Renewable Share of Primary Energy in 2009

- Fossil: 78%
- Renewables: 17%
- Nuclear: 5%

- Biofuels: 0.7%
- Heat (biomass, geothermal, solar): 1.1%
- Electricity (biomass/geothermal/wind/solar/ocean): 1.5%
- Electricity: Hydro: 6.1%
- Traditional Biomass: 7.4%
Irradiation outside atmosphere: $5450 \times 10^3$ EJ/yr

Human energy use: $500$ EJ/yr (average $2.5$ kW/person; range $0.1$-to-$10$ kW/person)

Available for conversion: $3870 \times 10^3$ EJ/yr (20 MW/person)

- Reflection in atmosphere
- Absorption in atmosphere
- Reflection at surfaces
- Absorption in lithosphere + biosphere (soil, rock, plants, etc.)
- Absorption in hydrosphere (water)
Historical and Projected Contribution to Global Electricity Generation
Electricity Generation by Source

- **2007**: 15 PWh
- **Baseline 2030**: 28 PWh
- **Baseline 2050**: 50 PWh
- **BLUE Map 2050**: 45 PWh

Legend:
- Other
- Solar
- Wind
- Biomass and waste + CCS
- Biomass and waste
- Hydro
- Nuclear
- Natural gas + CCS
- Natural gas
- Oil
- Coal + CCS
- Coal
Global Electricity Generation in the Energy [R]evolution Scenario

![Graph showing global electricity generation from various energy sources (2005-2050). The x-axis represents years (2005-2050), and the y-axis represents TWh/a (terawatt hours per annum). The chart includes categories such as Efficiency, Ocean Energy, Solar Thermal, PV, Geothermal, Wind, Hydro, Biomass, Gas&oil, Coal, and Nuclear. Each bar is divided into segments representing the contribution of each energy source over time.]
Primary Energy Use in the Energy [R]evolution Scenario

- Efficiency
- Ocean energy
- Geothermal
- Solar
- Biomass
- Wind
- Hydro
- Natural gas
- Crude oil
- Coal
- Nuclear
Electricity Generation from Biomass, Select Countries in 2007

The graph shows the trend of electricity generation from biomass in various countries from 1999 to 2009. The countries include USA, Germany, Brazil, Japan, Sweden, UK, Finland, Canada, and Rest of World. The y-axis represents TWh per year, and the x-axis represents the years from 1999 to 2009.
Primary Biomass Sources and Use of Fuelwood and Roundwood

(a) Pie chart showing the distribution of biomass sources with Fuelwood at 67%, Agriculture at 10%, Charcoal at 7%, Wood Industry Residues at 5%, Recovered Wood at 6%, Animal By-products at 3%, Agricultural By-products at 4%, Energy Crops at 3%, and MSW and Landfill Gas at 3%.

(b) Graph showing the increase in Fuelwood usage from 1961 to 2005, with a peak at 4 billion m³ in 2005, and the increase in World Industrial Roundwood for products.
Ethanol Production from Sugar and Starch Crops

The diagram illustrates the ethanol production from sugar and starch crops over the years, with data for the world total, Brazil, and the United States. The x-axis represents the years from 1990 to 2010, while the y-axis measures ethanol production in billion liters per year (left) and energy in EJ per year (lower heating value) on the right. The graph shows a significant increase in ethanol production from 1990 to 2010, with Brazil and the United States leading in production.
Main Conversions Routes for Biomass to Secondary Energy Carriers

Thermochemical conversion:
- Combustion
- Gasification
- Pyrolysis
- Liquefaction
- HTU

Biochemical conversion:
- Digestion
- Fermentation
- Extraction (oilseeds)
- Biogas
- Gas engine
- Distillation
- Esterification

Processes:
- Steam
- Gas
- Oil
- Charcoal
- Methanol
- Hydrocarbons
- Synthesis
- Fuel cell
- Upgrading
- Diesel
- Bio-diesel

Energy Carriers:
- Heat
- Electricity
- Fuels
### Stages of Development of Bioenergy

