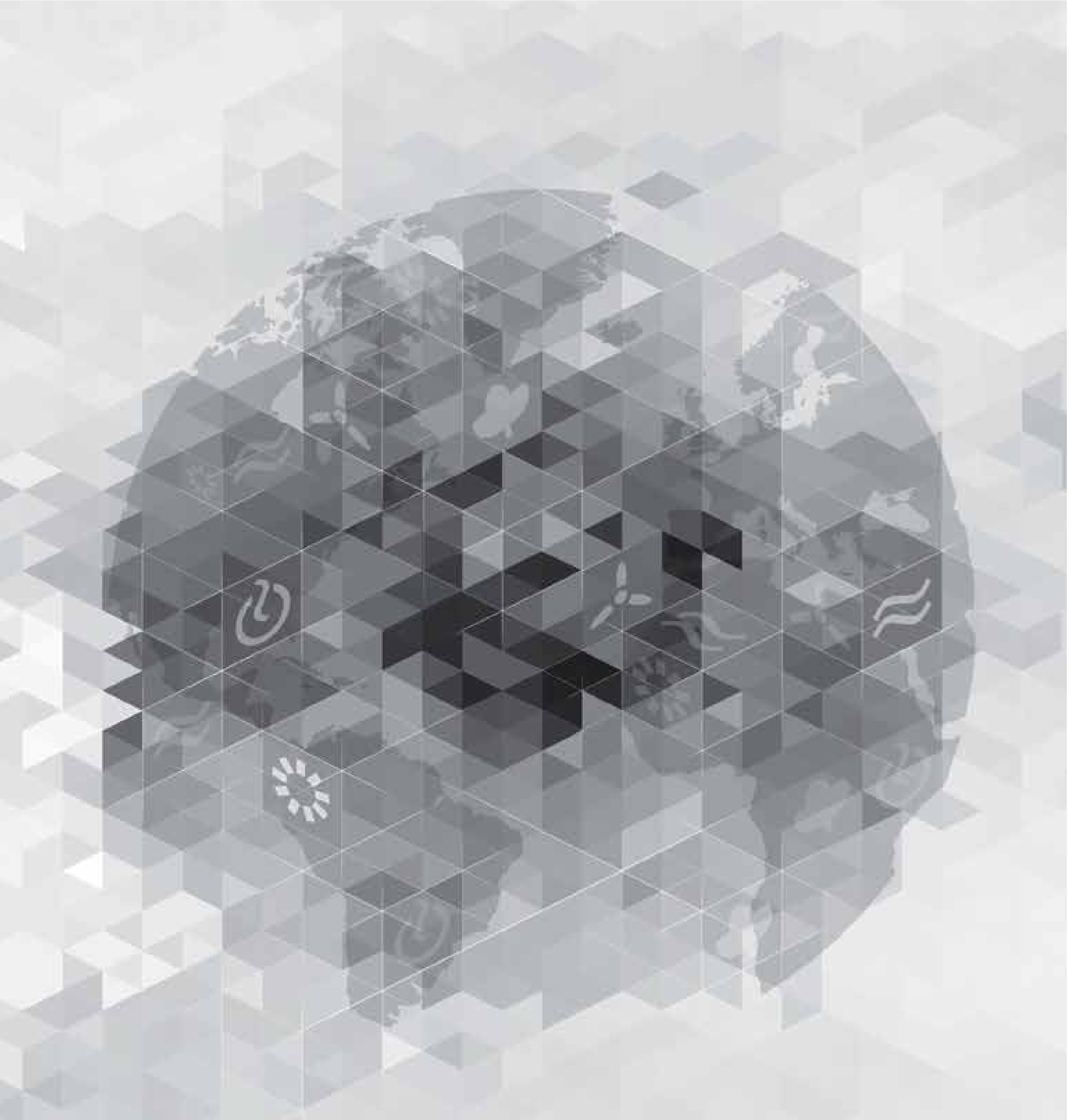
REN21 Renewable Energy Policy Network for the 21st Century



RENEWABLES GLOBAL FUTURES REPORT 2013

SUPPLEMENTARY MATERIALS: GLOSSARY, BIBLIOGRAPHY, AND ENDNOTES.

TABLE OF CONTENTS

REN21 RENEWABLES GLOBAL FUTURES REPORT
GLOSSARY, BIBLIOGRAPHY, AND ENDNOTES

Glossary 3

Bibliography 6

Endnotes 15

Suggested Citation: REN21. 2013. *Renewables Global Futures Report: Supplementary Materials* (Paris: REN21).

GLOSSARY

Biodiesel. A fuel for diesel engines installed in cars, trucks, buses, and other vehicles, and for stationary heat and power applications. Biodiesel is produced from oilseed crops such as soy, rapeseed (canola), palm oil, and mustard, and from other vegetable oil sources such as waste cooking oil and animal fats.

Biofuel. A wide range of liquid and gaseous fuels derived from biomass, including ethanol, biodiesel, and biogas, which can be burned as transport fuels and used for heating, cooking, and electricity generation. So-called "first generation" biofuels are made from a food crop, typically corn, sugar, wheat, or vegetable oils. Advanced biofuels are typically made from non-food biomass sources such as agricultural and forestry wastes, grasses, and other forms of cellulose. Advanced biofuels are generally those considered still in the pilot, demonstration, or early commercial stages, with the exception of hydro-treated vegetable oil (HVO), which is now commercially produced.

Biogas digester. Converts animal and plant organic material into a gas mixture, predominantly bio-methane that, like natural gas, can be used as fuel for lighting, cooking, heating, electricity generation, and transport.

Biomass energy/bioenergy. Power and/or heat generation from solid biomass, which includes forest product wastes, agricultural residues and waste, energy crops, and the organic component of municipal solid waste and industrial waste. Also includes power and process heat from biogas and combined heat and power plants.

Combined heat and power (CHP). Also called "cogeneration" plants, facilities that produce both heat and power, typically from burning fossil fuels or biomass, but also from geothermal and solar thermal resources. CHP plants are considered an improvement over conventional power plants that only produce electric power, because in a CHP plant, the available heat from combustion can be used productively, whereas in a conventional power plant it is lost as "waste heat" and discarded.

Concentrating solar thermal power (CSP). Systems that use mirrors or lenses to concentrate solar thermal energy into a smaller area, thereby converting the sun's incoming light energy into heat. The heat is then transported via a conducting fluid to a heat exchanger and stream turbine or Sterling engine, where it is used to generate electricity. The three main types of CSP are parabolic trough, solar power towers, and dish systems.

Demand response. In a conventional power system, power demand is taken as an uncontrollable (but well-predicted) phenomenon, and power supply is then adjusted on an ongoing basis to match demand. Demand response refers to the addition of controllable loads, so power demand can also be adjusted on an ongoing basis to match changes in power supply (for example from variable renewables). Loads may be controlled directly by the utility in a form of "dispatch" similar to the way power generation resources are dispatched, or loads may respond autonomously to technical and/or price signals according to pre-established criteria and conditions.

District heating and cooling. Provision of heating or cooling energy to multiple buildings through centralized networks (typically hot water or steam). Networks may be small, just a few buildings, or large, including tens of thousands of households. District heating and cooling systems may be supplied from conventional fossil fuels, from biomass, from solar thermal collectors, from geothermal sources, or from some combination of these sources. In some countries, the waste heat from large centralized power plants is fed into district heating networks to supply entire neighborhoods or districts of a city (with a practical limitation being the heat loss from long heat-piping networks).

Electric power grid. Typically a combination of generation, transmission, and distribution infrastructure that conveys power from large centralized plants to dispersed networks of consumers. Smaller "mini grids" or "micro grids" may serve smaller groups of consumers with local generation and no transmission. Power grids are typically designed, operated, and managed as an integrated system to provide high reliability and multiple redundancies against equipment failures to prevent blackouts. In some countries, multiple power grids serve different regions, with little or no interconnection between the multiple grids. A power grid can be composed of one or more "balancing regions," which is a part of the grid controlled by one central authority responsible for ensuring that power flows (supply and demand, imports and exports) are properly balanced within that region. That authority is typically called a "transmission system operator" (TSO) or "independent system operator."

Electric power transmission. High-capacity, high-voltage lines that carry power from central generating plants to areas of power demand, and that also interconnect different parts of a large power grid together, such as inter-city and inter-state connections. Transmission is typically designed with multiple redundant pathways and capacities, so that failure of any given line will not cause widespread outages. Transmission lines can either be overhead or buried underground.

Electric power utility. A company responsible for generation, transmission, and/or distribution components of an electric power grid, and/or provision of electric power services to consumers. In some countries, a single entity is responsible for all three functions, while in others (those that have "unbundled" their electric power sector), separate utility companies may own, operate, and be responsible for these individual functions.

Energy storage. A variety of technologies to store energy over periods of seconds to months. Most common are electricity storage technologies, such as batteries, flywheels, and supercapacitors. Pumped hydropower is the most common existing form of electricity storage. Hydrogen, either as gas or liquid, is also considered a form of energy storage, as the hydrogen can be created from electricity through an electrolyzer and then used to generate electricity through a fuel cell. Heat storage technologies are also used in buildings, using a variety of media such as bricks or water, or phase-change materials. Molten salt or oil is a form of heat storage medium in concentrating solar thermal (CSP) power plants.

Ethanol. A liquid fuel made from biomass (typically corn, sugar cane, or grains) that can replace ordinary gasoline in modest percentages for ordinary spark-ignition engines (stationary or in vehicles), or that can be used at higher blend levels (usually up to 85 percent ethanol—or 100 percent in Brazil) in slightly modified engines such as those used in "flex-fuel vehicles" that can run on various ethanol blends or on 100 percent gasoline.

Feed-in tariff (FIT). A policy that (a) guarantees grid access to renewable electricity producers; and (b) sets a fixed guaranteed price at which power producers can sell renewable power into the electric power network. Some policies provide a fixed tariff while others provide fixed premiums (premium payments) that are added to market- or cost-related tariffs. Other variations exist.

Gas turbine. A form of power generation from natural gas, generally high-efficiency. A gas turbine is the equivalent of a stationary aircraft engine that turns a shaft to generate electricity rather than producing thrust. Most gas turbines are "combined cycle," in which hot exhaust gases are used in a supplemental thermal cycle to also turn a generator shaft and generate power. "Single cycle" turbines do not use the supplemental thermal cycle, and thus are less efficient, as they waste the heat of the exhaust gases.

Geothermal. Heat energy emitted from within the Earth's crust, usually in the form of hot water or steam, which can be used to produce electricity or as direct heat for buildings, industry, and agriculture. Ground-source heat pumps use shallow geothermal heat for water and space heating.

Green power. Voluntary purchases of renewable energy, usually electricity, by residential, commercial, government, or industrial consumers, either directly from a utility company, from a third-party renewable energy generator, or through the trading of renewable energy certificates (RECs).

Hydropower. Electricity derived from the energy of water moving from higher to lower elevations. Categories of hydropower include "run-of-river," storage (reservoir) capacity behind a dam, pumped storage, or in-stream technology. Pumped storage plants are not energy sources but means for energy storage. Large hydropower is usually defined as more than 10 MW capacity, but the definition can vary by country. Other capacity scales of installations are called small-, mini-, micro-, or pico-hydropower.

Independent Power Producer (IPP). A company or any end-user that produces power and sells that power to a utility or to other end-users under specific contractual conditions, or through competitive power market trades.

Investment. In this report, "investment" in renewable energy denotes financial flows to new renewable energy power-generation and heat-supply projects. Total new investment in renewable energy includes venture capital and private equity, equity raised through public markets, corporate and government research and development spending, and asset financing.

