• professor at the business school at the University of Applied Sciences in Saarbruecken since 1995
• at the same time scientific head of the Institute for Future Energy Systems (IZES), a university based research institute focussing on renewable energies, energy efficiency and decentralised power generation
• author and co-author of several books and articles liberalised electricity markets, feed-in law regulations and instruments for promoting renewable energies in the heat market.
• expert member of the Enquete commission “Sustainable energy supply” of the 14th German Bundestag
• alternate Board Member of the Agency for the Cooperation of Energy Regulators (ACER) of the European Union
The IZES: The management boards

- Associates
- Supervisory board
- Scientific advisory board

Executives

Scientific direction

Four departments

Associated professors of the University of Applied Sciences

The IZES: The departments

Scientific Direction
Horst Altgeld, Frank Baur, Uwe Leprich

Executives
Michael Brand, Frithjof Spreeer

Departments

Biomass/Material Flow Management
Frank Baur

Energy Systems Engineering
Bodo Groß

Energy Economy/Future Markets
Uwe Leprich

Test Centre TZSB
Danjana Thels

Central services

IT Services
Public relations
Accountancy, staff management
Secretariat
1. Energy in Europe: current status
2. European Energy Targets
3. Scenarios for 2050
4. Critical Aspects

Electricity Generation

**FIGURE 18**

EU-27, ELECTRICITY GENERATION BY FUEL (in %) (2007)
Total electricity generation 2007 = 3 361.69 TWh (289.11 Mtoe)

Source: Eurostat
Electricity Generation: Development

EU-27, ELECTRICITY GENERATION (in TWh) (1995-2007)

Source: Eurostat

Electricity from RES

FIGURE 20

EU-27, ELECTRICITY FROM RES IN GROSS ELECTRICITY CONSUMPTION (in %) (2007)
Total = 525 578 TWh

Source: Eurostat

Quelle: EU Commission 2009
CO2 emissions

FIGURE 27

EU-27, GREENHOUSE GAS EMISSIONS BY SECTOR (in %) (2007)
Total = 5 015.1 Mt CO$_2$

Source: European Environment Agency
CO2 emissions by sector

EU-27, GREENHOUSE GAS EMISSIONS BY SECTOR (1990-2007)

Source: European Environment Agency
EU-27, ADDITIONAL OPERATIONAL ELECTRICITY CAPACITY (in GW) (1990-2008)

Source: © Platts (2009)
**Success Story Wind**

*Increase in capacity*
In a mere 20 years, the yield of wind turbines has increased 100-fold. With the new 5 MW turbines, it will multiply another fivefold.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>rated power</td>
<td>30 kW</td>
<td>80 kW</td>
<td>250 kW</td>
<td>600 kW</td>
<td>1,500 kW</td>
<td>5,000 kW</td>
</tr>
<tr>
<td>rotor diameter</td>
<td>15 m</td>
<td>20 m</td>
<td>30 m</td>
<td>46 m</td>
<td>70 m</td>
<td>115 m</td>
</tr>
<tr>
<td>hub height</td>
<td>30 m</td>
<td>40 m</td>
<td>50 m</td>
<td>78 m</td>
<td>100 m</td>
<td>120 m</td>
</tr>
<tr>
<td>annual energy yield</td>
<td>35,000 kWh</td>
<td>95,000 kWh</td>
<td>400,000 kWh</td>
<td>1,250,000 kWh</td>
<td>3,500,000 kWh</td>
<td>appr. 17,000,000 kWh</td>
</tr>
</tbody>
</table>
Offshore wind projects
major potential in northern Europe (North and Baltic Seas)

Recent OMA study on a North Sea ‘Energy Super Ring’ estimated a potential of 13,400 TWh of energy in North Sea alone

- Current EU electricity consumption is around 3,500 TWh.
- Current demand would be met and exceeded through 9 100 km² wind farms.
- More energy potential than available fossils in Russia and Saudi Arabia

