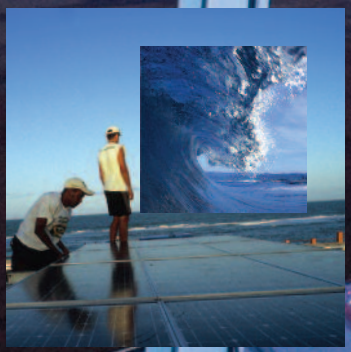
energy [r]evolution

EU ENERGY ROADMAPS COMPARED



GREENPEACE

the greenpeace/erec eu energy [r]evolution assessed alongside other european 2050 energy scenarios

"THE CHALLENGE IS TO FIND THE RIGHT MIX OF ENERGY SAVINGS AND TRULY SUSTAINABLE ENERGY TECHNOLOGIES"

image PHOTOVOLTAIC PANELS ON A ROOF.

Does the Energy [R]evolution path to a 100% renewable energy future measure up to other EU energy roadmaps? This study identifies specific differences between the Energy [R]evolution report 2010 and other recently published EU energy roadmaps.

The comparison includes the following studies:[1]

- **international energy agency (IEA):** World Energy Outlook 2009, 2009: 450ppm scenario
- **greenpeace/european renewable energy council (EREC):** Energy [R]evolution for the EU 27, 2010: advanced Energy [R]evolution scenario (E[R])
- **friends of the earth europe (FoEE)/SEI:** Europe's Share of the Climate Change, 2009: 100% renewable energy (RES) scenario
- **european climate foundation (ECF)/mckinsey:** 2050 Roadmap, 2010: 80% RE scenario
- **eurelectric (Eur):** Power Choices, 2010: Power Choices scenario

summary

The Energy [R]evolution holds its own when compared to other published EU energy scenarios. Its scenario is based on conservative assumptions, a realistic potential assessment and an ambitious political framework to show Europe the road to a clean and robust energy economy by 2050.

the main characteristics of the e[r]

The Energy [R]evolution employs renewable energy sources and energy efficiency measures to reduce greenhouse gas emissions, while phasing out nuclear power and eventually replacing fossil fuels.

the main differences between the e[r] compared to:

FoEE's 100% RES scenario: Under this scenario, emission reductions are comparable to the ones in the E[R], but the means to get there are different: the FoEE scenario includes even more ambitious energy efficiency measures and a slower phase out of nuclear power.

ECF's 80% RES scenario: The ECF assumes very limited energy efficiency measures. The scenario includes very large renewable energy capacities as well as fossil fuelled and nuclear power plants. At the same time, the full load hours of fossil power stations are projected to increase over the next decades. This assumption appears unrealistic, since an energy system with high quantities of renewables would not require an additional constant, high and centralised energy production (base load production) from fossil fuel or nuclear plants.

Eurelectric's power choices: The Power Choices scenario traces a roadmap for emission reductions driven solely by carbon prices. The emission reduction target of at least 80% is not reached under the Power Choices scenario, in spite of a CO_2 price projected to exceed 100 €/t. The E[R] illustrates that an additional political framework is needed to support a truly sustainable energy pathway.

footnotes

1 FOR ALL REPORTS, THE ENERGY SCENARIO WITH THE HIGHEST SHARE OF RENEWABLE ENERGY WAS TAKEN INTO ACCOUNT. THE EUROPEAN CLIMATE FOUNDATION'S 100% RENEWABLE ENERGY SCENARIO WAS EXCLUDED DUE TO MISSING DATA.

image WELDER WORKING AT VESTAS WIND TURBINE FACTORY, CAMPBELLTOWN, SCOTLAND.

primary energy demand & efficiency

analysis of individual scenarios

All scenarios are largely based on the same reference scenario, which is the IEA-WEO Reference scenario: 2020: 72,000 PJ, 2030: 75,000 PJ.

In all lower-emission scenarios, one can observe a general reduction in fossil fuel use in favour of an increased use of renewable energy sources (RES) and energy efficiency.

