THE TRANSFORMATION OF ENERGY SYSTEMS TOWARDS SUSTAINABILITY – EXPERIENCE GAINED IN GERMANY

Joachim Luther

Fraunhofer Institute for Solar Energy Systems (ISE), Germany
Solar Energy Research Institute of Singapore (SERIS), Singapore

ARC Photovoltaic Centre of Excellence, Seminar, Sydney, November 22, 2012
Benefits of an advanced energy system based on the sustainable use of renewable energy sources and energy efficiency, A

- Protection of the natural life support system
- Reduction of energy poverty in developing countries
- Promotion of peace, by reducing the dependence on regionally concentrated energy resource
Benefits of an advanced energy system based on the sustainable use of renewable energy sources and energy efficiency, B

- Increasing the security of energy supply
- Reducing uncertainties in cost of energy supply
- Promotion of future-compliant industries and jobs
Transformation of the energy system, annual cost of a complete energy supply system
Renewable energies in Germany
Electric energy from renewable sources, Germany

Annual electricity demand 604 TWh, Germany 2010
# Electricity from renewables first half-year 2012, Germany

<table>
<thead>
<tr>
<th>Source</th>
<th>Percentage</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>25.1%</td>
<td>67.9 TWh</td>
</tr>
<tr>
<td>PV</td>
<td>5.3%</td>
<td>14.4 TWh</td>
</tr>
<tr>
<td>Bio</td>
<td>6.6%</td>
<td>17.8 TWh</td>
</tr>
<tr>
<td>Wind</td>
<td>9.2%</td>
<td>24.9 TWh</td>
</tr>
<tr>
<td>Hydro</td>
<td>4.0%</td>
<td>10.8 TWh</td>
</tr>
</tbody>
</table>

Annual electricity demand 604 TWh, Germany 2010
External end energy demand of residential buildings, building codes and innovative buildings
## Energy policy - European and German targets

<table>
<thead>
<tr>
<th></th>
<th>base year</th>
<th>2020</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EU</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction of greenhouse gas emissions</td>
<td>1990</td>
<td>20%</td>
<td>min. 80%</td>
</tr>
<tr>
<td>Increase in energy efficiency</td>
<td>1990</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>Fraction of renewables</td>
<td>2009: 11,6%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td><strong>Germany</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction of greenhouse gas emissions</td>
<td>1990</td>
<td>40%</td>
<td>80-95%</td>
</tr>
<tr>
<td>Increase in energy efficiency</td>
<td>2008</td>
<td>20%</td>
<td>50%</td>
</tr>
<tr>
<td>Fraction of renewables, total energy</td>
<td>2011: 12,2%</td>
<td>18%</td>
<td>60%</td>
</tr>
<tr>
<td>Fraction of renewables, electricity</td>
<td>2011: 20,0%</td>
<td>35%</td>
<td>80%</td>
</tr>
</tbody>
</table>
The feed-in tariff, the Renewable Energy Sources Act (EEG)
Renewable Energy Sources Act (EEG)

Electricity from renewable sources:

- Priority, connection to the grid
- Priority, supply of electricity to the grid
- Fixed feed-in tariff over 20 years
- Yearly decrease of feed in tariff

Source: www.bmu.de
Levelised cost of electricity generation (LCOE)
Germany and Spain, May 2012

Feed-in tariff
Germany:
small PV
0.189 €/kWh
PV ground mounted
0.130 €/kWh

<- kWh/(m² a); h/a

Source: Fraunhofer ISE 2012, C. Kost, T. Schlegl
1 € = 1.3 AUD
## Levelised cost of PV electricity*

### September 2012

- **Module prices, Germany**: 0.7 €/W<sub>p</sub>
- **System prices (10 kW), Germany**: 1.5 €/W<sub>p</sub>
- **LCOE Southern Germany (1 300 kWh/(m<sup>2</sup> a)**: 0.12 €/kWh
- **LCOE at 2 500 kWh/(m<sup>2</sup> a)**: 0.06 €/kWh
- **LCOE at 3 400 kWh/(m<sup>2</sup> a)**: 0.05 €/kWh