Mandate/obligation. A measure that requires designated parties (consumers, suppliers, generators) to meet a minimum, and often gradually increasing, target for renewable energy such as a percentage of total supply or a stated amount of capacity. Costs are generally borne by consumers. In addition to renewable electricity portfolio standards/quotas, mandates can include building codes or obligations that require the installation of renewable heat or power technologies (often in combination with energy efficiency investments); renewable heat purchase requirements; and requirements for blending biofuels into transportation fuel.

Modern biomass energy. Energy from biomass-fueled technologies other than those defined for traditional biomass. They include cogeneration of power and heat, combustion, gasification, pyrolysis, anaerobic digestion to produce biogas, and production of liquid biofuels.

Net metering. A measure that allows a two-way flow of electricity between the electricity distribution grid and customers with their own generation system. The customer pays only for the net electricity delivered from the utility (total consumption minus self-production). A variation that employs two meters with differing tariffs for purchasing electricity or exporting excess electricity off site is called "net billing."

Ocean energy. Energy that can be captured from ocean waves, tides, salinity gradients, and ocean temperature differences. The technologies covered in this report tap the energy potential of waves and tides. Wave energy converters capture the energy of ocean surface waves to generate electricity. Tidal stream generators use the kinetic energy of moving water to power turbines, similarly to wind turbines capturing wind to generate electricity. Tidal barrages are essentially dams that cross tidal estuaries and make use of potential energy in the height differences between high and low tides.

Policy target. An official commitment, plan, or goal by a country to achieve a certain level of renewable energy by a future date. Some targets are legislated while others are set by regulatory agencies or ministries.

Power purchase agreement (PPA). A contract between a renewable energy generator (typically called an "Independent Power Producer" or IPP) and a utility company or end-user, for the utility or end-user to purchase the electricity output of that generator at specified rates over a specified time period (typically 5–20 years). Generally PPAs require that all generation be purchased, but clauses may limit such guaranteed uptake based on utility grid technical conditions and power demand.

Production tax credit (PTC). Provides the investor or owner of a qualifying property or facility with an annual tax credit based on the amount of renewable energy/fuel (electricity, heat, or biofuels) generated by that facility.

Ramping and cycling (of conventional power plant). Ramping and cycling refers to the changes in power output of a conventional power plant over time, for example, a coal, natural gas, or nuclear power plant. Such plants are typically designed to operate at a fixed output, and take time, on the order of minutes to hours, to vary their output. Ramping refers to one-time changes in output in response to power grid conditions (over- or under- supply relative to demand).

Cycling refers to daily changes of a more regular nature in response to changes in power demand on a grid.

Renewable energy certificate (REC). A certificate that is awarded to certify the generation of one unit of renewable energy (typically 1 MWh of electricity but also less commonly of heat). Certificates can be accumulated to meet renewable energy obligations and also provide a tool for trading among consumers and/or producers. They are also a means of enabling purchases of voluntary green energy.

Renewable portfolio standard (RPS). Also called renewable obligation or quota policy, it requires that a minimum percentage of total electricity or heat sold or generation capacity installed be provided using renewable energy sources. Obligated utilities are required to ensure that the target is met; if not, the utility usually pays a fine.

Solar photovoltaic (PV). A PV cell is the basic building block that converts sunlight into electricity. Cells are typically combined and manufactured into modules and panels suitable for installation on buildings. Thin-film solar PV materials can also be applied as films over existing surfaces or integrated with building components such as roof tiles. Such building-integrated PV (BIPV) materials can be used to replace conventional materials in parts of a building envelope, such as the roof or façade.

Solar thermal (heating and cooling). Solar collectors, usually rooftop mounted, that heat water and store it in a tank for later use as hot water or for circulation to provide space or process heating. The solar heat can also be used in chillers for space cooling.

Traditional biomass. Unprocessed solid biomass, including agricultural residues, animal dung, forest products, and gathered fuel wood, that is combusted in stoves, furnaces, or open fires to provide heat energy for cooking, comfort, and small-scale agricultural and industrial processing, typically in rural areas of developing countries.

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ENDNOTES

INTRODUCTION

1. For 2011, REN21 (2012) and BNEF/UNEP (2012) give net investment in renewable power capacity as some $40 billion higher than the same measure for fossil fuels. BNEF/UNEP (2012) and Schneider and Froggatt (2012) both estimate investment in new nuclear power plants at approximately $5 billion in 2011. For more details, see Endnote 2 for Chapter 3.
2. Investment in 2011 from BNEF/UNEP (2012). See also Footnote (a) on p. 33 of the report.
3. IEA projection from IEA WEO (2000). World Bank projection from World Bank (1996). Global wind power capacity in 2010 and China wind power and solar PV capacity in 2011 from REN21 (2012). For other historic projections and visions of the future, see Flavin (1994), Scheer (199), NREL (1999), IEA (2003), and German Advisory Council on Climate Change (2004).
4. For more discussion on motivations for renewable energy, see GEA (2012) Chapters 2–6. See also Scheer (2005) and Girardet and Mendonca (2009). Many of the published scenarios listed in Annex 1, particular high-renewables scenarios like Greenpeace (2012), also discuss the variety of motivations.
5. Good references for understanding energy systems and the context for renewable energy include Tester et al. (2006), Randolph and Masters (2008), Moselle et al (2011), IPCC (2011), and GEA (2012).
6. For basic discussion of cost comparisons, see Kammen and Pacca (2004), Owen (2004), IPCC (2011) Chapter 10, and GEA (2012) Chapter 6.
7. Examples of "high-renewables" scenarios modeling strong levels of policy support in the future together with continued cost reductions include Greenpeace (2012), GEA (2012), IEA RETD ACES (2010a).
8. Renewable energy policies are covered in many references, including IEA (2008), Sawin and Moomaw (2009), IEA (2011a), IPCC (2011) Chapter 11, and GEA (2012) Chapters 22–25.
9. Scenarios portraying high-renewables futures using only currently existing technologies include NREL (2012): "The central conclusion of the analysis is that renewable electricity generation from technologies that are commercially available today, in combination with a more flexible electric system, is more than adequate to supply 80% of total U.S. electricity generation in 2050 while meeting electricity demand on an hourly basis in every region of the United States" (p. iii). Scenarios showing total energy system cost to be roughly equal for renewables-centric and fossil fuel-centric cases include IEA ETP (2012a): "The cost of creating low-carbon energy systems now will be outweighed by the potential fuel savings enjoyed by future generations. A sustainable energy system will require USD 140 trillion in investments to 2050 but would generate undiscounted net savings of more than USD 60 trillion" (p. 29); UCS (2009): "Climate 2030 Blueprint shows that deep emissions cuts can be achieved while saving U.S. consumers and businesses $465 billion in 2030" (p. 3); IEA RETD (2010a): "when considering both initial investments and ongoing energy cost savings, there is virtually no difference in total energy system costs between aggressive climate mitigation scenarios and so-called "Reference" scenarios that contain little or no mitigation measures" (p. ii).
10. A good discussion of the many facets of integration of renewable energy can be found in IPCC (2011) Chapter 8.
11. Energy system transitions are discussed in a number of recent publications, such as Bradford (2006), Patterson (2007), Scheer (2007), Girardet and Mendonca (2009), Leggett (2009), IEA (2009), Palz (2011), Ochs and Makhijani (2012), and GEA (2012) Chapters 16–17.
12. Ibid.
13. ExxonMobil quotes from ExxonMobil (2012), pp. 46 and 30. ENI quote from ENI (2012). Chevron quote from Chevron (2010), p. 29. CLP Hong Kong Power quote from CLP Hong Kong Power (2012), p. 40. Another persistent myth not mentioned in Box 1 is that of "energy payback time," which is defined as the time (typically in months or years) that a renewable energy generator must operate to produce as much energy as was required to manufacture the renewable energy generator. A persistent myth has been that renewable technologies barely pay back over their entire lifetime the energy required for their manufacture. This myth, which was not uncommon decades ago, has lingered over the years and is still shared by some today despite strong scientific evidence of its complete inaccuracy. Indeed, relevant research has shown that renewable technologies return far more energy than that embodied in their life cycle. For instance, Kubiszewski et al. (2010) show a payback time of three to six months for wind turbines. Fthenakis (2012) and the Fraunhofer Institute (2012) demonstrate that today's solar PV systems have a payback time ranging between six months and 2.5 years. Finally, another persistent myth not mentioned in Box 1 is of the required "footprint" for renewable energy installations, in terms of land use; for discussion of that myth, see Lovins (2011).
14. The conclusions of the workshop on levelized cost are available at IRENA-IEA RETD (2012). For more on the transport cost assessment, see IEA ETP (2012a), p. 453.
15. Number of countries with policies promoting renewables in 2005 and 2012 from REN21 (2006) and REN21 (2012), respectively. ExxonMobil quote from ExxonMobil (2012), p. 1. IEA quote from IEA WEO (2010b), p. 277.

CHAPTER 1

1. REN21 (2012) gives 8.6% from traditional biomass and 8.2% from modern renewables. IEA (2012c) gives 9.6% from traditional biomass and 8.4% from modern renewables; both sets of figures are for share of *final* energy consumption (TFEC) in 2010. Other recent published figures for *primary* energy share from renewables are as low as 13%, for example in IPCC (2011) using the "physical" method. This is because there are several alternative approaches to calculating global energy share from renewables, all of which are analytically valid, but which produce different results. The two main types of indicators are primary energy share and final energy share. Final energy share has emerged in recent years as an accepted indicator that many consider better at capturing the true useful value of each energy source. For primary energy share, there several alternative ways to calculate shares, and in particular the "physical" method yields lower shares for hydro, solar PV, and wind power than the "substitution" method, relative to biomass, fossil fuel, and nuclear power. For further explanation and comparison of the different methodologies and metrics, three sources are recommended: REN21 (2008), Sidebar 1, page 21, for a brief summary; Martinot et al. (2007) for a detailed explanation; and IPCC (2011) Annex 2 for a side-by-side comparison of methodologies. Examples of historical projections include World Bank (1996), NREL (1999), EWEA and Greenpeace (1999), IEA (2000), Greenpeace (2001), Pearce (2002), IEA (2003), and EWEA (2003). For more on historical projections, see Topic #1, "Past Views," in the online supplement "Topical Discussion Report."
2. REN21 (2012). The phrase "total energy from renewables" can refer in the context of this report to either primary energy share or final energy share, depending on what is reported from the source being cited. The REN21 (2012) figures for share of energy refer mostly to

primary energy share, but some countries report and target final share only, and are cited by REN21 as final energy share. In general, the exact difference between primary and final energy share depends on the mix of energy sources and their end-uses, and is unique to each country. In some countries, both figures can be almost the same, while in others they can be substantially different; see the explanations in sources cited in Endnote 1. In most of these countries, hydro is the main renewable source. In others it is geothermal or biomass. Brazil, Iceland, and Sweden had close to or above 50%. Renewable energy share data from REN21 (2012), Table R9, except for Iceland and New Zealand, which come from IEA (2012d). All figures are most recent as of mid-2012, but lag behind current year due to data collection and reporting; for some countries the reported share in Table R9 is for 2009 not 2010. Some shares are for primary energy and some shares are for final energy. (See Endnote 1, Chapter 1, regarding primary vs. final energy.) For most countries, only one metric is available; however, when both metrics are available, the final energy share metric is used for purposes of this report. Denmark was 23% (final share) in 2009–2010, but has grown since then. Other countries above 20% include Barbados, Belize, Estonia, Guatemala, and Latvia. A number of countries shown in the REN21 (2012) Table R9 Annex at 100% share are incorrectly reported, but still have shares above 20%, including Costa Rica, Dominican Republic, El Salvador, Grenada, Haiti, Honduras, Nicaragua, Panama, and Paraguay. Data for renewable energy shares for the EU and United States also from REN21 (2012) Table R9, and for Japan from METI (2010). Per REN21 (2012), Endnote 12, Chapter 1, page 129, 102 GW of renewables and 106 GW of conventional power generation capacity were added in 2011. That includes about 4 GW of new nuclear capacity per International Atomic Energy Agency (2012). REN21 (2012) calls this comparison between renewable and conventional generation capacity for 2011 "almost half," but the numbers were considered close enough for general purposes of scale to label the comparison "about half" in the present report.

