INDIAN POINT UNIT 2 AND UNIT 3

Coastal Zone Management Act Consistency Certification

In support of
Renewal of Indian Point Unit 2 and Unit 3 USNRC Operating Licenses

Submitted by:

Entergy Nuclear Indian Point 2, LLC
Entergy Nuclear Indian Point 3, LLC
Entergy Nuclear Operations, Inc.

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SUPPLEMENTAL INFORMATION ON NATIONAL AND STATE INTERESTS

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LIST OF SUPPLEMENTAL ATTACHMENTS:

S-1	Alice L. Buck, A History of the Atomic Energy Commission, U.S. Department of Energy, July, 1983
S-2	Report of the Subcommittee on Research and Development on the Five-Year Power Reactor Development Program Proposed by the Atomic Energy Commission, March, 1954
S-3-1, 3-2; 3-3 and 3-4	Deed dated October 30, 1954, recorded at Liber 5392, Page 29; Deed dated December 1, 1954, recorded at Liber 5398, Page 340; Deed dated January 1, 1955, recorded at Liber 5419, Page 283; Deed dated January 31, 1955, recorded at Liber 5538, Page 404
S-4	Excerpt from Major Activities in the Atomic Energy Programs, January—December 1961, United States Atomic Energy Commission, January, 1962, at Appendix 8, *License Applications Filed and Actions Taken: Summary of License Actions.*
S-5	Excerpt from Final Environmental Statement Relating to the Operation of Indian Point Nuclear Generating Plant No. 3, United States Nuclear Regulatory Commission, February, 1975. Attachment 21 to Consistency Certification, December, 2012; excerpts included as Attachment S-5 to this Supplemental Filing.
S-6	Message of the Governor in relation to the Use of Atomic Energy for Peaceful Purposes, State of New York Legislative Document No. 46 (1959)
S-7	Act inserting Article 19-D, Atomic Energy Law, and establishing the New York Office of Atomic Development, 1959 N.Y. Sess. Law 72 (McKinney)
S-8	Deed from New York State to Consolidated Edison Company dated October 17, 1959, recorded at Liber 5973, Page 283
S-9	An Atomic Development Plan for the State of New York, A Report to Governor Nelson A. Rockefeller, New York Office of Atomic Development, December 1, 1959.
S-10	Pub. Auth. Law § 1850-a, 1962 N.Y. Sess. Law. 428 (McKinney) (c. 210).
S-11	Civilian Nuclear Power . . . a Report to the President—1962, Atomic Energy Commission, November, 1962
S-12	Energy Resources: A Report to the Committee on Natural Resources, National Academy of Sciences, National Research Council, December, 1962.

S-13	National Power Survey, Federal Power Commission, October 31, 1964.
S-14	A Report by the Federal Communications Commission on the Northeast Power Failure of November 9-10, 1965, and its Effect on Communications, Federal Communications Commission, February 23, 1966.
S-15	Certificate dated January 1, 1966, recorded at Liber 6589, Page 308.
S-16	Deed from New York State to Consolidated Edison Company dated April 21, 1966, recorded at Liber 6614, Page 70.
S-17	Dr. Glenn T. Seaborg, *A New Look at Nuclear Power* Volume 8, Number 3: 8 Atomic Energy L.J. No. 3, 191 (1966).
S-18	Oliver Townsend, *Atomic Power Development in New York State*, 8 Atomic Energy L.J. No. 3, 207, 215 (1966).
S-19	Civilian Nuclear Power—The 1967 Supplement to the 1962 Report to the President, Atomic Energy Commission, February, 1967.
S-20	Neal L. Moylan, *The Role of Power in Economic Development,* 10 Atomic Energy L.J., No. 1, (1968)
S-21	United States v. Consolidated Edison of New York, Inc., 580 F.2d 1122 (2nd Cir. 1978).
S-22	Committee on Energy and National Resources, Executive Energy Documents, Publication No. 95-114 (Comm. Print July 1978).
S-23	Deed from Consolidated Edison Company to New York State dated August 31, 1971, recorded at Liber 7006, Page 298.
S-24	Letter from Federal Power Commission (T.A. Phillips, Chief, Bureau of Power) to Atomic Energy Commission, dated May 10, 1972.
S-25	A Review of Consolidated Edison Company 1972 Summer Power Supply Problems and Twenty-Year Expansion Plans, Bureau of Power Federal Power Commission, September, 1972.
S-26	Excerpt from Final Environmental Statement Relating to the Operation of Indian Point Nuclear Generating Plant No. 2, United States Atomic Energy Commission, September, 1972. Attachment 20 to Consistency Certification; excerpts included as Attachment S-26 to this Supplemental Filing.
S-27	Legislative History of the Coastal Zone Management Act of 1972, as Amended in 1974 and 1976 With a Section-By-Section Index, U.S. Government Printing

	Office, December 1976, at 211, reprinting Senate Report No. 92-753 (1972).
S-28	Joint Committee on Atomic Energy, Understanding the "National Energy Dilemma", 99-730 (Joint Comm. Print 1973).
S-29	The Nation's Energy Future, Atomic Energy Commission, December 1, 1973.
S-30	Letter from Federal Power Commission (T.A. Phillips, Chief, Bureau of Power) to Atomic Energy Commission dated December 13, 1973.
S-31	Pub. Auth. Law § 1001-a (1974), "Emergency Provisions for the Metropolitan Area of the City of New York," N.Y. Sess. Law 1974 c. 369, 1974 N.Y. Sess. Laws 505 (McKinney).
S-32	Deed from Consolidated Edison Company to Power Authority of the State of New York, dated December 30, 1974, recorded at Liber 7306, Page 736.
S-33	Annual Report, The Power Authority of the State of New York, March 25, 1976.
S-34	Atomic Energy Commission, 1974 Annual Report to Congress, January 17, 1975.
S-35	1975 N.Y. Sess. Laws 669 (McKinney) (ch. 464).
S-36	Joint Committee on Atomic Energy, Towards Project Interdependence: Energy in the Coming Decade, (Jt. Comm. Print December, 1975.)
S-37	National Power Survey, The Adequacy of Future Electric Power Supply: Problems and Policies, Federal Power Commission, March, 1976.
S-38	Factors Affecting The Electric Power Supply: 1980-85, Federal Power Commission December 1, 1976.
S-39	Federal Power Commission, Electric System Disturbance on the Consolidated Edison Company of New York, Inc., System, (July 13-14, 1977, supplemented August 4, 1977.)
S-40	Letter of Basil A. Patterson, August 13, 1982; NYCMP II-1, at 2
S-41	Waterfront Revitalization and Coastal Resources Act of 1981, 1989 N.Y. Sess. L. 1696 (McKinney) (ch 842).
S-42	New York State Energy Master Plan, New York State Energy Planning Board, March, 1982.
S-43	New York State Assembly, The Electric Industry in New York, Sheldon

	Silver, Speaker of the Assembly, 1995.
S-44	Excerpt from PSC Cases 94-#-0952, et al., "Competitive Opportunities Regarding Electric Utilities."
S-45	Deed from Power Authority of State of New York to Entergy dated November 21, 2000, recorded at Westchester County Registry, Control Number 403340618.
S-46	National Energy Policy Report by the National Energy Policy Development Group (May, 2001)
S-47	Deed from Consolidated Edison Company to Entergy dated September 6, 2001, recorded at Westchester County Registry, Control Number 412500378.
S-48	A Roadmap to Deploy New Nuclear Power Plants in the United States by 2010, United States Department of Energy Office of Nuclear Energy, Science and Technology and its Nuclear Energy Research Advisory Committee Subcommittee of Generation IV Technology Planning (October 31, 2001)
S-49	The Future of Nuclear Power, An Interdisciplinary MIT Study, Massachusetts Institute of Technology, 2003.
S-50	White House National Economic Council, Advanced Energy Initiative, February, 2006.
S-51	Press Release, Governor Spitzer Unveils Cutting-Edge Global Warming Regulations, October 24, 2007.
S-52	Effects of Climate Change on Energy Production and Use in the United States, National Science and Technology Council, U.S. Climate Change Science Program, February 2008.
S-53	Press Release, "Governor Paterson Rings in New Era to Combat Climate Change," September 26, 2008.
S-54	Update of the MIT 2003 Future of Nuclear Power, An Interdisciplinary MIT Study, Massachusetts Institute of Technology, 2009.
S-55	U.S. Department of Energy, National Electric Transmission Congestion Study, December, 2009.
S-56	U.S. Department of Energy, Nuclear Energy Research and Development Roadmap, Report to Congress, April 2010.
S-57	President Obama, State of the Union Address, January 25, 2011.

S-58	Objective 1: Extend Life, Improve Performance, and Maintain Safety of the Current Fleet—Implementation Plan, U.S. Department of Energy, Office of Nuclear Energy, January, 2011.
S-59	Governor Cuomo 2012 State of the State Address.
S-60	Energy Security in the United States, Congressional Budget Office, May, 2012.
S-61	Mark Holt, Nuclear Energy Policy, Congressional Research Service, June 20, 2012.
S-62	Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste, U.S. Department of Energy, January, 2013.
S-63	Annual Energy Outlook 2013, Energy Information Administration, April, 2013.
S-64	Report to the President—Rebuilding America's Infrastructure: Cutting Timelines and Improving Outcomes for Federal Permitting and Review of Infrastructure Projects, The White House, May, 2013.
S-65	The President's Climate Action Plan, Executive Office of the President, June, 2013.
S-66	Restoring U.S. Leadership in Nuclear Energy—A National Security Imperative, Center for Strategic & International Studies, June, 2013
S-67	Redrawing the Energy-Climate Map, International Energy Agency, June 10, 2013.
S-68	PlaNYC: A Stronger, More Resilient New York, The City of New York and Mayor Michael R. Bloomberg, June 11, 2013.
S-69	The President, Memorandum of June 25, 2013—Power Sector Carbon Pollution Standards
S-70	U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather, U.S. Department of Energy, July 2013.
S-71	Hurricane Sandy Rebuilding Strategy, Hurricane Sandy Rebuilding Task Force, August, 2013.
S-72	Indian Point Contingency Plan, Final Generic Environmental Impact Statement (New York Public Service Commission, September, 2013)

S-73	Executive Order #13653, Preparing the United States for the Impacts of Climate Change
S-74	Excerpt from Climate Change Impacts in the United States, U.S. National Climate Assessment, U.S. Global Change Research Program, May, 2014
S-75	PlaNYC—New York City's Pathways to Deep Carbon Reductions, The City of New York, NYC Mayor's Office, December, 2013.
S-76	Annual Energy Outlook 2014, Energy Information Administration, May 7, 2014.
S-77	U.S. Environmental Protection Agency, Fact Sheet: Clean Power Plan State Roles (June 2, 2014)
S-78	2014 Reliability Needs Assessment, New York System Independent Operator, Final Report
S-79	U.S. Senators Lisa Murkowski and Tim Scott, Plenty at Stake: Indicators of American Energy Insecurity, An Energy 20/20 White Paper

International Energy Agency

REDRAWING THE ENERGY-CLIMATE MAP

World Energy Outlook Special Report

REDRAWING THE ENERGY-CLIMATE MAP

World Energy Outlook Special Report

Governments have decided collectively that the world needs to limit the average global temperature increase to no more than 2 °C and international negotiations are engaged to that end. Yet any resulting agreement will not emerge before 2015 and new legal obligations will not begin before 2020. Meanwhile, despite many countries taking new actions, the world is drifting further and further from the track it needs to follow.

The energy sector is the single largest source of climate-changing greenhouse-gas emissions and limiting these is an essential focus of action. The *World Energy Outlook* has published detailed analysis of the energy contribution to climate change for many years. But, amid major international economic preoccupations, there are worrying signs that the issue of climate change has slipped down the policy agenda. This Special Report seeks to bring it right back on top by showing that the dilemma can be tackled at no net economic cost.

The report:

- Maps out the current status and expectations of global climate and energy policy – what is happening and what (more) is needed?
- Sets out four specific measures for the energy sector that can be quickly and effectively implemented, at no net economic cost, to help keep the 2 °C target alive while international negotiations continue.
- Indicates elements of action to achieve further reductions, after 2020.
- Demonstrates that the energy sector, in its own interest, needs to address now the risks implicit in climate change – whether they be the physical impacts of climate change or the consequences of more drastic action later by governments as the need to curb emissions becomes imperative.

For more information, and the free download of this report, please visit:
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World Energy Outlook Special Report

10 June 2013

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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The European Commission also participates in the work of the IEA.

International Energy Agency

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Acknowledgements 3
Executive Summary 9

1 **Climate and energy trends** 13
Introduction 14
The energy sector and climate change 15
Recent developments 18
International climate negotiations 19
National actions and policies with climate benefits 20
Global status of energy-related CO_2 emissions 26
Trends in energy demand and emissions in 2012 26
Historical emissions trends and indicators 29
Outlook for energy-related emissions and the 450 Scenario 33
Sectoral trends 36
Investment 38
Broader benefits of the 450 Scenario 39

2 **Energy policies to keep the 2 °C target alive** 43
Introduction 44
GDP-neutral emissions abatement to 2020 45
Methodology and key assumptions 45
Emissions abatement to 2020 50
Abatement to 2020 by policy measure 53
Implications for the global economy 70
Building blocks for steeper abatement post-2020 75
The long-term implications of the 4-for-2 °C Scenario 75
Technology options for ambitious abatement post-2020 76
Policy frameworks post-2020 80

3 **Managing climate risks to the energy sector** 83
Introduction 84
Impacts of climate change on the energy sector 84
Energy demand impacts 87
Energy supply impacts 91
Climate resilience 96

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Economic impact of climate policies on the energy sector 97
Existing carbon reserves and energy infrastructure lock-in 98
Power generation 101
Upstream oil and natural gas 106
Coal supply 110
Implications of delayed action 113

Annexes **117**
Annex A. Units and conversion factors 117
Annex B. References 119

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The world is not on track to meet the target agreed by governments to limit the long-term rise in the average global temperature to 2 degrees Celsius (°C). Global greenhouse-gas emissions are increasing rapidly and, in May 2013, carbon-dioxide (CO_2) levels in the atmosphere exceeded 400 parts per million for the first time in several hundred millennia. The weight of scientific analysis tells us that our climate is already changing and that we should expect extreme weather events (such as storms, floods and heat waves) to become more frequent and intense, as well as increasing global temperatures and rising sea levels. Policies that have been implemented, or are now being pursued, suggest that the long-term average temperature increase is more likely to be between 3.6 °C and 5.3 °C (compared with pre-industrial levels), with most of the increase occurring this century. While global action is not yet sufficient to limit the global temperature rise to 2 °C, this target still remains technically feasible, though extremely challenging. To keep open a realistic chance of meeting the 2 °C target, intensive action is required before 2020, the date by which a new international climate agreement is due to come into force. Energy is at the heart of this challenge: the energy sector accounts for around two-thirds of greenhouse-gas emissions, as more than 80% of global energy consumption is based on fossil fuels.

The energy sector is key to limiting climate change

Despite positive developments in some countries, global energy-related CO_2 emissions increased by 1.4% to reach 31.6 gigatonnes (Gt) in 2012, a historic high. Non-OECD countries now account for 60% of global emissions, up from 45% in 2000. In 2012, China made the largest contribution to the increase in global CO_2 emissions, but its growth was one of the lowest it has seen in a decade, driven largely by the deployment of renewables and a significant improvement in the energy intensity of its economy. In the United States, a switch from coal to gas in power generation helped reduce emissions by 200 million tonnes (Mt), bringing them back to the level of the mid-1990s. However, the encouraging trends in China and the United States could well both be reversed. Despite an increase in coal use, emissions in Europe declined by 50 Mt as a result of economic contraction, growth in renewables and a cap on emissions from the industry and power sectors. Emissions in Japan increased by 70 Mt, as efforts to improve energy efficiency did not fully offset the use of fossil fuels to compensate for a reduction in nuclear power. Even after allowing for policies now being pursued, global energy-related greenhouse-gas emissions in 2020 are projected to be nearly 4 Gt CO_2-equivalent (CO_2-eq) higher than a level consistent with attaining the 2 °C target, highlighting the scale of the challenge still to be tackled just in this decade.