Source EWEA
Agenda

1. Energy in Europe: current status

2. European Energy Targets

3. Scenarios for 2050

4. Critical Aspects

The 20/20/20 Targets

The challenge: 20/20/20 by 2020

Political context

- Climate change considerations
- Higher relevance of security of energy supply

Policy implications

- **CO₂ abatement**: 20% reduction of CO₂ emissions by 2020
- **Energy efficiency**: 20% less energy consumed in 2020 than "business-as-usual"
- **Renewable energy**: 20% of consumed energy in 2020 from renewable sources
- **Biofuels**: 10% of all transportation fuels from bio-sources by 2020 (part of renewables)
1. Emissions target is legally binding and enforceable
2. Renewables target is legally binding, but is it enforceable?
3. Energy-efficiency target is neither legally binding nor enforceable
1. Energy in Europe: current status
2. European Energy Targets
3. Scenarios for 2050
4. Critical Aspects
Important Scenarios

1. European Climate Foundation (ECF)

2. Greenpeace International/European Renewable Energy Council (EREC)

3. Potsdam Institute for Climate Impact Research (PIK): RECIPE: The Economics of Decarbonization

4. PriceWaterhouseCoopers: 100% Renewable Electricity – a roadmap to 2050 for Europe and North Africa
Two scenarios

Scenarios European Climate Foundation (ECF)

The work on the three volumes of the Roadmap 2050 project has been undertaken by:

- Volume 1 - Technical and Economic Analysis: McKinsey & Company; KEMA; The Energy Futures Lab at Imperial College London; Oxford Economics and the ECF
- Volume 2 - Policy Report: E3G; The Energy Research Centre of the Netherlands and the FCF
- Volume 3 - Graphic Narrative: The Office for Metropolitan Architecture and the ECF

April 2010

Greenpeace International / European Renewable Energy Council (EREC) Scenarios

June 2010

research & co-authors
DLR, Institute of Technical Thermodynamics, Department of Systems Analysis and Technology Assessment, Stuttgart, Germany:
Dr. Wolfram Krewitt (†), Dr. Thomas Pregger, Dr. Sonja Simon, Dr. Tobias Naegler. DLR, Institute of Vehicle Concepts, Stuttgart, Germany:
Dr. Stephan Schmid, Ecofys BV, Utrecht, The Netherlands: Wina Graus, Eliane Blomen. Greenhouse Development Rights (Chapter 2.3)
EcoEquity, Paul Baer, Assistant Professor, School of Public Policy, Georgia Institute of Technology, Atlanta, USA

80% decarbonization overall means nearly full decarbonization in power, road transport and buildings

EU-27 total GHG emissions

Sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Total abatement</th>
<th>Abatement within sector¹,²</th>
<th>Abatement from fuel shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>95% to 100%</td>
<td>&gt; 95%</td>
<td>75% (electric vehicles, biofuels and fuel cells)</td>
</tr>
<tr>
<td>Road transport</td>
<td>95%</td>
<td>20%</td>
<td>20% (biofuels)</td>
</tr>
<tr>
<td>Air &amp; Sea transport</td>
<td>50%</td>
<td>30%</td>
<td>5% (heat pumps)</td>
</tr>
<tr>
<td>Industry</td>
<td>40%</td>
<td>35% (efficiency, CCS³)</td>
<td>50% (heat pumps)</td>
</tr>
<tr>
<td>Buildings</td>
<td>95%</td>
<td>45% (efficiency)</td>
<td></td>
</tr>
<tr>
<td>Wastes</td>
<td>100%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>20%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>Forestry</td>
<td>-0.25 GtCO₂e</td>
<td>Carbon sinks</td>
<td></td>
</tr>
</tbody>
</table>

1 Abatement estimates within sector up to 2030 based on the McKinsey Global GHG Abatement Cost Curve
2 Large efficiency improvements are already included in the baseline based on the IEA WEO 2009 (up to 2030), especially for Industry
3 CCS applied to 50% of large industry (cement, chemistry, iron and steel, petroleum and gas); not applied to other smaller industries

Power demand will go down due to higher efficiency and up due to additional demand from transport and building heating

EU-27, Norway and Switzerland power demand, TWh per year

1. Electrification of 100% LDVs and MDVs (partially plug-in hybrids). LDVs remain emitting ~10% while switching largely to biofuel or hydrogen fuel cells.
2. 90% of remaining primary energy demand converted to electricity (heating/cooling from heat pumps, assumed 4 times as efficient as primary fuel).
3. 10% of remaining primary energy demand for combustion converted to electricity (heating from heat pumps, assumed 2.5 times as efficient as primary fuel).
A balanced mix of production technologies has been assumed
In percentage of production