- IEA-WEO-450ppm: little use of energy efficiency (2030: -6% in energy use; presented as "avoided vs. REF" in graphs), focus on nuclear and fossil resources (partly combined with CCS); renewable energy share[2] in 2030: 25%.
- E[R]: balanced efficiency measures (2050: -40%), and high RES share (2050: 80%); phase-out of nuclear power by 2040 and fossil fuels after 2050.
- FoEE: strong energy efficiency and savings (2050: -70% of primary energy use), limiting fossil fuel use and causing a high renewable energy share (2050: 70%); phase out of nuclear by 2050.

comparison of all scenarios

- The E[R] assumes ambitious but realistic energy efficiency measures that are less ambitious than FoEE's assumptions, but by far more ambitious than the ones in the IEA's 450ppm scenario (energy savings compared to the Reference scenarios: IEA < E[R] < FoEE).
- The E[R] describes a faster nuclear phase out than FoEE, whereas the IEA, ECF and Eurelectric keep nuclear in (IEA assumes increasing use of uranium).
- The E[R] uses RES as main primary energy sources (RES share: IEA < FoEE < E[R]). At the same time, the absolute need for fossil fuels is smallest in the FoEE scenario, with 5,600 PJ vs. 6,800 PJ in the E[R].
- FoEE excludes the use of biofuels, whereas the E[R] assumes a limited use of biomass in all sectors, with strict sustainability criteria.

final energy demand

All scenarios show a strong shift from the direct use of fossil fuels (gas, oil) towards the use of electricity in the transport and heating sector. The total amount of electricity does not massively increase due to energy efficiency and savings measures. The E[R] reaches a renewable energy share of 92%.

figure 1: primary energy demand by scenario

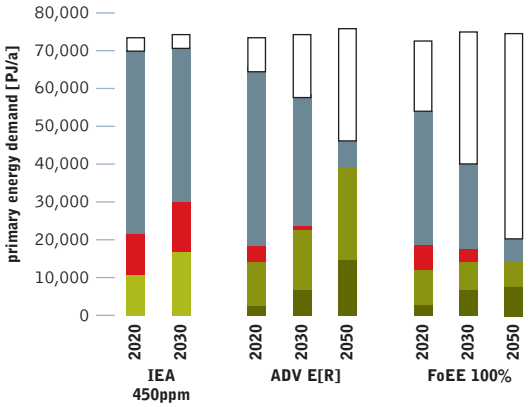


figure 2: primary energy demand by year

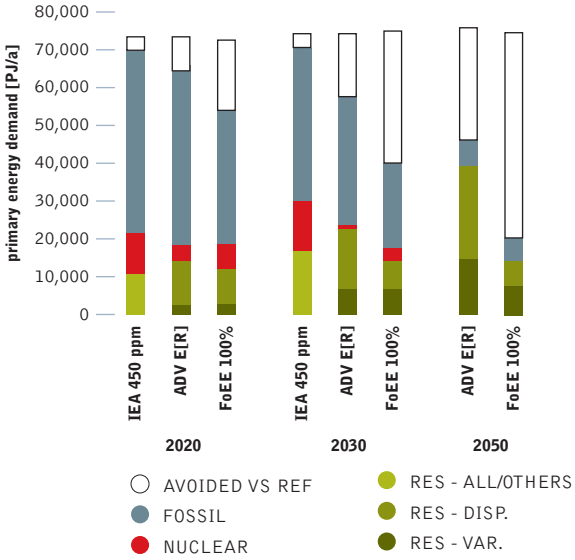
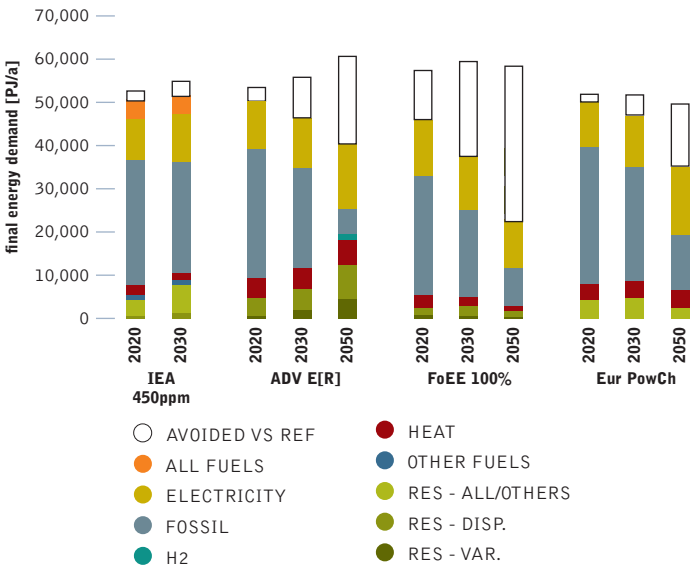


