

Renewable Energy Futures to 2050: Current Thinking

2050年へ向けた自然エネルギーの将来：最新の考え方

Dr. Eric Martinot

Report Author, REN21 *Renewables Global Futures Report*
Senior Research Director, Institute for Sustainable Energy Policies (Tokyo)

エリック・マーティノー博士

REN21 世界自然エネルギー未来白書 著者
環境エネルギー政策研究所 研究部長

<http://www.ren21.net/gfr>

<http://www.isep.or.jp/gfr>

<http://www.martinot.info/gfr>



RENEWABLES
GLOBAL FUTURES REPORT

2013

RENEWABLES 2005

GLOBAL STATUS REPORT



Paper prepared for
the REN21 Network by
The Worldwatch Institute

Lead Author: Eric Martinot



RENEWABLES 2012 GLOBAL STATUS REPORT



2012

FIGURE 1. RENEWABLE ENERGY SHARE OF GLOBAL FINAL ENERGY CONSUMPTION, 2010

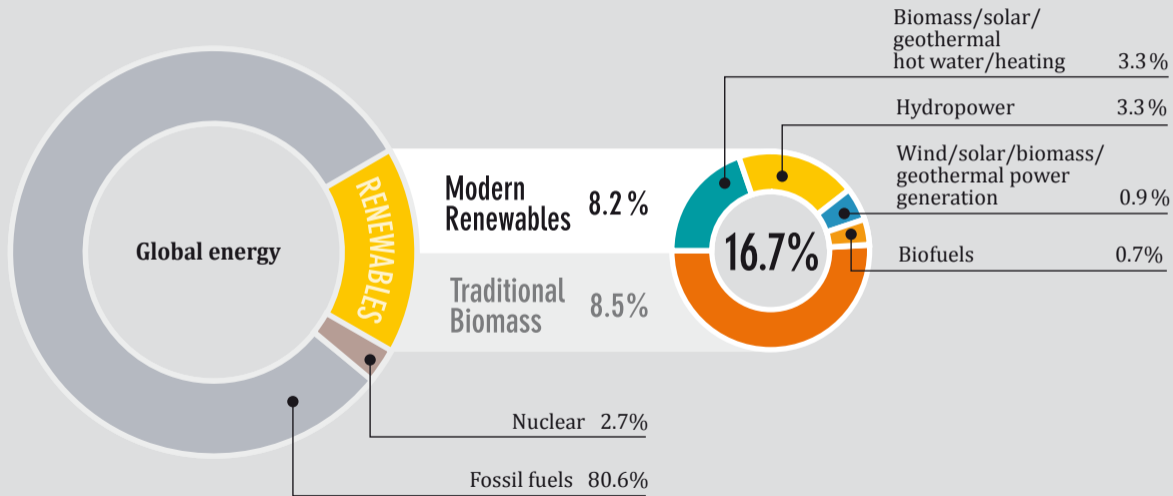


FIGURE 3. ESTIMATED RENEWABLE ENERGY SHARE OF GLOBAL ELECTRICITY PRODUCTION, 2011

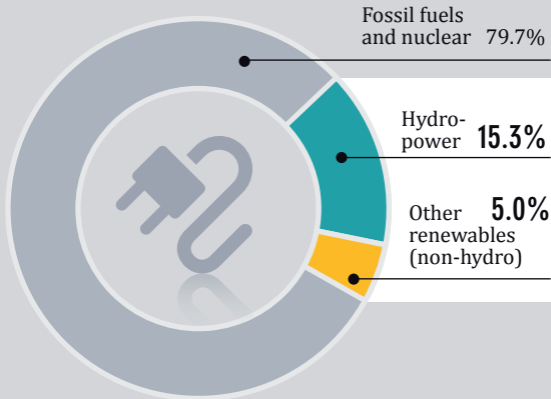


FIGURE 17. WIND POWER TOTAL WORLD CAPACITY, 1996–2011