3. IEA (2003) shows primary energy shares by 2050 of 15.7% for biomass and 18.9% for other renewables (page 129).

4. IEA ETP (2006) reference scenario was 11%. "ACT Map" showed a 24% share and "Tech Plus" showed 30%. Greenpeace energy shares reported in this section are all for primary energy share, although Greenpeace scenarios also project final energy shares as separate numbers, generally higher than primary energy share.

5. Unused.

6. All energy shares cited in this report are primary energy unless otherwise noted in endnotes. Chevron quote from Chevron (2012). Total quote from Total (undated).

7. Box 2 is based on the following sources: BP (2012a), ExxonMobil (2012), GEA (2012), Greenpeace (2012), IEA ETP (2012a), IEA RETD (2010a), IEA WEO (2012b), and IPCC (2011). For IEA ETP (2012a), the predecessor to the "2DS" scenario is the "Blue Map" scenario in the 2010 edition. For the IEA WEO (2012b), the reference case is the "Current Policies" scenario. For IEA ETP (2012a), the "6DS" scenario is taken as the reference case. Percentage reductions in energy demand for IEA ETP by 2050 is based on primary energy demand of 940 EJ by 2050 for "6DS" (reference case) and 697 EJ for "2DS", which is a 26% reduction relative to "6DS" (697 EJ is 26% less than 940 EJ). Similar calculations were done for IEA WEO (2012b), and GEA (2012), and Greenpeace (2012). Although many scenarios include carbon capture and storage (CCS) technologies, the "pace of deployment remains highly uncertain, with only a handful of commercial-scale projects currently in operation," according to IEA WEO (2012b), p. 25. IEA RETD (2010a) "ACES" projects a virtual decarbonization of electricity by 2030 from renewables, nuclear, and CCS on all fossil fuel power plants. Greenpeace (2012) primary energy share for 2030 is 41%. Equivalent final energy shares are 45% in 2030 and 88% in 2050.

8. GEA (2012) provides a number of "pathways" in the "Efficiency" case that range from 30% to 75%.

9. Credibility as used in this report entails many factors such as the type of authoring organizations and their experience, the number and breadth of experts involved, whether a scenario has become annually or biennially issued and based on an established long-standing process, if the process and methodologies are transparent, the degree of independent reviewer participation, and analytical rigor. All scenarios cited in this report meet these criteria to varying degrees and were deemed sufficient to be included in the "range of credible possibilities." For example, the Greenpeace (2012) scenario involves leading academics, researchers, and industry experts from around the world, has been published biennially since 2007, documents its methodologies, and relies on an extensive review process. As Greenpeace/EREC/GWEC (2012) notes, "the IPCC's Special Report Renewables (SRREN) chose the [Greenpeace scenario] as one of the four benchmark scenarios for climate mitigation energy scenarios…. Following the publication of the SRREN in May 2011…, the [Greenpeace scenario] became a widely quoted energy scenario and is now part of many scientific debates and referenced in numerous scientific peer-reviewed literatures" (p. 338).

10. The original "Fact Sheet" for the UN "Sustainable Energy for All" initiative gives a current global share from renewables of 15%, which would then mean a doubling to 30% share by 2030, see UN (2012). However, using a 17–18% current global share (see Endnote 1, Chapter 1) implies a 35% share by 2030. The UN initiative in 2012 was in the process of updating its share baseline and methodologies, a process that was expected to result in an implied 35% share by 2030. If a 13% current global share is used, based on primary energy share from IEA WEO (2012b) or IPCC (2011), then the target would only imply a 26% share by 2030. Given that the share of traditional biomass in 2011 was 8.6%, and assuming that share remains constant through 2030, and using a 35% target for the UN initiative, means a roughly 26% share of modern renewables by 2030, which is roughly triple the current share of 8.2%, based on Endnote 1, Chapter 1.

11. Selected national and regional scenarios are given in Annex 2, although many more such scenarios exist than could be complied for the present report. One research problem faced was that many national scenarios are not in English and require translation.

12. Ibid.

13. Number of countries with policy targets from REN21 (2006) and REN21 (2012). The EU collective target and individual country targets are all final energy targets; the EU adoption of this metric in 2007–2008 made it a "mainstream" indicator for the first time, as previously primary energy was the predominate metric; see REN21 (2008), Sidebar 1, p. 21. An EU 45% target for 2030 is also under discussion (see section on EU in Chapter 5). The full progression of targets for Germany is 18% (2020), 30% (2030), 45% (2040), and 60% (2050); these are final energy shares. The actual 2010 share for Germany was 11%. Shares for Denmark are also final energy shares; the actual 2010 share was 23%.

14. Target data from REN21 (2012) Table R9. Targets are Algeria 40% (2030), China 15% (2020), Indonesia 25% (2025), Jamaica 20% (2030), Jordan 10% (2020), Madagascar 54% (2020), Mali 15% (2020), Mauritius 35% (2025), Samoa 20% (2030), Senegal 15% (2025), South Korea 11% (2030), Thailand 20% (2022), Turkey 30% (2023), Ukraine 19% (2030), and Vietnam 8% (2025). Algeria's targets are final energy share. Indonesia's targets are 10.2% from biofuels, 6.3% from geothermal, and 1.4% from wind/solar/hydro by 2025 (REN21, 2012, Table R11). Shares for OECD countries without targets also from REN21 (2012) Table R9. Tonga and Fiji are listed in REN21 (2012) Table R9 with 100% targets by 2013, but these targets are considered as inaccurate or misinterpreted reporting, given that transport cannot be 100% renewable in that time frame. A few countries with already-large shares of renewables are listed with targets above 80%, including Fiji, Gabon, Tonga, and Uruguay.

15. The Chinese target is for primary energy share. Chinese energy experts expected nuclear to remain in the range of 2–4% by 2020, so renewables should attain an 11–13% energy share if the target is met.

China's target includes nuclear power and thus represents a "zero-carbon" target rather than a renewable energy target. Some observers expect China's nuclear share to reach 3–4% by 2020 (Martinot 2010), so the renewables share would be 11–12% in that case if the 15% target is exactly met. China also has a quota obligation for utilities, 3% of electricity and 8% of capacity by 2020, for non-hydro renewables only. China's share of energy from renewable energy in 2010–2011 (both years are considered similar) was roughly 9%, and the share of nuclear was roughly 1%, per Chinese Renewable Energy Industries Association (CREIA), December 2012, personal communication. The share of renewables in total power generation was 18% in 2011, but was expected to increase to 22% in 2012 due to an increase in hydropower generation. The share of electricity from nuclear power was 1.9% in 2011 (about one-tenth that of renewables), and was expected to increase to 2.2% in 2012. The "50% increase in renewable energy over 2010 levels" mentioned in the text actually means a "50% increase in renewable energy share over 2010 levels," based on the presumption that the renewables share increases from 9% to 13.5% and the nuclear share increases from 1% to 1.5% by 2020.

16. See REN21 (2012) Table R10 for countries with electricity share targets and for existing electricity shares.
17. See REN21 (2012) Table R11 for countries with heating and cooling targets.
18. See REN21 (2012) Table R11 for countries with targets for transport shares, and Table R14 for national and state/provincial biofuels blending mandates.
19. Transport shares given in Table 1 and in other scenarios generally include road, air, maritime, and rail transport, although some scenario projections only cover road transport specifically.
20. Global and EU share of electricity production from renewables data from REN21 (2012). For global electricity production, the share reported for hydropower is 15.3% and for other non-hydro renewables is 5.0%. Countries with renewable electricity production share above 30% from REN21 (2012) Table R10.
21. Most targets include both large and small hydropower, but some countries only have targets for small hydropower. For example, India targets small hydro separately, and reports on total renewables share excluding large hydro. All targets from REN21 (2012) except Malaysia; from Sustainable Energy Development Authority of Malaysia (2011). Thailand's target is for 2022. Australia's target is based on its national 20% quota obligation for electric utilities.
22. Targets from REN21 (2012), except Australia, which is from REN21 (2011). South Korea has a complete set of policy targets for electricity from all renewable technologies by 2030, including solar PV (2 TWh), solar thermal (2 TWh), wind (17 TWh), biomass and biogas (3 TWh), geothermal (3 TWh), ocean (6 TWh), and hydro (6 TWh), totaling 40 TWh by 2030. (For comparison, South Korea's total electricity generation in 2010 was 496 TWh, per BP (2012b).
23. Scotland target from REN21 (2012), Upper Austria and South Australia targets from REN21 (2010). Abu Dhabi target from Renewable Energy World (2009). Technically, 29 states plus Washington, DC, the U.S. possessions of Puerto Rico, and Mariana Islands also have RPS policies. REN21 (2012), Table R13 footnote has a list of additional targets and RPS policies not shown in Table R13. Additional Canadian provinces have targets but no RPS policies; see the policy chapter of REN21 (2012). Indian states with RPS policies were reported as 12 in REN21 (2010) and 15 in REN21 (2012).
24. Unused.
25. In Table 2 and Figure 2, current electricity shares from REN21 (2012), Table R10, except Japan from METI (2010) and China from Chinese Renewable Energy Industries Association, personal communication, December 2012. All targets for 2020, and German targets for 2030 and 2050 also from Table R10. Current electricity shares are typically for 2010 or 2011, although some sources are slightly ambiguous as to which years apply. Future share of 75% for Europe from SEI and Friends of the Earth (2009) is estimated from two graphics: Figure 27, page 38, shows that approximately 78% of the CHP feedstock will be biomass by 2030. From this assessment, and assuming that the share of biomass is the same in the heat and power generated, Figure 24, page 36, is then used to estimate 75% total share, including all renewables plus biomass used in CHP (assumed to be a 78% share of feedstock). UCS (2009) excludes hydropower. Another U.S. scenario "High-resolution modeling of the western North American power system demonstrates low-cost and low-carbon futures," Nelson et al. (2012), shows up to about 60% of electricity from renewables between 2026 and 2029 (high gas price scenario).
26. Unused.
27. EU member targets for heating and cooling from REN21 (2012) Table R11, except for Lithuania from EREC (2011a).
28. Unused.
29. IEA quote from IEA WEO (2012b), pp. 215–16 and 218. The IEA also says: "Global bioenergy use, excluding traditional biomass, for heat production grows from 294 Mtoe in 2010 to 480 Mtoe in 2035. Solar heat, mainly used in buildings, grows at 5.5% per year from 19 Mtoe to 73 Mtoe over 2010-2035.... Geothermal heat, also used mainly in buildings, grows at 7.8% per year from 3 Mtoe in 2010 to 19 Mtoe in 2035" (pp. 218–19). In the Greenpeace (2012) "Revolution" scenario for 2020, biomass will still be the dominant renewable energy source for heating, supplying almost three-quarters of renewables heating. Then from 2020 to 2040 solar collectors, geothermal heating, and heat pumps will represent 94% of the renewables heating growth and will ultimately become the dominant heating sources by 2050.
30. 2011 data for biofuels from REN21 (2012). For more information on the EU renewables transport target, see EU (2009). Sweden target from REN21 (2012) Table R11. Biofuels blending mandates from REN21 (2012) Table R14.
31. Biofuels production was roughly 110 billion liters in 2011, per REN21 (2012), so growth by a factor of 3 to 6 reflects those multiples of this 110 billion liters by 2035. In Table 1, p. 18, global scenarios take into account the transport sector as a whole including road transport, as well as air, maritime, and rail transport in their analysis (see also Endnote 19). This also applies to EREC (2010) and SEI and Friends of the Earth (2009). IEA RETD (2010a) may not include all forms of transport.
32. WWF (2011) projects that much of this transformation occurs after 2030, as the share of transport energy from renewables grows from 5% in 2010, to 12% in 2020, and then to 33% in 2030, before growing to 100% in 2050.
33. Unused.