figure 3: final energy demand



footnotes
2 DIFFERENT METHODS OF CALCULATING THE PRIMARY ENERGY DEMAND OF RENEWABLE ENERGY SOURCES WERE APPLIED IN THE DIFFERENT SCENARIOS.

power capacity

analysis of individual scenarios

Almost all low-emission scenarios show an increase in total installed capacity compared to their reference scenarios:

- IEA-WEO: push for additional RES capacity, while sticking to nuclear & fossil (partly CCS).
- E[R]: reaching a 98% RES share in 2050 (68% variable/30% dispatchable)[3], keeps 2% in flexible backup gas power plants in the system; replacement of fossil power plants from the Reference scenario demands a strong increase in capacity.
- FoEE: nuclear phase out around 2040, 100% RES in 2050 (72% variable/28% dispatchable).
- ECF: strongly increasing capacity due to low energy efficiency measures and despite almost constant fossil power capacities: 62% variable/18% dispatchable renewable energy sources + 13% gas + 3% coal + 3% nuclear.[4]
- Eur[5]: slightly increasing fossil fuel power, plus some additional renewable energy (share in 2050: 40% variable/14% dispatchable).

comparison of all scenarios

- Total energy capacity under the E[R] represents a near average value when measured against the complete scenario range:

- more installed capacity than the FoEE scenario, due to fewer energy efficiency measures.
- much less capacity than the ECF-80% scenario, with a comparably high renewable energy use, but additional conventional capacity.
- more renewable energy use than the Power Choices scenario.

- The renewable energy share of 97% in 2050 in the E[R] is comparable to the FoEE scenario, but much higher than in ECF and Power Choices reports.
- The share of dispatchable energy sources in the E[R] is comparable with the other scenarios.

figure 4: installed power capacity by scenario

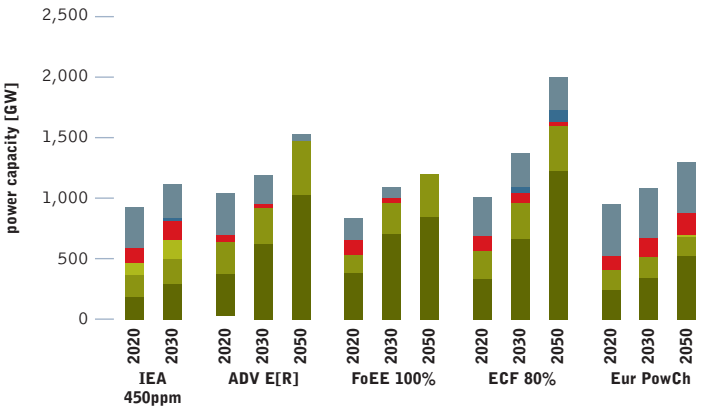
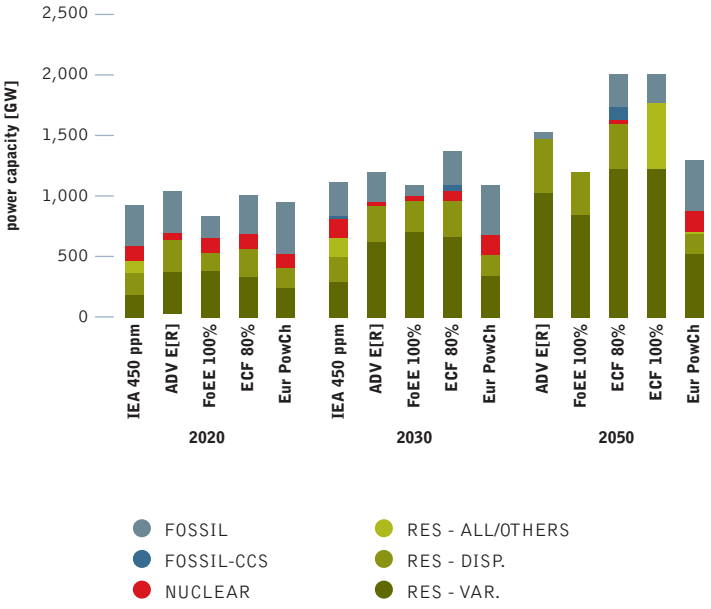


