Executive Summary

The Energy [R]evolution Scenario has became a well known and well respected energy analysis since it was first published for Europe in 2005. This is the fourth Global Energy [R]evolution scenario; earlier editions were published in 2007, 2008 and 2010.

The Energy [R]evolution 2012 provides a consistent fundamental pathway for how to protect our climate: getting the world from where we are now to where we need to be by phasing out fossil fuels and cutting CO_2 emissions while ensuring energy security.

The evolution of the scenarios has included a detailed employment analysis in 2010, and now this edition expands the research further to incorporate new demand and transport projections, new constraints for the oil and gas pathways and techno-economic aspects of renewable heating systems. While the 2010 edition had two scenarios – a basic and an advanced Energy [R]evolution, this edition puts forward only one; based on the previous 'advanced' case.

The fossil fuel dilemma

Raising energy demand is putting pressure on fossil fuel supply and now pushing oil exploration towards "unconventional" oil resources. Remote and sensitive environments such as the Arctic are under threat from increased drilling, while the environmentally destructive tar sands projects in Canada are being pursued to extract more marginal sources. However, scarcity of conventional oil is not the most pressing reason to phase-out fossil fuels: cutting back dramatically is essential to save the climate of our planet. Switching from fossil fuels to renewables also offers substantial benefits such as independence from world market fossil fuel prices and the creation of millions of new green jobs. It can also provide energy to the two billion people currently without access to energy services. The Energy [R]evolution 2012 took a closer look at the measures required to phase-out oil faster in order to save the Arctic from oil exploration, avoid dangerous deep sea drilling projects and to leave oil shale in the ground.

Climate change threats

The threat of climate change, caused by rising global temperatures, is the most significant environmental challenge facing the world at the beginning of the 21st century. It has major implications for the world's social and economic stability, its natural resources and in particular, the way we produce our energy.

In order to avoid the most catastrophic impacts of climate change, the global temperature increase must be kept as far below 2℃ as possible. This is still possible, but time is running out. To stay within this limit, global greenhouse gas emissions will need to peak by 2015 and decline rapidly after that, reaching as close to zero as possible by the middle of the 21st century. The main greenhouse gas is carbon dioxide (CO_2) produced by using fossil fuels for energy and transport. Keeping the global temperature increase to 2℃ is often referred to as a 'safe level' of warming, but this does not reflect the reality of the latest science. This shows that a warming of 2℃ above pre-industrial levels would pose unacceptable risks to many of the world's key natural and human systems[1]. Even with a 1.5℃ warming, increases in drought, heat waves and floods, along with other adverse impacts such as increased water stress for up to 1.7 billion people, wildfire frequency and flood risks, are projected in many regions. Neither does staying below 2℃ rule out large-scale disasters such as melting ice sheets. Partial de-glaciation of the Greenland ice sheet, and possibly the West Antarctic ice sheet, could even occur from additional warming within a range of 0.8 – 3.8℃ above current levels[2]. If rising temperatures are to be kept within acceptable limits then we need to significantly reduce our greenhouse gas emissions. This makes both environmental and economic sense.

Global negotiation

Recognising the global threats of climate change, the signatories to the 1992 UN Framework Convention on Climate Change (UNFCCC) agreed to the Kyoto Protocol in 1997. The Protocol entered into force in early 2005 and its 193 members meet continuously to negotiate further refinement and development of the agreement. Only one major industrialised nation, the United States, has not ratified the protocol. In 2011, Canada announced its intention to withdraw from the protocol. In Copenhagen in 2009, the members of the UNFCCC were not able to deliver a new climate change agreement towards ambitious and fair emission reductions. At the 2012 Conference of the Parties in Durban, there was agreement to reach a new agreement by 2015 and to adopt a second commitment period at the end of 2012. However, the United Nations Environment Program's examination of the climate action pledges for 2020 shows a major gap between what the science demands to curb climate change and what the countries plan to do. The proposed mitigation pledges put forward by governments are likely to allow global warming to at least 2.5 to 5 degrees temperature increase above pre-industrial levels.[3]

The nuclear issue

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1 W. L. Hare. A Safe Landing for the Climate. State of the World. Worldwatch Institute. 2009.