CHAPTER 2

1. Some experts dislike the "integration" concept, preferring instead to think of coming "transformations" of our energy systems. (See also the report's Conclusion.) One asks, "do we really need renewables to fit into the existing system, or do we need all energy technologies to evolve in different ways and with different roles and shares into a transformed energy system?" This report has presented "integration" as something of a middle ground between conservative approaches that see renewables remaining marginal, and grand-transformation visions. A common sentiment among experts was that in the coming decade or two, the "integration" concept would govern, but at some point, beyond a critical threshold, the view that [the system transforms to accommodate all energy technologies and their characteristics] will take hold. Of course, some of the most optimistic experts said such transformation was imminent in the coming several years!
2. For much more discussion and elaboration of the "integration" subjects covered in this chapter, see Chapter 8 of IPCC (2011), "Integration of Renewable Energy into Present and Future Energy Systems."

3. Some forms of ocean energy, for example tidal power, are also variable. The variability of CSP plants depends on the degree of embedded thermal storage. Many current plants are being built with 4–8 hours of daily storage, which allows operation into the evening hours, although longer storage times of 24–48 hours are possible with current technology. There is also a seasonal component to CSP variability, as well as daily variations due to weather conditions. Examples of technical and regulatory tolerances include reserve margin, voltage and frequency control, spinning reserve, and ancillary balancing services on varying time scales from minutes to hours. The term "electric utility" is used generically here to denote a variety of companies in the power sector. In most OECD countries and some developing countries, power grid functions have been split among different entities through a process of "restructuring" or "liberalization" over past decades. These include power generators, distribution utilities, and transmission system operators. Transmission system operators are typically called "independent system operators" (ISOs) or "transmission systems operators" (TSOs). For simplicity, this report uses the term "grid operators" for ISOs and TSOs, without differentiating the responsibilities of different classes of ISOs and TSOs.

4. Utilities must also contend with unpredictable and abrupt outages of large fossil fuel or nuclear plants, with reserve margins provided by other available working plants to replace a sudden unexpected loss of generation, and power systems have been designed for the past century for such contingencies. Historically, a limit of a 10–20% share of renewables on a grid without storage has often been cited by utilities. Over the past 10 years, however, many experts have taken the view that upwards of a 30–40% share without storage is possible on many grids, and only above 50–60% does storage become desirable or necessary.

5. Unused.

6. See, for example, IEA (2011b) and Cochran et al. (2012) for in-depth discussions. This diversity of solutions is clear from the variety of country case studies in Cochran et al. (2012).

7. In particular, sources and experts cite creating or strengthening specialized power markets, including capacity markets, balancing/ancillary services markets (secondary and tertiary), and energy time-shifting. The term "balancing area" can signify different degrees of isolation; the IEA (2011b) defines a balancing area as "the area of the power market over which balance is maintained as a unit," and notes that "balancing areas are defined to a large extent by the historical development of the grid, and by the distinct utilities and institutions that drove that development and persisted subsequently. Protocols will exist governing the flow of electricity across these boundaries, and long-term collaborations may exist; but these may not necessarily allow for interchanges of electricity inside the balancing timeframe" (p. 59). The IEA also notes that "larger (effective) balancing areas have greater flexible resources to deploy, and benefit substantially from smoothing of both load and variable renewable generation through geographical and technological diversity" (p. 59). In Spain, this is well advanced and some models have already been in use for 10 years. Still, improvement of such models is an ongoing process and will result in better balancing, said one expert.

8. Experts disagreed over which of these six technical-operational measures would become most important or cost-effective in the future, and how the options should be prioritized. Experts even disagreed with the order of presenting these options in Chapter 2.

9. For more information on curtailment, see Fink et al. (2009) and Ela (2009). For more information on the CECRE, see www.ree.es/ingles/operacion/cecre.asp. Spain power generation shares from wind in 2012 from statistics provided by Red Eléctrica de Espana (REE).

10. For more information on demand response, see Osborne and Warrier (2007). Other sources address demand response as a form of real-time pricing; see for example Allcott (2011). Two definitions of demand response are: (1) "Demand Response programs offer incentives to electricity users to reduce their power use in response to a utility's need for power due to a high, system-wide demand for electricity or emergencies that could affect the transmission grid" (EnerNOC, undated); (2) "Demand Response increases systems efficiency, bringing several important environmental and financial benefits within today's electricity markets. It substantially reduces the need for investment in peaking generation by shifting consumption away from peak hours. It acts as a cost effective GHG free balancing resource for wind and solar generation. Adding stability to the system, it lowers the need for coal and gas fired spinning reserves—power plants that run offline, burning fuel continuously, in order to be ready to supply power and short notices. It reduces wholesale energy costs by lowering the point at which the demand curve intersects the supply curve. And it can decrease the need for local network investments, as it can shift consumption away from peak hours in regions with tight network capacity. Demand response delivers these benefits through providing consumers; residential, commercial or industrial, with control signals and/or financial incentives to lower or adjust their consumption at strategic times." (Smart Energy Demand Coalition, 2011, pp. 4–5). Many demand response measures can be implemented through so-called "smart grids," see Endnote 31.

11. ERCOT could supply more than 50% of reserves via demand response, but there is a regulatory limit of 50% imposed; see Wattled (undated) and Wattles (2012). One example of a scenario that incorporates demand response is the Lovins and RMI (2012) "Transform" scenario, which models mostly demand response for managing variability, including distributed storage (notably ice storage and air conditioning and smart charging and discharging of electric vehicles), coupled with diversifying renewables by type and location, and advance weather forecasts. That scenario found that an 80% renewables electricity scenario for the entire U.S., including half distributed and half centralized renewables, could manage variability with these options alone, without requiring the next costlier option, bulk energy storage.

12. Simple cycle is also called single cycle. The Spain case points to the future interplay among renewables, gas turbines, and existing fossil capacity, and how, given legacy infrastructure and long lifetimes, this interplay will persist for many years.

13. For more information about the Danish case, see Danish Electricity Infrastructure Committee (2008).

14. For further information on overhead vs. underground lines, see Fenrick and Getachew (2011). For further information on high-voltage DC transmission, see Teichier and Levitine (2010) and Larruskin et al. (2011). For further information on Desertec, see Erdle (2010), Trieb and O'Sullivan (2011), and Desertec Foundation (2009). For more on the "Asian Super Grid" concept, see Whitlock (2012) and Burgess (2012).

15. For further information on storage technologies, see Baxter (2006), Denholm et al. (2010), Eyer and Corey (2010), Hadjipaschalis et al. (2009), Ibrahim et al. (2008), and Zito (2010). For the role of solar thermal power (CSP) storage, see IEA (2010c) and Sioshansi and Denholm (2010). The most common battery technology used today for grid-tied storage is high-temperature sodium batteries, followed closely now by lithium-ion batteries, which have gained in application in recent years, according to storage experts. Other battery technologies that are starting to be used for grid-tied storage are redox-flow and advanced lead-acid batteries. Conventional lead-acid batteries have been a traditional form of end-user storage medium for backup and uninterruptable power supplies by high-reliability commercial consumers, and have also been common for many years in some developing countries with frequent grid outages, such as India.

16. Compressed air energy storage (CAES) is another option. However, there are currently only a handful of demonstration compressed air plants around the world, and none operating on a commercial basis. Other storage options include electrochemical capacitors and thermal storage using ice.

17. "Conventional plants" includes both fossil fuel and nuclear plants. For discussion of ramping and cycling of fossil-fuel plants, see IEA WEO (2012b), pp. 190 and pp. 237, and IPCC (2011), p. 636. See also Cochran

et al. (2012). In the Canadian province of Ontario, and also in Denmark, utilities have "very high ramp capabilities in their coal fleet—it's normal for them," said one utility expert. So this is not a theoretical concept but already a practiced one, which tends to occur utility by utility, for "fleets" of plants, as the expert noted.