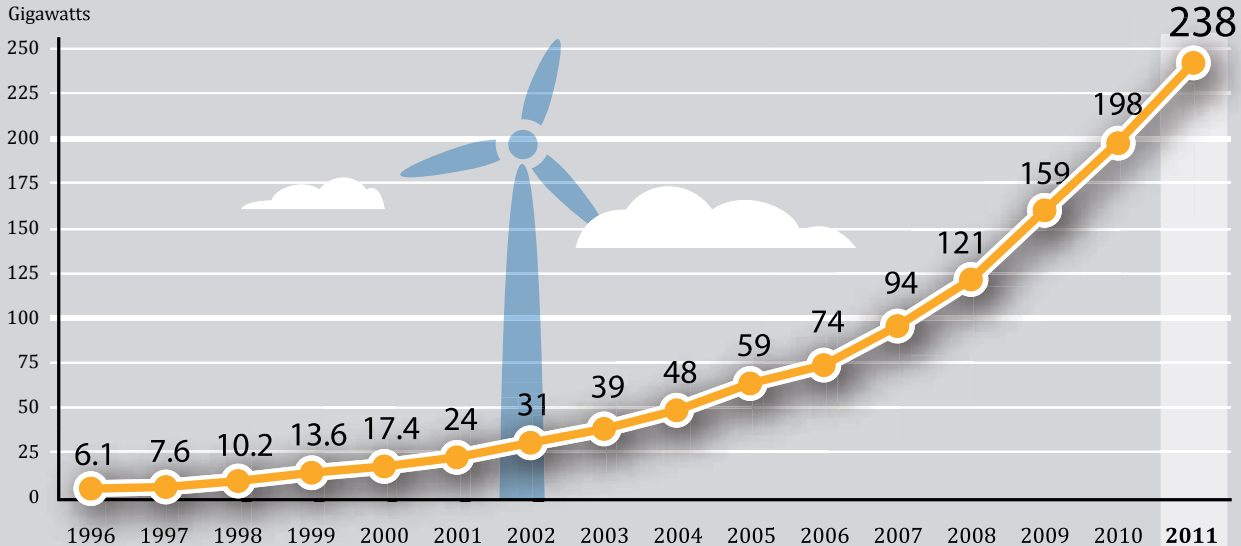


FIGURE 11. SOLAR PV TOTAL WORLD CAPACITY, 1995–2011

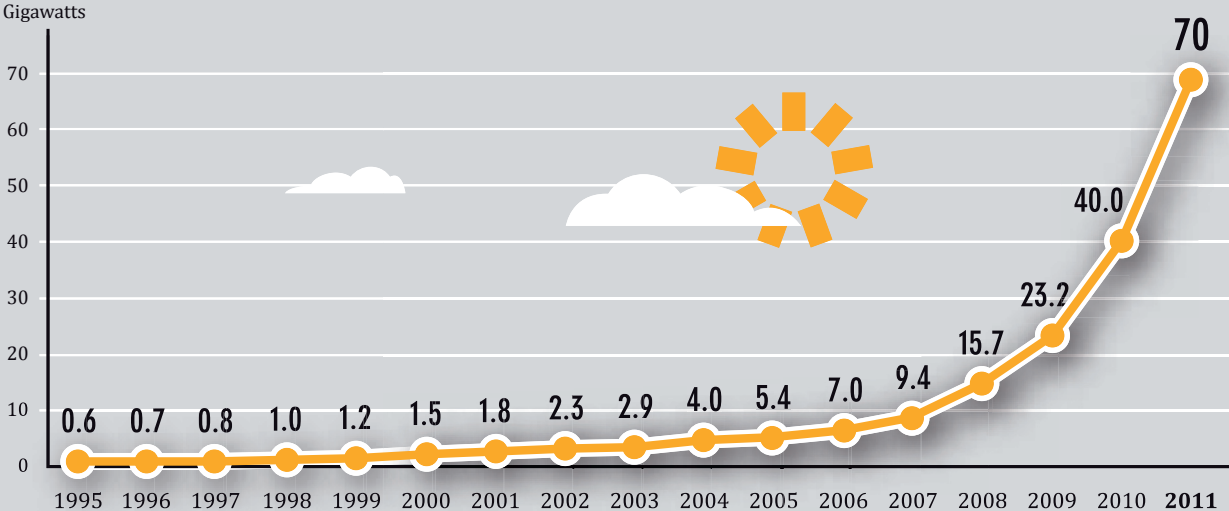


FIGURE 8. GLOBAL WOOD PELLET PRODUCTION, 2000–2011

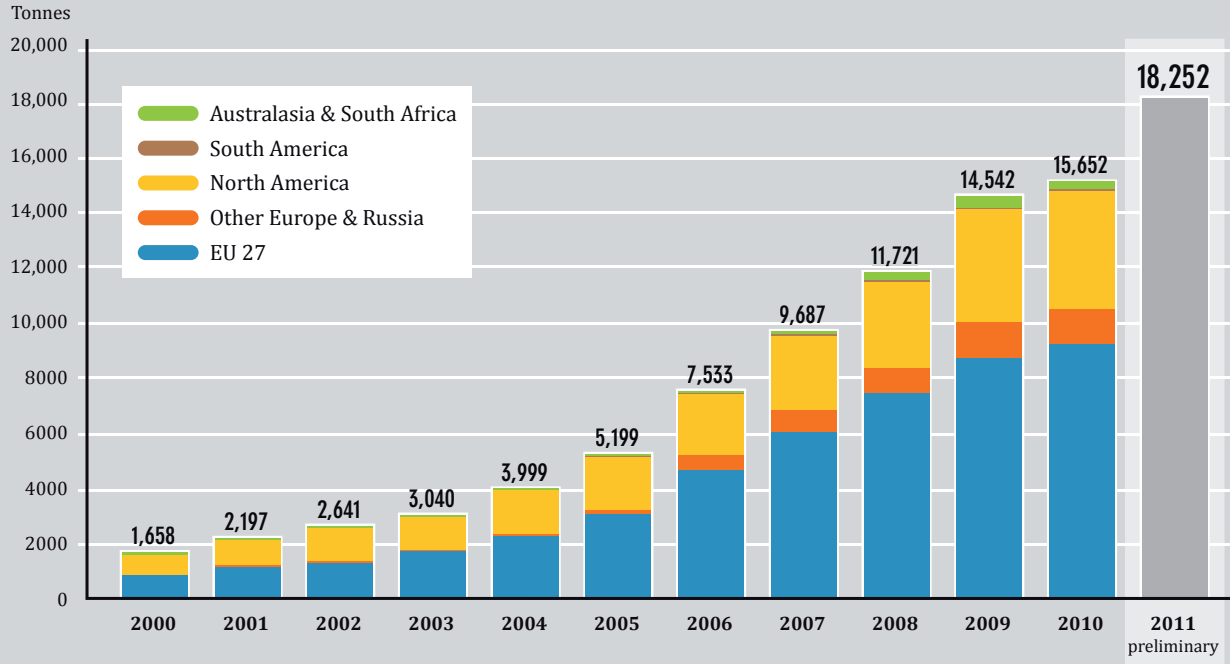


FIGURE 2. AVERAGE ANNUAL GROWTH RATES OF RENEWABLE ENERGY CAPACITY AND BIOFUELS PRODUCTION, 2006–2011

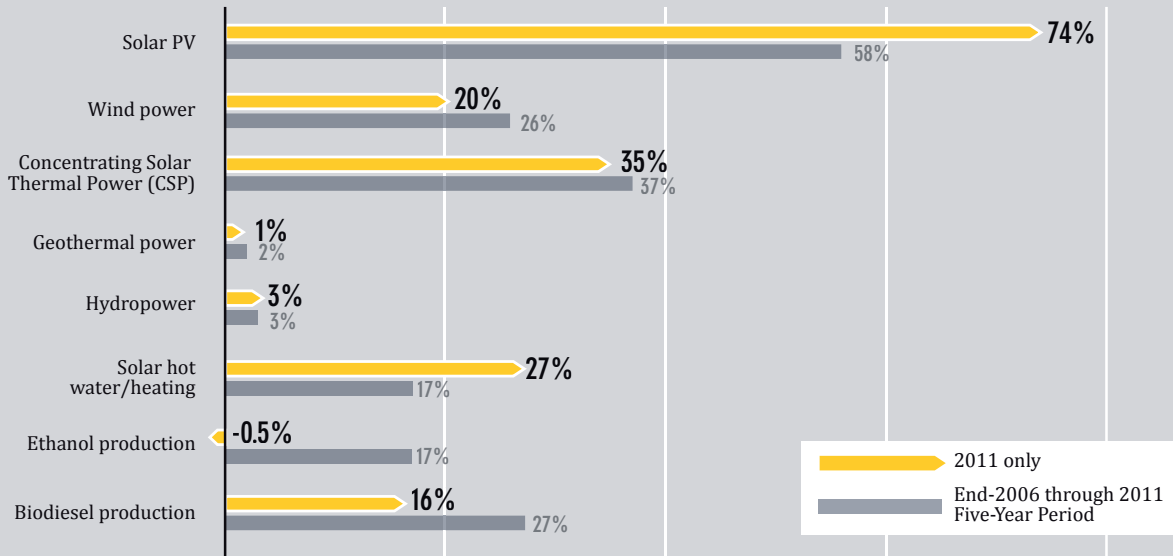
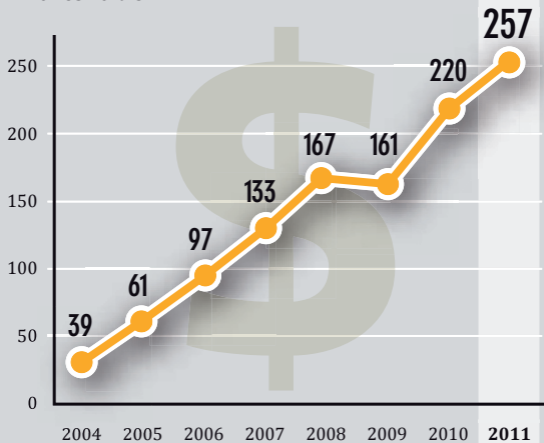
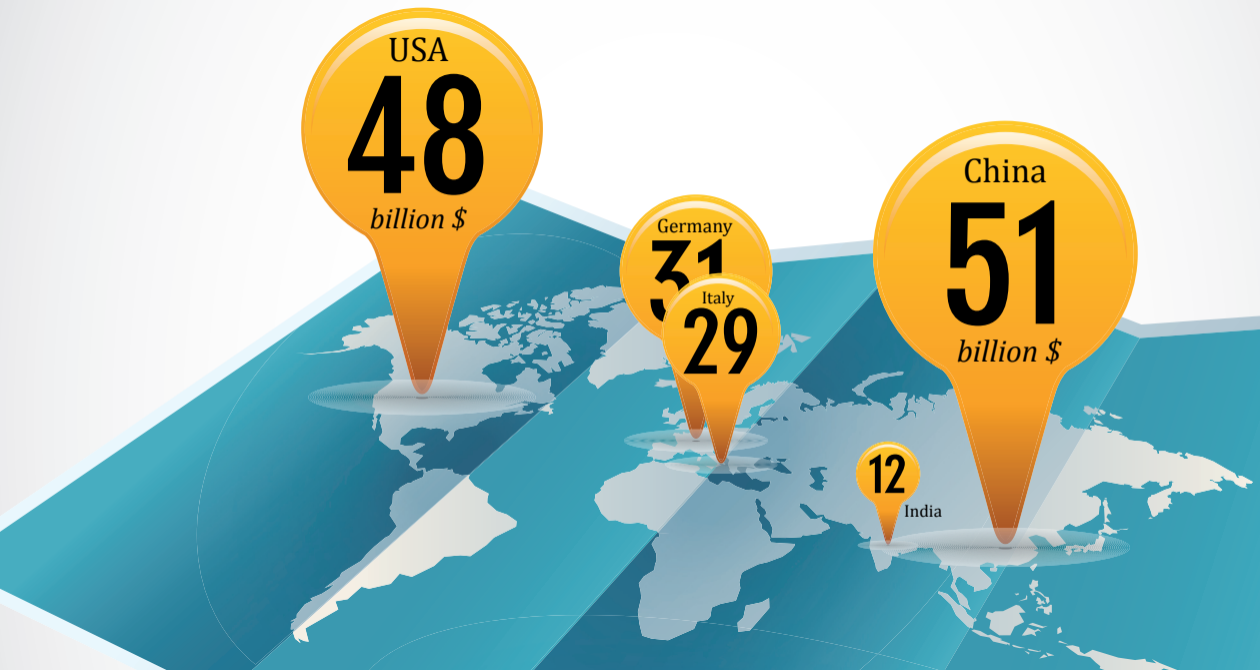