Four energy policies can keep the 2 °C target alive

We present our 4-for-2 °C Scenario, in which we propose the implementation of four policy measures that can help keep the door open to the 2 °C target through to 2020 at no net economic cost. Relative to the level otherwise expected, these policies would reduce greenhouse-gas emissions by 3.1 Gt CO_2-eq in 2020 – 80% of the emissions reduction

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required under a 2 °C trajectory. This would buy precious time while international climate negotiations continue towards the important Conference of the Parties meeting in Paris in 2015 and the national policies necessary to implement an expected international agreement are put in place. The policies in the 4-for-2 °C Scenario have been selected because they meet key criteria: they can deliver significant reductions in energy-sector emissions by 2020 (as a bridge to further action); they rely only on existing technologies; they have already been adopted and proven in several countries; and, taken together, their widespread adoption would not harm economic growth in any country or region. The four policies are:

- Adopting specific energy efficiency measures (49% of the emissions savings).
- Limiting the construction and use of the least-efficient coal-fired power plants (21%).
- Minimising methane (CH_4) emissions from upstream oil and gas production (18%).
- Accelerating the (partial) phase-out of subsidies to fossil-fuel consumption (12%).

Targeted energy efficiency measures would reduce global energy-related emissions by 1.5 Gt in 2020, a level close to that of Russia today. These policies include: energy performance standards in buildings for lighting, new appliances, and for new heating and cooling equipment; in industry for motor systems; and, in transport for road vehicles. Around 60% of the global savings in emissions are from the buildings sector. In countries where these efficiency policies already exist, such as the European Union, Japan, the United States and China, they need to be strengthened or extended. Other countries need to introduce such policies. All countries will need to take supporting actions to overcome the barriers to effective implementation. The additional global investment required would reach $200 billion in 2020, but would be more than offset by reduced spending on fuel bills.

Ensuring that new subcritical coal-fired plants are no longer built, and limiting the use of the least efficient existing ones, would reduce emissions by 640 Mt in 2020 and also help efforts to curb local air pollution. Globally, the use of such plants would be one-quarter lower than would otherwise be expected in 2020. The share of power generation from renewables increases (from around 20% today to 27% in 2020), as does that from natural gas. Policies to reduce the role of inefficient coal power plants, such as emissions and air pollution standards and carbon prices, already exist in many countries. In our 4-for-2 °C Scenario, the largest emissions savings occur in China, the United States and India, all of which have a large coal-powered fleet.

Methane releases into the atmosphere from the upstream oil and gas industry would be almost halved in 2020, compared with levels otherwise expected. Around 1.1 Gt CO_2-eq of methane, a potent greenhouse-gas, was released in 2010 by the upstream oil and gas industry. These releases, through venting and flaring, are equivalent to twice the total natural gas production of Nigeria. Reducing such releases into the atmosphere represents an effective complementary strategy to the reduction of CO_2 emissions. The necessary technologies are readily available, at relatively low cost, and policies are being adopted in some countries, such as the performance standards in the United States. The largest reductions achieved in the 4-for-2 °C Scenario are in Russia, the Middle East, the United States and Africa.

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Accelerated action towards a partial phase-out of fossil-fuel subsidies would reduce CO_2 emissions by 360 Mt in 2020 and enable energy efficiency policies. Fossil-fuel subsidies amounted to $523 billion in 2011, around six times the level of support to renewable energy. Currently, 15% of global CO_2 emissions receive an incentive of $110 per tonne in the form of fossil-fuel subsidies while only 8% are subject to a carbon price. Growing budget pressures strengthen the case for fossil-fuel subsidy reform in many importing and exporting countries and political support has been building in recent years. G20 and Asia-Pacific Economic Cooperation (APEC) member countries have committed to phase out inefficient fossil-fuel subsidies and many are moving ahead with implementation.

Adaptation to the effects of climate change is necessary

The energy sector is not immune from the physical impacts of climate change and must adapt. In mapping energy system vulnerabilities, we identify sudden and destructive impacts (caused by extreme weather events) that pose risks to power plants and grids, oil and gas installations, wind farms and other infrastructure. Other impacts are more gradual, such as changes to heating and cooling demand, sea level rise on coastal infrastructure, shifting weather patterns on hydropower and water scarcity on power plants. Disruptions to the energy system can also have significant knock-on effects on other critical services. To improve the climate resilience of the energy system, governments need to design and implement frameworks that encourage prudent adaptation, while the private sector should assess the risks and impacts as part of its investment decisions.

Anticipating climate policy can be a source of competitive advantage

The financial implications of stronger climate policies are not uniform across the energy industry and corporate strategy will need to adjust accordingly. Under a 2 °C trajectory, net revenues for existing nuclear and renewables-based power plants would be boosted by $1.8 trillion (in year-2011 dollars) through to 2035, while the revenues from existing coal-fired plants would decline by a similar level. Of new fossil-fuelled plants, 8% are retired before their investment is fully recovered. Almost 30% of new fossil-fuelled plants are fitted (or retro-fitted) with CCS, which acts as an asset protection strategy and enables more fossil fuel to be commercialised. A delay in CCS deployment would increase the cost of power sector decarbonisation by $1 trillion and result in lost revenues for fossil fuel producers, particularly coal operators. Even under a 2 °C trajectory, no oil or gas field currently in production would need to shut down prematurely. Some fields yet to start production are not developed before 2035, meaning that around 5% to 6% of proven oil and gas reserves do not start to recover their exploration costs in this timeframe.

Delaying stronger climate action to 2020 would come at a cost: $1.5 trillion in low-carbon investments are avoided before 2020, but $5 trillion in additional investments would be required thereafter to get back on track. Delaying further action, even to the end of the current decade, would therefore result in substantial additional costs in the

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energy sector and increase the risk that the use of energy assets is halted before the end of their economic life. The strong growth in energy demand expected in developing countries means that they stand to gain the most from investing early in low-carbon and more efficient infrastructure, as it reduces the risk of premature retirements or retrofits of carbon-intensive assets later on.

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Climate and energy trends

Measuring the challenge

Highlights

- There is a growing disconnect between the trajectory that the world is on and one that is consistent with a 2 °C climate goal – the objective that governments have adopted. Average global temperatures have already increased by 0.8 °C compared with pre-industrial levels and, without further climate action, our projections are compatible with an additional increase in long-term temperature of 2.8 °C to 4.5 °C, with most of the increase occurring this century.

- Energy-related CO_2 emissions reached 31.6 Gt in 2012, an increase of 0.4 Gt (or 1.4%) over their 2011 level, confirming rising trends. The global increase masks diverse regional trends, with positive developments in the two-largest emitters, China and the United States. US emissions declined by 200 Mt, mostly due to low gas prices brought about by shale gas development that triggered a switch from coal to gas in the power sector. China's emissions in 2012 grew by one of the smallest amounts in a decade (300 Mt), as almost all of the 5.2% growth in electricity was generated using low-carbon technologies – mostly hydro – and declining energy intensity moderated growth in energy demand. Despite an increase in coal use, emissions in Europe declined (-50 Mt) due to economic contraction, growth in renewables and a cap on emissions from the industry and power sectors. OECD countries now account for around 40% of global emissions, down from 55% in 2000.

- International climate negotiations have resulted in a commitment to reach a new global agreement by 2015, to come into force by 2020. But the economic crisis has had a negative impact on the pace of clean energy deployment and on carbon markets. Currently, 8% of global CO_2 emissions are subject to a carbon price, while 15% receive an incentive of $110 per tonne in the form of fossil-fuel subsidies. Price dynamics between gas and coal are supporting emissions reductions in some regions, but are slowing them in others, while nuclear is facing difficulties and large-scale carbon capture and storage remains distant. Despite growing momentum to improve energy efficiency, there remains vast potential that could be tapped economically. Non-hydro renewables, supported by targeted government policies, are enjoying double-digit growth.

- Despite the insufficiency of global action to date, limiting the global temperature rise to 2 °C remains still technically feasible, though it is extremely challenging. To achieve our 450 Scenario, which is consistent with a 50% chance of keeping to 2 °C, the growth in global energy-related CO_2 emissions needs to halt and start to reverse within the current decade. Clear political resolution, backed by suitable policies and financial frameworks, is needed to facilitate the necessary investment in low-carbon energy supply and in energy efficiency.

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Introduction

Climate change is a defining challenge of our time. The scientific evidence of its occurrence, its derivation from human activities and its potentially devastating effects accumulate. Sea levels have risen by 15-20 centimetres, on average, over the last century and this increase has accelerated over the last decade (Meyssignac and Cazenave, 2012). Oceans are warming and becoming more acidic, and the rate of ice-sheet loss is increasing. The Arctic provides a particularly clear illustration, with the area of ice covering the Arctic Ocean in the summer diminishing by half over the last 30 years to a record low level in 2012. There has also been an increase in the frequency and intensity of heat waves, resulting in more of the world being affected by droughts, harming agricultural production (Hansen, Sato and Ruedy, 2012).

Global awareness of the phenomenon of climate change is increasing and political action is underway to try and tackle the underlying causes, both at national and international levels. Governments agreed at the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties in Cancun, Mexico in 2010 (COP-16) that the average global temperature increase, compared with pre-industrial levels, must be held below 2 degrees Celsius (°C), and that this means greenhouse-gas emissions must be reduced. A deadline was set at COP-18 in Doha, Qatar in 2012 for agreeing and enacting a new global climate agreement to come into effect in 2020. But although overcoming the challenge of climate change will be a long-term endeavour, urgent action is also required, well before 2020, in order to keep open a realistic opportunity for an efficient and effective international agreement from that date.

There is broad international acceptance that stabilising the atmospheric concentration of greenhouse gases at below 450 parts per million (ppm) of carbon-dioxide equivalent (CO_2-eq) is consistent with a near 50% chance of achieving the 2 °C target, and that this would help avoid the worst impacts of climate change. Some analysis finds, however, that the risks previously believed to be associated with an increase of around 4 °C in global temperatures are now associated with a rise of a little over 2 °C, while the risks previously associated with 2 °C are now thought to occur with only a 1 °C rise (Smith, *et al.*, 2009). Other analysis finds that 2 °C warming represents a threshold for some climate feedbacks that could significantly add to global warming (Lenton, *et al.*, 2008). The UNFCCC negotiations took these scientific developments into account in the Cancun decisions, which include an agreement to review whether the maximum acceptable temperature increase needs to be further reduced, including consideration of a global average temperature rise of 1.5 °C.

Global greenhouse-gas emissions continue to increase at a rapid pace. The 450 ppm threshold is drawing ever closer (Figure 1.1). Carbon-dioxide (CO_2) levels in the atmosphere reached 400 ppm in May 2013, having jumped by 2.7 ppm in 2012 – the second-highest

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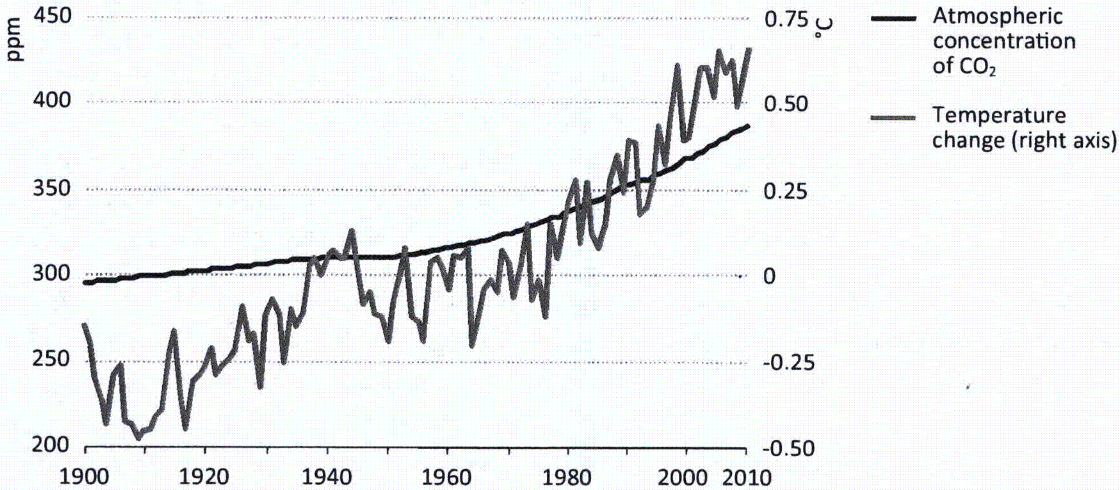
rise since record keeping began (Tans and Keeling, 2013).[1] Average global temperatures have already increased by around 0.8 °C, compared with pre-industrial levels, and, without additional action, a further increase in long-term temperature of 2.8 °C to 4.5 °C appears to be in prospect, with most of the increase occurring this century.[2]

Figure 1.1 ▷ World atmospheric concentration of CO_2 and average global temperature change



Note: The temperature refers to the NASA Global Land-Ocean Temperature Index in degrees Celsius, base period: 1951-1980. The resulting temperature change is lower than the one compared with pre-industrial levels.

Sources: Temperature data are from NASA (2013); CO_2 concentration data from NOAA Earth System Research Laboratory.

The energy sector and climate change

The energy sector is by far the largest source of greenhouse-gas emissions, accounting for more than two-thirds of the total in 2010 (around 90% of energy-related greenhouse-gas emissions are CO_2 and around 9% are methane [CH_4], which is generally treated, in this analysis, in terms of its CO_2 equivalent effect). The energy sector is the second-largest source of CH_4 emissions after agriculture and we have estimated total energy-related CH_4 emissions to be 3.1 gigatonnes (Gt) of carbon-dioxide equivalent (CO_2-eq) in 2010 (around 40% of total CH_4 emissions). Accordingly, energy has a crucial role to play in tackling climate change. Yet global energy consumption continues to increase, led by fossil fuels, which account for over 80% of global energy consumed, a share that has been increasing gradually since the mid-1990s.

1. The concentration of greenhouse gases measured under the Kyoto Protocol was 444 ppm CO_2-eq in 2010 and the concentration of all greenhouse gases, including cooling aerosols, was 403 ppm CO_2-eq (EEA, 2013).

2. The higher increase in temperature is consistent with a scenario with no further climate action and the lower with a scenario that takes cautious implementation of current climate pledges and energy policies under discussion, the New Policies Scenario. Greenhouse-gas concentration is calculated using MAGICC version 5.3v2 (UCAR, 2008) and temperature increase is derived from Rogelj, Meinhausen and Knutti (2012).

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Carbon pricing is gradually becoming established, and yet the world's largest carbon market, the EU Emissions Trading System (ETS), has seen prices remain at very low levels, and consumption of coal, the most carbon-intensive fossil fuel, continues to increase globally. Some countries are reducing the role of nuclear in their energy mix and developing strategies to compensate for it, including with increased energy efficiency. Renewables have experienced strong growth and have established themselves as a vital part of the global energy mix but, in many cases, they still require economic incentives and appropriate long-term regulatory support to compete effectively with fossil fuels. Action to improve energy efficiency is increasing, but two-thirds of the potential remains untapped (IEA, 2012a). It is, accordingly, evident that if the energy sector is to play an important part in attaining the internationally adopted target to limit average global temperature increase, a transformation will be required in the relationship between economic development, energy consumption and greenhouse-gas emissions. Is such a transition feasible? Analyses conclude that, though extremely challenging, it is feasible (IEA 2012a; OECD 2012).

Our 450 Scenario, which shows what is needed to set the global energy sector on a course compatible with a near 50% chance of limiting the long-term increase in average global temperature to 2 °C, suggests one pathway. Achieving the target will require determined political commitment to fundamental change in our approach to producing and consuming energy. All facets of the energy sector, particularly power generation, will need to transform their carbon performance. Moreover, energy demand must be moderated through improved energy efficiency in vehicles, appliances, homes and industry. Deployment of new technologies, such as carbon capture and storage, will be essential. It shows that, to stay on an economically feasible pathway, the rise in emissions from the energy sector needs to halted and reversed *by 2020.* Action at national level needs to anticipate implementation of a new international agreement from 2020. Achieving a 2 °C target in the absence of such action, while technically feasible, would entail the widespread adoption of expensive "negative emissions" technologies (Box 1.1), which extract more CO_2 from the atmosphere than they add to it. By the end of the century, energy-related CO_2 emissions in the 450 Scenario need to decrease to around 5 Gt CO_2 per year, *i.e.* less than one-sixth today's levels.[3]

It is the cumulative build-up of greenhouse gases, including CO_2, in the atmosphere that counts, because of the long lifetime of some of those gases in the atmosphere. Analysis has shown that, in order to have a 50% probability of keeping global warming to no more than 2 °C, total emissions from fossil fuels and land-use change in the first half of the century need to be kept below 1 440 Gt (Meinshausen, *et al.*, 2009). Of this "carbon budget", 420 Gt CO_2 has already been emitted between 2000 and 2011 (Oliver, Janssens-Maenhout and Peters, 2012) and the *World Energy Outlook 2012* (*WEO-2012*) estimated that another 136 Gt CO_2

3. The RCP2.6 Scenario in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change is based on negative emissions from 2070 (IPCC, 2013). The RCP2.6 Scenario is more ambitious than the 450 Scenario in that it sets out to achieve an 80% probability of limiting the long-term (using 2200 as the reference year) global temperature increase to 2 °C, while the probability is around 50% in the 450 Scenario.