18. Daily or weekly cycling of nuclear plants is true at least in France and Germany. The 2011 OECD study quotes from OECD Nuclear Energy Agency (2011), p. 49.
19. Unused.
20. One utility expert highlighted the concept of "flexibility supply curves" as the best means to work out which measures could offer what levels of flexibility at what costs. He said that such curves could guide the step-wise adoption of flexibility measures according to least-cost principles.
21. GEA (2012), p. 17. NREL (2012), Vol. 1, says, "Electricity supply and demand can be balanced in every hour of the year in each region with nearly 80% electricity from renewable resources, including nearly 50% from variable renewable generation, according to simulations of 2050 power system operations" (p. xviii).
22. In the NREL study, less storage was needed in the cases with more CSP, which was modeled with embedded thermal storage, whereas greater levels of wind and/or solar PV resulted in higher storage needs. See NREL (2012), Vol. 2, pp. 12–28.
23. IEA quote from IEA (2011), p. 15.
24. Quote translated from Electricité de France (2012), p. 28. The use of the word "intermittent" for renewables was common in the 1980s and 1990s, but in the past decade, experts and publications have begun to consistently use "variable" instead, as more reflective of the true nature of power grids. One expert also pointed out that conventional generation sources also present challenges for power system reliability, especially nuclear power, which poses challenges due to the possibility of abrupt and unexpected shut-downs that require additional system reserves be available as quick-response contingency. E.ON quote from E.ON (2012), p. 71; CLP Hong Kong Power quote from CLP Hong Kong Power (2012), p. 40; American Electric Power quote from American Electric Power (undated).
25. ExxonMobil quote from ExxonMobil (2012), p. 15.
26. For more information on base load and its definition, see Lovins and Harding (2009), Renews (2010), and New York AREA (2008). For an example of a natural gas company vision, see Tokyo Gas (2011).
27. Vattenfall quote from Vattenfall (2012), p. 23. E.ON quote from E.ON (2012), p. 71.
28. Unused.
29. Net metering involves one meter that runs forward and backward. Net billing involves two meters, one for incoming power and one for outgoing power. Different jurisdictions use different options. See REN21 (2012) for more policy details on net metering. Net metering laws exist at the national level in at least 14 countries, and at the state/provincial level in 8 Canadian provinces and 43 U.S. states plus the District of Columbia and Puerto Rico.
30. For further information on hybrid fossil fuel/renewable power plants, see Phadke et al. (2008). Biomass and coal co-gasification systems also offer the option of carbon sequestration. Statistics on number of co-fired plants operating from REN21 (2011). According to one Spanish expert, virtually all CSP plants in Spain also burn natural gas, permissible by regulation for up to 15% of their output, for purposes such as meeting dispatch commitments, better start-up conditions, and pre-heating heat-transfer oil.
31. For further information on smart grids, see EPRI (2009), IEA (2011e), NREL (2010), US Department of Energy (undated), European Technology Platform SmartGrids (2010) and European Commission (2006). See also Fox-Penner (2010). By itself, the term "smart grids" concerns much more than renewable energy. The U.S. Electric Power Research Institute (2009) defines a smart grid as "a modernization of the electricity delivery system so it monitors, protects and automatically optimizes the operation of its interconnected elements—from the central and distributed generator through the high voltage network and distribution system, to industrial users and building automation systems, to energy storage installations and to end use consumers…and their devices." (p. 6). Bazilian et al. (2010) reviewed literature on smart grids and found that much of it focuses on two-way information flows between suppliers and users to increased network efficiency. Some, but not all treatments of smart grids also focus on integrating large-scale intermittent generation, as well as control of distributed generation, such as the European Technology Platform (2010).
32. For further information on renewables integrated with buildings, including heating and cooling integration, see IEA (2007), IEA (2009), Girardet and Mendonca (2009), GEA (2012), Chapter 10, and Yudelson (2008). In particular, IEA (2007) on renewables heating and cooling contains much explanatory information difficult to find elsewhere.
33. GEA (2012) models a 46% reduction in heating and cooling energy demand compared with a 2005 baseline.
34. Solar thermal data for 2011 from REN21 (2012). New solar collectors capacity is for glazed systems only and additions include net annual capacity additions only; it is expected that gross annual additions were higher due to retirements. Estimate of 25 million homes based on author's assumption of average 3 m2 per home, or 2.1 kWth. Average sizes in China, where most of the global market is, are less, closer to 2 m2 per home, while average sizes in Europe are higher than 3 m2. 2010 data for China's solar collectors capacity from REN21 (2011); it reached 135.5 GWth in 2011, per REN21 (2012).
35. Saudi Arabia example from REN21 (2012).
36. Unused.
37. Unused.
38. Costs will depend on building density, and can be lower for planned subdivisions. Greenpeace quote from Greenpeace (2012), p. 81.
39. For more information, see EU (2010).
40. Unused.
41. Unused.
42. REN21 (2012): "Although the economic downturn has slowed construction, which in turn has dampened BIPV growth, an estimated 1.2 GW was added during 2010" (p. 49). A total of 16.8 GW of solar PV was added in 2010, so the BIPV share is 7%.
43. Unused.
44. For further information on renewable energy integrated with industry, see Taibi et al. (2012), UNIDO (2010), UNIDO and TERI (2012), and GEA (2012), Chapter 8.
45. The IEA ETP (2012a) defines temperature ranges in industry as follows: low temperature heat (<100 °C), medium temperature heat (100–400 °C), and high temperature heat (>400 °C), see p. 195. In Weiss and Biemayr (2009), low temperature for industrial process heat is considered < 250 °C.
46. Unused.
47. UNIDO (2010) shows 67 EJ total renewable energy use in industry, including 37 EJ biomass and 10 EJ of solar thermal and heat pump in manufacturing industry by 2050. (For comparison, global industrial energy demand in 2010 was about 100 EJ per IEA, *Key World Energy Statistics* (2012e), including electricity.)
48. For GEA (2012), 45% share from personal communication, K. Riahi, December 2012, which also includes the renewable share of electricity that is used in the industry sector. IEA quote from IEA WEO (2010b), p. 346.

49. Dow Chemical quote from Dow Energy (2012), p. 23; Huntsman quote from Huntsman (2008), p. ii.

50. Share of biofuels in global road transport from REN21 (2012). For further information on vehicle technologies and integration of renewable energy in transport, see Sperling and Gordon (2008), Bradley and Frank (2009), Sovacool and Hirsh (2009), IEA RETD (2010b), IPCC (2011), Chapter 8, and GEA (2012), Chapter 9.

51. For further information on syngas from renewables, see Mota et al. (2011), Karl et al (2009), and Van der Drift and Boerrigter (2006). Many experts point out that when electric vehicles consume grid-based power (as opposed to local dedicated charging based only on renewables), only a portion of the electric power used for charging comes from renewables—and on grids with large shares of coal power, then much of the charging comes from coal rather than renewables.

52. Electric and plug-in hybrid vehicles today predominantly utilize lithium-ion and nickel-metal hydride batteries. Other battery technologies are being developed. In addition, a variety of other storage technologies are possible in electric vehicles, such as super-capacitors (which are particularly feasible for urban buses with frequent recharging stops along fixed routes) and flywheels (which can absorb braking energy for subsequent use). Methanol is also a possible fuel for fuel cell vehicles. Methanol can be produced from coal or biomass through a gasification process.

53. Unused.

54. Unused.

55. Unused.

56. Royal Dutch Shell quote from Shell (2012), p. 24; BP quote from BP (2011), p. 31; ExxonMobil quote from ExxonMobil (2012), p. 20.

57. IEA quote from IEA WEO (2010b), p. 357. Estimate of hundreds of millions of vehicles based on author's assumption of at least kWh storage capacity per vehicle.

58. From GEA (2012): "the analysis below distinguishes between two sets of assumptions about the transportation sector transition, labeled Advanced Transportation and Conventional Transportation. The Advanced Transportation setup is characterized by a transition to electricity or hydrogen, or both, as main transportation fuels in the medium to long term. By 2050 these two fuels would have to deliver between roughly 20% and more than 60% of the transportation sector's final energy, depending strongly on overall transportation demand," (p. 1232). These setups apply to all the GEA pathways (Efficiency, Supply and Mix) (p. 1216).

59. Other automakers with PHEV or EV development and/or commercial plans include Dongfeng, Ford, Volvo, Porsche, BMW, Daimler, and Volkswagen. See Mitsubishi (undated).

60. Mitsubishi (2011), p. 9; BMW (2011), p. 23; See also Audi (undated) and Stevens (2012).

61. Mitsubishi (2011), p. 9.

62. Unused.

63. See Toyota (2012).

64. Reference to IEA (2009) is in IPCC (2011), p. 671.

CHAPTER 3

1. Unused.

2. Investment figures from BNEF/UNEP (2012). Investment figures are for capacity additions and new manufacturing plants only, not for public share transfers or the value of mergers and acquisitions, figures that tend to get mixed in with new capacity investments by some sources or reporting channels. Note that BNEF/UNEP (2012) and REN21 (2012) both report investment in "solar power" as USD 147 billion, but this includes CSP investment of USD 20 billion. The statement in REN21 (2012) that "solar PV attracted nearly twice as much investment as wind" (p. 61) is factually incorrect and should read "solar power (including CSP)" not "solar PV." BNEF/UNEP (2012) gives net investment in renewable power capacity at USD 262.5 billion (excluding solar water heating net investment, estimated over USD 10 billion, but including large hydro estimated approximately at USD 25.5 billion) and USD 223 billion in fossil fuel capacity in 2011. Investment in new nuclear power plants in 2011 was an estimated USD 5 billion (estimated from graphic). Note: "All the investment costs have been included in the year in which construction was started, rather than spreading out the investment over the construction period. Furthermore, the nuclear investment figures do not include revised budgets if cost overruns occur." Sources: BNEF (2012) and WNISR (2012), pp. 41–42.

3. Unused.

4. Figures are 2011 dollars. Technology shares of investment from IEA WEO (2012b) are for the New Policies Scenario, and provided per personal communication, Marco Baroni, IEA, December 2012.

5. BNEF (2011).

6. Greenpeace quote from Greenpeace (2012), p. 79.

7. Unused.

8. Unused.

9. For a recent prognosis of sweeping changes in near-term utility markets, investment, and business models, see Rogol (2011).

10. E.ON and RWE both announced they are targeting 20% by 2020. See E.ON (2012), p. 71, and RWE (2012), p. 5. EDF is aiming for 25% by 2020. See EDF (2012), p. 17. Dong Energy of Denmark plans to increase wind power capacity from 1 GW in 2011 to 3 GW by 2020. Iberdrola 51% of renewables installed capacity from Iberdrola (2012a), p. 4; and NEER 55% of renewables installed capacity from NEER (undated). For Dong Energy climate-related target, see Dong Energy (2012).

11. Investments by Total from Enerzine.com (2009) and from Total (2012), p. 4. BP Investments from BP (undated).

12. BP was investing in solar in the past but is now selling off its solar assets.

13. For more information about Google investments in renewable energy projects, see Google (undated). (January 2013 update: Google has now committed over $1 billion to wind and solar projects.)

14. Unused.

15. From SteelPath (2010): "Master Limited Partnerships, or MLPs, are engaged in the transportation, storage, processing, refining, marketing, exploration, production, and mining of minerals or natural resources. By confining their operations to these specific activities, their interests, or units, are able to trade on public securities exchanges exactly like the shares of a corporation, without entity level taxation" (p. 3).

16. See Great Debate 8, "Will Green Power Purchasing Scale Up Like Organic Food Has," on p. 37 of report.

17. Unused.

18. Unused.

19. Number of countries with some type of policy and/or target to promote renewable energy from REN21 (2012). Dollar figures in text are rounded to nearest USD 10 billion from IEA figures as exact figures are not necessary for showing the scale of trends. For 2011, the exact figure is USD 88 billion.

20. Data from IEA WEO (2012b), Figure 7.12, "Global Subsidies to Renewables-Based Electricity Generation and Biofuels by Region in the New Policies Scenario" (p. 235), and associated text on p. 236. Exact figure for the United States is USD 58 billion around 2030, for

China USD 35 billion during the late 2020s, and for India USD 26 billion by 2035. 2009 figures are estimated from Figure 7.12.

21. Unused.
22. See also Würtenberger et al. (2012).
23. In 2010, Nissan partnered with Daikyo, one of Japan's largest condominium marketers, to establish EV charging points in new housing. See Nissan (2011).
24. Approved in 2007, the city of Berkeley (California) launched the Financing Initiative for Renewable and Solar Technology (FIRST) in 2009, which "allows residential and commercial property owners to install improvements in their buildings. The city covers the up-front expense through a bond or other /financing mechanism, and the individuals pay that back through a special fee on their property tax bills, spread over 20 years" (Kammen, 2009). In November 2008, Boulder (Colorado) passed Measure 1A, which "allows the county to issue up to $40 million in special assessment bonds to finance clean energy improvements." See Fuller, Compagni, and Kammen (2009).
25. Unused.
26. Many examples exist of community energy programs around the world. Ontario, Canada, has been a leader in fostering such programs. See Community Energy Partnerships Program Web site, www.communityenergyprogram.ca.
27. See the Policies section of annual editions of the REN21 *Renewables Global Status Report* for further description of trends in green power purchasing. See also WindMade Web site, www.windmade.org.
28. Unused.
29. For more on the business models mentioned in Box 5, see the following sources: PG&E (2010); Maui Electric (undated); New Jersey Natural Gas (undated); SMUD (undated); Salt River Project (undated); and Tucson Electric Power (undated).