<table>
<thead>
<tr>
<th>Coal</th>
<th>Coal CCS retrofit</th>
<th>Gas</th>
<th>Gas CCS</th>
<th>Gas CCS retrofit</th>
<th>Nuclear</th>
<th>Wind</th>
<th>Solar</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>80% RES 10% CCS 10% nuclear</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>60% RES 20% CCS 20% nuclear</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>40% RES 30% CCS 30% nuclear</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Baseline 34% RES 40% coal/gas 17% nuclear</td>
<td>21</td>
<td>0</td>
<td>0</td>
<td>28</td>
<td>0</td>
<td>0</td>
<td>17</td>
</tr>
</tbody>
</table>

A combination of solar and wind is more stable than wind alone

Yearly energy balance, 20% DR, TWh per week

---

Quelle: ECF 2010
## Production mix and capacity requirements per pathway

<table>
<thead>
<tr>
<th>Pathways</th>
<th>Production – incl. fuel shift</th>
<th>Capacity GW, 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent, 2050, 100% = 4900 TWh</td>
<td></td>
</tr>
<tr>
<td>Baseline¹</td>
<td>49% 17% 34%</td>
<td>410 110 470 120 1,110</td>
</tr>
<tr>
<td>80% RES 10% CCS 10% nuclear</td>
<td>10% 80%</td>
<td>80 1,610 270 2,020</td>
</tr>
<tr>
<td>60% RES 20% CCS 20% nuclear</td>
<td>20% 20% 60%</td>
<td>160 1,180 240 1,700</td>
</tr>
<tr>
<td>40% RES 30% CCS 30% nuclear</td>
<td>30% 30% 40%</td>
<td>185 670 190 1,280</td>
</tr>
</tbody>
</table>

¹ Supply of 4800 TWh, technology split by PRIMES, forecast updated with IEA WEO 2009 and Oxford economics.
² Additional back-up capacity to meet peak demand. Assumed to be OCGT in the costing, but could be any equivalent. 20% DR case shown.
INTER-REGIONAL TRANSMISSION REQUIREMENTS

2010
Existing Capacity

2050
Total Transmission Requirements
Assuming 80% RES & 20% DR
The higher RES pathways have higher cost of electricity in the early years
Ranges of the levelized cost of electricity of new builds, € per MWh (real terms)

Baseline and average of decarbonized pathways

Baseline and 40% RES pathway

Baseline and 60% RES pathway

Baseline and 80% RES pathway

1 Based on a WACC of 7% (real after tax), computed by technology and weighted across technologies based on their production; including grid. LCoE ranges are based on: Carbon price from €0 to 35 per tCO₂e; Fossil fuel prices: IEA projections +/- 25%; Learning rates: default values +/- 25%.
THE COST OF THE DECARBONIZED PATHWAYS AND THE BASELINE ARE LIKELY TO DIFFER LESS THAN € 250 PER YEAR PER HOUSEHOLD
Annual full cost for energy is lower for the decarbonized pathways than the baseline.

Annual spending on energy, 2050, € billion

<table>
<thead>
<tr>
<th>Year</th>
<th>Baseline</th>
<th>Decarbonized pathway</th>
<th>Baseline</th>
<th>Decarbonized pathway</th>
<th>Baseline</th>
<th>Decarbonized pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>925</td>
<td>845 -9%</td>
<td>1,125</td>
<td>920 -18%</td>
<td>1,445</td>
<td>1,090 -25%</td>
</tr>
<tr>
<td>2030</td>
<td>410</td>
<td>340</td>
<td>510</td>
<td>300</td>
<td>635</td>
<td>265</td>
</tr>
<tr>
<td>2050</td>
<td>225</td>
<td>125</td>
<td>275</td>
<td>120</td>
<td>370</td>
<td>100</td>
</tr>
</tbody>
</table>

1 Includes biofuels and H2.
2 Includes up to € 100 billion per year in 2050 to account for the additional capex from efficiency, EVs, heat pumps, industry CCS.
3 38% RES / 20% CCS / 20% Nuclear pathway.
Energy cost decreases in the baseline, but even more so in the decarbonized pathways

Energy cost per unit of GDP output, € (real terms)

Lower energy cost in the decarbonized pathways due to improved productivity and less GHG emissions which reduce the impact of the carbon price.
ECF Roadmap 2050: Policy Recommendations (1)