FIGURE 20. GLOBAL NEW INVESTMENTS IN RENEWABLE ENERGY, 2004–2011

Billion US Dollars





USA
48
billion \$

Germany
31

Italy
29

12
India

China
51
billion \$

TABLE 3. RENEWABLE ENERGY SUPPORT POLICIES

- national-level policy
- state/provincial policy

	REGULATORY POLICIES						FISCAL INCENTIVES				PUBLIC FINANCING	
	Feed-in tariff (incl. premium payment)	Electric utility quota obligation/RPS	Net metering	Biofuels obligation/mandate	Heat obligation/mandate	Tradable REC	Capital subsidy, grant, or rebate	Investment or production tax credits	Reductions in sales, energy, CO ₂ , VAT, or other taxes	Energy production payment	Public investment, loans, or grants	Public competitive bidding
HIGH INCOME COUNTRIES												\$\$\$\$
Australia	○			○		●	●				●	
Austria	●			●		●	●				●	
Belgium		○	●	●		●	○	●				●
Canada	○	○	○	●			●	●			●	●
Croatia	●						●				●	
Cyprus	●			●			●					
Czech Republic	●			●		●	●	●			●	
Denmark	●		●	●		●	●	●			●	●
Estonia	●			●			●	●		●		
Finland	●			●		●	●	●	●			
France	●			●		●	●	●			●	●
Germany	●			●	●		●	●			●	
Greece	●			●			●	●			●	
Hungary	●			●			●	●			●	
Ireland	●			●	○	●						●
Israel	●	●			●			●			●	●
Italy	●	●	●	●	●	●	●	●			●	●
Japan	●	●	●			●	●				●	
Luxembourg	●						●					
Malta	●		●				●	●				
Netherlands	●			●		●	●	●	●		●	
New Zealand							●					
Norway				●		●	●	●			●	
Poland		●		●		●	●	●			●	●
Portugal	●	●	●	●	●		●	●			●	●
Singapore			●								●	
Slovakia	●						●	●				
Slovenia	●					●	●	●			●	●
South Korea ¹		●	●	●		●	●	●			●	
Spain ²	●			●	●		●	●	●		●	
Sweden		●		●		●	●	●			●	
Switzerland	●						●	●				
Trinidad and Tobago							●	●				
United Arab Emirates		○			○					○		○
United Kingdom	●	●		●	●	●	●	●	●		●	
United States ³	○	○	○	●	○	○	●	●	○		●	○

Source: See Endnote 18 for this section.



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01 HOW MUCH RENEWABLES?

Future renewable energy shares are in the range of 15–20% in conservative scenarios, 30–45% in moderate scenarios, and 50–95% in high-renewables scenarios. Attaining high shares of electricity is considered easiest, high shares of heating/cooling most difficult, and high shares of transport energy most uncertain.



Historic Projections Fall Short...