CHAPTER 4

1. For further information on local/city policies, planning, and infrastructure, see the following sources: IEA (2009); REN21 (2011); KPMG (2011); ARUP (2011); HafenCity University and World Future Council Foundation (2010), and European Union Covenant of Mayors Web site, www.conventiondesmaires.eu.
2. For example, the city of Hamburg, Germany, a highly industrialized, densely populated economic hub and home to Europe's third largest port, aims to build up capacity of sources of renewable energy (electricity and heat) in the city with 100% renewable energy in 2050 as a long-term goal. To reach this goal, Hamburg has built a strong renewable energy cluster, including over 160 member companies, which facilitates the growth of renewable energy manufacturers and service companies. The city notably brings special attention to the development of green urban mobility, heating system, and buildings. See Renewable Energy Hamburg (2012). The city of Copenhagen, Denmark, plans to invest in biomass, solar energy, and wind farms; electric cars and bike paths; and to improve energy efficiency in buildings, transport, heating, and industry in order to become the world's first carbon-neutral capital by 2025. The city plan mirrors the national climate plan, which aims to be carbon neutral by 2035 and to achieve 100% renewable energy by 2050. Over two-thirds of the planned emission reductions in the city will come from an increase in the production of renewable energy, including replacing coal with biomass and waste at district heat and power stations, installing 100 wind turbines (on and offshore) around the city and solar panels on all council buildings, expanding the geothermal facility on Amager, and having all city vehicles run on electricity, hydrogen, or biofuels. The city aims to have 1% of local electricity roof-sourced from roof-mounted PV. The plan is also seen as part of a green growth strategy. According to the city, the plan will require municipal investment of around 2.7 billion Danish crowns up to 2025 and new private investment of 20–25 billion crowns, resulting in employment of about 35,000 man-years until 2025. See Stanners (2012).
3. Over the coming decades, cities will employ intelligent distributed renewable energy strategies that maximize every unit of energy available to meet as much of the demand for electricity, heating, cooling, and transport as possible. Cities will utilize both local renewable energy sources as well as imports from more distant regions. Many cities will first try to satisfy demand from locally available sources and then go to more remote sources as a secondary strategy, while others may have no choice but to accept remote sources in parallel with local development.
4. As of January 2013, the EU Covenant of Mayors reported 4,641 signatories. According to CDP (2011), 42 cities out of the 58 reported have adopted action plans for climate change.
5. Emissions-reduction targets from REN21 (2012) Table R15, subheading titled "CO2 emissions reductions targets, all consumers." Tokyo relative base year is 2000, Oslo 1991, and Chicago and Hamburg 1990. In 1990, per-capita CO2 emissions were 5.5 tons in Stockholm. Rajkot targets a 10% reduction in conventional energy by 2013, and Bhubaneswar 15% by 2012, from REN21 (2012) Table R15. "Carbon-neutral cities": Dallas, Texas, USA (by 2030), and "fossil-free cities": Växjö, Sweden (by 2030) and Göteborg, Sweden (by 2050), from REN21 (2012) Table R15.
6. For renewable targets for shares of total electricity consumption within local jurisdictions and re target share of electricity consumption by local governments, see REN21 (2012) Table R15.
7. Calgary target from REN21 (2011). Seoul total renewables target from REN21 (2012). Biofuels use targets in public transport or vehicle fleets from REN21 (2012) Table R15. Total amount of installed renewables capacity targets and targets for number of installed units from REN21 (2012) Table R15.
8. For the research for this chapter, cities and towns were first identified and selected on the basis of having a renewable energy or a carbon reduction target and/or renewable energy specific policy framework. This was largely facilitated by resources including REN21/ISEP/ICLEI (2011) and the local policies sections of annual editions of the *Renewables Global Status Report*, as well as resources such as ICLEI, C40, EU Covenant of Mayors, etc. This was also facilitated in developing-country workshops conducted in Morocco, South Africa, and India. At these workshops, experts provided further information on the role of cities in the respective regions and identified resources, publications, institutes, and actors to get more information. In each selected city/town, 3–5 actors were identified who held different but complementary roles (e.g., city officials, urban planners, and utility or program managers, grid operators, etc.) to understand how renewable energy was being integrated in different ways to reach the overall goals outlined in the city plan. For example, in Amsterdam, an interview was conducted with a grid operator (regional grid operator working closely with cities like Amsterdam and the local utility), an urban planner, a former local utility manager and currently manager of the cities ICT program, and a city official working on integrating the three different city divisions under sustainable development. In Hamburg, interviews were conducted with the manager of the city's renewable energy industry cluster, the head of the international building association, and an NGO representing those fighting to remunicipalize the utility. In London, interviews were conducted with the advisor to the mayor and head of environmental affairs in the city department as well as an independent policy expert/advisor to the city plan, among others. Each interview lasted 1–2 hours. During the interviews or in follow up to the interviews, reference was made to city documents that would otherwise have been inaccessible as they were in development or in another language. The physical interviews helped to overcome this problem as the interviewees would go through the document with the author of this report and translate it in the process (for example, in Amsterdam or Hamburg). Further, documents, magazine clippings, and/or debates from meetings would be sent in personal communication and/or in follow up to the discussion.

9. Unused.
10. For more information, see EU (2010).
11. An IEA research group, the Research for Energy Optimized Building (EnOB), has documented and analyzed around 300 net zero-energy and energy-plus buildings worldwide. For more on the "Towards Net Zero Energy Solar Buildings" project, see EnOB (undated). The International Living Building Challenge (ILBC) is a certification scheme that rates buildings, communities and infrastructures. There are more than 80 Living Building projects being developed or in operation in cities around the world, in Australia, Ireland, Mexico, and the United States. Certified "Living Buildings" must obtain 100% of the building's energy demand using on-site renewable energy (net-zero-energy) and capture and treat the building's own water needs for at least 12 continuous months at full occupancy, in addition to standards for sustainable materials and indoor environmental quality." For more information, see "Living Building Challenge," at http://living-future.org/lbc.
12. Examples from REN21 (2012). In Hamburg, hotels will have a primary energy requirement of less than 95 kWh/m2/year using passive solar building design. For more on the Hamburg Renewable Heating Act, see Hamburg Coordination Center for Climate Issues (2012).
13. A fast expansion of the use of district heat is one of the important assumptions taken into account by Greenpeace (2012) in its "Revolution" scenario.
14. Unused.
15. Unused.
16. Information from REN21 (2012), except for Copenhagen from Municipality of Copenhagen (2009), and Hamburg from Augsten (2011).
17. For more information on the Boulder smart-grid project, see Danish Architecture Centre (2012).
18. Unused.
19. San Francisco, Austin, and Boulder from REN21 (2012). Amsterdam, Copenhagen, Munich, and Sacramento from Hafen City University Hamburg and World Future Council Foundation (2010). For more on German municipal utilities, see Yapp (2012).
20. Yokohama from City of Yokohama (2011); Hamburg from hySOLUTIONS GmbH (2011); São Paulo from REN21 (2012).
21. For more on the C-Train wind-power commuter system in Calgary, see ESCI (2012). For Genoa, see Municipality of Genoa (2010).
22. Forms of supply to charging stations: local PV or green power purchasing.
23. All examples from REN21 (2012), except for Hamburg from hySOLUTIONS GmbH (2011).
24. Mexico City zero emission taxi program from REN21 (2012) and from Adrián (2011).
25. Unused.
26. New Delhi and Portland from REN21 (2012); Kyoto from Environment Bureau City of Kyoto (2007); Frederikshavn from Nordic Folkecenter for Renewable Energy (2009).
27. As one recent example, Copenhagen and MIT are developing a new electric bike (the "Copenhagen Wheel"), which will integrate ICT—in this case providing real-time information on traffic congestion.
28. Unused.
29. Frederikshavn from Energy City Frederikshavn Web site, www.energycity.dk, viewed 20 December 2012; Moura and Rizhao fromGirardet and Mendonca (2009), pp. 163–66; Malmö and Gothenburg from ICLEI (undated); San Francisco from Sullivan (2010); Sydney from Sydney 2030 (undated).
30. REN21 (2012); Toronto and Vancouver from Sustainable Infrastructure Group University of Toronto (2010); Amsterdam from Nieuw Amsterdams Klimaat Web site, www.nieuwamsterdamsklimaat.nl, viewed 20 December 2012; Chicago from see Chicago Climate Action Plan Web site, www.chicagoclimateaction.org, viewed 20 December 2012.
31. Stadtwerke München GmbH (2012).
32. In the city of Malmö, a former industrial area, the Western Harbor district, has become energy self-sufficient thanks to renewables through the development of the city's district heating grid and power supply network. The Aktern heat pump plant is the heart of the energy system, and produces energy for heating and cooling. A local 2 MW wind power plant provides the electricity needed to power the heat pumps and also supplies 1,000 apartments with electricity, per SymbioCity (undated). Västra Hamnen, another district in Malmö, is now entirely self-sufficient with renewable energy from water, wind, sun and compostable waste. A wind power plant nearby serves powers the district's energy system. Solar cells are used for electricity. Aquifers store warm sea water from the summer in the bedrock and use it in the winter as district heating for residential housing. In the winter cool sea water is stored to be used as district cooling in the summer. Solar collectors connected to the district heating network are also used for heat and hot water (700,000 kWh). Biogas is derived from the domestic waste and fed into Malmö's natural gas network.
33. One of the earliest Masdar projects was a 10 MW solar PV plant; see also Masdar City (undated). PlanIT from Woods (2011); Songdo from SongdoIBD (undated); Tianjin Eco City from King and Wright (2011).

CHAPTER 5

1. For complete list of scenarios, see Annex 2. For specific scenarios projections, see the online supplement "Scenario Profiles Report."
2. Unused.
3. It is impossible to cover all countries and regions adequately in a few pages. Countries given here reflect the majority of interviews conducted for the report, plus a balance of developing countries, and results from workshops in three developing countries (see Annex 1). For more details on these countries and others, see the online Topical Discussion Report. It is hoped that additional country profiles can be added to that online report and any future editions of the present report.
4. European Union target share from renewable energy sources by 2020 from European Commission (2008), and from European Parliament and Council (2009). In 2011, EREC called on the European Commission, Member States, and the European Parliament to "deliver on the European Union's long-term climate commitment by proposing and endorsing a legally binding EU target of at least 45% renewable energy by 2030," per EREC (2011b), p. 5.
5. Wind power targets from REN21 (2012) Table R11. Estimate for France 19 GW onshore and 6 GW offshore is based on calculation from 25 GW total including 6 GW offshore, which is the official target. In EWEA (2011), offshore wind plays a significant role in the growth of the wind power industry. Indeed, the report estimates 150 GW of offshore wind installed capacity by 2030, a 50-fold increase compared to 2010. See also PricewaterhouseCoopers (2010) for high electricity shares.
6. Data for 2011 from REN21 (2012). For Germany solar PV target, see Roland Berger Strategy Consultants and Prognos AG (2010). In EREC (2010), solar PV will have become by far the most important renewable energy source by 2050; almost 50% of the total renewables installed capacities, and more than twice the ones of the second most important renewable energy (wind).
7. Unused.
8. See "Europe" topic in Topical Discussion Report for further discussion.

9. Other recent U.S. scenarios include US DOE (2008) and Tonn et al (2010).

10. An RPS, or quota, policy mandates utilities to obtain a certain share of power from renewables by future years, typically 2015, 2020, or 2025, and typically ranging from 10% to 30%. As of early 2012, 29 U.S. states plus the District of Columbia and the U.S. possessions of Puerto Rico and the Northern Mariana Islands had RPS policies, per REN21 (2012).

11. Unused.

12. Data for 2011 on U.S. solar PV market from REN21 (2012).

13. RPS policies have been widely credited with accelerating wind power markets in the U.S.; see for example Wiser and Bolinger (2012). Data for 2011 on U.S. wind power market from REN21 (2012).