2 Joel B. Smith, Stephen H. Schneider, Michael Oppenheimer, Gary W. Yohe, William Hare, Michael D. Mastrandrea, Anand Patwardhan, Ian Burton, Jan Corfee-Morlot, Chris H. D. Magadza, Hans-Martin Füssel, A. Barrie Pittock, Atiq Rahman, Avelino Suarez, and Jean-Pascal van Ypersele: *Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) "reasons for concern".* Proceedings of the National Academy of Sciences. Published online before print February 26, 2009, doi: 10.1073/pnas.0812355106. The article is freely available at:http://www.pnas.org/content/early/2009/02/25/0812355106.full.pdf. A copy of the graph can be found on Appendix 1.

3 United Nations Environment Programme (UNEP): 'Bridging the emissions gap'. A UNEP Synthesis Report, Nov. 2011

The nuclear industry promises that nuclear energy can contribute to both climate protection and energy security, however their claims are not supported by data. The most recent Energy Technology Perspectives report published by the International Energy Agency[6] includes a Blue Map scenario including a quadrupling of nuclear capacity between now and 2050. To achieve this, the report says that on average 32 large reactors (1,000 MWe each) would have to be built every year from now until 2050. According to the IEA's own scenario, such massive nuclear expansion would cut carbon emissions by less than 5%. More realistic analysis shows the past development history of nuclear power and the global production capacity make such expansion extremely unviable. Japan's major nuclear accident at Fukushima in March 2011 following a tsunami came 25 years after the disastrous explosion in the Chernobyl nuclear power plant in former Soviet Union, illustrating the inherent risks of nuclear energy. Nuclear energy is simply unsafe, expensive, has continuing waste disposal problems and can not reduce emissions by a large enough amount.

Climate change and security of supply

Security of supply – both for access to supplies and financial stability – is now at the top of the energy policy agenda. Recent rapidly fluctuating oil prices are lined to a combination of many events, however one reason for these price fluctuations is that supplies of all proven resources of fossil fuels are becoming scarcer and more expensive to produce. Some 'non-conventional' resources such as shale oil have become economic, with devastating consequences for the local environment. The days of 'cheap oil and gas' are coming to an end. Uranium, the fuel for nuclear power, is also a finite resource. By contrast, the reserves of renewable energy that are technically accessible globally are large enough to provide more than 40 times more energy than the world currently consumes, forever, according to the latest IPCC Special report Renewables (SRREN). Renewable energy technologies are at different levels of technical and economic maturity, but a variety of sources offer increasingly attractive options. Cost reductions in just the past two years have changed the economic of renewables fundamentally, especially wind and solar photovoltaics. The common feature of all renewable energy sources, the wind, sun, earth's crust, and ocean is that they produce little or no greenhouse gases and are a virtually inexhaustible 'fuel'. Some technologies are already competitive; the solar and the wind industry have maintained double digit growth rates over 10 years now, leading to faster technology deployment world wide.

Energy efficiency is a sleeping giant – offering the most cost competitive way to reform the energy sector. There is enormous potential for reducing our consumption of energy, while providing the same level of energy services. New business models to implement energy efficiency must be developed and must get more political support. This study details a series of energy efficiency measures which can substantially reduce demand across industry, homes, business and services as well as transport.

The Energy [R]evolution key principles

The expert consensus is that this fundamental shift in the way we consume and generate energy must begin immediately and be well underway within the next ten years in order to avert the worst impacts of climate change.[4] The scale of the challenge requires a complete transformation of the way we produce, consume and distribute energy, while maintaining economic growth. The five key principles behind this Energy [R]evolution will be to:

- Implement renewable solutions, especially through decentralised energy systems and grid expansions
- Respect the natural limits of the environment
- Phase out dirty, unsustainable energy sources
- Create greater equity in the use of resources
- Decouple economic growth from the consumption of fossil fuels

Decentralised energy systems, where power and heat are produced close to the point of final use reduce grid loads and energy losses in distribution. Investments in 'climate infrastructure' such as smart interactive grids and transmission grids to transport large quantities of offshore wind and concentrating solar power are essential. Building up clusters of renewable micro grids, especially for people living in remote areas, will be a central tool in providing sustainable electricity to the almost two billion people around who currently don't have access to electricity.

Projections to reality

Projection of global installed wind power capacity at the end of 2010 in the first Global Energy [R]evolution, published in January 2007.	>> 156 GW
Actual global installed renewable capacity at the end of 2010	>> 197 GW

While at the end of 2011 already 237 GW have been installed.

More needs to be done.

[4] IPCC – Special Report Renewables, Chapter 1, May 2011

The Energy [R]evolution – key results

Renewable energy sources account for 13.5% of the world's primary energy demand in 2009. The main source is biomass, which is mostly used in the heat sector.

