASTING THE CLIMATE

- Waste water and landfills produce about 3 percent of global greenhouse gas emissions, in the form of methane and nitrous dioxide. Through a global adoption of readily available technologies, such as land-fill and sewage gas recovery, emissions can be reduced by more than 90 percent in 2050 compared to business as usual.

LIVE SMARTER TO REDUCE CLIMATE IMPACT

- Increased climate awareness and higher prices on emission-intensive products and services will encourage people to change their daily lives to reduce ecological impact. For instance, they will travel more by public transport, eat food with a lower carbon footprint, and lower indoor temperature. While such a lifestyle change clearly would reduce emissions significantly, calculating an accurate figure for 2050 is extremely complex. In our scenario, the emission reduction from lifestyle change is probably modest.
 - In addition to direct emission reductions, more ecologically aware voters and consumers will put pressure on politicians and business leaders alike to ensure that the technologies with the lowest possible carbon footprint are deployed.

THE WAY FORWARD

The Bellona Scenario shows that the solutions necessary to tackle global warming are available today. Courageous political leadership is key to implementing the scenario.

When world leaders gather at the United Nations Climate Change Conference in Copenhagen in December 2009, they need to develop a global policy framework that features:

01

A pledge to reduce emissions by 85 percent by 2050, and a plan for how to achieve it. This essentially means setting a global cap on emissions and a schedule for tightening it.

02

A radical increase in public funding for developing and demonstrating new climate-friendly technologies. While the needed technologies already exist, substantial efforts are needed to reduce costs and speed their implementation at large scale.

03

A change of market conditions to make it financially attractive to protect the climate. In essence, this means giving climate-friendly technologies an advantage by putting a price on emissions and making the polluter pay.

THE BEST WAY TO PREDICT THE FUTURE IS TO INVENT IT.

— ALAN KAY

ABOUT THIS PUBLICATION

This publication is the executive summary of a report with the same name. The report has been prepared by Bellona for the Climate Conference 08: Technology and Finance in Climate Cooperation, jointly hosted in June 2008 by The Bellona Foundation, The Club of Madrid and the utility company Hafslund ASA.



The full report is available online at:
www.bellona.org/reports_section.

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FROM POLLUTION TO SOLUTION: ABOUT THE BELLONA FOUNDATION

The Bellona Foundation is an international environmental NGO based in Norway. Founded in 1986 as a direct action protest group, Bellona has become a recognised technology and solutions-oriented organisation with offices in Oslo, Brussels, Washington DC, St. Petersburg and Murmansk. Altogether, some 60 engineers, ecologists, nuclear physicists, economists, lawyers, political scientists and journalists work at Bellona.

Bellona endeavours to identify and implement sustainable solutions to the world's most pressing environmental problems. These include the fight against global warming, the environmental impact of the oil and gas industry in Europe and Russia, and the cleanup after the legacy of the Cold War in Russia.

In all of its pursuits, Bellona understands that it is important to cooperate with scientific, business and political leaders to find more ecologically sound methods of operation. Bellona strongly believes that through such cooperation, new solutions to environmental problems can be found and implemented.

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