14. Softbank expects to build the largest solar plants in Japan with an installed capacity between 200 MW and 340 MW, able to provide electricity for roughly 100,000 homes in Hokkaido Prefecture. The Chief Executive Officer of the company Masayoshi Son, who is playing an important role in Japan's green shift, has also decided to invest in the Gunma, Kyoto and Tokushima Prefectures, see Westlake (2012a). Toshiba will spend ¥30 billion in a solar farm project of 100 MW installed capacity in Fukushima Prefecture, which is supposed to begin constructed in the current business year and operate by fiscal year 2014, see Japan Times (2012b). Kyocera, along with Mizuho Corporate Bank and IHI Corporation, expects to build a 70MW solar plant able to provide electricity for roughly 22,000 homes in Kagoshima Prefecture, on the southwestern island of Kyushu, see Westlake (2012b). The Obayashi group plans to launch giant solar power plants in four locations with a combined capacity of 20MW, including a 15MW facility planned in the town of Ashikita in Kumamoto Prefecture, see Japan Times (2012a). The Federation of Electric Power Companies of Japan has also announced that its members are building 20 mega-solar facilities for a total installed capacity of 103 MW, which will provide electricity by March 2015, see Kurtenbach and Yamaguchi (2012). As of the end of September 2012, 1,480 MW of solar projects had already been approved by the Ministry of Economy, Trade and Industry (METI), see Watanabe (2012).

15. Unused.

16. Data for 2011 on solar PV from REN21 (2012).

17. Data for 2011 on wind power capacity from Japanese Wind Energy Association, cited in Rose (2012).

18. British Columbia, Nova Scotia, Ontario, and Prince Edward Island have RPS policies. Wind power capacity targets for Québec (4 GW by 2015), Manitoba (1 GW by 2014), and Prince Edward Island (0.5 GW by 2013) from Agriculture and Agri-Food Canada (2009). Ontario target (7.1 GW by 2018) from ClearSky Advisors Inc. (2011). For other renewable energy policies and information mentioned here, see REN21 (2012), and endnote 23 of Chapter 1.

19. REN21 (2008); REN21 (2010); REN21 (2011).

20. For hydropower and pumped hydro installed capacity, see REN21 (2012). LNBL (2011) shows 400 GW in its "Accelerated Improvement Scenario," Zhang et al. (2010) shows 380 GW, and China ERI (2009) shows 430 GW. China's state grid operator pumped hydro plans from Lee (2010).

21. Data for 2011 on wind power installed capacity from REN21 (2012). China's target for wind power capacity by 2020 from REN21 (2012). Data for 2011 for new wind power installed capacity from REN21 (2012). The capacity 18 GW denotes constructed capacity, whereas only 15 GW became operational. As this disparity in China and elsewhere was becoming large, REN21 started to document both figures.

22. For wind power installed capacity in China, IEA WEO (2012b) "New Policies" shows 326 GW by 2035, BNEF (2011) 350 GW by 2030, and IEA WEO (2012b) "450" 468 GW by 2035. By 2050, China ERI (2009) shows 400 GW, and LBNL (2011) "Accelerated Improvement Scenario" shows 500 GW. At the higher end, Greenpeace (2012) "Revolution" shows over 1,100 GW, of which 133 GW is offshore in 2050.

23. Data for 2011 on solar PV capacities from REN21 (2012). NDRC Medium and Long Term Development Plan, September 2007; see Martinot and Li (2007) for details. These targets were not necessarily official, but called "provisional" by some. China's 12th Five-Year Plan (July 2012 update) sets target for solar PV installed capacity to 50 GW by 2020, per IEA WEO (2012b), p. 213.

24. About new solar PV promotion policies and decreasing costs leading to a domestic growth of solar PV in China, see Martinot (2010). For solar PV installed capacity in China, BNEF (2012) shows 194 GW by 2030, Greenpeace (2012) "Revolution" 221 GW by 2030, and IEA WEO (2012b) "450" 256 GW by 2035. By 2050, China ERI (2009) shows 300 GW, and Greenpeace (2012) "Revolution" 803 GW.

25. Data for 2011 on biomass power capacity in China from REN21 (2012). Target for biomass includes waste-to-energy from BNEF (2012). Scale of 500–1,000 kW is for use with smaller gas engines and gas turbines.

26. Data for 2011 on biofuels from REN21 (2012). China's biofuels targets from Biofuels & the Poor (undated).

27. Data for 2010 and 2020 target for solar heating from REN21 (2011).

28. For feed-in and RPS policies in India at national and state levels, see REN21 (2012) Tables R12 and R13.

29. REN21 (2012).

30. Data for 2010 from REN21 (2011). Data for 2011 on wind power capacity is 16 GW, per REN21 (2012). India still ranked 5th in 2011. Reference goal; the government plan calls for up to a 15% electricity share from renewables by 2022 to be achieved. For wind power installed capacity in India, GWEC (2012) "Advanced Scenario" shows 89 GW by 2020, and 192 GW by 2030; Greenpeace (2012) "Revolution" shows 96 GW and 185 GW, respectively.

31. Data for 2012 on solar PV capacity in India from Government of India (undated). National solar capacity target for 2022 from REN21 (2012), Table R11. Chhattisgarh's target from PV Power Plants 2012 (2012).

32. Target for solar thermal collectors capacity in REN21 (2012) Table R11.

33. According to the IEA WEO (2012b), hydropower installed capacity represented 71% of India's renewables installed capacity in 2010. While the growth of hydropower in India is undisputed the scale of its deployment is relatively uncertain. Greenpeace (2012) "Revolution" estimates 64 GW of hydropower capacity by 2030 (compared to 39 GW in 2009), less than half of what the IEA WEO (2012b) "450" projects; 148 GW.

34. Target for rural lightning systems in REN21 (2012) Table R11.

35. For more developing countries perspectives, see topics Unused. in the Topical Discussion Report.

36. Brazil Government Law No. 9648, of May 27, 1998 defines small hydro as 30 MW or less, per IPCC (2011), p. 450. Data for wind power capacity by 2021 from Brazil Ministry of Mines and Energy (2012). Brazil 2011 wind market from GWEC (2012), with 582 MW added. REN21 (2012) Table R4 indicates 21 billion liters of ethanol produced in Brazil in 2011. The Empresa de Pesquisa Energética expects this production to reach 63 billion liters by 2020, per EPE (2012). The South African Energy Plan that the main text is referring to is the "Integrated Resource Plan for 2030."

37. Targets data from REN21 (2012) Table R11, except for Brazil and South Africa. Brazil 2011 and 2021 data from Brazil Ministry of Mines and Energy (2012); Brazil's wind target in REN21 (2012) is 11.5 GW by 2020. South Africa from South Africa Department of Energy (2010).

38. Philippines and Tunisia from REN21 (2012) Table R11. Developing countries' targets for share of renewable energy in electricity from REN21 (2012) Table R10. Online interactive map for complete targets database at www.map.ren21.net.

39. For rural (off-grid) renewable energy targets, see REN21 (2012) Table R11.

40. Unused.

41. Unused.

42. The replacement or supplementation of diesel generators with renewables is a potentially huge market, as there are millions of diesel generators in rural areas around the world. IRENA (2012) indicates that over 50% of the power generation capacities in the Democratic Republic of Congo, Equatorial Guinea, and Mauritania, and 17% in West Africa, are based on diesel fuel because of the current important need of diesel generators to overcome daily power outages.

43. Unused.

44. The unbundling and liberalization of power markets is often perceived as theoretically making possible the introduction of massive quantities of renewable energy in the grids through notably increasing competition among power producers. Unbundling generation and transmission of electric power makes it easier for smaller utilities to send and sell the electricity they generate to consumers, as such reform puts an end to monopolies' control over transmission of power. In addition, on the one hand deregulating the power system means that smaller energy companies can enter the market and vie for consumers, and on the other hand that consumers are able to choose their own electric companies. As a result, consumers with environmental consciousness are able to pay for electricity generated from utilities supplying power from renewable energy sources. Denmark is an illustrative successful example of this type of reform.

45. The Greenpeace scenario mentioned here is the "Advanced Revolution" one.

46. In this regard IRENA (2012) notes that: "There is a range of concrete developments in place to create new interconnections and significant interest has been shown in improving current grid interconnection in Africa in order to provide security of supply and facilitate the development of large electricity generation projects. The southern African Power Pool (SAPP) is an effort by the national electricity companies of 12 countries in Southern Africa to improve cooperation through grid connection. Similarly, the Economic Community of West African States (ECOWAS) West Africa Power Pool (ECOWAPP) includes all the ECOWAS countries. The Central African Power Pool includes 11 utilities…. The Arab Maghreb Union has a set of interconnections…that connect the countries of North Africa" (p. 33).

47. Unused.

48. Unused.

49. REN 21 (2012) notes that, "The expansion of hydropower production must take into account the potential for significant evaporative water losses from the regional watershed as well as the environmental impacts associated with altering natural water flows and siltation patterns" (p. 52). In the World Bank scenario, it is estimated that hydropower capacity represented 53% of the 295 GW total power capacity in Latin America and the Caribbean in 2008 (data from the Organización Latinoamericana de Energía (OLADE), 2009). The World Bank estimates that 239 GW of new power capacity will be required to meet the electric demand of the region by 2030, of which 36% will be hydro. As a result, there will be approximately 240 GW of hydropower capacity in Latin America and the Caribbean in 2030. Hydropower installed capacity in Africa in 2009 was 25 GW, per Greenpeace (2012).

50. IPCC (2011), while referring to Egré and Milewski (2002), notes that the "classification according to size has led to concepts such as 'small hydro' and 'large hydro,' based on installed capacity measured in MW as the defining criterion. Small-scale hydropower plants (SHP) are more likely to be run-of-river facilities than are larger hydropower plants, but reservoir (storage) hydropower stations of all sizes will utilize the same basic components and technologies. Compared to large-scale hydropower, however, it typically takes less time and effort to construct and integrate small hydropower schemes into local environments. For this reason, the deployment of SHPs is increasing in many parts of the world, especially in remote areas…. Nevertheless, there is no worldwide consensus on definitions regarding size categories. Various countries or groups of countries define 'small hydro' differently" (p. 450). In the same report, Table 5.3, p. 450, shows various ranges for small hydropower capacity; from 1.5 MW or less in Sweden to 100 MW in the United States.

51. See Endnote 1, Chapter 1 for definition of traditional biomass.

52. See REN21 (2012). Some experts particularly noted the expanded use of cogeneration in agricultural industries.

53. Data for 2011 on wind power capacities and annual additions in developing countries from GWEC (2012b). Share of wind power capacity existing in developing countries in 2005 and 2011 from GWEC (2006) and GWEC (2012).

54. For Africa, GWEC (2012) "Advanced Scenario" is 83 GW and IRENA (2012) is 95 GW.

55. One expert also noted, however, that, "the notion that we must use "the best wind areas" or "the best solar areas" is a "big and pervasive fallacy" prevalent in many countries.

56. For global repartition of solar PV operating capacity, see REN21 (2012), Figure 12. For Africa, IRENA (2012) gives approximately 90 GW of solar installed capacity in 2030 and 320 GW in 2050; Greenpeace (2012) gives 91 GW (49 GW of solar PV and 42 GW of CSP) and 316 GW (155 GW of solar PV and 161 of CSP), respectively. For 2030 only, Greenpeace (2012) gives: Middle East 162 GW of solar PV and 102 GW of CSP; Latin America 74 GW of solar PV and 21 GW of CSP; and Non-OECD Asia 199 GW of solar PV and 64 GW of CSP.

57. For more on energy access, see the "Off-Grid (Rural) Energy" section of REN21 (2012).

58. Unused.

CHAPTER 6

1. Unused.

2. Data from REN21 (2012). In this edition the hydropower capacity does not include pure pumped storage anymore; see notes for Table R2. This is the reason why the hydropower capacity in the 2012 edition is lower than in the 2011 one (i.e., 1,010 GW, of which 136 was estimated to be pumped storage, 2010 data from REN21 (2011)). The distinction is done because pumped storage is not an energy source, but rather a means of storage. Global power generating capacity was estimated at 5,360 GW in 2011, per REN21 (2012).