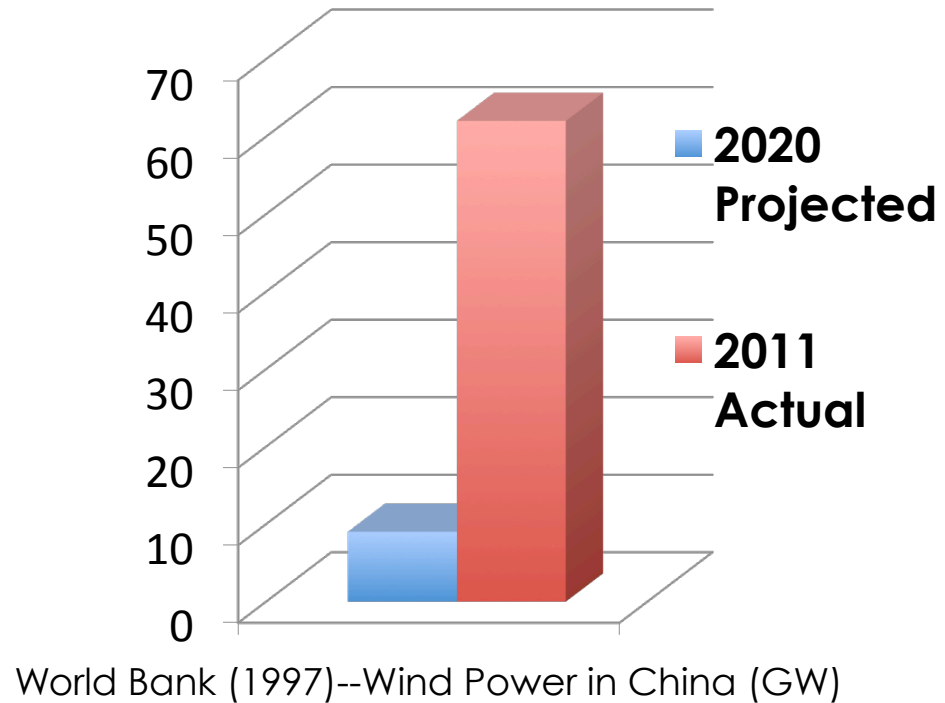
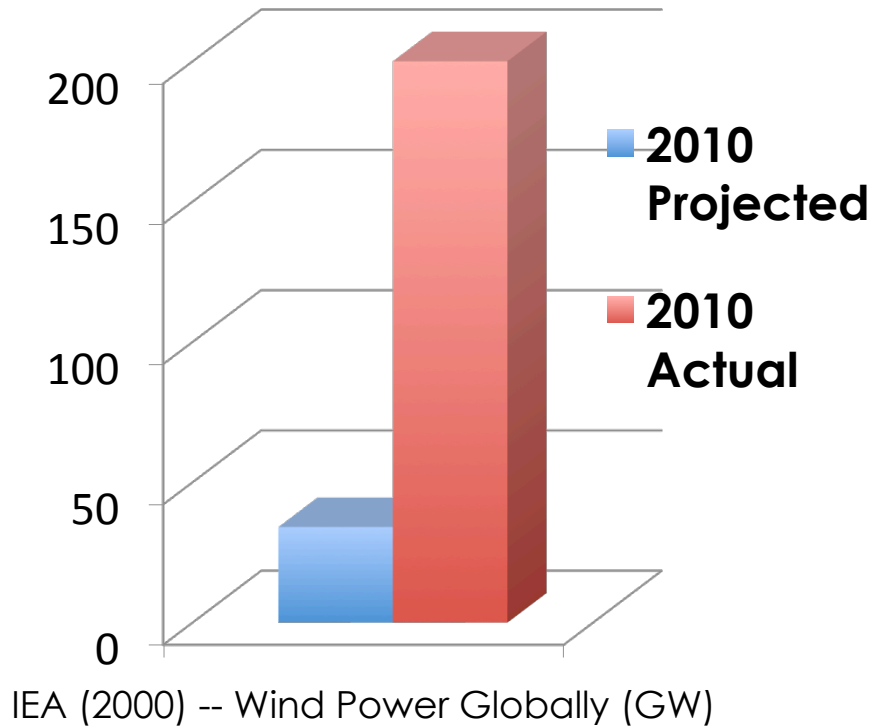
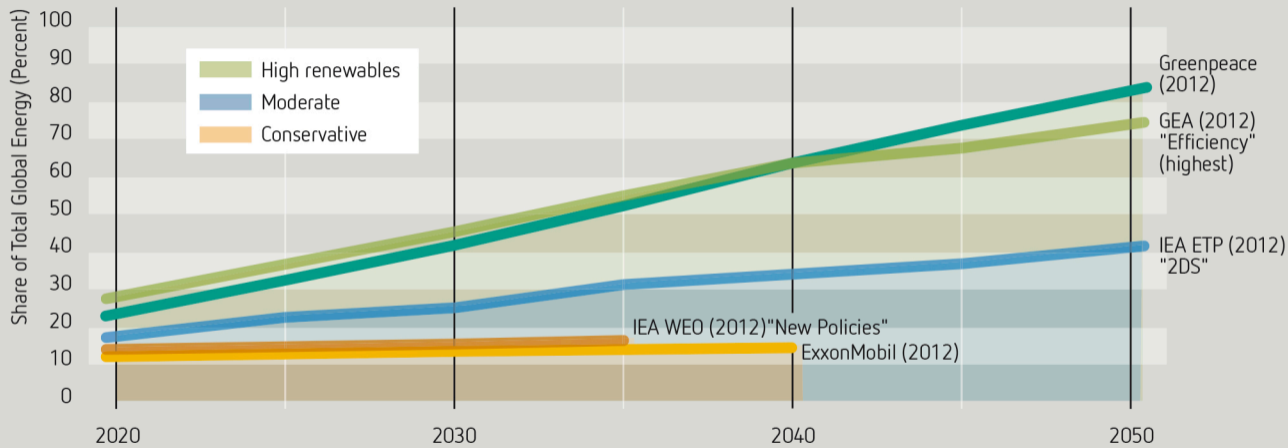


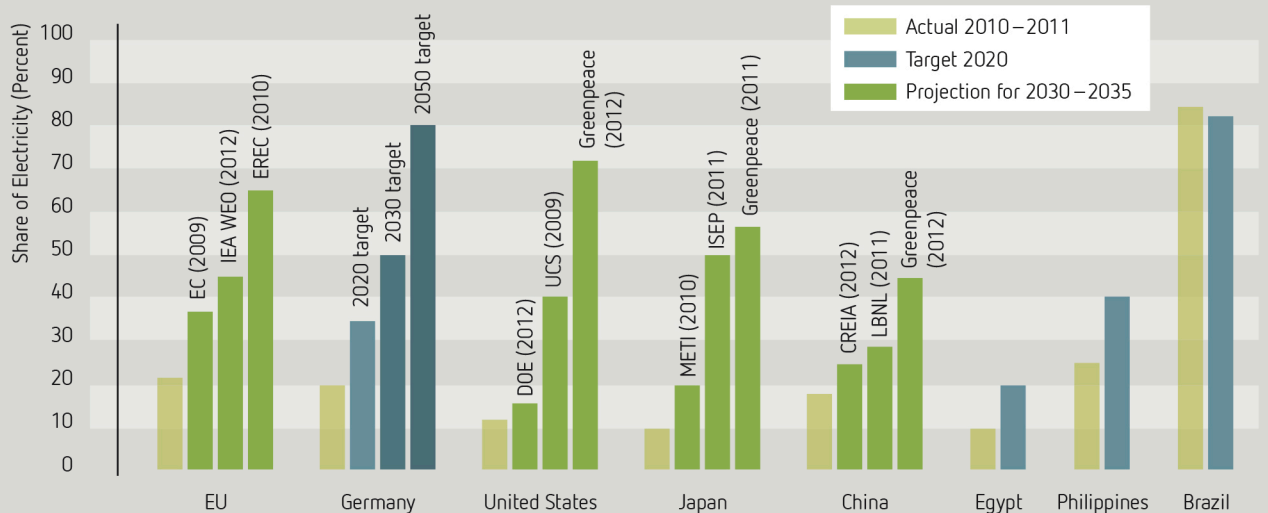
Figure 1: Conservative, Moderate, and High-Renewables Scenarios to 2050



Source: See Annex 2 for full scenario names and citations.