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will be emitted from non-energy related sources in the period up to 2050. This means that the energy sector can emit a maximum of 884 Gt CO_2 by 2050 without exceeding its residual budget. When mapping potential emissions trajectories against such a carbon budget, it becomes clear that the longer action to reduce global emissions is delayed, the more rapid reductions will need to be in the future to compensate (Figure 1.2). Some models estimate that the maximum feasible rate of such emissions reduction is around 5% per year (Elzen, Meinshausen and Vuuren, 2007); Chapter 3 explores further the implications of delayed action in the energy sector.

Box 1.1 ▷ What are negative emissions?

Carbon capture and storage (CCS) technology could be used to capture emissions from biomass processing or combustion processes and store them in deep geological formations. The process has the potential to achieve a net removal of CO_2 from the atmosphere (as opposed to merely avoiding CO_2 emissions to the atmosphere as is the case for conventional, fossil fuel-based CCS). Such "negative emissions" result when the amount of CO_2 sequestered from the atmosphere during the growth of biomass (and subsequently stored underground) is larger than the CO_2 emissions associated with the production of biomass, including those resulting from land-use change and the emissions released during the transformation of biomass to the final product (IEA, 2011a). So-called bio-energy with carbon capture and storage (BECCS) could be used in a wide range of applications, including biomass power plants, combined heat and power plants, flue gas streams from the pulp and paper industry, fermentation in ethanol production and biogas refining processes.

From a climate change perspective, BECCS is attractive for two reasons. First, net gains from BECCS can offset emissions from a variety of sources and sectors that are technically difficult and expensive to abate, such as emissions from air transportation. Second, BECCS can mitigate emissions that have occurred in the past. For a given CO_2 stabilisation target, this allows some flexibility in the timing of emissions – higher emissions in the short term can, within limits, be compensated for by negative emissions in the longer term. Of course, the projects have to be economically viable.

To achieve net negative emissions, it is essential that only biomass that is *sustainably* produced and harvested is used in a BECCS plant. Assuring the sustainability of the biomass process will require dedicated monitoring and reporting. As this will encompass activities that are similar to those required to monitor and verify emissions reduction from deforestation and forest degradation (REDD), the development of national and international REDD strategies will contribute to the deployment of BECCS and *vice versa*. Increasing the share of sustainably managed biomass in a country's energy mix, in addition to decreasing CO_2 emissions, has a number of benefits in terms of economic development and employment.

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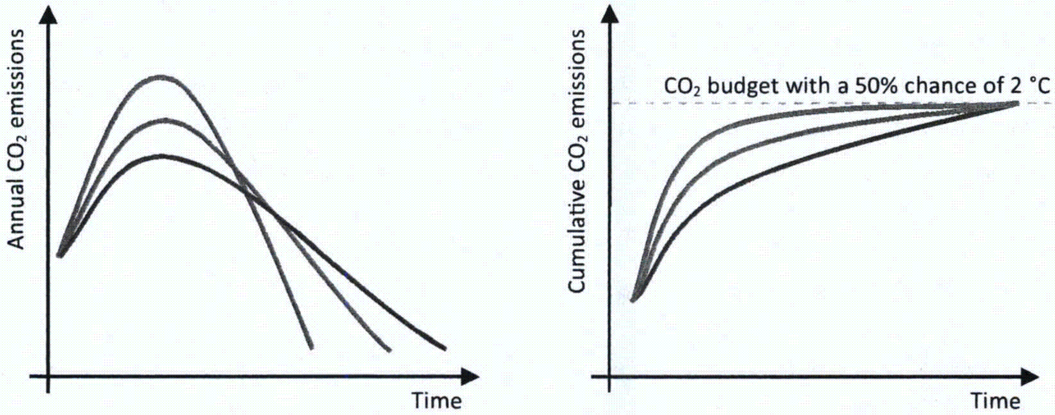
Figure 1.2 ▷ Mapping feasible world CO_2 emissions trajectories within a carbon budget constraint



Taking as its starting point the proportionate contribution of the energy system to the global greenhouse-gas emissions, this chapter focuses on the disconnect between the level of action that science tells us is required to meet a 2 °C climate goal and the trajectory the world is currently on. It looks at recent developments in climate policy, both at global and national levels, and at those elements of energy policy that could have a significant positive impact on the mitigation of climate change. It maps the current status of global greenhouse-gas emissions, illustrating the dominant role of energy-related CO_2 emissions in this picture and the important underlying trends, drawing on the latest emissions estimates for 2012. It then looks at the prospective future contribution of the energy sector to the total emissions up to 2035, comparing the outcome if the world pursues its present course (our New Policies Scenario) with a trajectory compatible with limiting the long-term increase in average global temperature to 2 °C (our 450 Scenario) (IEA, 2012a). This enables us to highlight the additional efforts that would be necessary to achieve the 2 °C climate goal and to point to the short-term actions (see Chapter 2) which could contribute significantly to make its realisation possible.

Recent developments

Government policies are critical to tackling climate change: what has been happening? Answering this question requires an examination both of policies that are directed mainly at climate change and of policies with other primary objectives, such as energy security and local pollution, which also have consequences for global emissions. While key climate commitments may be international, implementing actions will be taken primarily at national and regional levels. So far, to take one indicative example, carbon pricing applies only to 8% of energy-related CO_2 emissions, while fossil-fuel subsidies, acting as a carbon incentive, affect almost twice that level of emissions.

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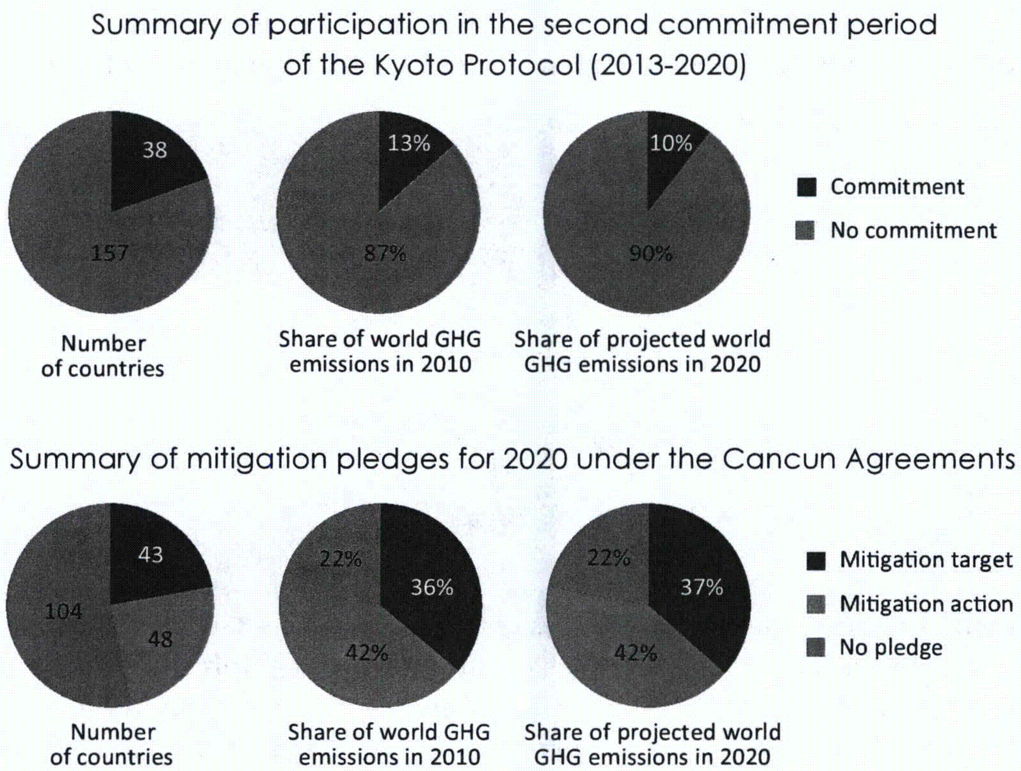
International climate negotiations

As a result of the UNFCCC COP-18 in 2012, international climate negotiations have entered a new phase. The focus is on the negotiation of "a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties", to be negotiated by 2015 and to come into force in 2020. If such an agreement is achieved, it will be the first global climate agreement to extend to all countries, both developed and developing. COP-18 also delivered an extension of the Kyoto Protocol to 2020, with 38 countries (representing 13% of global greenhouse-gas emissions) taking on binding targets (Figure 1.3). As part of the earlier (2010) Cancun Agreements, 91 countries, representing nearly 80% of global greenhouse-gas emissions, have adopted and submitted targets for international registration or pledged actions. These pledges, however, collectively fall well short of what is necessary to deliver the 2 °C goal (UNEP, 2012).

Figure 1.3 ▷ Coverage of existing climate commitments and pledges



COP-18 set out a work programme for the negotiations towards the 2015 agreement. One track provides for the elaboration of the new agreement. A second track aims to increase mitigation ambition in the short term, a vital element of success, as to postpone further action until 2020 could be regarded as pushing beyond plausible political limits the scale and cost of action required after that date (see Chapter 2 for key opportunities for additional climate action until 2020, and Chapter 3 for an analysis of the cost of delay). The architecture of the new agreement is yet to be agreed: it is unlikely to resemble the highly-

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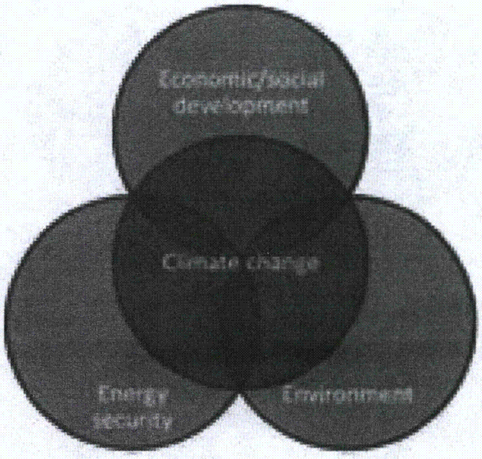
centralised set of commitments that characterise the Kyoto Protocol, in order to allow for flexibility to take account of national circumstances. It is expected to bring together existing pledges into a co-ordinated framework that builds mutual trust and confidence in the total emissions abatement that they represent. It will also need to create a process that provides for the ambition of these pledges to be adequately developed to match the evolving requirements of meeting the 2 °C goal.

National actions and policies with climate benefits

As discussed above, policies adopted at the national level which deliver emissions reductions are central to tackling climate change whether that is their primary motivation or not. The global economic crisis has constrained policy makers' scope for action in recent years, but there have been some encouraging developments. In particular, many developing countries that made voluntary emissions reduction pledges under the Cancun Agreements have announced new strategies and policies, in many cases involving measures in the energy sector (Figure 1.4).

Figure 1.4 ▷ Linkages between climate change and other major policies



Carbon pricing is one of the most direct ways of tackling emissions. Currently some 8% of global energy-related CO_2 emissions are subject to carbon pricing. This share is expected to increase, as more countries and regions adopt this practice (Spotlight). However, the roll-out is by no means free of concerns, notably on competitiveness and carbon leakage.

Power plant emissions are being regulated in a number of countries. Regulations limiting emissions from new power plants, which would have an impact particularly on investment in new conventional coal generation, have been proposed by the US Environmental Protection Agency (EPA). New standards are also expected to be promulgated for existing plants. US EPA regulations targeting conventional pollutants are also expected to promote modernisation of the power generation fleet (though they may face legal challenge). Canada has introduced regulations for new power plants that rule out new conventional coal investment. High levels of local pollution continue to be a significant issue for some

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of China's largest cities and the government has stipulated mandatory reductions in sulphur dioxide (SO_2) and nitrogen oxide (NO_x) emissions per kilowatt-hour (kWh) of power generated by coal-fired power plants and a target to cut by at least 30% the emissions intensity of particulate matter ($PM_{2.5}$) coming from energy production and use. These national measures will all have associated climate change benefits.

Although *WEO-2012* demonstrated that only a fraction of the available energy efficiency benefits are currently being realised, fortunately, many countries are taking new steps to tap this potential. In early 2013, the US government announced a goal to double energy productivity by 2030. *WEO-2012* had already highlighted the contribution new fuel-economy standards could make in moving the United States towards lower import needs and the question now is whether similar effects can be achieved in other sectors of the economy. The US Department of Energy has put in place in recent years energy efficiency standards for a wide range of products, including air conditioners, refrigerators and washing machines. More standards are expected to come into force for efficiency in buildings and appliances. The European Union has adopted an Energy Efficiency Directive, to support its target of improving energy efficiency by 20% by 2020 and pave the way for further improvements beyond this. In China, the 12th Five-Year Plan (2011-2015) includes indicative caps on total energy consumption and on power consumption for 2015. There are also mandatory targets to reduce the energy intensity of the economy by 16% and to reduce CO_2 emissions per unit GDP by 17% – the first time a CO_2 target has been set. China has published energy efficiency plans consistent with the 12th Five-Year Plan, including the "Top 10 000" programme that sets energy savings targets by 2015 for the largest industrial consumers. In India, a National Mission on Enhanced Energy Efficiency has been launched, aimed at restraining growth in energy demand. India's "Perform Achieve and Trade" mandatory trading system for energy efficiency obligations in some industries was launched in 2011, and is a key element in plans to deliver its pledge to reduce carbon intensity by 20-25% by 2020 (from 2005 levels).

Many forms of intervention to support renewable energy sources have contributed to the strong growth of the sector in recent years. Installed wind power capacity increased by 19% in 2012, to reach 282 gigawatts (GW), with China, the United States, Germany, Spain and India having the largest capacity (GWEC, 2013). Sub-Saharan Africa's first commercial wind farm also came online, in Ethiopia. US solar installations increased by 76%, to 3.3 GW in 2012 (Solar Energy Industries Association, 2013) and, while a federal target is not in place, most US states have renewable energy portfolio standards designed to increase the share of electricity generated from renewable sources. The European Union has in place a target contribution from renewable energy to primary demand of 20% by 2020. Japan has also expressed strong expectations for renewables, mainly solar photovoltaics (PV), in its new energy strategy following the Fukushima Daiichi nuclear accident. China has an extensive range of targets for all renewables, which are regularly upgraded. One example is the recent strengthening of the target for PV installations to 10 GW per year, promising to make China the world leader for PV installation from 2013 onwards. India

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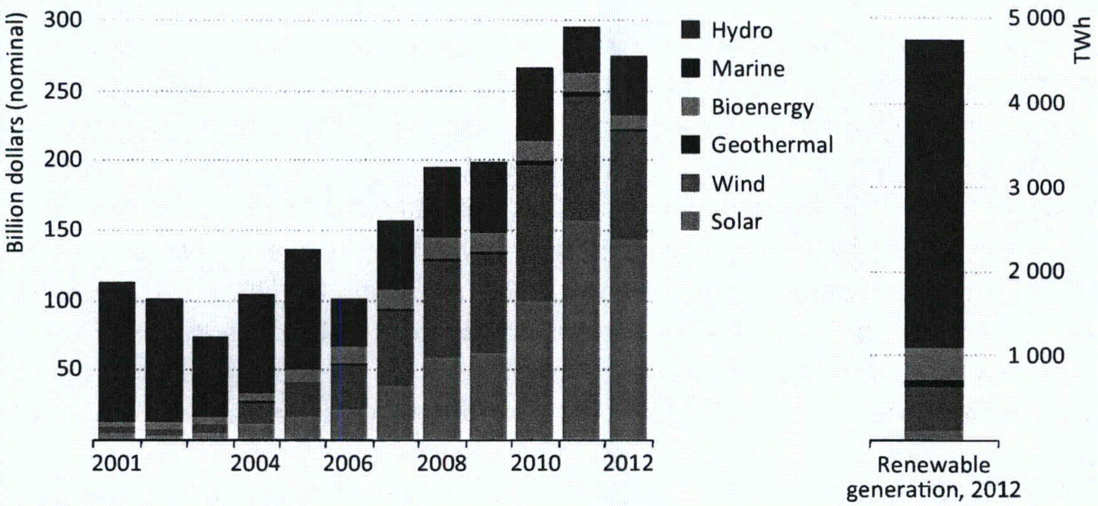
has stated a goal of reaching 55 GW of non-hydro renewable capacity by 2017. Pakistan published its National Climate Change Strategy in September 2012, which, among other things, gives preferential status to hydropower and commits to promote other renewable energy resources (Pakistan Ministry of Climate Change, 2012). In 2012, Bangladesh passed specific legislation to promote the production and use of "green" energy. South Africa aims to reach 35 GW of solar by 2030.