1. Dramatically Accelerate Energy Efficiency
   - Action to convert the non-binding 2020 efficiency goal into a requirement to deliver the target whilst allowing Member States flexibility on how this should be achieved
   - Revise the Energy Services Directive to support a tripling of the energy efficiency policy impact, which is required to achieve the 2020 energy savings goal
   - Strengthen the Eco-Design of Energy Using Products Directive with mandatory minimum energy performance requirements based on ‘best available technology’ on the global market and a sufficient updating process (‘frontrunner approach’)
   - Full implementation of the Energy Performance of Buildings Directive to ensure that all new buildings meet zero net energy requirements by 2020
   - Progress legislation that will establish the framework for efficiently delivering climate objectives allocating limited resources beyond 2020 and out to 2050

2. Deliver Combination Of Instruments To Drive Power Sector Decarbonisation

■ Develop complementary measures to the EU ETS which safeguard the long-term transition of the power sector and maintain a non-distorted carbon price signal

■ Review EU ETS reduction targets to ensure they are consistent with delivery of 2050 emissions targets

■ Request Member States to come forward with long term targets for deployment of key renewable generation technologies and adopt parallel measures for CCS

■ Introduce new provisions requiring Member States to identify a long term planning generation and demand-side resource mix out to 2050 that is consistent with decarbonisation objectives and can underpin strategic network development
3. Realise The Potential Of The European Grid To Reduce The Costs And Risks Of Decarbonisation

- Build on the existing institutional arrangements to ensure appropriate regulation and system operation in a more interconnected European power network

4. Ensure The Transition Can Be Financed
A basic Energy [R]evolution reduces EU-wide carbon dioxide emissions by 80% compared to 1990 levels by 2050, while phasing out expensive nuclear power production and its dangerous radioactive waste. To achieve this, the scenario exploits Europe’s large potential for energy efficiency. At the same time, available cost-effective renewable energy sources are used for heat and electricity generation, and transport.

An advanced Energy [R]evolution dramatically improves energy security, boosts green technology leadership and pulls the emergency brake on greenhouse gas emissions, achieving close to a fully renewable energy system by 2050. The advanced scenario reduces EU-wide carbon dioxide emissions by 95% by 2050, matching the upper range of the emissions reduction target adopted by EU leaders in October 2009. This scenario requires the rapid phasing out of nuclear power generation and assumes a maximum lifetime of 20 years for coal-fired power plants, half the technical lifetime of such plants.
Figure 4.5: Development of electricity generation structure under 3 scenarios

(Reference, Energy Revolution and Advanced Energy Revolution) ["Efficiency" = reduction compared to the reference scenario]
investment shares - reference versus energy [r]evolution

Reference scenario 2007 - 2050:
- Total 2.0 trillion €
- 38% Renewables
- 15% CHP
- 18% Fossil
- 9% Nuclear power

Advanced energy [r]evolution scenario 2007 - 2050:
- Total 3.8 trillion €
- 74% Renewables
- 20% CHP
- 6% Fossil

Energy [r]evolution scenario 2007 - 2050:
- Total 2.7 trillion €
- 51% Renewables
- 25% CHP
- 8% Fossil
Figure 4.6: Development of total electricity supply costs & development of specific electricity generation costs under 3 scenarios.
1. develop a vision for a truly sustainable energy economy for 2050 to guide European climate and energy policy
   • Demonstrate how the EU will play its role in slashing global emissions until 2050
   • Move the energy system towards 100% renewable energy and high efficiency in all sectors
2. adopt and implement ambitious and legally binding targets for emissions reductions, energy savings and renewable energy
   • Commit to legally binding emissions reductions of 30% as the next step, and lead by example
   • Set legally binding targets for energy savings by 2020
   • Implement the binding renewable energy targets of at least 20% by 2020
3. remove barriers to a renewable and efficient energy system
   • Reform the electricity market and network management
   • Phase out all subsidies and other support measures for inefficient plants, appliances, vehicles and buildings, as well as for fossil fuel use and nuclear power
   • Close existing loopholes for nuclear waste

4. implement effective policies to promote a clean energy economy
   • Update the EU Emission Trading Scheme
   • Implement stable support for renewable energy and secure the successful enforcement of the Renewable Energy Directive
   • Set energy efficiency standards for vehicles, consumer appliances, buildings and power production
   • Initiate robust and harmonised EU green taxation

5. ensure that the transition is financed
The center of gravity of the EU power system will shift away from coal/nuclear

Thermo-electric will have to be more flexible and will have less running hours

Storage, balancing and other grid services will be growing “business”
IEA 450 Scenario 2050: Efficiency is most important!