Figure 2: National and EU Electricity Shares from Renewables, 2010–2030

(2010 Actual, 2020 Targets, and 2030–2035 Projections)



Source: See Endnote 25 for this chapter.

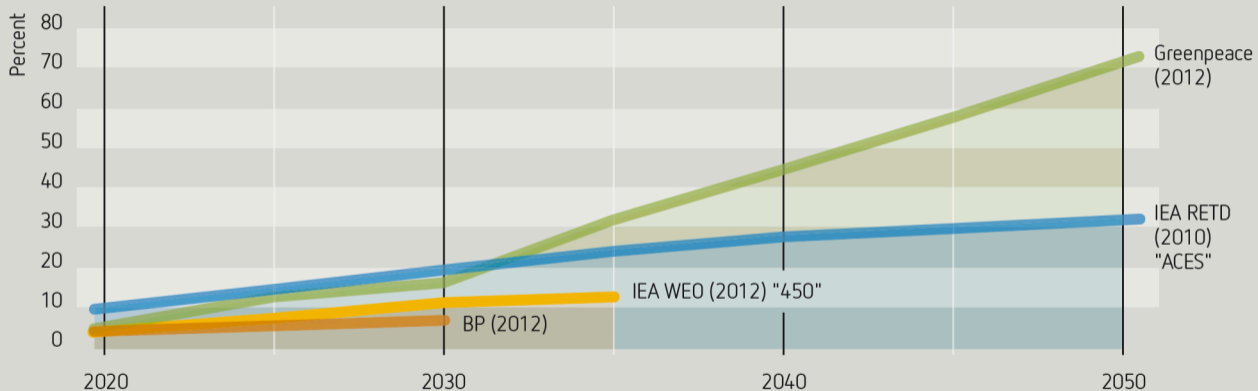
Table 4: Global Renewable Power Capacity by 2030 in Recent Scenarios

	Hydro	Wind	Solar PV	CSP	Biomass	Geothermal	Ocean
	GW						
Actual 2006 Capacity for Comparison	–	74	8	0.4	45	9.5	0.3
Actual 2011 Capacity for Comparison	970	238	70	1.8	72	11	0.5
IEA WEO (2012) "New Policies"	1,580	920	490	40	210	40	10
IEA WEO (2012) "450"	1,740	1,340	720	110	260	50	10
IEA ETP (2012) "2DS"	1,640	1,400	700	140	340	50	20
BNEF GREMO (2011)	—	1,350	1,200		260	30	—
IEA RETD (2010) "ACES"	1,300	2,700	1,000	120	340	—	—
Greenpeace (2012)	1,350	2,900	1,750	700	60	170	180

Table 3: U.S. Renewable Power Capacity by 2030–2035 and 2050 in Recent Scenarios

	Wind	Solar PV	CSP	Biomass	Geothermal	Ocean
	GW					
Actual 2011 Capacity for Comparison	47	4	0.5	14	3	0
By 2030–2035						
DOE EIA <i>Annual Energy Outlook</i> (2012)	70	8	1	6	6	—
IEA <i>World Energy Outlook</i> (2012) “New Policies”	160	70	10	40	8	1
IEA <i>World Energy Outlook</i> (2012) “450”	270	120	60	50	12	1
Greenpeace <i>Energy [R]evolution</i> (2012, U.S. edition)	650	390	140	1	50	15
By 2050						
NREL <i>Electricity Futures Study</i> (2012) “80% ITI”	460	170	60	80	25	—
Lovins/RMI <i>Reinventing Fire</i> (2011) “Renew”	500	480	80	40	15	—

Figure 3: Global Share of Transport Fuel to 2050



Source: See Annex 2 for full scenario names and citations.