figure 5: installed power capacity by year



footnotes

3 VARIABLE RES: WIND, PHOTOVOLTAIC, WAVE AND TIDAL. DISPATCHABLE ENERGY SOURCES ARE UNDERSTOOD AS A HIGHLY FLEXIBLE, CONTINUOUSLY AVAILABLE ENERGY SOURCE THAT CAN BALANCE SHORT TERM VARIABILITY OF SUPPLY AND DEMAND. DISPATCHABLE RES: GEOTHERMAL, CONCENTRATED SOLAR THERMAL POWER, PUMPED HYDRO, BIOMASS. DISPATCHABLE FOSSIL ENERGY SOURCES: GAS TURBINES.
4 THE ECF STUDY INCLUDES NORWAY AND SWITZERLAND, BUT THE COMBINED CAPACITY OF THESE TWO COUNTRIES AMOUNTS ONLY TO 6% OF TOTAL EU IN 2007 CAPACITY.
5 THE DATA INCLUDED WAS ONLY AVAILABLE IN THE FORM OF A DIAGRAM AND IS THEREFORE AN ESTIMATE.

image NORTH HOYLE WIND FARM, UK'S FIRST WIND FARM IN THE IRISH SEA WHICH WILL SUPPLY 50,000 HOMES WITH POWER.

electricity generation mix

All low-emission scenarios assume a growing electricity use:

- The E[R] and the FoEE scenario project a nearly full renewable electricity supply by 2050 with 97% renewable energy share in the E[R] and 90% in the FoEE scenario.
- The ECF[6] only reaches an 80% renewable share, using nuclear (10%) and fossil fuels with CCS (coal: 5%, gas 5%) for the remaining 20%.
- Eurelectric's Power Choices scenario[7] only reaches a 40% renewable energy share, a 30% nuclear share and a 30% fossil fuel share (possibly with CCS).

full load hours

In contrast to the E[R], ECF and Power Choices predict an increasing number of full load hours for coal and nuclear power plants over coming decades. Even with very ambitious grid extension and demand-side-management measures that permit to balance energy supplies across regions and to adjust energy demand to the supply side, this assumption is unrealistic. A constant, high and centralised energy production from fossil fuel or nuclear plants cannot be efficiently integrated into an energy system with high quantities of renewables. At the same time, ECF expects the employment of gas power plants to drop to nearly zero, as they are used only as back-up. The assumed full load hours of geothermal plants under the ECF scenario are much higher than the average value (above 8,000 hours per year), making the envisaged 80% target very uncertain.

The full load hours of other renewable energy sources are on comparable levels to the E[R] and are mainly projected to increase.

specific investment costs & learning rates

Since renewable energy sources do not depend on fossil fuel and CO_2 prices, specific investment costs (capital expenditures = CAPEX) can be a helpful indicator for their potential deployment.Comparing the specific CAPEX for different renewable technologies shows that the ECF assumes photovoltaic prices to be about 40% higher than under the E[R] and 30%-50% higher for on-/offshore wind. Under E[R] assumptions, costs for concentrated solar thermal power (CSP) and geothermal power plants are respectively 10%-30% and 50%-100% higher. These differences can be explained by different assumptions of learning rates[8], e.g. for photovoltaics: ECF: 15% price reduction, E[R]: 20% price reduction while doubling of the total installed capacity.