<table>
<thead>
<tr>
<th>Type of Plant</th>
<th>Type of Product</th>
<th>Stage of Development of Process for Product(s) or System(s)</th>
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<tbody>
<tr>
<td></td>
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<td>Basic and Applied R&amp;D</td>
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<tr>
<td>Densified Biomass</td>
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<td>Torrefaction</td>
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<td>Coal</td>
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<td>Protolysis (Biochar)</td>
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<td>Combustion Coupled with</td>
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<tr>
<td>Power or CHP</td>
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<td>Stirling Engine</td>
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<tr>
<td></td>
<td></td>
<td>Indirect</td>
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<td>Gasification (G) or Integrated Gasification (IG)</td>
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<td>Wet Waste</td>
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<td>Anaerobic Digestion to Biogas</td>
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<td>Gasification</td>
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<td>Microbial Fuel Cell</td>
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<tr>
<td>Sugar or Starch Crops</td>
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<td>Sugar Fermentation</td>
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<td></td>
<td></td>
<td>Microbial Processing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conesial/Diesel/Jet Fuel</td>
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<td></td>
<td></td>
<td>Biodiesel/Biotanol</td>
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<tr>
<td>Fuel</td>
<td></td>
<td>Extraction and Esterification</td>
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<tr>
<td>Vegetable or Waste</td>
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<td>Extraction and Hydrogenation</td>
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<tr>
<td></td>
<td></td>
<td>Extraction and Refining</td>
</tr>
</tbody>
</table>

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Main Feedstocks and Conversion Steps for First-Generation Biofuels

**SUGAR CROPS**
- Sugar cane
- Sugar beet
- Sweet Sorghum

**STARCH CROPS**
- Maize
- Wheat
- Barley
- Rye
- Potatoes
- Cassava

**OIL CROPS**
- Rapeseed
- Soy bean
- Oil palm
- Sunflower
- Peanut
- Jatropha

**ETHANOL**
- Fermentation and Distillation
- Saccarification, Fermentation and Distillation

**Biodiesel**
- Extraction and Esterification
Production Paths to Liquid Fuels from Biomass and Fossil Fuels
Third-Generation Biofuels

Solar Energy

Photocatalytic Nanodevices (>10%) → Solar Fuel

Photosynthetic Microorganisms (>5%) → Primary Biofuels

Biomass (<1%) → Secondary Biofuel
Projected Production Costs for Biomass to Power and CHP

Production Cost
(US ¢ per kWh)

- CHP
- Power

- Combustion + Turbine (10-100 MW)
- Combustion + Engine/turbine (1-5 MW)
- Combustion + Turbine (10-50 MW)
- Combustion + Stirling engine (<0.1 MW)
- Combustion + Organic Rankine cycle (0.2-1.5 MW)
- Direct co-firing in coal plant (5-100 MW)
- Parallel co-firing in coal plant (<10 MW)
- Gasification + Gas engine (0.1-1 MW)
- BIGCC (5-10 MW demo)
- BIGCC (30-300 MW future)
- Anaerobic digestion + Engine (0.3-10 MW)
Selling Price for Ethanol in Brazil versus Cumulative Production

Learning rate:
~10% reduction per doubling of cumulative production
Range of Production Cost Estimates for Second-generation Biofuels

Wholesale petroleum product price (USD/l)

Brent crude (USD/bbl)

Gasoline

Diesel

Ethanol from lignocellulose

BTL diesel

Present cost ranges

Cost estimates by 2030
Lifecycle Fossil Energy Use Estimates in Production of Several Biofuels

- **BIODIESEL**
  - Soy
  - Sunflower
  - Rapeseed

- **ETHANOL**
  - Sugarcane, Brazil
  - Wheat, straw CHP
  - Wheat, NG GTCHP
  - Wheat, lignite CHP
  - Sugarbeets
  - Maize, US range