For electricity generation renewables contribute about 19.3% and for heat supply, around 25%, much of this is from traditional uses such as firewood. About 81% of the primary energy supply today still comes from fossil fuels and 5.5% from nuclear energy.

The Energy [R]evolution scenario describes development pathways to a sustainable energy supply, achieving the urgently needed CO_2 reduction target and a nuclear phase-out, without unconventional oil resources. The results of the Energy [R]evolution scenario which will be achieved through the following measures:

- **Curbing global energy demand:** The world's energy demand is projected by combining population development, GDP growth and energy intensity. Under the Reference scenario, total primary energy demand increases by 61% from about 500 EJ (Exajoules) per year in 2009 to 806 EJ per year in 2050. In the Energy [R]evolution scenario, demand increases by only 10% compared to current consumption until 2020 and decreases slightly afterwards to 2009 levels.
- **Controlling global power demand:** Under the Energy [R]evolution scenario, electricity demand is expected to increase disproportionately, the main growth in households and services. With adequate efficiency measures, however, a higher increase can be avoided, leading to electricity demand of around 41,000 TWh/a in 2050. Compared to the Reference scenario, efficiency measures avoid the generation of 12.800 TWh/a.
- **Reducing global heating demand:** Efficiency gains in the heat supply sector are even larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can eventually be reduced significantly. Compared to the Reference scenario, consumption equivalent to 46,500 PJ/a is avoided through efficiency measures by 2050. The lower demand can be achieved by energy-related renovation of the existing stock of residential buildings, introduction of low energy standards; even 'energy-plus-houses' for new buildings, so people can enjoy the same comfort and energy services.
- **Development of global industry energy demand:** The energy demand in the industry sector will grow in both scenarios. While the economic growth rates in the Reference and the Energy [R]evolution scenario are identical, the growth of the overall energy demand is different due to a faster increase of the energy intensity in the alternative case. Decoupling economic growth with the energy demand is key to reach a sustainable energy supply by 2050, the Energy [R]evolution scenario saves 40% less energy per $ GDP than the Reference case.

- **Electricity generation:** A dynamically growing renewable energy market compensates for phasing out nuclear energy and fewer fossil fuel-fired power plants. By 2050, 94% of the electricity produced worldwide will come from renewable energy sources. 'New' renewables – mainly wind, PV and geothermal energy – will contribute 60% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 37% already by 2020 and 61% by 2030. The installed capacity of renewables will reach almost 7,400 GW in 2030 and 15,100 GW by 2050.
- **Future costs of electricity generation:** Under the Energy [R]evolution scenario the costs of electricity generation increase slightly compared to the Reference scenario. This difference will be on average less than 0.6 US$ cent/kWh up to 2020. However, if fossil fuel prices go any higher than the model assumes, this gap will decrease. Electricity generation costs will become economically favourable under the Energy [R]evolution scenario by 2025 and by 2050, costs will be significantly lower: about 8 US$ cents/kWh – or 45% below those in the Reference version
- **the future electricity bill:** Under the Reference scenario, the unchecked growth in demand, results in total electricity supply costs rising from today's US$ 2,364 billion per year to more than US$ 8,830 billion in 2050. The Energy [R]evolution scenario helps to stabilise energy costs, increasing energy efficiency and shifting to renewable energy supply means long term costs for electricity supply are 22% lower in 2050 than in the Reference scenario (including estimated costs for efficiency measures).
- **Future investment in power generation:** The overall global level of investment required in new power plants up to 2020 will be in the region of US$ 11.5 trillion in the Reference case and US$ 20.1 trillion in the Energy [R]evolution. The need to replace the ageing fleet of power plants in OECD countries and to install new power plants in developing countries will be the major investment drivers. Depending on the local resources, renewable energy resources (for example wind in a high wind area) can produce electricity at the same cost levels as coal or gas power plants. Solar photovoltaic already reach 'grid parity' in many industrialised countries. For the Energy [R]evolution scenario until 2050 to become reality would require about US$ 50,400 billion in investment in the power sector (including investments for replacement after the economic lifetime of the plants). Under the Reference scenario, total investment would be split 48% to 52% between conventional power plants and renewable energy plus cogeneration (CHP) up to 2050. Under the Energy [R]evolution scenario 95% of global investment would be in renewables and cogeneration. Up to 2030, the power sector investment that does go to fossil fuels would be focused mainly on cogeneration plants. The average annual investment in the power sector under the Energy [R]evolution scenario from today to 2050 would be US$ 1,260 billion, compared to US$ 555 billion in the Reference case.
- **Fuel costs savings:** Because renewable energy, except biomass, has no fuel costs, the fuel cost savings in the Energy [R]evolution scenario reach a total of US$ 52,800 billion up to 2050, or US$ 1320 billion per year. The total fuel cost savings therefore would cover more than two times the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

- **Heating supply**: Renewables currently provide 25% of the global energy demand for heat supply, the main contribution coming from the use of biomass. In the Energy [R]evolution scenario, renewables provide more than

50% of the world's total heat demand in 2030 and more than 90% in 2050. Energy efficiency measures can decrease the current demand for heat supply by 10 %, and still support improving living standards of a growing population.