figure 6: electricity generation

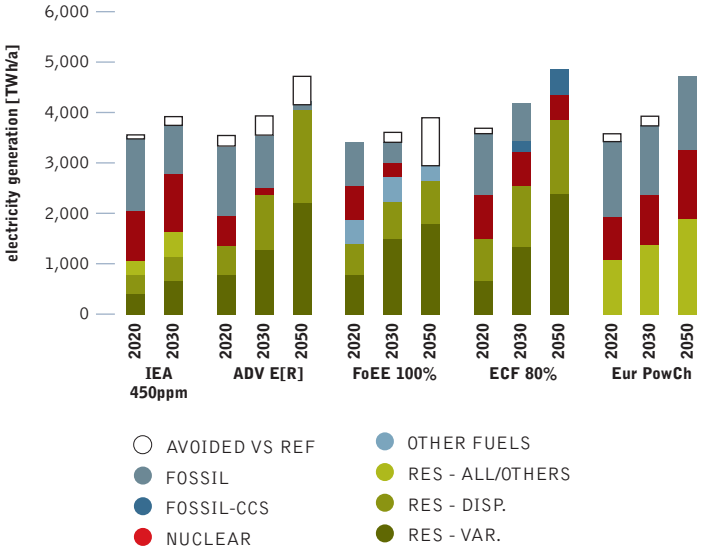


figure 7: full load hours

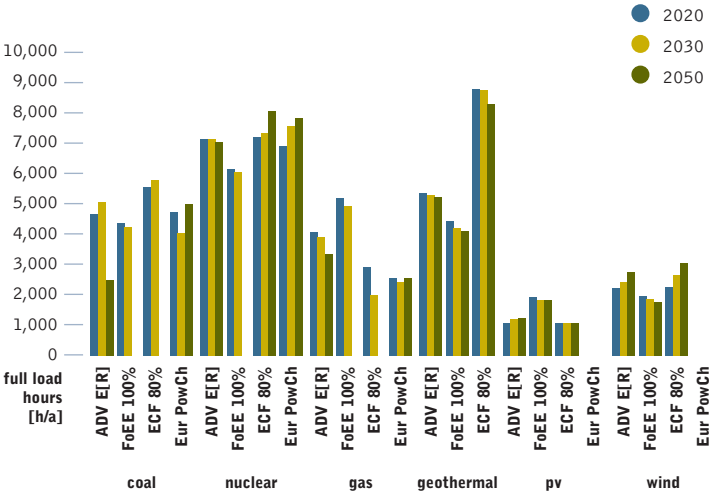
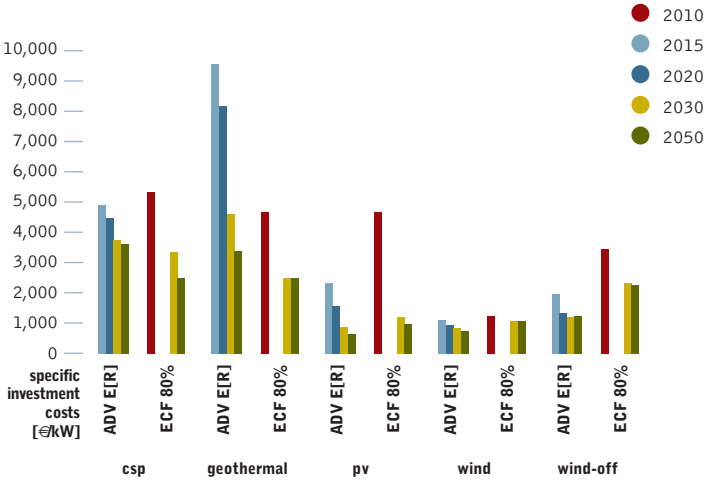


figure 8: specific investment costs (capex)



footnotes

6 INCLUDES NORWAY AND SWITZERLAND; THEIR ELECTRICITY GENERATION CORRESPONDED TO 3.5% OF THE EU 27 OVERALL AMOUNT IN 2007.