- **PETROLEUM FUELS**
  - Crude oil to diesel
  - Crude oil to gasoline

GJ fossil energy input per GJ final biofuel (LHV)
Estimated Life-cycle GHG Emissions for First-generation Biofuels

<table>
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<tr>
<th>Biofuel Type</th>
<th>GHG Emissions (Low)</th>
<th>GHG Emissions (High)</th>
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<tr>
<td>Soy</td>
<td>20%</td>
<td>40%</td>
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<tr>
<td>Sunflower</td>
<td>30%</td>
<td>60%</td>
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<tr>
<td>Rapeseed</td>
<td>40%</td>
<td>80%</td>
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<tr>
<td>Ethanol</td>
<td>50%</td>
<td>100%</td>
</tr>
<tr>
<td>Sugarcane, Brazil</td>
<td>60%</td>
<td>120%</td>
</tr>
<tr>
<td>Wheat, straw CHP</td>
<td>70%</td>
<td>140%</td>
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<td>Wheat, NG GTCHP</td>
<td>80%</td>
<td>160%</td>
</tr>
<tr>
<td>Wheat, lignite CHP</td>
<td>90%</td>
<td>180%</td>
</tr>
<tr>
<td>Sugarbeets</td>
<td>100%</td>
<td>200%</td>
</tr>
<tr>
<td>Maize, US range</td>
<td>110%</td>
<td>220%</td>
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<tr>
<td>Crude oil to diesel</td>
<td>120%</td>
<td>240%</td>
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<tr>
<td>Crude oil to gasoline</td>
<td>130%</td>
<td>260%</td>
</tr>
</tbody>
</table>
Estimated Life-cycle GHG Emissions for Second-generation Biofuels
Global Installed Hydropower Capacity in 2009

- Asia: Installed Capacity: 350 GW, Under Construction: 50 GW
- Europe: Installed Capacity: 300 GW, Under Construction: 30 GW
- North & Central America: Installed Capacity: 200 GW
- South America: Installed Capacity: 150 GW, Under Construction: 10 GW
- Africa: Installed Capacity: 50 GW

GW
Hydropower Tariff Versus Average Electricity Generation Costs

![Graph showing the comparison between hydropower tariffs and average electricity generation costs over years.](image-url)
IHA Sustainability Assessment Protocol Assessment Tools

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<th>ES - Early Stage</th>
<th>P - Preparation</th>
<th>I - Implementation</th>
<th>O - Operation</th>
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<td>ES-1 Demonstrated Need &amp; Consultation</td>
<td>P-1 Communications &amp; Consultation</td>
<td>I-1 Communications &amp; Consultation</td>
<td>O-1 Communications &amp; Consultation</td>
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<td>ES-2 Options Assessment</td>
<td>P-2 Governance</td>
<td>I-2 Governance</td>
<td>O-2 Governance</td>
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<td>P-3 Demonstrated Need &amp; Strategic Fit</td>
<td>I-3 Environmental &amp; Social Impact Assessment &amp; Mgmt</td>
<td>O-3 Environmental &amp; Social Issues Mgmt</td>
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<td>ES-4 Political Risks</td>
<td>P-4 Siting &amp; Design</td>
<td>I-4 Integrated Project Management</td>
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<td>ES-5 Institutional Capacity</td>
<td>P-5 Environmental &amp; Social Impact Assessment &amp; Mgmt</td>
<td>I-5 Environmental &amp; Social Issues Mgmt</td>
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<td>ES-7 Social Issues &amp; Risks</td>
<td>P-7 Hydrological Resource</td>
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<td>ES-8 Environmental Issues &amp; Risks</td>
<td>P-8 Infrastructure Safety</td>
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<td>P-11 Economic Viability</td>
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<td>P-13 Project Affected Communities &amp; Livelihoods</td>
<td>I-13 Project Affected Communities &amp; Livelihoods</td>
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<td>P-17 Cultural Heritage</td>
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<td>P-19 Biodiversity &amp; Invasive Species</td>
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<td>P-20 Erosion &amp; Sedimentation</td>
<td>I-20 Erosion &amp; Sedimentation</td>
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<td>P-21 Water Quality</td>
<td>I-21 Water Quality</td>
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<td>P-22 Reservoir Planning</td>
<td>I-22 Reservoir Preparation &amp; Filling</td>
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<td>P-23 Downstream Flow Regimes</td>
<td>I-23 Downstream Flow Regimes</td>
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</table>
Installed Geothermal Electricity Capacity