Table 1: Sectoral Shares of Renewable Energy in Recent Global Scenarios

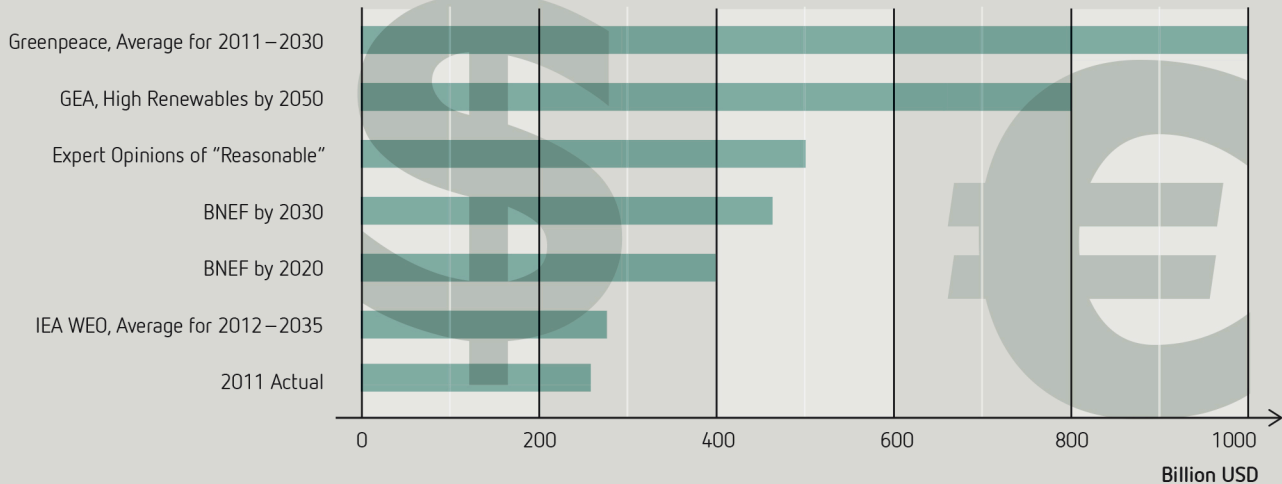
Scenario	By Year	Electricity	Heat	Transport
By 2030–2040				
ExxonMobil <i>Outlook for Energy: A View to 2040</i> (2012)	2040	16%	—	—
BP <i>Energy Outlook 2030</i> (2012)	2030	25%	—	7%
IEA <i>World Energy Outlook</i> (2012) “New Policies”	2035	31%	14%	6%
IEA <i>World Energy Outlook</i> (2012) “450”	2035	48%	19%	14%
Greenpeace (2012) <i>Energy [R]evolution</i>	2030	61%	51%	17%
By 2050				
IEA <i>Energy Technology Perspectives</i> (2012) “2DS”	2050	57%	—	39%
GEA <i>Global Energy Assessment</i> (2012)	2050	62%	—	30%
IEA <i>Energy Technology Perspectives</i> (2012) “2DS High Renewables”	2050	71%	—	—
Greenpeace (2012) <i>Energy [R]evolution</i>	2050	94%	91%	72%
WWF (2011) <i>Ecofys Energy Scenario</i>	2050	100%	85%	100%



03 INVESTMENT FUTURES: FLOWS, INVESTORS, AND BUSINESS MODELS

Annual investment in renewable energy reached US\$ 260–290 billion in 2011 and is projected to increase annually through 2020 and well beyond. Innovative new forms of investment and finance are projected from new sources, such as pension funds along with new business models for energy services for households and businesses and for mobility services.

Figure 5: Annual Investment Flows to Renewable Energy in Scenarios



Source: See Endnote 6 for this chapter. See Annex 2 for full scenario names and citations.

Notes: All scenarios are 2012 except BNEF is 2011; figures are for renewable energy capacity additions, although accounting methods and counted investments vary across sources, see endnote.

New Sources of Finance

- Pension funds
- Insurance funds
- Aggregated securities funds (like mortgage-back securities)
- Community funds
- Oil companies
- Equipment suppliers / vendors
- Sovereign wealth funds and national governments

Future Business Models

- **Third-party energy services** – leasing, bundling with energy efficiency, per-KW pricing
- **Mobility services** – kilometer-based pricing, joint ownership, integrated with buildings and power grid balancing
- **Utility business models** – on-the-bill financing, smart metering, new pricing models, energy storage sales into “grid balancing markets”
- **Community and cooperative ownership** – joint ownership, new social models, multi-family and multi-building heat supply (micro-district heating)
- **Industry and retailer involvement** – power contracts with reliability specifications, green power purchases, “WindMade” consumer label

02 INTEGRATED FUTURES: CHALLENGES AND POSSIBILITIES

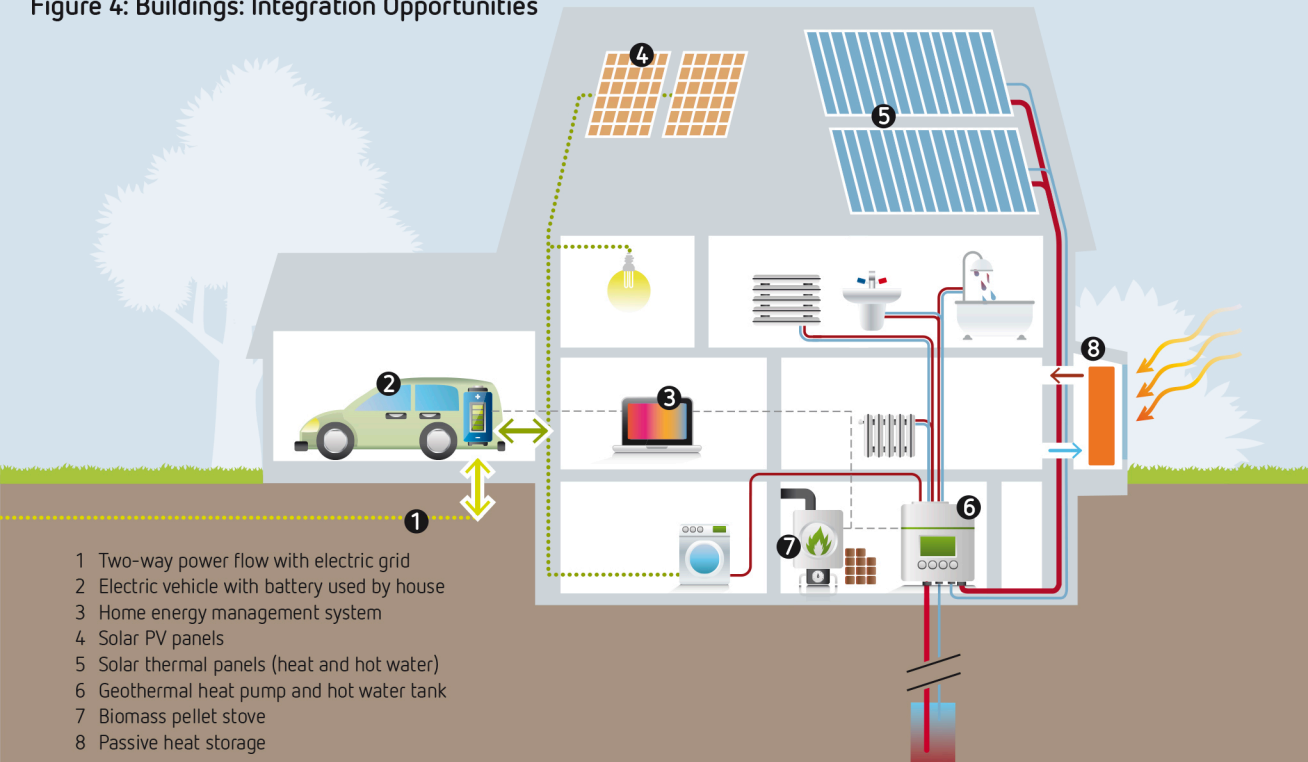
Many policymakers, utilities, builders, automakers, and industries recognize that stronger integration of renewable energy is the next “frontier.” This means new and flexible ways to manage variability on power grids, to think about building design and construction, to fuel industry, and to provide mobility with renewable energy.