Figure 1.5 ▷ World renewables-based power sector investment by type and total generation



Note: TWh = terawatt-hours.

Sources: BNEF (2013); Frankfurt School UNEP Collaborating Centre and Bloomberg New Energy Finance (2012); and IEA data and analysis.

Globally, recent trends for renewables are in line with those needed to achieve a 2 °C goal (IEA, 2013a). However, while the role of non-hydro renewables has been growing, particularly in power generation, this growth starts from a low base and sustaining high growth rates overall will be challenging. Also, despite generally strong growth, the renewables sector has not been immune to the global economic crisis, with a glut in capacity resulting in some markets. Global investment in renewables, excluding large hydro, is reported to have fallen by 11% in 2012, but this is due mainly to reductions in the cost of solar and wind installations: deployment has grown overall (Figure 1.5).

SPOTLIGHT

Carbon markets – fixing an energy market failure?

Emissions trading schemes have recently begun operation in Australia, California, Quebec and Kazakhstan, expanding the coverage of carbon pricing to around 2.5 Gt of emissions (Figure 1.6). An emissions trading scheme is being rolled out in South Korea, as are pilot systems in cities and provinces in China, which collectively account for more

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than one-quarter of national GDP and a population of around 250 million. The pilot schemes are seen as informing the potential implementation of a nation-wide scheme after 2015. The World Bank's Partnership for Market Readiness is helping sixteen developing and emerging economies develop their policy readiness and carbon markets. Some of these schemes have plans to be linked: California and Quebec in January 2014, and Australia and the European Union by 2018.

But it is also a time of significant challenge for carbon markets. The most long-standing emissions trading markets – the EU ETS and the US-based Regional Greenhouse Gas Initiative (RGGI)[4] – are working toward reform. RGGI has announced that the carbon budget will be cut by 45% to reflect lower actual emissions due to economic conditions and the availability of low cost shale gas. The EU ETS covers around 45% of EU greenhouse-gas emissions and is a key instrument to deliver the European Union's 20% emissions reduction target in 2020. But its carbon prices have declined from over €20/tonne in early 2008 to around €3.5/tonne in May 2013, a level unlikely to attract sufficient investment in low-carbon technologies. The European Commission expects there to be a surplus of more than 2 Gt of allowances over the period to 2020, unless changes are made (European Commission, 2012a and 2012b). The excess provision is due to a combination of the effects of the economic crisis and a large influx of international credits. The European Parliament rejected in April 2013 the European Commission proposal to withdraw some allowances from the market. At the time of writing, the proposal was back before the Parliament's Environment Committee for further consideration.

The Clean Development Mechanism (CDM), which allows Kyoto Protocol countries with targets to undertake some emissions reductions in developing countries, is in crisis. Action is underway to streamline CDM project approvals, but a serious mismatch between the supply of credits and demand had driven prices down to €0.3/tonne in March 2013. The effect of this has been a dramatic fall-off in CDM project development with, for example, China approving only eleven projects in the first two months of 2013, compared to more than 100 per month during 2012 (Point Carbon, 2013). As part of UNFCCC negotiations, work is underway to develop a new market mechanism that targets emissions reductions across broad segments of the economy rather than being project-based. It is hoped that it will be in place to support the new 2015 agreement and that this will stimulate more demand for international market units of emissions reductions. International negotiations are also progressing on a framework to determine how emissions reduction units from linked ETS can be counted towards national targets under the UNFCCC. This will be an important step in supporting such linking and reshaping the global carbon map.

4. RGGI includes the US states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island and Vermont.

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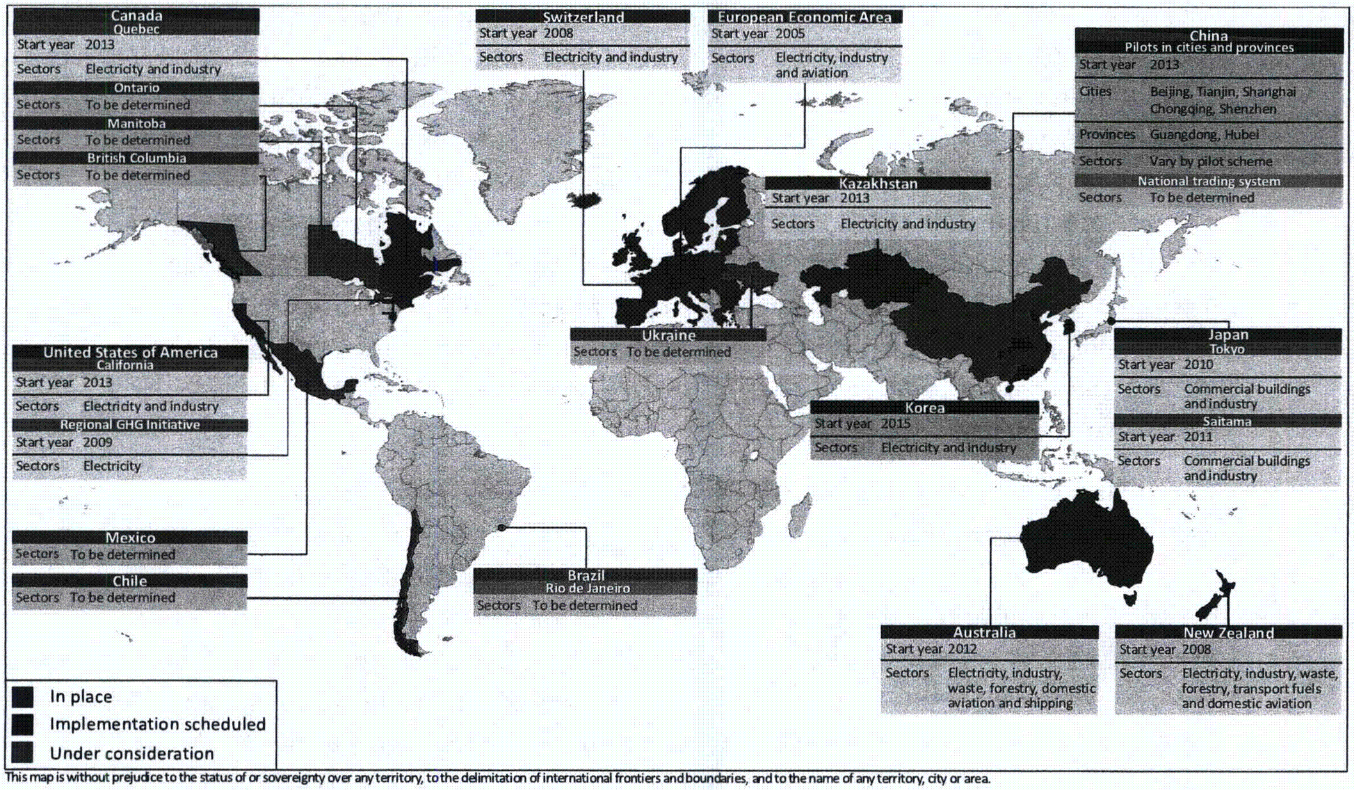
Figure 1.6 ▷ Current and proposed emissions trading schemes



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

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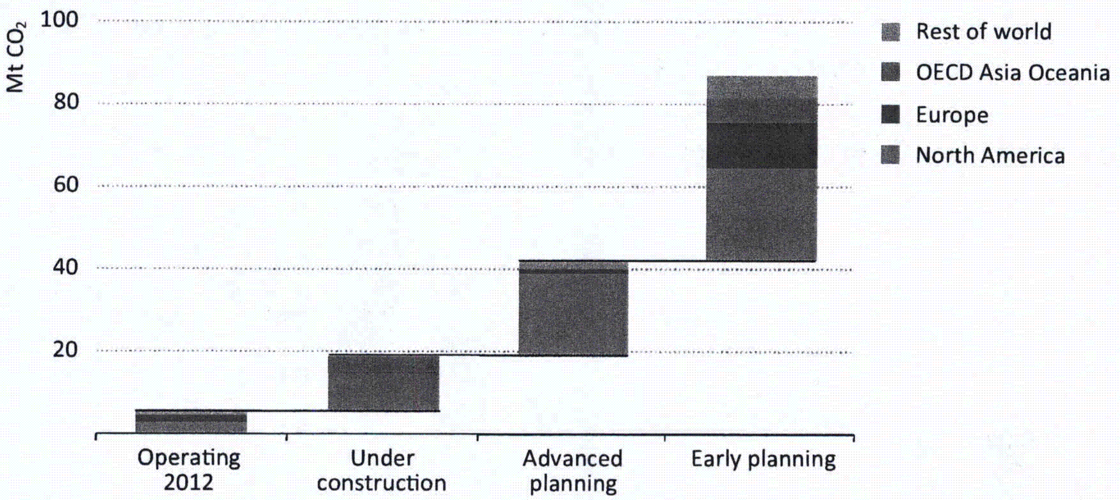
Nuclear policies vary by country. In 2012, Japan announced new energy efficiency and renewable energy targets, supported by feed-in tariffs, in light of the 2011 accident at the Fukushima Daiichi nuclear power station. However, plans in the major nuclear growth markets, such as China, India and Korea, are largely being maintained. Confidence in the availability of low-carbon alternatives needs to be high in countries contemplating moving away from nuclear power.

In transport, policies to increase efficiency and support new technologies go hand-in-hand. Most major markets have fuel-economy standards for cars and have scope to introduce similar standards for freight. Sales of plug-in hybrids and electric vehicles more than doubled, to exceed 100 000, in 2012. Nonetheless, these sales are still well below the level required to achieve the targets set by many governments. Collectively these amount to around 7-9 million vehicles by 2020 (IEA, 2013a).

Figure 1.7 ▷ CCS capacity by region and project status, 2012



Notes: Relates to large-scale integrated projects and, where a range is given for CO_2 capture capacity, the middle of the range has been taken. Existing EOR projects are not included where they are not authorised and operated for the purpose of CCS.

Sources: Global CCS Institute (2013) and IEA analysis.

Carbon capture and storage (CCS) technology can, in principle, reduce full life-cycle CO_2 emissions from fossil-fuel combustion at stationary sources, such as power stations and industrial sites, by 65-85% (GEA, 2012). However, the operational capacity of large-scale integrated CCS projects, excluding enhanced oil recovery (EOR), so far provides for the capture of only 6 million tonnes (Mt) of CO_2 per year, with provisions for a further 13 Mt CO_2 under construction as of early-2013 (Figure 1.7). If all planned capacity were to be constructed, this would take the total to around 90 Mt CO_2, still equivalent to less than 1% of power sector CO_2 emissions in 2012. While the technology is available today, projects need to be scaled-up significantly from existing levels in order to demonstrate carbon capture and storage from a typical coal-fired power plant. Experience gained from

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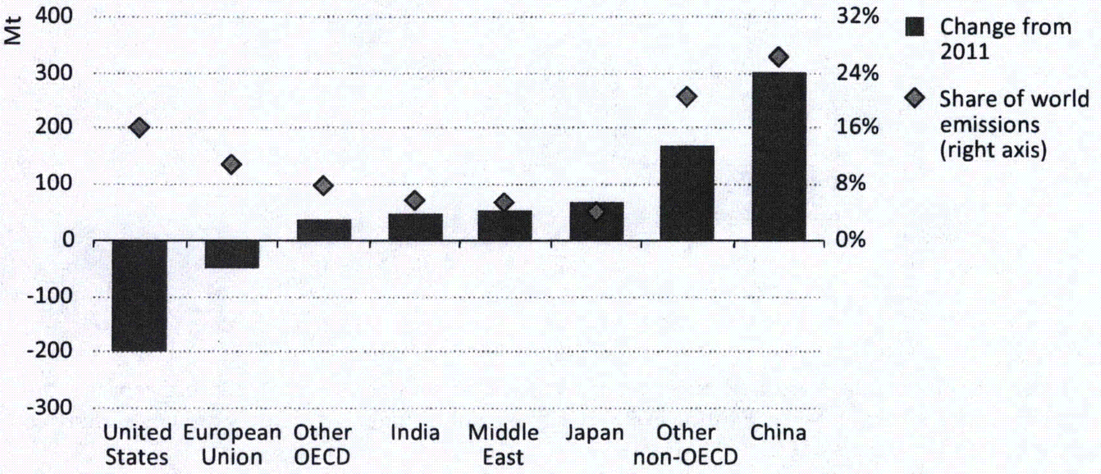
large demonstration projects will be essential, both to perfecting technical solutions and driving down costs. Ultimately, a huge scale-up in CCS capacity is required if it is to make a meaningful impact on global emissions (see Chapter 2).

Global status of energy-related CO_2 emissions

Trends in energy demand and emissions in 2012

Global CO_2 emissions from fossil-fuel combustion increased again in 2012, reaching a record high of 31.6 Gt, according to our preliminary estimates.[5] This represents an increase of 0.4 Gt on 2011, or 1.4%, a level that, if continued, would suggest a long-term temperature increase of 3.6 °C or more. The growth in emissions results from an increase in global fossil-fuel consumption: 2.7% for natural gas, 1.1% for oil and 0.6% for coal. Taking into account emissions factors that are specific to fuel, sector and region, natural gas and coal each accounted for 44% of the total energy-related CO_2 emissions increase in 2012, followed by oil (12%). The global trend masks important regional differences: in 2012, a 3.1% increase in CO_2 emissions in non-OECD countries was offset, but only partly, by a 1.2% reduction in emissions in OECD countries (Figure 1.8).

Figure 1.8 ▷ CO_2 emissions trends in 2012



While China made the largest contribution to the global increase, with its emissions rising by 300 Mt, or 3.8%, this level of growth is one of the smallest in the past decade and less than half of the emissions increase in 2011, reflecting China's efforts in installing low-carbon generating capacity and achieving improvements in energy intensity. Coal demand grew by 2.4%, most of it to supply industrial demand. While electricity generation in China increased 5.2%, coal input to power generation grew by only 1.2%. Most of the additional demand was met by hydro, with 18 GW of capacity additions coming online in 2012, complemented by a wet year in 2012. Increased wind and solar also played a role. Hydro capacity at the end of 2012 was 249 GW, on track to meet the 2015 target of 290 GW. The

5. Global emissions include international bunkers, which are not reflected in regional and country figures.

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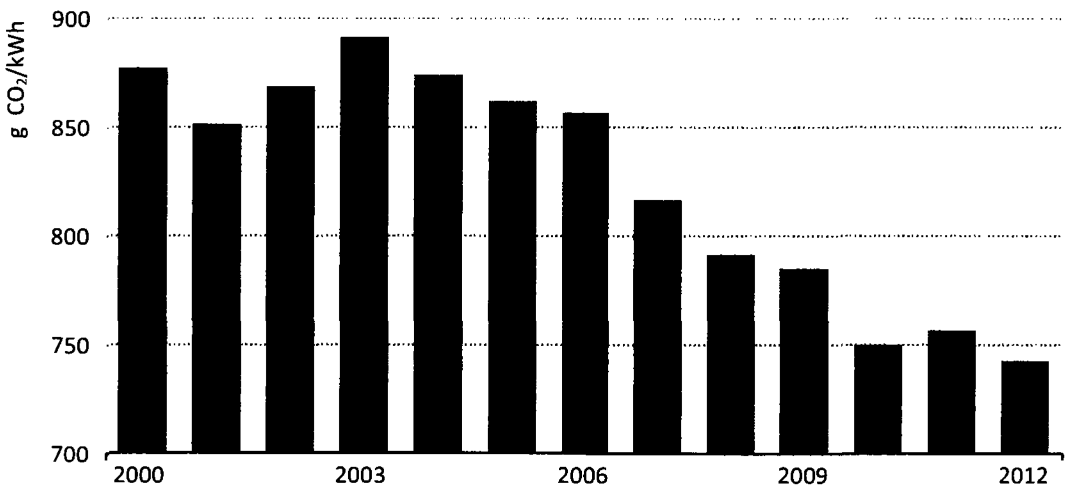
decarbonisation efforts in the power sector resulted in a decade long improvement of its emissions per unit of generation (Figure 1.9). Energy intensity improved by 3.8%, in line with the 12th Five-Year Plan target, indicating progress in diversifying the economy and in energy efficiency.