7 THE DATA INCLUDED WAS ONLY AVAILABLE IN THE FORM OF A DIAGRAM AND IS THEREFORE AN ESTIMATE.

8 LEARNING RATES ARE PRICE REDUCTION ESTIMATES. THE ESTIMATED REDUCTIONS ARE APPLIED EVERY TIME THE INSTALLED CAPACITY OF A TECHNOLOGY DOUBLES.

fuel prices

Price estimations for all scenarios (no information on FoEE and Power Choices) are based on the IEA-WEO 2009 reference scenario. Since the IEA projections only reach 2030, further assumptions have to be taken for the following years.

the main differences in fuel price assumptions:

The **oil** price in the E[R] scenario is the same as in the High Price Sensitivity Case (HPC) of the IEA-WEO, reaching 150 $/bbl in 2030 and staying at this level until 2050, due to a decreased use of oil. The ECF scenario uses the IEA Reference price of 110 $/bbl in 2030 until 2050.

The same procedure applies to **coal**: the E[R] assumes the HPC price of 143 $/t in 2030, going up to 172 $/t in 2050, whereas the ECF assumes the coal price peaking in 2030 at 109 $/t (IEA Reference price).

For **gas**, the E[R] assumes a price development which is even higher than the HCP price: 2030: 19 $/GJ, 2050: 26 $/GJ. This can be compared to the IEA-WEO reference price of about 14 $/GJ in 2013 used by the ECF, which remains constant until 2050.

The **CO_2** price varies strongly among the different scenarios, with the E[R] making the most cautious assumptions of the whole range (20 $/t in 2020, up to 50 $/t in 2050). The ECF uses the price of the IEA's 450ppm scenario for its 80%: 50 $/t in 2020 and 110 $/t from 2030 until 2050. Eurelectric's scenario lies between both, assuming a 2020 price of 25 $/t, stepping up to 103 $/t in 2050 ($CO_2$ price range in 2020/2050: E[R] < Eur < ECF).