Power Grids: Technical, Planning, Market, and Regulatory Options to Balance Variable Renewables

- New power market designs that support greater flexibility
- Expanded diversity of resources within geographic grid balancing areas
- Co-ordination/merging of balancing areas under balancing authorities
- Faster balancing response times through market/operational mechanisms
- New types of system optimization
- Power dispatch models that incorporate day-ahead weather forecasts
- Controlled curtailment of renewables
- Demand response
- Gas turbines (peaking and non-peaking)
- Strengthened transmission capacity and interconnection
- Energy storage
- Ramping and cycling of conventional plants



Figure 4: Buildings: Integration Opportunities



- 1 Two-way power flow with electric grid
- 2 Electric vehicle with battery used by house
- 3 Home energy management system
- 4 Solar PV panels
- 5 Solar thermal panels (heat and hot water)
- 6 Geothermal heat pump and hot water tank
- 7 Biomass pellet stove
- 8 Passive heat storage

Roles of Different Types of Companies

- Electric Utilities
- Oil companies
- Automakers
- Information-technology (IT) companies
- Technology integration companies (i.e., Siemens)
- Buildings materials manufacturers (i.e., architectural glass)



04

FUTURES AT THE LOCAL/ CITY LEVEL: INITIATIVE, PLANNING, AND POLICY

Innovative approaches and visions for renewable energy futures are found at the local/city level in a rapidly growing number of jurisdictions around the world. Elements include public infrastructure, community investment, municipal utilities, planning approaches for low-energy buildings and renewable heating/cooling, public transport fleets, electric vehicle infrastructure, and “smart cities” concepts.



Futures at the Local/City Level



Innovative Approaches and Visions at the Local/City Level

- Public infrastructure
- Community investment
- Municipal utilities
- Planning approaches for low-energy buildings
- Renewable (and district) heating and cooling
- Public transport fleets
- Electric vehicle infrastructure
- Smart cities

05 FUTURES AT THE NATIONAL AND EU LEVELS: MARKET GROWTH AND POLICY SUPPORT

National renewable energy markets are projected to grow strongly in the coming decade and beyond, as shown by current policies and targets, and by scenario and expert projections. Snapshots of Europe, the United States, Japan, China, and India show many emerging and possible developments. Projected markets in a much greater number of developing countries will create a diverse geographic base.

Developing Countries – Unique Opportunities for Renewables

- New electric power infrastructure
- Diesel generator replacement
- New settlements
- New power-market rules
- Regional cooperation frameworks
- Local manufacturing
- Rural (off-grid) energy services

Projected markets in a much greater number of developing countries on a bigger scale will create a diverse geographic base for renewables

06 EVOLUTION OF TECHNOLOGIES, COSTS, AND GLOBAL MARKET GROWTH

Global markets for renewable energy have boomed over the past decade. This expansion has brought considerable innovation and cost reduction and will continue to do so. Projections for future market growth are equally dramatic, driven in part by further technology improvements and continuation of cost trends. Markets have already reached the point where technology is no longer the “bottleneck,” many say.















“Great Debates”

1. Is Renewable Energy More Expensive Than Conventional Energy?
2. What Is the Future Role of Policy?
3. Is Energy Storage Necessary for High Levels of Renewables?
4. Is the Concept of “Base Load” Meaningful for Future Energy Systems?
5. Centralized or Decentralized Power Grids?
6. Will Utilities Lead, Follow, Push Back, or Perish?
7. What Roles Will Oil and Gas Companies Play?
8. How Will Feed-in Tariffs Evolve?
9. What Is the Future of Coal Power in India Relative to Renewables?
10. What Are the Pros and Cons of Offshore Wind Power?
11. How Sustainable Can Biofuels Become in the Long-Term?

Some Research Topics on Renewable Energy Futures

1. What **input and model factors** are most significant in differences among scenario outcomes?
2. How can **distributed generation, micro-grids, storage, and utility grid balancing** be better incorporated into future scenarios?
3. **Integration** into power grids, transport, and buildings: challenges and issues with regulation, policy, markets, and business models
4. **“Policy Evolution”**: What is the next generation of policies that go beyond price-focus or cost-focus – for example focus on risk-return and finance, building codes, markets for renewables-integrated building materials, electric vehicle charging infrastructure, electric power markets for balancing services, utility demand-response, etc.
5. **Local/city-level policies and investment**: community funds, city-government finance and/or ownership, transport infrastructure and fuels, low-energy buildings, district heating and cooling infrastructure, etc.