Figure 1.9 ▷ CO_2 emissions per unit of electricity generation in China



In the Middle East, energy-related CO_2 emissions increased by around 55 Mt CO_2, or 3.2%, on the back of rising gas consumption in power generation and the persistence of subsidised energy consumption. India's emissions grew by some 45 Mt CO_2, or 2.5%, mainly driven by coal. This figure was much lower than the previous year due to lower GDP growth and issues related to domestic coal production.

In OECD countries, the trends are very different. CO_2 emissions declined in the United States year-on-year in 2012 by 200 Mt, or -3.8%, around half as a result of the ongoing switching from coal to natural gas in power generation (Box 1.2). Other factors contributed to the decline: increased electricity generation from non-hydro renewables, lower demand for transport fuels and mild winter temperatures reduced the demand for heating. CO_2 emissions in the United States have now declined four of the last five years, 2010 being the exception (Figure 1.10). Their 2012 level was last seen in mid-1990s.

CO_2 emissions in the European Union in 2012 were lower year-on-year by some 50 Mt, or 1.4%, but trends differ markedly from country to country. With electricity demand declining by 0.3% in 2012, in line with a contraction in the economy, cheap coal and carbon prices meant that many large emitters turned partly to coal to power their economies. Coal demand grew 2.8%, compared with an average 1.3% decline over the past decade. Yet data show a 0.6% decline in power sector emissions that are capped under the EU ETS, and a larger, 5.8% fall in emissions from industry sectors such as cement, glass and steel. Non-hydro renewables generation increased by 18%, thanks to support policies. Emissions in Europe's biggest economy, Germany, increased by 17 Mt CO_2 or 2.2% (UBA, 2013). Driven by low coal and low CO_2 prices, consumption of coal in power generation increased by 6%.

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CO_2 emissions increased also in the United Kingdom by 21 Mt, or 4.5%, due to higher coal use in power generation and higher demand for space heating (DECC, 2013). Electricity generation from coal increased by 32%, displacing gas in the electricity mix.

Box 1.2 ▷ The benefits – and limits – of switching from coal to gas

The decline in energy-related CO_2 emissions in the United States in recent years has been one of the bright spots in the global picture. One of the key reasons has been the increased availability of natural gas, linked to the shale gas revolution, which has led to lower prices and increased competitiveness of natural gas versus coal in the US power sector. Over the period 2008-2012, when total US power demand was relatively flat, the share of coal in US electricity output fell from 49% to 37%, while gas increased from 21% to 30% (and renewables rose from 9% to 12%).[6] The large availability of spare capacity facilitated this quick transformation. In 2011, when the share of gas had already increased significantly, the utilisation rate of combined-cycle gas turbines was still below 50% (IEA, 2013b). Gas-fired combined-cycle plants produce on average half the emissions per kilowatt hour than conventional coal-fired generation. Part of this gain, however, is offset on a life-cycle basis due to methane emissions from natural gas production and distribution.

Whether the trend in emissions reduction from coal-to-gas switching in power generation will continue depends on relative coal and gas prices. Preliminary signs of a reversal were seen in the first quarter of 2013: coal consumption in power generation increased 14% compared with the same period in the previous year, as natural gas prices at Henry Hub increased by around 40% from $2.45 per million British thermal units (MBtu) in 2012 to $3.49/MBtu in the same period of 2013. In the absence of environmental or other regulations posing additional restrictions on CO_2 emissions standards on existing power plants, existing coal plants could again become economic relative to gas for natural gas prices in the range $4.5-5/MBtu or higher.

The resource base for unconventional hydrocarbons holds similar promise for other countries heavily relying on coal in the power sector, such as China. But due to the expected relative coal to gas prices in regions outside North America, the US story is not expected to be replicated on a large scale in the period up to 2020. Our analysis demonstrates increased gas use in all scenarios, including that compatible with a 2 °C trajectory (the 450 Scenario), but on its own, natural gas cannot provide the answer to the challenge of climate change (IEA, 2011b and 2012b). In the 450 Scenario, for example, global average emissions from the power sector need to come down to 120 g CO_2/kWh by the 2030s, almost one-third the level that could be delivered by the most efficient gas-fired plant in the absence of CCS technology.

6. Based on US Energy Information Administration data for 2012.

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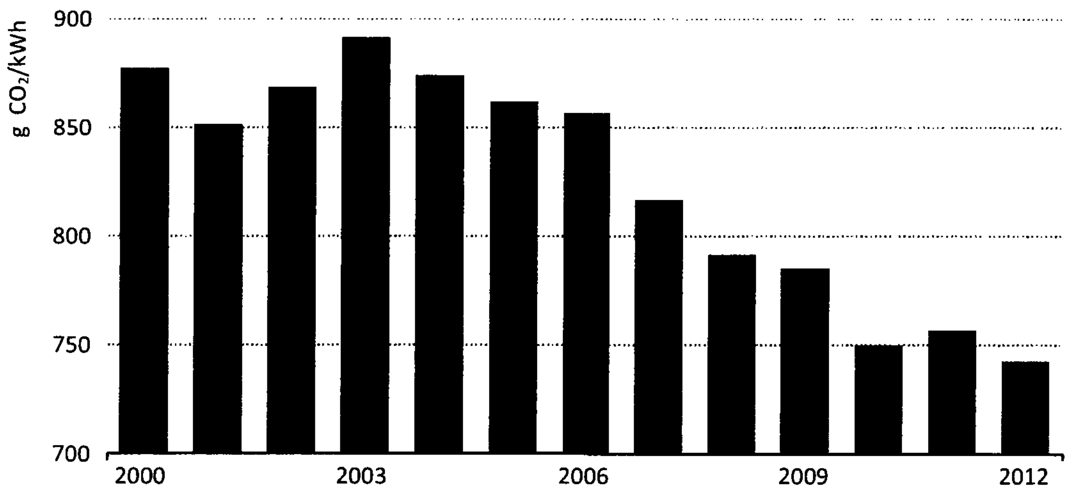
decarbonisation efforts in the power sector resulted in a decade long improvement of its emissions per unit of generation (Figure 1.9). Energy intensity improved by 3.8%, in line with the 12th Five-Year Plan target, indicating progress in diversifying the economy and in energy efficiency.

Figure 1.9 ▷ CO_2 emissions per unit of electricity generation in China



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6. Based on US Energy Information Administration data for 2012.

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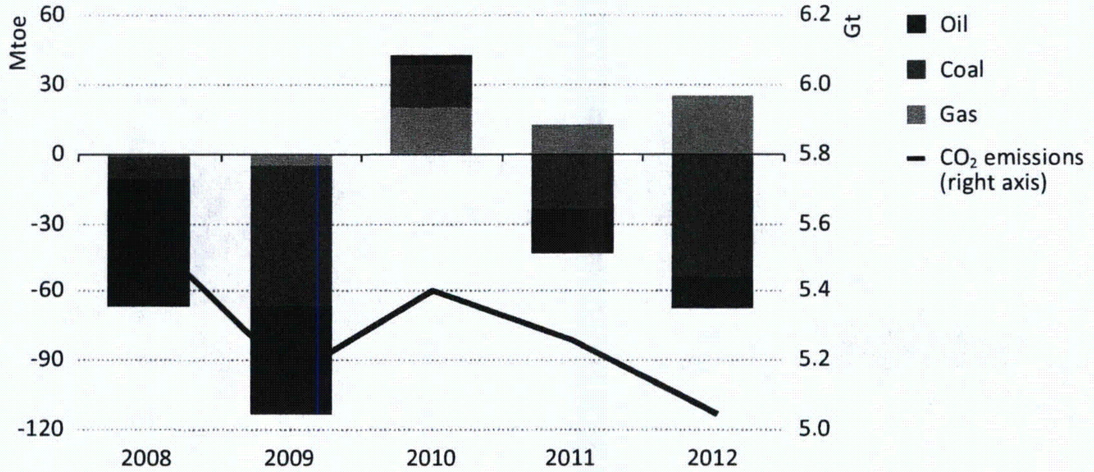
Figure 1.10 ▷ Change in fuel consumption and total energy-related CO_2 emissions in the United States



Japan's emissions rose by some 70 Mt CO_2,or 5.8%, in 2012 a rate of growth last seen two decades ago, as a consequence of the need to import large quantities of liquefied natural gas and coal in order to compensate for the almost 90% reduction in electricity generation from nuclear power following the Fukushima Daiichi accident. The increase in fuel import costs was a key reason for Japan's record high trade deficit of ¥6.9 trillion ($87 billion) in 2012.

Historical emissions trends and indicators

The data for 2012 need to be seen in a longer term perspective. Since 1900, emissions levels and their geographical distribution have changed significantly, with the first decade of this century seeing the accumulation in the atmosphere of eleven times more CO_2 than the first decade of the previous century. Excluding international bunkers, OECD countries accounted for almost all of the global emissions in the 1900s, yet now non-OECD emissions account for 60%. OECD countries emitted 40% of global energy-related CO_2 emissions in 2012, down from 55% in 2000 (Figure 1.11). This compares with around 40% of total primary energy demand and 53% of global GDP (in purchasing power parity terms). The growth in China's emissions since 2000 is larger than the total level of emissions in 2012 of the other BRICS (Brazil, Russia, India, China, South Africa) countries combined. India's emissions increased in 2012, reinforcing its position as the world's third-largest emitter. Developing countries tend to be net exporters of products whose production gives rise to CO_2 emissions, opening up scope for debate as whether responsibility for the emissions lies with the producer or the importer.

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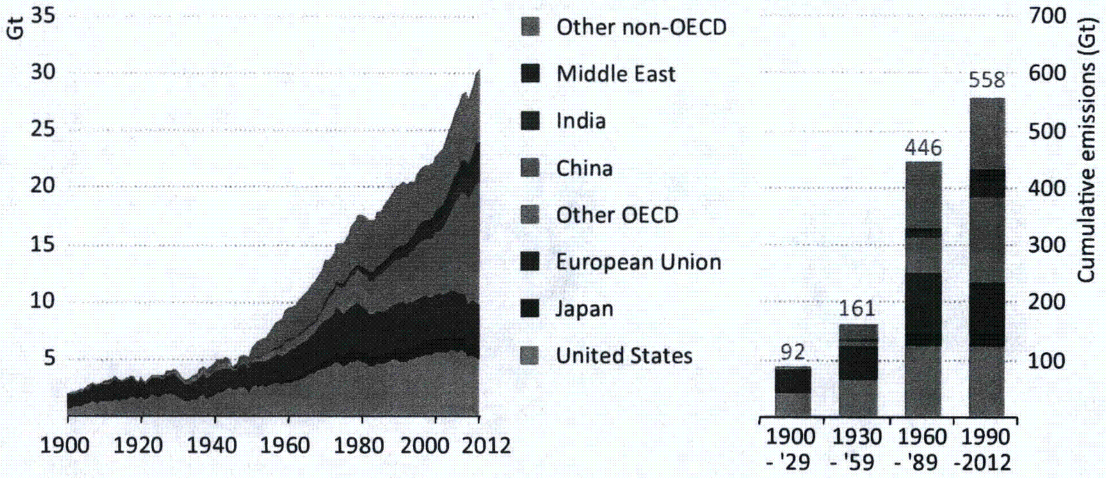
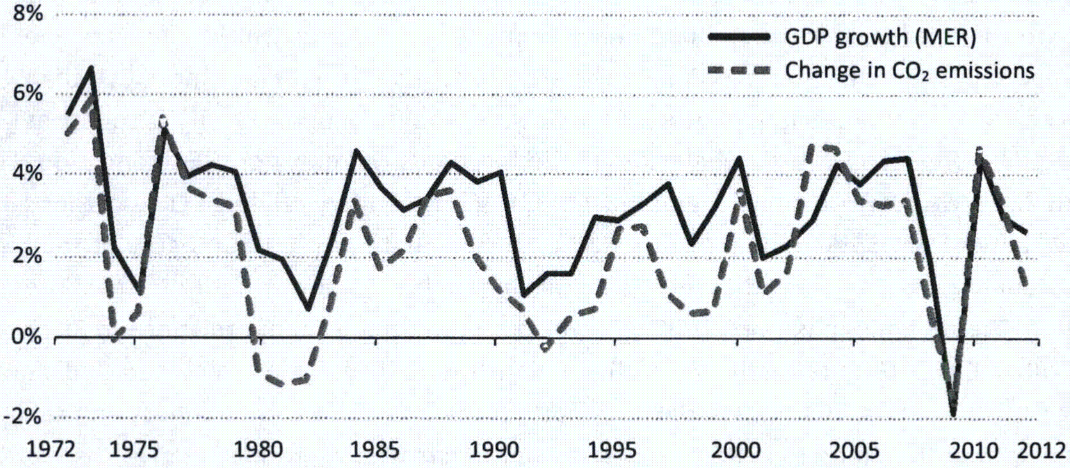
Figure 1.11 ▷ Energy-related CO_2 emissions by country



Sources: IEA databases and analysis; Boden *et al.*, (2013).

Trends in energy-related CO_2 emissions continue to be bound closely to those of the global economy (Figure 1.12), with the few declines observed in the last 40 years being associated with events such as the oil price crises of the 1970s and the recent global recession. The carbon intensity of the economy has generally improved over time (GDP growth typically exceeds growth in CO_2 emissions), but the last decade has seen energy demand growth accelerate and the rate of decarbonisation slow – mainly linked to growth in fossil-fuel demand in developing countries.

Figure 1.12 ▷ Growth in global GDP and in energy-related CO_2 emissions



Note: MER = market exchange rate.

A simple comparison between OECD Europe or the United States, and China or India reveals a significant difference in GDP and CO_2 trends over time (Figure 1.13). In OECD Europe and the United States, GDP has more than doubled or tripled over the last 40 years while CO_2 emissions have increased by 2% and 18% respectively. In China and India, GDP and CO_2 emissions have grown at closer rates, reflecting their different stage of economic

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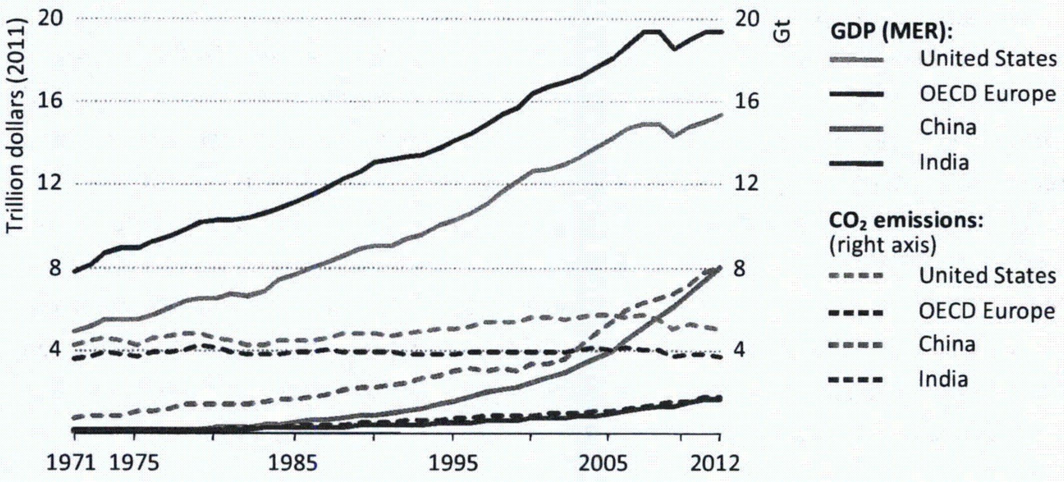
development. This resulted in China's emissions overtaking those of the United States in 2006, despite its economy being less than one-third the size.