figure 9: oil price

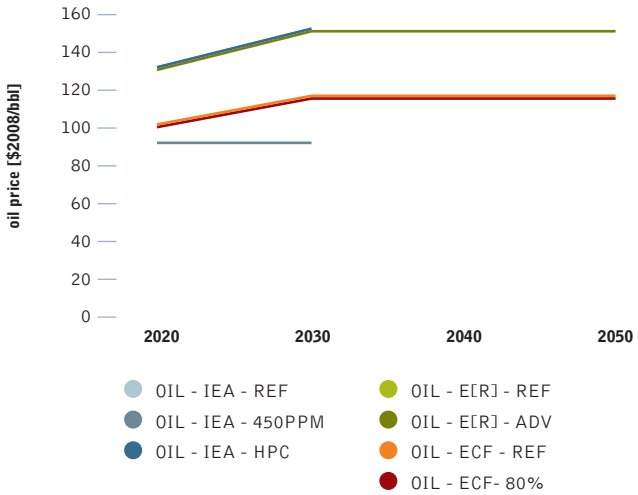


figure 10: coal price

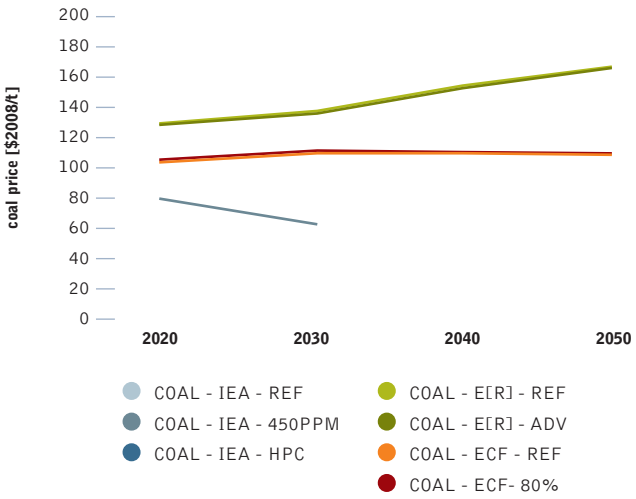


figure 11: gas price

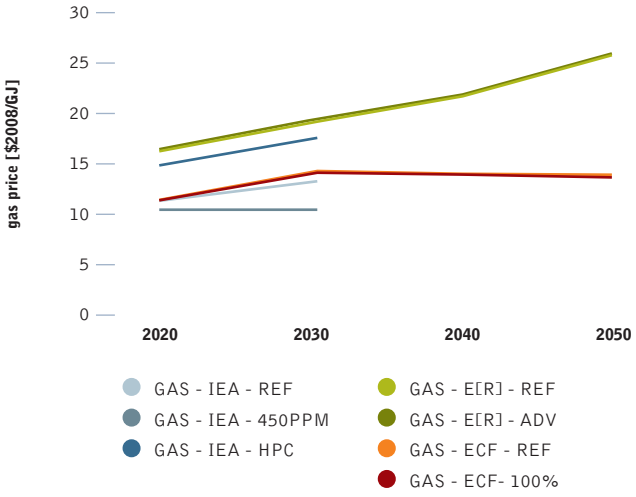
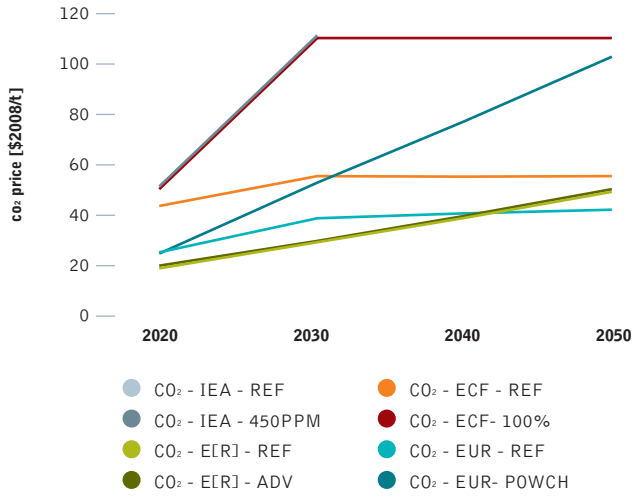


figure 12: CO_2 price



footnotes

9 THE ECF NUMBERS INCLUDE NON-CO_2 EMISSIONS. THE EXCLUSION OF THE AGRICULTURE AND FORESTRY SECTORS, WHICH ARE RELATED TO THE HIGHEST NON-CO_2 EMISSIONS, ALLOWS FOR A BETTER COMPARABILITY OF DATA IN THIS ANALYSIS.

10 OPERATIONAL COSTS UNDER THE ECF SCENARIO ACCOUNT FOR ALL NEW AND OPERATING PLANTS. THEY INCLUDE VARIABLE COSTS, FIXED COSTS, AS WELL AS FUEL COSTS. THEY ALSO INCLUDE OPEX FOR ADDITIONAL BACKUP PLANTS AND ADDITIONAL GRID DEVELOPMENT.

11 INCLUDING COSTS FOR POWER PLANTS AND COGENERATION PLANTS.

image THE BIOENERGY VILLAGE OF JUEHNDE WHICH WAS THE FIRST COMMUNITY IN GERMANY TO PRODUCE ALL ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY, WITH CO_2 NEUTRAL BIOMASS.

CO_2 emissions

All scenarios present a close to carbon neutral power sector, while CO_2 emissions from overall energy conversion processes (excluding agriculture, forestry and bunker fuels due to missing data) differ considerably.

The E[R] is the only scenario that reaches a CO_2 emission reduction of 95% compared to 1990 levels (around 4,000 Mt) in 2050, followed by the FoEE scenario (90%).

The ECF scenario[9] and the Power Choices scenario reach reductions of 80% or less.

These latter two scenarios barely reach the energy sector CO_2 emission reduction targets called for by the United Nations' Intergovernmental Panel on Climate Change (80%-95% by 2050 for developed countries). This creates a dangerous situation, since emission reductions in the non-energy sector are even more difficult to achieve.

costs

Complete cost calculations for the power supply have only been carried out by ECF and Greenpeace/EREC.

ECF's 80% renewable energy scenario requires investment in power generation assets (CAPEX) of €2,620 billion in the 2011-2050 period. Since those investments are partly used for fossil fuel power plants, fuel costs and thus operational costs (OPEX)[10] remain on a very high level of €5,700 billion over the same period, causing total costs of €8.3 trillion.