- **Near future** system price: one €/W<sub>p</sub>
- **LCOE**: 0.08 €/kWh
  - 0.05 €/kWh - 0.03€/kWh

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*Applying the rule of proportion

1 € = 1.3 AUD
Levelised cost of electricity* (LCOE)

Caveats

- The comparability between different types of energy generation is enabled through the concept of LCOE

- But the LCOE is not a direct measure for the value of electricity. The value is determined by
  - The LCOE
  - The time pattern of load and generation
  - The predictability of the electricity generation
  - Political boundary conditions, market schemes

* LCOE = (present value of expenditures)/(present value of electricity generated)
Cost parity between conventional and photovoltaic electricity generation

Innovation and mass production

Monetising of social costs

Cost of conventional electricity

Cost of PV electricity

Cost parity

Time [years]

Cost [€/kWh]
Financing of renewable energy installations, Germany 2011

- Private Persons: 40%
- Venture: 14%
- "Big Four" Utilities: 7%
- Other Energy Utilities: 7%
- Fond/Banks: 11%
- Farmer: 11%
- Business: 9%
- Other: 1%

Source: trend research 2011, Deutschland hat unendlich viel Energie
Annual PV installations [GW] and growths rates, Germany

Source: BSW 2012

EEG support for PV will run out at a cumulative PV capacity of 52 GW
Evolution of the feed-in tariff

Light blue  < 10 kWp
Red  0.1 -1.0 MWp
Light green  ground based systems

Residential electricity prices
Industry prices
Reduction of the feed-in tariff
Average residential electricity price (Germany) and fraction due to the feed-in scheme

Source: German Federal Network Agency, 2011  
* = expected
Allocation of costs, feed-in tariff, Germany 2013

Compensation of losses 2012
Liquidity reserve
Market bonus
Industry privilege
Decline of electricity stock market price
Net promotion of renewables

5.21 ct/kWh

0.69
0.13
0.14
1.29
0.69
2.26
Integration of fluctuating renewable electricity into power supply structures
Smart grids, merging energy and information technologies

- Matching demand and generation on the local and central level
  - Control of non time-sensitive loads
  - Control of the energy demand through variable tariffs
  - Control of renewable and conventional electricity generation
  - Energy weather forecast
  - Energy storage
- Large area (inter-) continental grids
Electricity generation in Germany, selected days
03.01.2012 und 25.05.2012

Renewables, installed (rated) power, August 2012
PV 30 GW, wind 29 GW

Source: B. Burger, Fraunhofer ISE, 2012
An extreme model of a future German energy system*

energy sources: 100% from wind, solar, hydro, biomass; no import/export

PV  220 GW,  214 TWh
Wind  253 GW,  596 TWh
Hydro  5 GW,  21 TWh
Bio  50 TWh
Energy efficient buildings  -50%

Peak load  132 GW
Max. generation  321 GW

Source H. Henning, A. Palzer, Fraunhofer ISE 2012  *heat and electricity; liquid fuels not included
Handling excess electricity generation from solar and wind - examples

- Load management
- Large area electricity exchange (export/import)
- Energy storage electricity
  - Hydro, pressurised air
  - Batteries
- Energy storage - heat
  - Water, building components
- Energy storage – gas
  - Methane, Hydrogen
- Energy storage – transport
  - Batteries
Cost of electrical energy storage

Examples

- **Hydrogen**
  - Costs: $> 10$ Years today

- **CAES (adiabatic)**
  - Costs: $> 10$ Years today

- **Pumped Hydro Storage**
  - Costs: depending on location today

- **Zinc-Bromine**
  - Costs: in 5 to 10 years today

- **Redox-flow (Vanadium)**
  - Costs: NaNiCl (HT) NaS (HT) Lithium-Ion NiCd Lead acid batteries

Load levelling:
1 GW for 8h, 1 cycle per day

Load levelling and peak shaving:
100 kW for 2.5 h, 2 cycles per day

Source: VDE ETG, 2008
Levelised cost of electricity generation (LCOE)
Germany and Spain, May 2012

Residential electricity price Germany:

~ 0.25 €/kWh

Source: Fraunhofer ISE 2012, C. Kost, T. Schlegl
1 € = 1.3 AUD
Final remarks
Prerequisites for an effective transformation of our energy systems towards sustainability