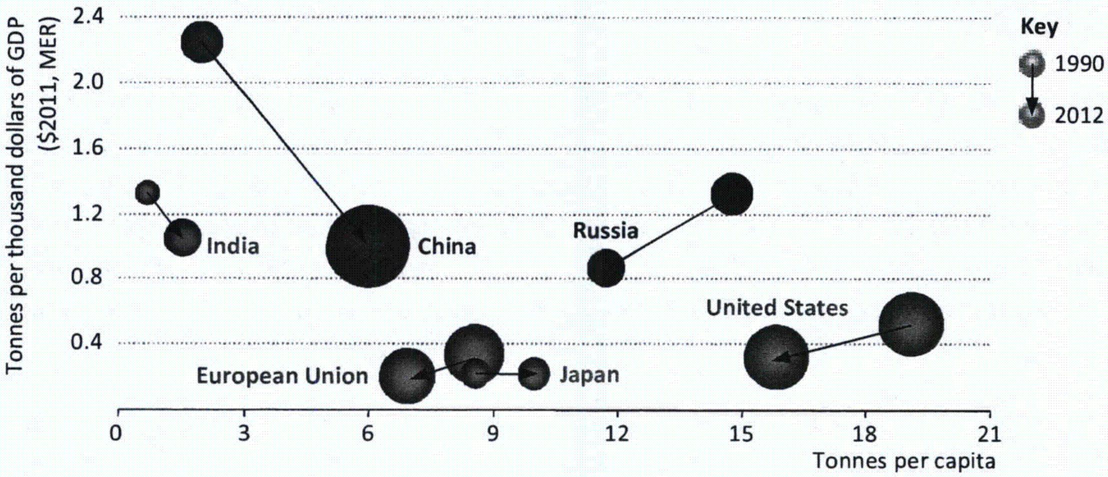
Figure 1.13 ▷ GDP and energy-related CO_2 emissions in selected countries



Note: MER = market exchange rate.

Global CO_2 per-capita emissions, having fluctuated within a range from around 3.7 to 4 tonnes CO_2 from the early 1970s to the early 2000s, have now pushed strongly beyond it, to 4.5 tonnes. Developed countries typically emit far larger amounts of CO_2 per capita than the world average, but some developing economies are experiencing rapid increases (Figure 1.14). Between 1990 and 2012, China's per-capita emissions tripled, rapidly converging with the level in Europe, while India's more than doubled, though remaining well below the global average. Over the same period, per-capita emissions decreased significantly in Russia and the United States, yet remained at relatively high levels.

Figure 1.14 ▷ Energy-related CO_2 emissions per capita and CO_2 intensity in selected regions



Notes: Bubble area indicates total annual energy-related CO_2 emissions in that region. MER = market exchange rate.

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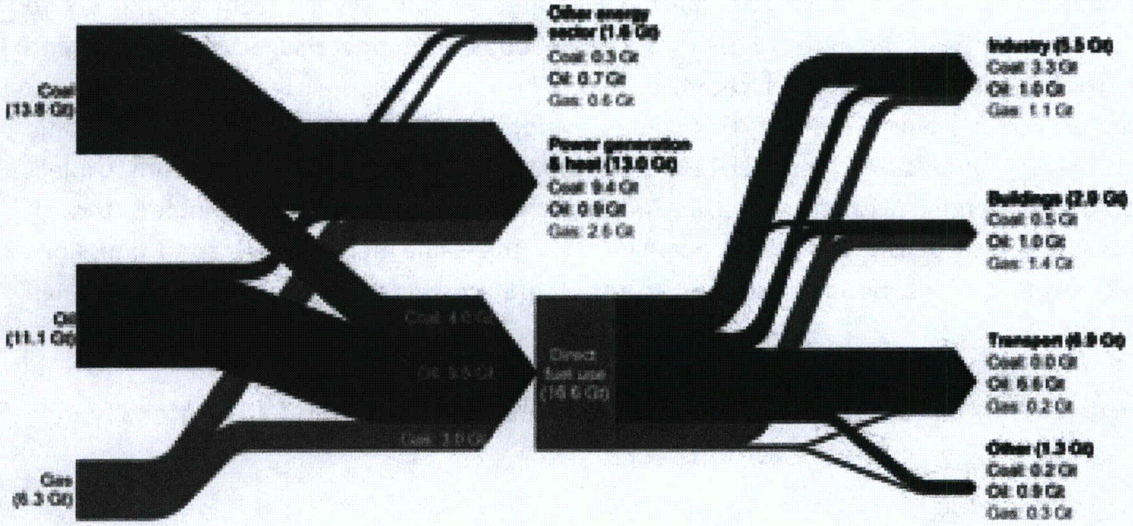
Trends by energy sector

The power and heat sector is the largest single source of energy sector CO_2 emissions. It produced over 13 Gt of CO_2 in 2011[7] (Figure 1.15), more than 40% higher than in 2000. Trends in CO_2 emissions per kilowatt-hour of electricity produced in a given country largely reflect the nature of the power generation. Countries with a large share of renewables or nuclear, such as Brazil, Canada, Norway and France have the lowest level. Of those regions relying more heavily on fossil fuels, the large natural gas consumers, such as Europe and Russia, have levels below the world average. Despite efforts in many countries to develop more renewable energy, in global terms the power sector is still heavily reliant on coal, accounting for nearly three-quarters of its emissions. Australia, China, India, Poland and South Africa are examples of countries still heavily reliant on coal to produce electricity, reflecting their resource endowment. In the United States, electricity generation from coal has decreased 11% since 2000, coal consumption for power generation falling by 64 million tonnes of oil equivalent (Mtoe) and yielding a decline in overall emissions from the power sector of 0.8% per year on average.

Figure 1.15 ▷ World energy-related CO_2 emissions by fuel and sector, 2011



CO_2 emissions from transport, the largest end-use sector source, were just under 7 Gt in 2011.[8] Emissions from the sector, which is dominated by oil for road transport, have increased by 1.7% per year on average since 2000, but with differing underlying regional trends. OECD transport emissions are around 3.3 Gt: having declined to around year-2000 levels during the global recession, they have remained broadly flat since. Market saturation in some countries and increasing efficiency and emissions standards appear to be curtailing

7. CO_2 emissions data by sector for the year 2012 were not available at the time of writing. Unlike previous sections, this one uses 2011 as latest data point.

8. At the global level, transport includes emissions from international aviation and bunkers.

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emissions growth. Non-OECD transport CO_2 emissions have increased by more than 60% since 2000, reaching 2.5 Gt in 2011, with increased vehicle ownership being a key driver. Emissions in China and India have both grown strongly but, collectively, their emissions from transport are still less than half those of the United States. More than 50 countries have so far mandated or promoted biofuel blending to diminish oil use in transport. Emissions from international aviation and marine bunkers are on a steady rise. They reached 1.1 Gt in 2011, up from 0.8 Gt in 2000.

Having remained broadly stable at around 4 Gt for much of the 1980s and 1990s, CO_2 emissions from industry have increased by 38% since the early 2000s, to reach 5.5 Gt. All of the net increase has arisen in non-OECD countries, with China and India accounting for some 80% of the growth in these countries. China now accounts for 60% of global coal consumption in industry. Iron and steel industries account for about 30% of total CO_2 emissions from the industrial sector.

Total energy-related CO_2 emissions in the buildings sector (which includes residential and services) reached 2.9 Gt in 2011, continuing the gradually increasing trend of the last decade. Natural gas is the largest source of emissions – about 50% of the total – with the OECD (mainly the United States and Europe) accounting for two-thirds of the total. Non-OECD emissions from oil overtook those of the OECD, which are in decline, in 2011. Many other changes in the buildings sector, such as increasing electricity demand for lighting, cooking, appliances and cooling, are captured in changes in the power sector.

Outlook for energy-related emissions and the 450 Scenario

This section analyses the disconnect between the energy path the world is on and an energy pathway compatible with a 2 °C climate goal. It does so by presenting and analysing, by fuel, region and sector, the essential differences between the New Policies Scenario, a scenario consistent with the policies currently being pursued, and the 450 Scenario, a 2 °C climate scenario, both of which were fully developed in *WEO-2012* (Box 1.3). Our analysis shows that the energy projections in the New Policies Scenario are consistent, other things being equal, with a 50% probability of an average global temperature increase of 3 °C by 2100 (compared with pre-industrial levels) and of 3.6 °C in the longer term.[9] This compares to 1.9 °C by 2100 and 2 °C in the long term in the 450 Scenario. This indicates the extent to which the energy world is going to have to change: continuing on today's path, even with the assumed implementation of new policies, would lead to damaging climatic change.

The present energy trajectory indicates increasing energy-related CO_2 emissions through to 2035. By contrast, to meet the requirements of the 450 Scenario, emissions need to peak by 2020 and decline to around 22 Gt in 2035 – around 30% lower than in 2011, a level last seen in the mid-1990s (Figure 1.16). The cumulative "emissions gap" between

9. The long-term temperature change is associated with a stabilisation of greenhouse-gas concentrations, which is not expected to occur before 2200.

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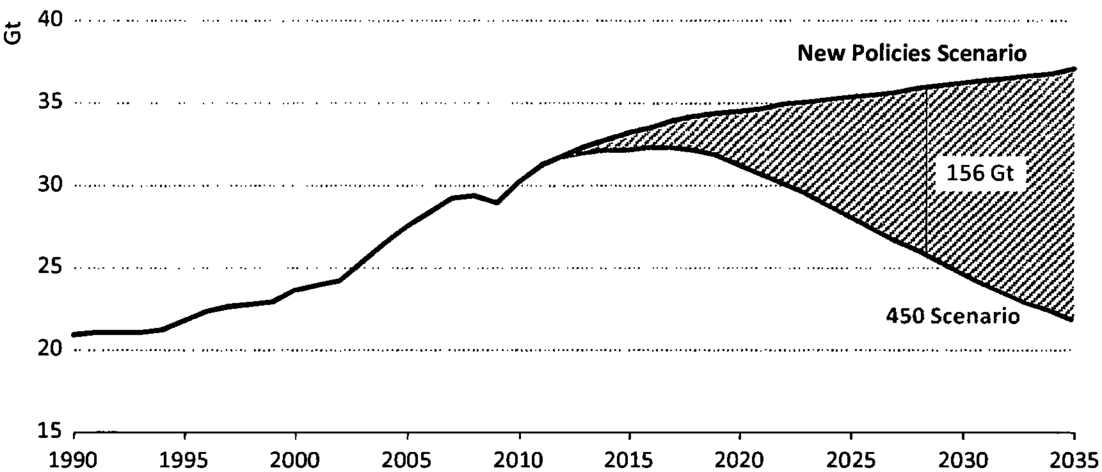
the scenarios over the projection period is around 156 Gt, an amount greater than that emitted by the United States over the last 25 years. Such a path of declining emissions demands unprecedented change. The 450 Scenario shows how it could be achieved, based on policies and technologies that are already known; but, crucially, it requires urgent commitment to strong action, followed by robust, unwavering implementation. If the 450 Scenario trajectory is successfully followed, by 2035, non-OECD countries will have achieved more than 70% of the total reduction (10.5 Gt) in annual CO_2 emissions in the 450 Scenario, compared with the New Policies Scenario.

Figure 1.16 ▷ World energy-related CO_2 emissions by scenario



In both scenarios considered here, GDP growth averages 3.1% per year and population growth averages 0.9%, pushing total primary energy demand higher; but this demand is met increasingly from low or zero-carbon sources. To be consistent with the required trajectory in the 450 Scenario, energy-related CO_2 emissions must begin to decline this decade, even though the level of energy demand is expected to increase by 0.5% per year, on average: CO_2 emissions peak by 2020 and then decline by 2.4% per year on average until 2035. Looking across the fossil fuels, gas demand increases by 0.7% per year on average, oil decreases by 0.5% per year and coal declines by 1.8% per year. Energy efficiency policies are the most important near-term emissions mitigation measure (see Chapter 2 for more on ways to save CO_2 in the short term). By 2035, actions to improve energy efficiency successfully reduce global emissions in that year by 6.4 Gt – equivalent to about 20% of global energy-related CO_2 emissions in 2011. The payback periods for many energy efficiency investments are short, but non-technical barriers often remain a major obstacle. It is these barriers that governments need to tackle (see *WEO-2012* and Chapter 2).

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Box 1.3 ▷ Overview of the New Policies Scenario and the 450 Scenario

The analysis in this chapter of the disconnect between the energy path the world is currently on and an energy trajectory consistent with a 50% chance of achieving the 2 °C climate goal relies on two scenarios, both of which were fully developed in the *WEO-2012*.[10]

- The **New Policies Scenario**, though founded essentially on existing policies and realities, also embodies some further developments likely to improve the energy trajectory on which the world is currently embarked. To this end, it takes into account not only existing energy and climate policy commitments but also assumed implementation of those recently announced, albeit in a cautious manner. Assumptions include the phase-out of fossil-fuel subsidies in importing countries and continued, strengthened support to renewables. The objective of this scenario is to provide a benchmark against which to measure the potential achievements (and limitations) of recent developments in energy policy in relation to governments' stated energy and climate objectives.
- The **450 Scenario** describes the implications for energy markets of a co-ordinated global effort to achieve a trajectory of greenhouse-gas emissions consistent with the ultimate stabilisation of the concentration of those gases in the atmosphere at 450 ppm CO_2-eq (through to the year 2200). This scenario overshoots the 450 ppm level before stabilisation is achieved but not to the extent likely to precipitate changes that make the ultimate objective unattainable. The 450 Scenario offers a carefully considered, plausible energy path to the 2 °C climate target. For the period to 2020, we assume policy action sufficient to implement fully the commitments under the Cancun Agreements. After 2020, OECD countries and other major economies are assumed to set emissions targets for 2035 and beyond that collectively ensure an emissions trajectory consistent with ultimate stabilisation of greenhouse-gas concentration at 450 ppm, in line with what was decided at COP-17 to establish the "Durban Platform on Enhanced Action", to lead to a new climate agreement. We also assume that, from 2020, $100 billion in annual financing is provided by OECD countries to non-OECD countries for abatement measures.

The projections for the scenarios are derived from the IEA's World Energy Model (WEM) – a large-scale partial equilibrium model designed to replicate how energy markets function over the medium to long term.[11] The OECD's ENV-Linkages model has been used to provide the macroeconomic context and for the projections of greenhouse-gas emissions other than energy-related CO_2.[12]

10. The detailed list of policies by region, sector and scenario is available at: *www.worldenergyoutlook.org/media/weowebsite/energymodel/policydatabase/WEO2012_AnnexB.pdf*.

11. A full description of the WEM is available at *www.worldenergyoutlook.org/weomodel*.

12. For more information on the OECD ENV-Linkages model see Burniaux and Chateau (2008).

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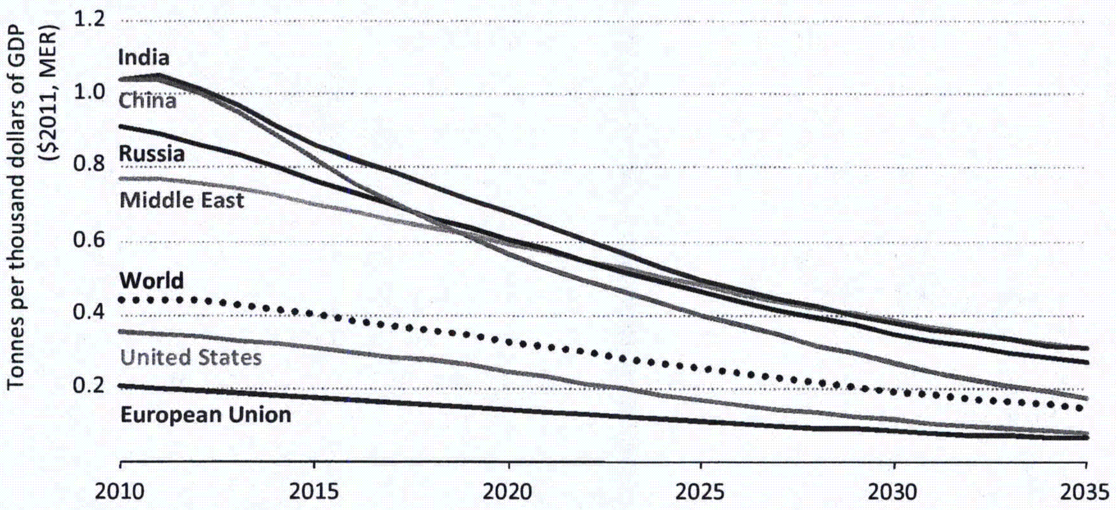
In the 450 Scenario, CO_2 emissions per capita decline gradually prior to 2020 and then, reflecting more robust policy action, decline more rapidly, the global average reaching 2.6 tonnes CO_2 per capita in 2035 (compared with 4.3 tonnes CO_2 in the New Policies Scenario). Significant variations persist across regions, with the non-OECD average per capita level still being less than half that of the OECD in 2035.