Quelle: IEA 2009

1. Energy in Europe: current status
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Critical Aspects

a) System conflict between renewables and baseload plants

b) How to amortise backup capacities for the intermittent generators?

c) How to integrate intermittent generation into the existing electricity markets?

d) Energy efficiency: how to trigger a market?
System Conflict (1)

Loads and plants

- Gas turbines
- Storage
- Hard coal
- Lignite
- Nuclear

Leprich, 21. August 2010, Otzenhausen
The residual load in Germany 2020

BEE-Szenario: Residuale Last für 2020 – EE-Anteil: 47%

Where has the base load gone?

System Conflict (3)

Negative prices at the power exchange

Figure 3: EEX spot prices and residual load (10/2008 – 11/2009)

[Graph showing EEX spot prices and residual load]

Quelle: Nicolosi 2010

System Conflict (4)

Figure 4: Power plant utilisation by fuel

Quelle: Nicolosi 2010
b) How to amortise backup capacities for the intermittent generators?
Backup Capacities: Investment problem (1)

Different types of “costs” available in economic theory with different relevance for investments

![Graph showing different types of costs for investment problems](attachment:backup_capacities_investment_problem.png)
Backup Capacities: Investment problem (2)
The backup capacity solution?

Ofgem’s policy options

- **A** Targeted Reforms
  - Minimum carbon price
  - Improved ability for demand side to respond
  - Improved price signals
  - Enhanced obligations on suppliers and system operator
  - Centralised renewables market
  - Replace RO with renewables tender

- **B** Enhanced Obligations (EO)

- **C** EO & Renewables Tenders

- **D** Capacity Tenders
  - Tenders for all capacity

- **E** Central Energy Buyer
  - Central buyer of energy (including capacity)

Quelle: OFGEM 2010

c) How to integrate intermittent generation into the existing electricity markets?
Market Integration of wind Energy straightforward?

Are hence wind power plants in 2018 „marketable“?
The power exchange has a different rationale!

There is a negative correlation between wind feed-in and spot market prices

\[ \text{results rather in the following price curve} \]
The merit order effect (1)

Leprich, 21. August 2010, Otzenhausen
The merit order effect (2)

Wholesale price decreases

additional renewable energies

Equilibrium

Supply (reference)

Supply (RE)

Demand
The merit order effect (3)

- With increase in capacity of RE installations (with small marginal costs), the power price decreases:
  - Average annual power price
  - Hourly power price (especially with strong wind)

- Consequently, the average revenue of wind farms also decreases (always) if they produce.
  - Example: strong wind, weak demand → power price zero → no revenue

- The characteristics of costs and fluctuating supply results in an inherent revenue problem for RE installation (the stronger, the higher the market penetration is)
  - Incentive to invest in additional installations decreases with increasing market penetration in liberalise markets
d) Energy efficiency: how to trigger a market?
Energy efficiency markets? (1)

„Lebenslügen“ / Sustained Delusions

1. Energy efficiency investments pay for themselves
2. The more information, the more efficiency investments by end-use customers
3. The energy efficiency markets will unlock the efficiency potentials
4. There is no dissent about the need to exploit the energy efficiency potentials
First insights

1. Energy efficiency investments have often very long payback times \(\Rightarrow\) very few investors accept them

2. There is already a lot of information about EE available \(\Rightarrow\) the end-use customer is the weakest addressee for influencing the diffusion of efficiency technologies

3. The participants in the energy efficiency markets calculate with short payback periods and are usually risk-averse \(\Rightarrow\) they will unlock only a small part of the efficiency potentials

4. Nearly nobody really wants to exploit the energy efficiency potentials

Resource efficiency as a “leitmotiv” in EU 2020 strategy

New energy efficiency action plan with special focus on electricity savings:

- Speeding up replacement of old by new technologies (LED, variable speed motors,...)
- Demand side obligations for retailers
- Systematic phase out of the 150 TWh of existing inefficient electric heating

Quelle: Türmes 2010
Thank you very much for your attention!

Institut für ZukunftsEnergieSysteme (IZES)

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