- Low cost generation of energy from renewable sources
- Sustainable production, installation and recycling of components and systems
- Efficient integration of fluctuating renewable energies into electricity supply systems – empowering grids, integration of storage systems
- In all sectors: efficient use of energy
- Smart financing, market design, emission trading
- International co-operation
Thank you for your attention
## Parameters for cost calculations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Germany</th>
<th>Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PV Klein</td>
<td>PV Groß/Fläche</td>
</tr>
<tr>
<td>Eigenkapital-Anteil</td>
<td>20,0%</td>
<td>20,0%</td>
</tr>
<tr>
<td>Fremdkapital-Anteil</td>
<td>80,0%</td>
<td>80,0%</td>
</tr>
<tr>
<td>Eigenkapital-Rendite</td>
<td>6,0%</td>
<td>7,5%</td>
</tr>
<tr>
<td>Fremdkapital-Zins</td>
<td>4,0%</td>
<td>4,5%</td>
</tr>
<tr>
<td>WACC (Weighted Average Cost of Capital)</td>
<td>4,4%</td>
<td>5,1%</td>
</tr>
<tr>
<td>Jährliche Betriebskosten</td>
<td>30 €/kWp</td>
<td>30 €/kWp</td>
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<tr>
<td>Jährlicher Anstieg der Betriebskosten</td>
<td>2,00%</td>
<td>2,00%</td>
</tr>
<tr>
<td>Jährliche Degression Stromoutput</td>
<td>0,20%</td>
<td>0,20%</td>
</tr>
</tbody>
</table>

Source: Fraunhofer ISE 2012, C. Kost, T. Schlegl
Investments, different technologies

<table>
<thead>
<tr>
<th>Technologie</th>
<th>Anlagen</th>
<th>Mittlerer Wert</th>
<th>Untere Grenze</th>
<th>Obere Grenze</th>
<th>Quellen</th>
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</thead>
<tbody>
<tr>
<td>Photovoltaik</td>
<td>Kleinanlagen bis 10 kWP</td>
<td>1900</td>
<td>1700</td>
<td>2200</td>
<td>BSW Preimonitor (2012), Fraunhofer ISE (SCost-System)</td>
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<tr>
<td></td>
<td>Großenanlagen bis 1000 kWp</td>
<td>1700</td>
<td>1500</td>
<td>1800</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Freiflächen ab 1000 kWp</td>
<td>1600</td>
<td>1500</td>
<td>1700</td>
<td></td>
</tr>
<tr>
<td>CSP</td>
<td>Parabol 100 MW ohne Speicher</td>
<td>4700</td>
<td>3600</td>
<td>5000</td>
<td>Nevada One, Acciona (Majadas de Tietar)</td>
</tr>
<tr>
<td></td>
<td>Parabol 100 MW mit 8h-Speicher</td>
<td>5400</td>
<td>5200</td>
<td>6600</td>
<td>Andasol1-3 (ES)</td>
</tr>
<tr>
<td></td>
<td>Fresnel 100 MW ohne Speicher</td>
<td>3700</td>
<td>3400</td>
<td>4000</td>
<td>PE2 power station (ES)</td>
</tr>
<tr>
<td></td>
<td>Turm 100 MW mit 8h-Speicher</td>
<td>6500</td>
<td>6000</td>
<td>9000</td>
<td>Crescent Dunes (US), Abengoa (RSA)</td>
</tr>
<tr>
<td>Wind</td>
<td>Onshore (1,5 – 2 MW)</td>
<td>1200</td>
<td>1000</td>
<td>1350</td>
<td>EWEA (2009)</td>
</tr>
<tr>
<td></td>
<td>Onshore (2 – 3 MW)</td>
<td>1400</td>
<td>1200</td>
<td>1600</td>
<td>Windguard (2011)</td>
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<tr>
<td></td>
<td>Offshore (3 – 5 MW)</td>
<td>3200</td>
<td>2700</td>
<td>4000</td>
<td>EWEA (2009), Gerdes (2006), Krewitt (2009), Projekte: Borkum West 2, Baltic1</td>
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