Under the Energy [R]evolution scenario, the increased deployment of renewable energy sources goes along with a strong increase of investment costs of €3,600 billion. But these are balanced by a strong decrease in fossil fuel costs of €3,300 billion. The total costs under the Energy [R]evolution scenario would be €6.9 trillion until 2050[11] - about 17% less than under the ECF scenario.

The Energy [R]evolution scenario is characterised by its ambitious but realistic deployment of energy efficiency and renewable energy sources. The scenario is the most promising driver of carbon dioxide emission reductions. The Energy [R]evolution outlines a robust and sustainable energy pathway with costs comparable or even lower than in other scenarios that include nuclear and fossil fuel technologies.

figure 13: energy related co_2 emissions

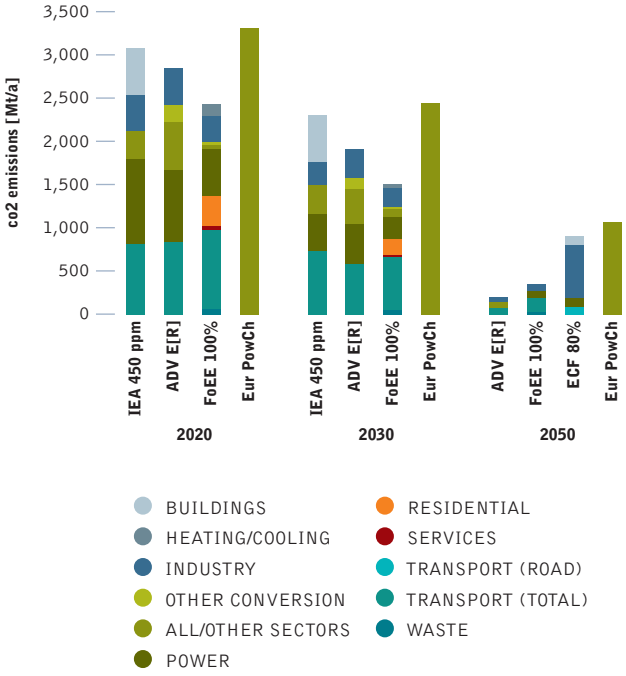
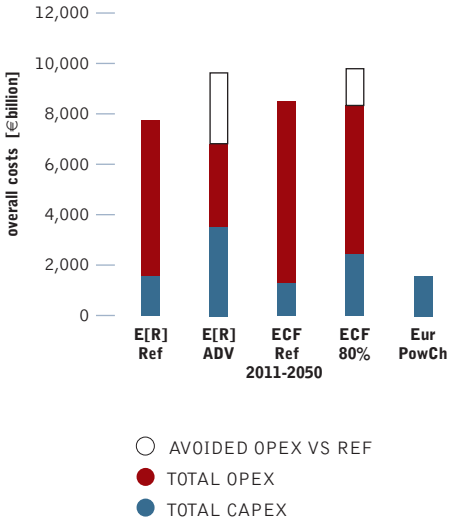


figure 14: overall system costs (CAPEX+OPEX)



energy [r]evolution

GREENPEACE

Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Africa, Asia and the Pacific. It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants.

Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area west of Alaska, where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today, and ships are an important part of all its campaign work.

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image ICE MELTING ON A BERG ON THE GREENLANDIC COAST. GREENPEACE AND AN INDEPENDENT NASA-FUNDED SCIENTIST COMPLETED MEASUREMENTS OF MELT LAKES ON THE GREENLAND ICE SHEET THAT SHOW ITS VULNERABILITY TO WARMING TEMPERATURES. **front cover images** INSTALLATION AND TESTING OF A WINDPOWER STATION IN RYSUMER NACKEN NEAR EMDEN WHICH IS MADE FOR OFFSHORE USAGE ONSHORE, © PAUL LANGROCK/ZENIT/GREENPEACE. INSTALLING PV PANELS, © GP/FLAVIO CANNALONGA. THE POWER OF THE SEA, © MCDONNELL/ISTOCK. **authors** TOBIAS BOßMANN, FRAUKE THIES **design & layout** ONEHEMISPHERE, SWEDEN, WWW.ONEHEMISPHERE.SE