3. REN21 (2012) notes that about 86% of the global demand for biomass for energy purposes "is used to produce heating (and cooling), for cooking, and for industrial applications…. Of the remaining 14%, nearly three-fourths is used for electricity generation and combined heat and power" (p. 31). REN21 (2012) data on solar heating capacity include solar cooling.

4. Data for biofuels from REN21 (2012).

5. Many future cost projections make use of so-called "experience curves," and a long-standing literature has emerged. See IEA/OECD (2000), Neij et al (2003), and Alberth (2007).

6. Scenario projections can take several approaches, including learning-curve analysis and engineering and manufacturing advancement models. In contrasting the two, NREL (2012) notes that for its model: "Although the methods used in RE Futures to project the future cost of each renewable electricity technology differ to some degree by technology, the resulting forecasts are largely based on anticipated scientific and engineering advancements rather than on learning-curve-based estimates that are endogenously driven by an assumed learning rate applied to cumulative production or installation," vol.1, page A-5. For discussion on the sustainability and recycling questions

noted in footnote (b), p. 53, see U.S. DOE (2010), Resnick Institute (2011), and Silicon Valley Toxics Coalition (2009).

7. Unused.

8. Data for 2011 from REN21 (2012).

9. RWE quote from RWE (undated a). Gas Natural Fenosa quote from Gas Natural Fenosa (undated).

10. IRENA (2012b) shows onshore wind power costs per kWh of U.S. 6–14 cents (in 2010 dollars) in 2010: 6–11 cents in China and India, 8–14 cents in Europe, and 7–11 cents in North America. GEA (2012) shows onshore wind power costs per kWh of U.S. 4–15 cents (in 2005 dollars) in 2009, potentially declining to U.S. 3–15 cents in the future. One expert pointed out that U.S. wind contract prices in 2012 for standard commercial utility-class wind turbines, for good sites, were U.S. 4–5 cents/kWh, based on empirical data from Wiser and Bolinger (2012).

11. IEA ETP (2012a) cost projections are just for the United States and are in 2010 dollars.

12. Unused.

13. Unused.

14. Unused.

15. WWEA quote from WWEA (2012), p. 11. For small wind turbines WWEA (2012) projects an increase from 443.3 MW in 2010 to 3.817 GW in 2020.

16. Unused.

17. IEA quote from IEA WEO (2010b), p. 330.

18. IRENA (2012b) shows offshore wind power costs of U.S. 14–19 cents/kWh (in 2010 dollars) in Europe in 2010. GEA (2012) shows offshore wind power costs of U.S. 7–25 cents/kWh (in 2005 dollars) in 2009, potentially declining to U.S. 5–15 cents/kWh in the future. "Technology Roadmap" for wind power from IEA ETP (2012a), pp. 498–99.

19. E.ON quote from E.ON (undated); RWE quote from RWE (2011), p. 10; Iberdrola quote from Iberdrola (2012b), p. 32; Vattenfall quote from Vattenfall (undated); RWE quote from RWE (undated b).

20. EWEA (2011) in its "High" scenario" estimates up to 3 GW of offshore wind power installed capacity in Sweden by 2020, up from 164 MW in 2010. In this case, offshore wind power capacity will represent about one-third of the country's total new wind power capacity added during the decade.

21. EWEA (2011) develops a scenario with average offshore turbine size of 5 MW in 2020.

22. Greenpeace (2012) projects over 4,500 GW of solar PV installed capacity by 2050.

23. Data for 2011 data on global solar PV market growth and Europe's share of the considered market from REN21 (2012).

24. In some countries, grid parity is also confounded by public subsidies to retail consumer electricity prices. Further, in many countries, industry receives cross-subsidies from other classes of consumers, so grid parity for industry is distorted. In India, the opposite is true; cross-subsidies flow from industry to consumers. See Glossary for these terms. There are many utility rate structures in use today that confound the meaning of "grid parity" and make solar PV cheaper than many existing rates under these structures today. Peak pricing generally refers to time-of-day-based rates, and peak rates can be double or triple off-peak rates. Rates can also vary by season. And some customers can face higher "demand charges," meaning that power costs increase significantly above a certain threshold of use. As one example of prices linked to grid conditions, Pacific Gas and Electric in California has a new "SmartMeter" option that charges high per-kWh rates on days of high power demand (i.e., hot days linked to air conditioning use), offset by lower off-peak rates; the cost of solar PV electricity is significantly lower than peak retail rates on these high-demand days (some rates have been exceeding $1.00/kWh). [Cost- or price-based policy support is generally a capital investment subsidy or tax credit, or a feed-in tariff (preferential power purchase pricing). However, other forms of policy support may continue to be needed even at grid parity, such as net metering rules, interconnection standards, and guaranteed-purchase mandates.]

25. Unused.

26. One example of an expert claim that grid parity including subsidy/tax support already exists: one U.S. expert said, "one obvious piece of evidence about grid parity is that Sun Run, Sungevity, Sun Edison, and Solar City operate collectively in about 20 U.S. states where they can often finance rooftop PV systems with no down payment and guarantee to beat your utility bill [including available tax/subsidy support]. Case closed." [Claims of grid parity often do not distinguish whether they are based on subsidized or unsubsidized costs. Generally, the presumption is that claims are based on subsidized costs under current policy regimes, such as California and Hawaii, but based on unsubsidized costs in areas with feed-in tariffs but no other policy support.]

27. "Technology Roadmap" for solar PV from IEA ETP (2012a), pp. 494–95.

28. One solar PV expert stated that prices had fallen below $1/watt in 2012 for high-volume orders.

29. Solar PV costs for rooftop and utility-scale installations from REN21 (2012). IRENA (2012c) shows solar PV costs per kWh of U.S. 25–65 cents (in 2010 dollars) for a residential system without battery storage, and U.S. 36–71 cents for a residential system with battery storage. The report also shows solar PV costs of U.S. 26–59 cents/kWh (in 2010 dollars) for a utility-scale system. GEA (2012) shows solar PV costs of U.S. 15–70 cents/kWh (in 2005 dollars) in 2009, potentially declining to U.S. 3–13 cents/kWh in the future. Some experts cited radically lower numbers for Europe, in the range of U.S. 9–13 cents/kWh rather than the U.S. 22–44 cents/kWh given by REN21. One expert said in 2012, "Germany may well have achieved already the U.S. 9–10 cents/kWh unsubsidized cost that the IEA foresees for 2035." Another pointed out that extremely low interest rates were lowering solar PV generation costs, perhaps artificially and temporarily.

30. IEA ETP (2012a) cost projections are just for the United States and are in 2010 dollars.

31. Unused.

32. Another expert said $2.50/watt for balance of system (BOS) was too high, and must include more than just BOS.

33. Unused.

34. Unused.

35. The point of view in Greenpeace (2012) is that, "Technologies like PV thin film (using alternative semiconductor materials) or dye sensitive solar cells are developing quickly and present a huge potential for cost reduction" (p. 63). NREL (2012) notes that: "Several promising next-generation PV device concepts are being developed, but they have not yet reached sufficient maturity to be introduced to the market. Examples include dye-sensitized PV cells and several PV nanostructures like quantum dots. These, and other, next-generation PV technologies have the potential to lower module costs by using less expensive materials and simpler manufacturing processes, but there have been challenges in reaching high-efficiency and long-term durability for the materials explored to date" (Vol. 2, p. 10-6).

36. Unused.

37. IRENA (2012d) shows parabolic trough costs of U.S. 14–36 cents/kWh (in 2010 dollars) in 2011, and solar tower costs of U.S. 17–29 cents/kWh. GEA (2012) shows CSP without heat storage costs of U.S. 10–30 cents/kWh (in 2005 dollars) in 2009, potentially declining to U.S. 5–15 cents/kWh in the future. IEA ETP (2012a) cost projections are just for the United States and are in 2010 dollars.

38. IEA quote from IEA WEO (2010b), p. 309.
39. Unused.
40. Quote from IEA ETP (2010a), p. 503. No similar statement was made in IEA ETP (2012a), so reference is retained to the 2010 edition. IPCC (2011) notes: "Although CSP is now a proven technology at the utility scale, technology advances are still taking place. As plants are built, both mass production and economies of scale are leading to cost reductions. There is scope for continuing improvement in solar-to electricity efficiency, partly through higher collector temperatures. To increase temperature and efficiency, alternatives to the use of oil as the heat-transfer fluid—such as water (boiling in the receiver) or molten salts—are being developed, permitting higher operating temperatures" (p. 67).
41. IEA ETP (2012a) notes that improvements in heat-transport media and storage systems are critical in order to reduce the technology costs of CSP (p. 80).
42. Unused.
43. IEA quote from IEA WEO (2010b), p. 282.
44. Unused.
45. Unused.
46. Greenpeace (2012) notes that: "Biomass can provide a large temperature range of heat and can be transported over long distances, which is an advantage compared to solar thermal or geothermal heat. However, sustainable biomass imposes limits on volume and transport distance" (p. 257).
47. See IPCC (2011) for more on advanced or second generation biorefineries that would be based on more sustainably derived biomass feedstocks, and which would aim to optimize the use of biomass and resources in general (including water and nutrients), while mitigating greenhouse gas emissions.
48. IRENA (2012e) shows biomass technologies costs in the range of U.S. 4–29 cents/kWh. Greenpeace quote from Greenpeace (2012), pp. 64 and 67.
49. GEA (2012) shows hydropower costs of U.S. 1.5–12 cents/kWh (in 2005 dollars) in 2009, with a very slight decrease in the future, to U.S. 1.5–10 cents/kWh. IRENA (2012f) shows large hydro costs of U.S. 2–19 cents/kWh (in 2010 dollars), and small hydro costs of U.S. 2–27 cents/kWh.
50. NREL quote from NREL (2012), Vol. 2, pp. 12–22. IEA ETP (2012b), p. 226.
51. IEA ETP (2012b) also shows 130 GW of pumped hydro capacity globally. IEA quote from IEA ETP (2012b), p. 224, IEA cites Pieper and Rubel (2011). IEA ETP (2012) Figure 7.2, "Levelised costs of electricity storage," p. 245; U.S. 10–15 cents/kWh estimated from graph. Only CAES was equivalent to or cheaper than pumped hydro. GEA (2012) Figure 11.70 "Electricity storage costs for different storage options," p. 864.
52. Data from REN21 (2012). GEA (2012) shows geothermal costs of U.S. 3–9 cents/kWh (in 2005 dollars) in 2009, with no decline in the future. Greenpeace quote from Greenpeace (2012), p.65.
53. REN21 (2012). GEA (2012) does not offer cost projection for salinity gradient energy.
54. Greenpeace quote from Greenpeace (2012), p. 65.
55. For debates on sustainability, see REN21 (2010), Sidebar 7, p. 43. One developing country expert said: "I am afraid [the world] is placing excessive emphasis on bio fuels. This would virtually mean diversion of land in developing and poor countries from food crops to fuel crops - a strategy that may not be acceptable to all the countries."
56. Chevron quote from Chevron (2010), p. 41; IEA quote from IEA WEO (2012a), p. 222. IEA (2011c), p. 35.
57. Unused.
58. See IEA WEO (2012a), p. 47.
59. Unused.

ANNEX 4

Note: Endnotes for Annex 4 will elaborate on the "Great Debates" presented in Annex 4, but are pending publication of the associated online supplement "Topical Discussion Report," which will also have cross-references with the "Great Debates" in Annex 4.

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REN21
c/o UNEP
15, Rue de Milan
F-75441 Paris CEDEX 09
France

www.ren21.net

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