In the 450 Scenario, the carbon intensity of the world economy is around one-third of existing levels by 2035, with many non-OECD countries delivering the biggest improvements (Figure 1.17) as they seize the opportunity to base their extensive investment programmes in additional energy supply on low-carbon sources. OECD countries are, however, far from free of challenge. In the 450 Scenario, energy-related CO_2 emissions in the OECD are around half current levels by 2035, reaching just over 6 Gt – a decline of nearly 3% per year on average.

Figure 1.17 ▷ CO_2 intensity in selected regions in the 450 Scenario



Note: MER = market exchange rate.

Sectoral trends

The 450 Scenario requires a rapid transformation of the power sector. In some respects it involves only an acceleration of trends already underway, such as moving to more efficient generation technologies and the increased deployment of renewables, but innovation is also required, such as the adoption of CCS technology. Overall, electricity generation in 2035 is 13% lower than in the New Policies Scenario, but CO_2 emissions from the power sector are more than 10 Gt (70%) less (Figure 1.18). Electricity demand in transport in that year is 85% higher in the 450 Scenario than in the New Policies Scenario, but it is 17% lower in buildings, due to more efficient appliances, heating equipment and lighting. In industry, electricity demand is 12% lower in 2035, mainly due to more efficient motor systems.

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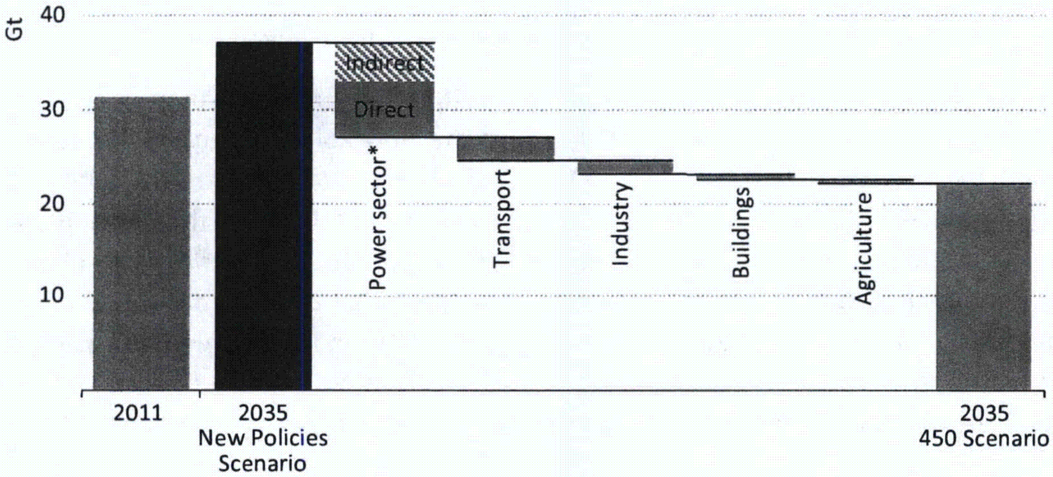
Figure 1.18 ▷ World energy-related CO_2 emissions abatement by sector in the 450 Scenario relative to the New Policies Scenario



*Indirect electricity savings in the power sector result from demand reduction in end-use sectors, while direct savings are those savings made within the power sector itself (*e.g.* plant efficiency improvements). Direct savings include heat plants and other transformation.

In the 450 Scenario, the share of electricity generation from fossil fuels declines from more than two-thirds in 2011 to one-third in 2035. Electricity generation from coal declines to half of existing levels by 2035 and installed capacity is 1 100 GW lower than in the New Policies Scenario (see Chapter 3 on the risk of stranded assets). In the OECD, the greatest change in coal-fired capacity occurs in the United States, but the biggest changes globally are in non-OECD countries, where the recent reliance on new fossil-fuel capacity (especially coal) to meet rising demand gives way to increased use of low-carbon sources. Natural gas is the only fossil fuel with increasing electricity generation in the 450 Scenario, but it still peaks before 2030 and then starts to decline, ending 18% higher in 2035 than in 2011. CCS becomes a significant source of mitigation from 2020 and saves 2.5 Gt CO_2 in 2035, equivalent to around one-and-a-half times India's emissions today. In several countries, including China and the United States, very efficient coal-fired power stations are built up to 2020 and are retrofitted with CCS in the following years. Installed global nuclear capacity doubles by 2035 in the 450 Scenario, significantly higher than in the New Policies Scenario, with the largest increases in China and India, and additional capacity being installed in the United States and Europe. Electricity generation from renewables increases almost 11 000 terawatt-hours (TWh) to 2035, with wind, hydro and solar PV growing most strongly. Renewables-based electricity generation supplies almost half the world's electricity in 2035.

In the 450 Scenario, global transport CO_2 emissions peak around 2020 but then decline, ending 5% below 2011 levels in 2035 (2.4 Gt below the level in the New Policies Scenario in 2035). A range of mitigation measures is incorporated in the 450 Scenario, with fuel efficiency gains and an increase in the use of biofuels being particularly important up to 2020. Such policies are already in place in the United States, which has mandated the use

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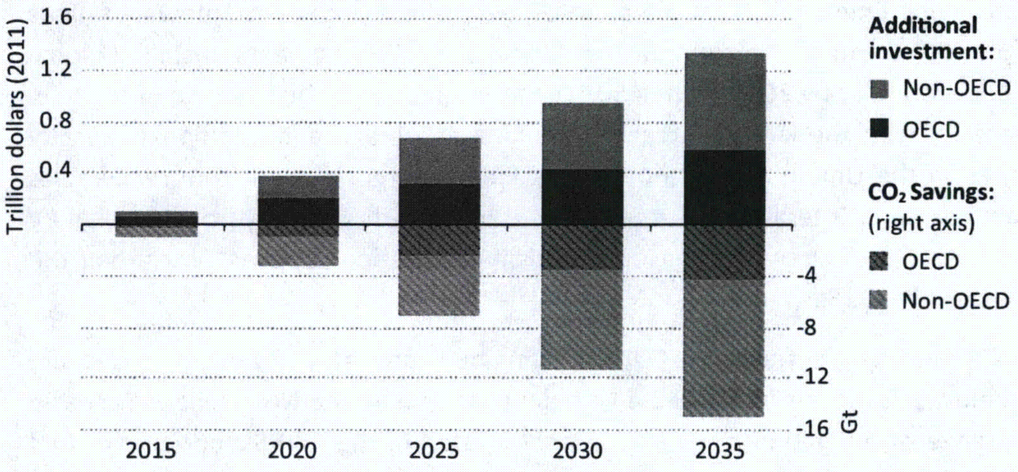
of 36 billion gallons of biofuels by 2022, and in the European Union, where the Renewable Energy Directive requires a mandatory share of 10% renewable energy in transport by 2020. Improved efficiency becomes even more important globally after 2020, alongside lower growth in vehicle usage in countries where subsidies are removed.

In industry, global energy-related CO_2 emissions in 2035 are 5% lower than in 2011 in the 450 Scenario, at around 5.2 Gt, 21% lower than the New Policies Scenario. Improved energy efficiency accounts for more than half the reduction in cumulative terms, with CCS in energy-intensive industries and fuel switching also playing a role. More than 80% of the CO_2 savings in the sector in the 450 Scenario come from non-OECD countries, with China, India and the Middle East all making notable improvements. By 2035, global emissions in buildings are 11% lower than 2011 in the 450 Scenario, at around 2.6 Gt, with the savings relative to the New Policies Scenario being spread relatively evenly between OECD and non-OECD countries. Much more energy efficient buildings are adopted from around 2020 onwards.

Investment

A 2 °C world – as in the 450 Scenario – requires increased investment in the power sector and in end-use sectors, but reduced investment in fossil-fuel supply. In the 450 Scenario, total investment in fossil-fuel supply is $4.9 trillion lower than in the New Policies Scenario through to 2035, and investment in power transmission and distribution networks is around $1.2 trillion lower. However, this saving is more than offset by a $16.0 trillion increase in investment in low-carbon technologies, efficiency measures and other forms of intervention. Part of the incremental investment is offset by savings in consumers' expenditure on energy. Additional investment across OECD countries reaches around $590 billion per year in 2035 and in non-OECD countries around $760 billion (Figure 1.19).

Figure 1.19 ▷ World annual additional investment and CO_2 savings in the 450 Scenario relative to the New Policies Scenario



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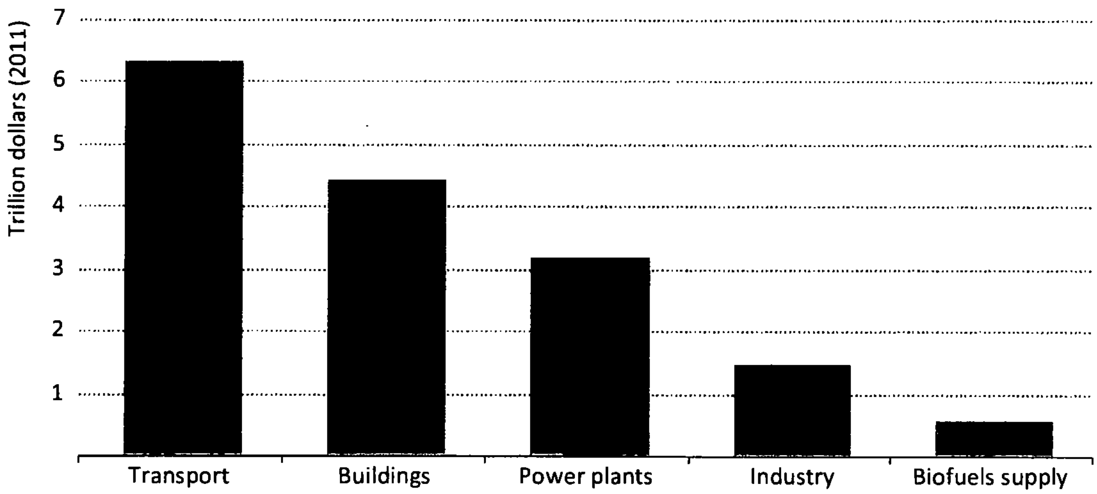
Transport requires the largest cumulative additional investment in the 450 Scenario, relative to the New Policies Scenario – $6.3 trillion (Figure 1.20). Most of this is directed towards the purchase of more efficient or alternative vehicles. The buildings sector requires $4.4 trillion in cumulative additional investment, but this reflects investment that both delivers direct abatement from buildings and indirect abatement through reduced electricity demand. The decarbonisation of the power sector requires a net additional $2.0 trillion, after accounting for the lower investment need for transmission and distribution lines. More than 80% of the additional investment in electricity generation goes to renewables-based technologies. Industry invests an additional $1.5 trillion, around one-quarter of it directed to CCS.

Figure 1.20 ▷ Cumulative change in world investment by sector in the 450 Scenario relative to the New Policies Scenario, 2012-2035



Note: Investment in power plants increases, but investment for transmission and distribution (not shown here) declines by a cumulative total of around $1.2 trillion over the period.

Broader benefits of the 450 Scenario

The transformation of the global energy system in the 450 Scenario delivers significant benefits in terms of reduced fossil-fuel import bills, enhanced energy security, better air quality, positive health impacts and reduced risk of energy-related water stress. Fossil-fuel prices are lower in the 450 Scenario than the New Policies Scenario (Table 1.1), driven by lower demand. In real terms, the IEA crude oil import price needed to balance supply and demand in the 450 Scenario reaches $115/barrel (in year-2011 dollars) around 2015 and then declines to $100/barrel in 2035 ($25/barrel lower than the New Policies Scenario). Coal and gas prices are also lower in the 450 Scenario. The steam coal import price in the OECD is almost 40% cheaper in 2035 and the natural gas price in Europe and the Pacific is around 20% cheaper. Lower international fuel prices and lower demand might be expected, other things being equal, to lead to lower fuel expenditure by consumers. But we assume that end-use fuel prices in the transport sector are kept at higher levels through taxation,

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reducing potential savings to consumers but increasing the revenues of the governments of importing countries. Also, higher CO_2 prices and lower fossil-fuel subsidies reduce customers' demand for carbon-intensive technologies and wasteful fuel consumption.

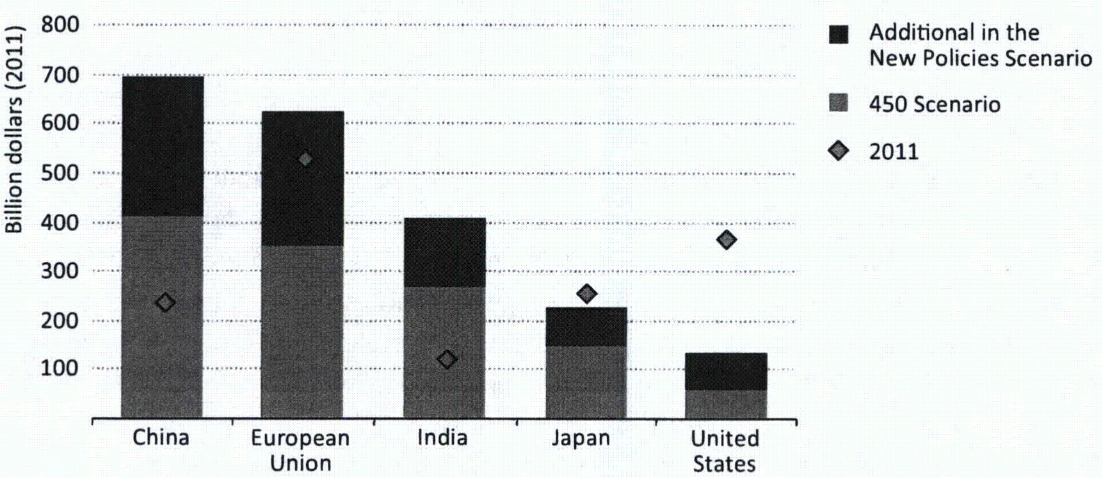
Table 1.1 ▷ Fossil-fuel import prices by scenario (in year-2011 dollars per unit)

			New Policies Scenario			450 Scenario		
	Unit	2011	2020	2030	2035	2020	2030	2035
IEA crude oil imports	barrel	108	120	124	125	113	105	100
Natural gas								
United States	MBtu	4.1	5.4	7.1	8.0	5.5	7.6	7.6
Europe imports	MBtu	9.6	11.5	12.2	12.5	10.8	10.0	9.6
Japan imports	MBtu	14.8	14.3	14.7	14.8	13.5	12.5	12.2
OECD steam coal imports	tonne	123	112	114	115	98	78	70

Notes: Gas prices are weighted averages expressed on a gross calorific-value basis. All prices are for bulk supplies exclusive of tax. The US price reflects the wholesale price prevailing on the domestic market. MBtu = million British thermal units.

Collectively, in 2035, the five-largest fossil-fuel importers spend $850 billion less in the 450 Scenario than in the New Policies Scenario (Figure 1.21). This is equivalent to 1% of their GDP in that year. In 2035, China's oil imports are 3.6 million barrels per day (mb/d) lower, while imports into the European Union are 2 mb/d lower, in the United States 1.3 mb/d lower and in India 1 mb/d lower. North America as a whole becomes a net oil exporter slightly sooner in the 450 Scenario (before 2030) and is a net exporter of larger volumes by 2035. European net imports of gas are around 190 billion cubic metres lower in 2035 in the 450 Scenario, compared with the New Policies Scenario, reducing the gas import bill by around $120 billion.

Figure 1.21 ▷ Fossil-fuel import bills in selected regions by scenario in 2035



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The 24% reduction in the cost of local pollution controls (for SO_2, NO_X and $PM_{2.5}$) in 2035 in the 450 Scenario, relative to the New Policies Scenario, is small when compared with energy sector investment costs or potential fossil-fuel import bill savings, but is associated with improved quality of life and health. In China, local pollution in several cities has already prompted increased government action. In our New Policies Scenario, pollution control costs increase by nearly 80% to 2035, and non-OECD pollution control costs as a whole overtake those of the OECD around the middle of the projection period (Table 1.2). In the 450 Scenario, world pollution control costs still rise, but at a much slower rate, with the OECD level being similar to 2011 in 2035 and the non-OECD level being much lower than in the New Policies Scenario.