Year

Installed Capacity (MW)
Growth of the Globally Installed Capacity of Geothermal Power Production
Installed Geothermal Electric Capacity in 2009

- USA: 3,093 MW
- Mexico: 958 MW
- Guatemala: 52 MW
- Costa Rica: 166 MW
- El Salvador: 204 MW
- Nicaragua: 88 MW
- Portugal: 29 MW
- Iceland: 575 MW
- Germany: 6.6 MW
- France: 16 MW
- Italy: 843 MW
- Turkey: 82 MW
- Austria: 1.4 MW
- China: 24 MW
- Thailand: 0.3 MW
- Russia: 82 MW
- Japan: 536 MW
- Philippines: 904 MW
- Papua New Guinea: 56 MW
- New Zealand: 628 MW
- Australia: 1.1 MW
- Ethiopia: 7.3 MW
- Kenya: 167 MW
- Indonesia: 1,197 MW
- Portugal: 29 MW
- Iceland: 575 MW
- Germany: 6.6 MW
- France: 16 MW
- Italy: 843 MW
- Turkey: 82 MW
- Austria: 1.4 MW
- China: 24 MW
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- Russia: 82 MW
- Japan: 536 MW
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- New Zealand: 628 MW
- Australia: 1.1 MW
- Ethiopia: 7.3 MW
- Kenya: 167 MW
- Indonesia: 1,197 MW

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Worldwide Growth of Installed Capacity of Geothermal Direct Use

![Graph showing the growth of installed capacity of geothermal direct use over years from 1975 to 2010. The x-axis represents the year, ranging from 1975 to 2010, and the y-axis represents the MWt installed capacity. The graph shows a steady increase in capacity over time.]
Typical Direct Use Geothermal Heating System Configuration

- **Production Wellhead Equipment**
  - Geothermal
  - 180°F (80°C)

- **Injection Wellhead Equipment**
  - 140°F (60°C)

- **Plate Heat Exchanger**
  - 170°F (75°C)

- **Energy User System**
  - 130°F (55°C)

- **Peaking/Backup Unit**
Single-stage Flash Steam Plant Using a Water-dominated Geothermal Resource with a Separator to Produce Steam

Diagram showing the flow of steam, water, air, and condensate through the turbine, generator, condenser, cooling tower, separator, production well, and injection well.
Organic Rankine Cycle Plant using a Low Temperature Geothermal Resource

Diagram of the Organic Rankine Cycle Plant:
- **Turbine**
- **Generator**
- **Condenser**
- **Cooling Tower**
- **Heat Exchanger**
- **Cooled Water**
- **Pump**
- **Production Well**
- **Geothermal Reservoir**
- **Injection Well**

Flow Pathways:
- Organic Vapor
- Air & Water Vapor
- Air
- Water
- Cooled Water

Connections:
- Production Well to Geothermal Reservoir
- Geothermal Reservoir to Injection Well
- Turbine to Generator
- Condenser to Cooling Tower
- Heat Exchanger

The diagram illustrates the flow of organic vapor through the turbine, generator, condenser, and cooling tower, with air and water vapor, air, and water involved in the cooling process.
Cascading the use of a Geothermal Resource for Multiple Applications

Cascading to maximize use of the geothermal energy
Calculated Ground Temperature Change

Production period

Recuperation period

Temperature Change [K]

Time [years]

\( \Delta T \)
Global Wind Resource

Wind speed over water

Wind speed over land

5 10 15 20 m/s

3 6 9 m/s
Wind Energy Generation

![Wind Energy Generation Chart]