- **Future investments in the heat sector:** The heat sector in the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. In particular enormous increases in installations are required to realise the potential of the not yet common solar and geothermal technologies and heat pumps. Installed capacity needs to increase by a factor of 60 for solar thermal and by a factor of over 3000 for geothermal and heat pumps. Because the level of technological complexity in this sector is extremely variable, the Energy [R]evolution scenario can only be roughly calculated, to require around US$ 27 trillion investment in renewable heating technologies up to 2050. This includes investments for replacement after the economic lifetime of the plant and is approximately US$ 670 billion per year.

- **Future employment in the energy sector:** The Energy [R]evolution scenario results in more global energy sector jobs at every stage of the projection.
    - There are 23.3 million energy sector jobs in the Energy [R]evolution in 2015, and 18.7 million in the Reference scenario.
    - In 2020, there are 22.6 million jobs in the Energy [R]evolution scenario, and 17.8 million in the Reference scenario.
    - In 2030, there are 18.3 million jobs in the Energy [R]evolution scenario and 15.7 million in the Reference scenario.

  There is a change in job numbers under all scenarios for each technology between 2010 and 2030. Jobs in the coal sector decline in both scenarios, leading to a small decline in overall energy jobs in the Reference scenario. Strong growth in the renewable sector leads to an increase of 4% in total energy sector jobs in the Energy [R]evolution scenario by 2015. Renewable energy accounts for 65% of energy jobs by 2030, spread quite evenly over wind, solar PV, solar heating, and biomass.

- **Global transport:** In the transport sector it is assumed that, energy consumption will continue to increase under the Energy [R]evolution scenario up to 2020 due to fast growing demand for services. After that it falls back to the level of the current demand by 2050. Compared to the Reference scenario, transport energy demand is reduced overall by 60% or about 90,000 PJ/a by 2050. Energy demand for transport under the Energy [R]evolution scenario will therefore increase between 2009 and 2050 by only 26% to about 60,500 PJ/a. Significant savings are made from a shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains – together with reducing vehicle kilometres travelled per year. In 2030, electricity will provide 12% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 44%.

- **Primary energy consumption:** Under the Energy [R]evolution scenario the overall primary energy demand will be reduced by 40% in 2050 compared to the Reference scenario. In this projection almost the entire global electricity supply, including the majority of the energy used in buildings and industry, would come from renewable energy sources. The transport sector, in particular aviation and shipping, would be the last sector to become fossil fuel free.

- **Development of CO_2 emissions:** Worldwide CO_2 emissions in the Reference case will increase by 62% while under the Energy [R]evolution scenario they will decrease from 27,925 million tons in 2009 to 3,076 million t in 2050. Annual per capita emissions will drop from 4.1 t CO2 to 2.4 t CO2 in 2030 and 0.3 t CO2 in 2050. Even with a phase out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long term, efficiency gains and greater use of renewable electricity for vehicles will also reduce emissions in the transport sector. With a share of 33% of CO_2 emissions in 2050, the transport sector will be the main source of emissions ahead of the industry and power generation. By 2050 the Global Energy related CO_2 emissions are 85% under 1990 levels.

Policy changes

To make the Energy [R]evolution real and to avoid dangerous climate change, Greenpeace, GWEC and EREC demand that the following policies and actions are implemented in the energy sector:

1. Phase out all subsidies for fossil fuels and nuclear energy.
2. Internalise the external (social and environmental) costs of energy production through 'cap and trade' emissions trading.
3. Mandate strict efficiency standards for all energy consuming appliances, buildings and vehicles.
4. Establish legally binding targets for renewable energy and combined heat and power generation.
5. Reform the electricity markets by guaranteeing priority access to the grid for renewable power generators.
6. Provide defined and stable returns for investors, for example by feed-in tariff programmes.
7. Implement better labelling and disclosure mechanisms to provide more environmental product information.
8. Increase research and development budgets for renewable energy and energy efficiency.