Table 1.2 ▷ Pollution control costs by region and scenario ($2011 billion)

		New Policies Scenario		450 Scenario	
	2011*	2020	2035	2020	2035
OECD	**203**	**256**	**261**	**244**	**206**
United States	72	89	85	86	65
Europe	81	106	112	100	94
Japan	22	23	21	22	15
Other OECD	29	38	42	36	32
Non-OECD	**124**	**234**	**325**	**220**	**237**
Russia	8	14	18	14	14
China	49	96	124	89	81
India	6	15	34	14	28
Middle East	11	21	32	20	24
Latin America	17	31	41	30	33
Other non-OECD	33	57	76	53	58
World	**327**	**489**	**586**	**463**	**443**
European Union	86	108	124	100	94

* Estimate.

Source: IIASA (2012).

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Energy policies to keep the 2 °C target alive

Short-term actions for long-term gain

Highlights

- The absence of early, tangible achievement in the international climate negotiations and the sluggish global economy are threatening the viability of the 2 °C climate goal by weakening confidence in the investment case for a low-carbon economy. To keep the door to the 2 °C target open, we propose a set of pragmatic policy actions that, without harming economic growth and using available technologies and policies, can result in a global peak in energy-related GHG emissions by 2020. The four priority areas in our 4-for-2 °C Scenario are: specific energy efficiency measures; limits to the use and construction of inefficient coal power plants; minimising methane (CH_4) releases to the atmosphere in oil and gas production; and a partial phase-out of fossil-fuel subsidies.
- In the 4-for-2 °C Scenario, energy-related CO_2 and CH_4 emissions increase from 33.3 Gt in 2010 to 34.9 Gt in 2020 (measured on a CO_2-eq basis) and decline thereafter. Emissions in 2020 are 3.1 Gt lower than the course on which we otherwise appear to be set, delivering 80% of the abatement needed to be on track with a 2 °C trajectory.
- Energy efficiency accounts for 49% of the savings realised, limitations on inefficient coal-fired power plants for 21%, lower methane emissions in upstream oil and gas for 18%, and the partial phase-out of fossil-fuel subsidies for 12%. Restrictions on coal use support the growth of renewables, which increase their share in power generation to 27% in 2020, up from around 20% today.
- In addition to addressing climate change, the policies assumed in the 4-for-2 °C Scenario reduce local air pollution and increase energy security without hampering economic growth of any given region. Required additional investment to 2020 is more than offset by reduced spending on fuel bills. A gradual reorientation of the economy resulting from the implementation of the four policies entails losses in some sectors, including oil and gas upstream and electricity, but gains in other areas.
- The 4-for-2 °C Scenario buys precious time to keep the 2 °C target alive, while international negotiations continue, avoiding much carbon lock-in; but it is insufficient to limit the long-term temperature increase to 2 °C. A framework conducive to more ambitious abatement after 2020 needs to be developed, not least to provide clear market signals to businesses and long-term investors, notably including a global carbon price and roll-out of low-carbon technologies at scale. In the 450 Scenario, delaying CCS deployment by ten years would increase the cost of decarbonisation in the power sector by $1 trillion and result in lost revenues for coal producers ($690 billion) and oil and gas producers ($660 billion).

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Introduction

Various initiatives have recently been undertaken with the explicit objective of reducing greenhouse-gas emissions, such as new schemes to price carbon-dioxide (CO_2) emissions (either through cap-and-trade programmes or carbon taxes) in Australia, Korea and California, along with other measures that serve implicitly to incorporate CO_2 pricing into investment decisions in the energy sector (Chapter 1). Some actions taken primarily for other purposes, for example to reduce local air pollution or improve energy efficiency or in response to price changes, also benefit CO_2 abatement. The recent switch from coal to natural gas in the power sector of the United States as a result of lower gas prices is one example of climate benefits derived from changes driven by the market, rather than by deliberate climate policy action. Nonetheless, the chance of achieving abatement on the scale needed to follow a trajectory consistent with a global average temperature rise of no more than 2 degrees Celsius (°C) now appears more remote than it was several years ago, particularly as governments grapple with economic crisis in many parts of the world. A first effect of lower economic activity in some regions has been to reduce the expected level of emissions; but the crisis has also curtailed direct government action to limit climate change, partly as a result of fears that more stringent climate policies could result in a loss of economic competitiveness. In some cases, these concerns have been heightened by wide divergences in energy prices between different regions.

In view of the long lifetime of capital stock in the energy sector, lack of momentum towards concerted global climate policy action directly increases the scale of the challenge to meet the 2 °C climate goal by failure to deter additional investment in emissions-intensive infrastructure, thereby "locking in" emissions for decades to come. The date at which the existing energy infrastructure will "lock in" all the CO_2 emissions from the energy sector provided for in a global CO_2 emissions budget consistent with a 2 °C trajectory, leaving no provision for emissions from new carbon-emitting infrastructure to meet growing demand, is close. Thereafter, it becomes ever more costly and difficult to achieve the stated goal (see Chapter 3). In addition, research suggests that there is a point of no return at which climate feedbacks could become self-reinforcing (though there is remaining uncertainty as to exactly when this occurs), thus closing the door to 2 °C forever (Lenton, *et al.*, 2008). While the timetable to which international climate negotiators are working provides for implementation of a legally-enforceable agreement to reduce emissions from 2020, our projections suggest that, without earlier additional action at national level, global energy-related CO_2 and methane (CH_4) emissions in 2020 will already be 3.9 gigatonnes (Gt) CO_2-equivalent (CO_2-eq) above the level needed to follow a 2 °C trajectory.

It thus becomes essential to consider what can be done in the short term to keep the door to 2 °C open. It seems unlikely that national policy makers will implement actions that are challenging to their national economy given the economic situation in many countries. In this chapter, therefore, we set out to identify a set of pragmatic and achievable policy measures which, in net terms, do no harm to national economic growth yet which, taken together, would reduce global greenhouse-gas emissions in the period to 2020 by substantially more

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than the reduction expected to be achieved by existing and planned policies alone. These measures would take us only part of the way towards an emissions trajectory that would achieve the 2 °C goal; but in the second part of the chapter we explore additional elements to support ambitious abatement after 2020, which would help the overall goal to be met.

GDP-neutral emissions abatement to 2020

Methodology and key assumptions

Many policies to support the growth of low-carbon technologies and to moderate the growth of energy demand until 2020 and beyond are in place or already planned today: these are the policies embodied in the New Policies Scenario of the *World Energy Outlook 2012* (*WEO-2012*), a scenario consistent with the course on which governments appear at present to be embarked (IEA, 2012a). Exceptionally, as a result of the policy focus over the last decade, the deployment of renewables today is already broadly on track towards the more ambitious level required to deliver their expected contribution in 2020 to meeting long-term climate targets (IEA, 2013a). On the other hand, while energy efficiency, too, has been high on the policy agenda in recent years, existing and planned policies are likely to leave two-thirds of the global economically viable energy efficiency potential untapped (IEA, 2012a). Therefore, much wider adoption of efficiency measures will be necessary to fulfil the energy efficiency expectations of a scenario consistent with the achievement of the international 2 °C climate target.

The short-term measures considered in this chapter, collectively embodied in what we describe as the 4-for-2 °C Scenario, go beyond policies already adopted and entail measures that require either significant further strengthening and wider adoption, or that are currently not high on the policy agenda, even though the measures required to implement the relevant policies are known and their adoption could make a significant additional difference. This is the approach adopted in the 4-for-2 °C Scenario, which is based on two core assumptions. First and foremost, the measures that are assumed to be adopted are readily available today, meaning they do not require the identification and implementation of innovative sets of energy policies or the deployment of technologies that have yet to be proven in the market. Though the individual measures have not yet been adopted everywhere, they have already been proven in some countries, and therefore just need to be tailored to national circumstances elsewhere. Second, the set of measures adopted, when taken together and in net terms, does not adversely affect economic growth in any given country or region. Although the proposed measures involve an initial deployment cost, the set of proposed policies as a whole is calculated to deliver economic savings (such as through lower fuel bills) to the extent that the initial deployment costs of the proposed policies are offset within each economy, considered as a whole.[1] As a consequence, the set of policies proposed does not harm overall economic growth up to 2020. Beyond 2020, it actually improves the competitiveness of the economies concerned

1. The judgement expressed here about economic effects apply to regions taken as a whole, using standard groupings in the *World Energy Outlook* series (see *www.worldenergyoutlook.org*).

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and the ability of their energy system to make the transition towards a low-carbon basis in the long term.

The emphasis of the 4-for-2 °C Scenario is on measures which can be implemented effectively in the short term, to provide breathing space for the international negotiations aimed at policy implementation by 2020. The measures adopted produce valuable results in the period to 2020, though their effect continues beyond that date. In developing the 4-for-2 °C Scenario, we reviewed a wide range of measures that we assessed as being both practical and implementable in a short time frame and capable of having a significant impact on global greenhouse-gas emissions in the period to 2020. We then analysed the impact on global energy consumption and emissions of the implementation of the package of measures under consideration using the IEA's World Energy Model (WEM) and the impact on GDP at regional level using the ENV-Linkages model of the Organisation for Economic Co-operation and Development (OECD).[2] If the package of measures as a whole was found to reduce economic growth in the period to 2020 in any region, then the level of ambition of the policies with the most severe negative impact on GDP was reduced or – where applicable – the measure was abandoned.

Based on this iterative process, we have identified a package of four measures, elaborated below, that meet the criteria of making a significant contribution to CO_2 abatement in the period to 2020 without adversely affecting economic growth. Each of the measures selected can be readily implemented and does not require the use of new technologies with high upfront deployment costs that would require time to apply beyond niche markets (such as electric vehicles), nor major technological breakthroughs, nor radical changes in consumer behaviour (except those induced by changing prices or increased availability of capital in certain sectors). Many of the measures that were excluded from the 4-for-2 °C Scenario might well be cost-effective in the long-run, but they are judged to have less certain potential to make a significant impact on global emissions by 2020. Highly successful existing policies, like support for renewables, have not been selected for enhancement in the short term if they appear to be broadly on track to deliver in 2020 the contribution that they are required to make in the (more demanding) 450 Scenario, which is consistent with achievement of the long-term climate objective.

The four policy measures adopted in the 4-for-2 °C Scenario are (Figure 2.1):

- Targeted specific energy efficiency improvements in the industry, buildings and transport sectors.
- Limiting the use and construction of inefficient coal-fired power plants.
- Minimising methane emissions in upstream oil and gas production.
- Further partial phase out of fossil-fuels subsidies to end-users.

2. WEM is a partial equilibrium model. ENV-Linkages is a computational general equilibrium model. The coupling of both models allows the impact of energy policy on economic growth to be assessed.

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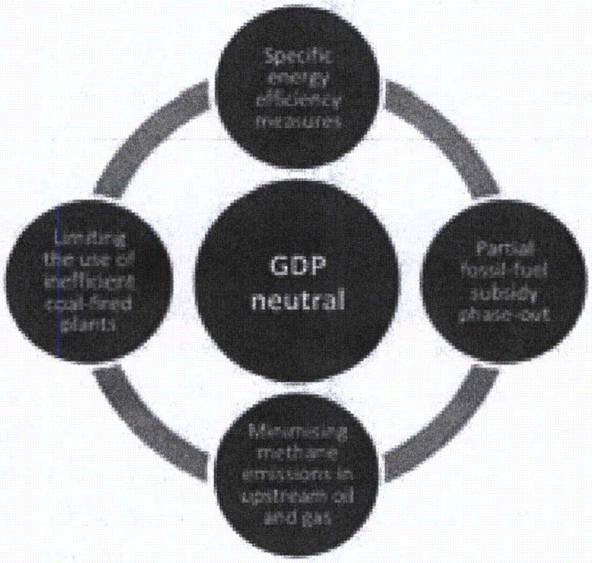
Figure 2.1 ▷ Policy pillars of the 4-for-2 °C Scenario



Although the adoption of these measures is primarily directed at the reduction of greenhouse-gas emissions, they also offer important co-benefits and often complement each other (Table 2.1, see also Box 2.3). The phase-out of fossil-fuel subsidies, for example, would incentivise energy efficiency improvements, while the use of more efficient end-use technologies complements the limitation on the use of inefficient coal power generation by moderating growth in electricity demand.

Table 2.1 ▷ Multiple benefits of policies in the 4-for-2 °C Scenario

	Climate	Local air pollution	Energy security	Economic growth	Energy poverty
Improving energy efficiency	✓	✓	✓	✓	✓
Limiting inefficient coal use in power	✓	✓	✓		
Reducing upstream methane emissions	✓	✓	✓		✓
Fossil-fuel subsidy phase-out	✓	✓	✓	✓	✓

In a special focus on **energy efficiency**, the *WEO-2012* identified an extensive range of measures, by country and by sector, capable of reducing energy consumption in a cost-effective manner (IEA, 2012a). However, since implementation of some of the efficiency policies identified in *WEO-2012* would depend upon the prior elimination of serious market barriers (which in practice could take considerable time), only a selected sub-set of the measures are adopted in 4-for-2 °C Scenario, namely: (i) reducing energy use from new space and water heating, as well as cooling equipment; (ii) more efficient lighting and new appliances; (iii) improving the efficiency of new industrial motor systems; and (iv) setting standards for new vehicles in road transport. Measures to meet the objectives are already widely deployed in many countries, using readily available technologies and methods. While there are some market barriers, steps to

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overcome them have been identified and successfully implemented. Bilateral and/or multilateral agreements could facilitate their adoption and implementation on a wider scale.

In **the power sector**, we first assume that a ban is introduced on the construction of new subcritical coal-fired power plants (although it does not apply to units already under construction). The means of implementing such a policy is likely to differ by market, but a variety of options is already available including: the adoption of stringent energy efficiency or CO_2 emissions standards for coal power plants; the adoption of air pollution standards; or pricing the use of carbon, for example through an emissions trading scheme. Second, for existing inefficient coal power plants, we assume that their level of operation is reduced to the extent achievable, with the constraint of maintaining adequate electricity supply. The impact of this assumption varies by region, reflecting differences in the power generation fleet, the quality of coal used and the level of electricity demand. Intervention for existing units is likely to take a more direct regulatory form, for example assigning power production limits to each generator according to the make-up of its power plant fleet (in liberalised markets), or allocating generation slots, renewing (or not) operational licences or altering the dispatch schedule to favour more efficient plants (in regulated markets).

In the 4-for-2 °C Scenario, we also assume that policies are adopted **to reduce releases of methane to the atmosphere in upstream oil and gas production**. This primarily affects locations where the incentive to reduce methane releases are currently insufficient, *e.g.* due to a lack of domestic demand. When producing oil and natural gas, a certain proportion of gas often escapes into the atmosphere, either intentionally as part of normal venting operations, or inadvertently, for example due to the reliance on old infrastructure. In addition some natural gas can be released due to incomplete combustion either during short-term flaring (which is sometimes necessary for safety reasons or may be temporarily permitted to test the size of newly discovered reservoirs), or when natural gas produced in association with oil is flared on a routine basis, as it is at a number of locations around the world, due to lack of infrastructure to utilise the gas. Most of the natural gas that is released into the atmosphere in these ways is methane, which is a greenhouse gas with a Global Warming Potential (GWP) 25 times higher than that of CO_2 over 100 years.[3] Globally, we estimate that in 2010 natural gas releases to the atmosphere during upstream oil and gas operations resulted in 45 million tonnes (Mt) of CH_4 emissions (1 115 Mt CO_2-eq), or around 50% of total oil- and gas-related CH_4 emissions. Other significant sources of methane leakage include leakage from transmission and distribution pipelines. Measures to reduce greenhouse-gas emissions from such sources could have a significant impact, but they have not been included in the 4-for-2 °C Scenario, as it is unlikely that they could be put in place prior to 2020, in particular in countries with large transmission pipeline networks, such as Russia, or with ageing gas distribution networks, such as the United States, Europe and Russia.

3. Global Warming Potential estimates the warming effect of different greenhouse gases relative to each other.

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