- GWEC Baseline
- GWEC Moderate
- GWEC Advanced


Wind Energy Generation, TWhr

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Cumulative Wind Installed Capacity in Europe

- **Europe**
  - 2003: 40,301 MW
  - 2006: 74,306 MW
  - 2009: 160,084 MW

- **USA**
  - 2003: 10,000 MW
  - 2006: 20,000 MW
  - 2009: 30,000 MW

- **Asia**
  - 2003: 5,000 MW
  - 2006: 10,000 MW
  - 2009: 20,000 MW

- **Rest of World**
  - 2003: 1,000 MW
  - 2006: 2,000 MW
  - 2009: 3,000 MW
Top 10 Wind Turbine Suppliers

- GOLDWIND (PRC) 7.2%
- ENERCON (GE) 8.5%
- SINOVEL (PRC) 9.2%
- DONGFANG (PRC) 6.5%
- SUZLON (IND) 6.4%
- SIEMENS (DK) 5.9%
- GE WIND (US) 12.4%
- VESTAS (DK) 12.5%
- GAMESA (ES) 6.7%
- REPOWER (GE) 3.4%
- Others 18.5%
Relative Contribution of Generation Types to Capacity Additions in the US and EU
Development and Size Growth of Wind Turbines Since 1980
Installed Wind Project Costs over time in Denmark and the United States

Wind power plant costs in Denmark

Wind power plant costs in the USA

- Individual Project Investment Cost
- Capacity-Weighted Average Project Investment Cost
- Polynomial Trend Line

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Capital Costs for Installed and Announced Offshore Wind Projects

- **Investment Cost for Operating European Project**
- **Announced Investment Cost for Proposed U.S. Project**
- **Announced Investment Cost for Proposed European Project**
- **Capacity-Weighted Average Project Investment Cost**

Investment Cost (2005$/kW) vs. Capacity

- Axis labels: Year (1990 to 2015)
- Data points indicate varying investment costs over time.
Water Bird Flight Trajectories around Wind Farms
Cumulative Installed PV Capacity, 1995-2009
Annual Solar Cell Production by Region

The bar chart shows the annual production of solar cells by region from 2000 to 2009. The regions depicted are:
- Rest of World
- United States
- Taiwan
- PR China
- Europe
- Japan

The chart indicates a significant increase in production over the years, with Japan and PR China leading in production.
Schematic Cross-Section of a Solar Cell
Trends in Conversion Efficiencies for Various Solar Cell Technologies
Possible Development of Commercial PV Module Efficiencies

I - Crystalline silicon technologies: single crystalline, multi-crystalline, ribbon

II - Thin-film technologies: cadmium-telluride, copper-indium/gallium-diselenide/disulphide and related II-VI compounds, thin-film silicon

III - Emerging technologies and novel concepts

IV - Concentrating photovoltaics

Quantum wells, up-down converters, intermediate band gaps, plasmonics, thermo-photovoltaics, etc
PV Module Experience Curve

Solar Price Experience Curve

- cSi
- Thin Film
- PEF 20%
Schematic Representation of Grid Parity Points

[Diagram showing the cost of PV generation compared to utility peak and bulk power over time from 1990 to 2040.]

- **900 h/a**: €0.32 kWh
- **1,800 h/a**: €0.16 kWh

Legend:
- Orange: PV Generation cost at lowest price
- Yellow: Utility peak power
- Pink: Utility bulk power

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Payback Time of on-roof PV Systems for an In-plane Irradiation of 1700 kWh/m²/yr

on-roof installation in Southern Europe
1700 kWh/m²·yr irradiation on optimally-inclined modules

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<th>Technology</th>
<th>Year</th>
<th>Efficiency</th>
<th>Peak Power (MWp)</th>
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<td>mono</td>
<td>2008</td>
<td>14.4%</td>
<td>14.1%</td>
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<tr>
<td>multi</td>
<td>2009</td>
<td>11.3%</td>
<td>210-960</td>
</tr>
<tr>
<td>CdTe</td>
<td>2010</td>
<td>10.0%</td>
<td>120</td>
</tr>
<tr>
<td>µm-Si</td>
<td>2012e</td>
<td>11.0%</td>
<td>20</td>
</tr>
<tr>
<td>CIGS</td>
<td>2010</td>
<td>11.0%</td>
<td></td>
</tr>
</tbody>
</table>

glass-EVA-backsheet | glass-EVA-backsheet | glass-EVA-glass | glass-EVA-glass | glass-PVB-glass

Payback Time of on-roof PV Systems for an In-plane Irradiation of 1700 kWh/m²/yr
Possible Production and Consumption of CSP Electricity in 2050

The diagram illustrates the possible production and consumption of CSP (Concentrated Solar Power) electricity in 2050. Each region is represented by bars indicating production (red) and consumption (blue). The regions include North America, South America, Middle East, China, Africa, Eu+Turkey, India, Pacific, Central Asia, and Russia. The consumption values are shown in the range of 0 to 1600 TWh, while production values range from 0 to 600 TWh.
CSP Technology Curve and Evolutionary Changes

CSP Technologies in Development

Scaling Manufacturing
Parabolic Trough
Central Receiver
Linear Fresnel
Dish Engine

Critical Technology Shifts

- Improve mirror designs (e.g., weight, reflectivity, durability)
- Minimize structural materials with enhanced designs and materials (steel, aluminum)
- Water utilization and minimization
- Validate storage solutions and deploy hybrid systems

- Verify system configurations (e.g., cluster, single tower)
- Advance molten salt technology for heat transfer and storage
- Improve heliostat tracking accuracy and cost
- Validate delivered costs with commercially proven system

- Demonstrate consistent temperature and steam pressures
- Deliver commercial system in the field beyond demonstration

- Deploy beyond demonstration scale
- Validate competing dish engine technologies
- Prove engine’s operational capability

Time and R&D

Adoption

Planned
Solar Thermal Power Plants
Two-tank Molten-salt Indirect Storage System
Customer load profile and power production profile of a CSP system with storage and a non-tracking PV system over 24 hours
Capital Cost Breakdown for Parabolic Trough Plant

- Collector Frame: 33%
- Mirrors: 33%
- Receiver Tubes: 34%
- Solar Field: 58%
- Power Block: 23%
- Engineering: 8%
- Construction: 11%

Levelized Cost of Energy (US$/kW):
- CSP (Parabolic Trough): US$0.25 per kW

Total Capital Cost: US$4,500 per kW
Super Grid Envisioned by DESERTEC
Total Capacity of Solar Collectors, 2008, in Top 10 Countries

Installed Capacity [MWth]

- China: 80,329.7 MWth
- United States: 7,500 MWth
- Germany: 6,000 MWth
- Turkey: 4,500 MWth
- Australia: 3,000 MWth
- Japan: 1,500 MWth
- Brazil: 1,000 MWth
- Austria: 1,000 MWth
- Greece: 1,000 MWth
- Israel: 1,000 MWth

Legend: Blue = unglazed, Yellow = glazed, Red = evacuated tube
Annual Installed Capacity of Flat-plate and Evacuated Tube Collectors

Annually Installed Capacity [MW_thermal/year]

- Africa
- United States + Canada
- Middle East
- Asia
- China
- Japan
- Australia + New Zealand
- Central + South America
- Europe

Middle East: Israel, Jordan
Africa: Namibia, South Africa, Tunisia, Zimbabwe
Central & South America: Barbados, Brazil, Chile, Mexico, Uruguay
Asia: India, South Korea, Taiwan, Thailand
Europe: EU 27, Albania, Macedonia, Norway, Overseas Dep. of France, Switzerland, Turkey
Applications of Glazed and Evacuated Tube Collectors in 2008

Middle East: Israel, Jordan
Africa: Namibia, South Africa, Tunisia, Zimbabwe
Central & South America: Barbados, Brazil, Chile, Mexico, Uruguay
Asia: India, South Korea, Taiwan, Thailand
Europe: EU 27, Albania, Macedonia, Norway, Overseas Dep. of France, Switzerland, Turkey
DHW: Domestic Hot Water
Active Solar Thermal Technologies, Collectors, and Working Temperature Ranges

- Concentrating collectors
  - Advanced flat-plate, CPC-collectors
  - Flat-plate, evacuated tube collectors
  - Unglazed collectors

- Working Temperature (°C)
  - pool heating, crop drying
  - water & space heating
  - space cooling
  - industrial process heat
A Passive Thermo Syphon SWH System (left) and an Active Forced Circulation SWH System (right)
Number of Ocean Energy Conversion Schemes and their Maturity

- Commercial Production
- Pre-Commercial
- Full-Scale
- Part-Scale (Sea)
- Part-Scale (Tank)
- Concept Design

Number of systems:
- Salinity Gradient
- Tidal barrage
- Thermal Gradient
- Tidal Stream
- Ocean Wave

Technology
Ocean Energy Technologies
Three Technologies to Convert Ocean Current Energy
Schematic Representation of Mechanisms and Devices to Use Wave Energy
A Closed Cycle OTEC Power Plant
Electricity Storage Costs for Different Storage Options

- **Long-term storage**
  - Hydrogen
  - CAES
  - Pumped hydro

- **Load leveling**
  - Hydrogen
  - CAES
  - Pumped hydro

Costs in $ct/kWh
Integration of Renewables and Electric Vehicles into a Supply System

Solar - CSP

Wind

Photovoltaic

HVDC

110 / 220 / 380 kV

10 / 20 kV

400 V

Import / Export

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Concept of a HVDC-based Transcontinental “Super-grid”
The Renewable Combi-Plant

Combined Power Plant

Solar

Wind

Central control unit

Biogas

Reservoirs

Power Demand

forecasts

schedule

District heat deliveries 1992-2003

- World
- Russia
- World excl Russia
- Europe excl Russia
- EU25+ACC4+EFTA3
- EU25
- EU15
- NMS10
Renewable Heating and Cooling System in the Renewable Energy House, Brussels, Belgium

<table>
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<tr>
<th>Energy Source</th>
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<th>Storage</th>
<th>Conversion</th>
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<td>4000 l heat storage tank</td>
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<td>heat exchanger in ventilation system</td>
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<td>solar radiation</td>
<td>solar thermal collector</td>
<td>1000 l heat storage tank</td>
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<td>radiators</td>
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<td>(back-up in winter)</td>
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<td>geothermal heat</td>
<td>4 geothermal loops &amp; heat pump</td>
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<td>solar radiation</td>
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**winter heating circuit**

**summer cooling circuit**
Financial New Investments in New Renewable Energy

![Financial New investments (US$ billions 2005)](image)

- **Marine**
- **Geothermal**
- **Small Hydro**
- **Biomass & waste**
- **Biofuels**
- **Solar**
- **Wind**
Investments in Larger-scale Hydropower, 2004-2010
New Financial Investments in Renewable Energy, By Region, 2004-2010

North America

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<th>Year</th>
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South America

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Middle East & Africa

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Asia & Oceania

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Global Transactions in Renewable Energy in 2010

Investments, US$2005, Billions

- Venture capital: 2
- Corporate R&D: 3
- Government R&D: 5
- Private equity: 3
- Public markets new equity: 13
- Total company investment: 25
- Reinvestment: -5
- Asset finance: 52
- Small distributed capacity: 182
- Total investment: 50
- Mergers & acquisitions: 231
- Total transactions:
Overview of Innovation System

Government

Policy & Programme Interventions

Product/Technology Push

Basic R&D

Applied R&D

Demonstration

Pre Commercial

Niche Market & Supported Commercial

Fully Commercial

Cost per unit

Market engagement programmes

Technology “Valley of Death”

Strategic deployment policies

Barrier removal

Market expansion

Idea

Investments

Business and finance community

Market Pull

Consumers

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