Sarah RIESEBERG*

100% RENEWABLE ELECTRICITY SUPPLY BY 2050**

Abstract: In order to achieve an 80–90% reduction in Greenhouse Gas (GHG) emissions by 2050 we will first have to transform our electricity supply system. The energy sector holds a key function regarding GHG emissions by currently causing more than 80% of the emissions in Germany[1]. Within this sector the electricity supply is responsible for about 40% of energy-related CO_2 emissions. The potential for reducing emissions in the electricity sector is very high. Provided a highly efficient use of electricity and energy conversion, as well as an energy supply system that is completely based on renewable energies, it will be possible to reach a level of nearly zero GHG emissions.

For Germany, the technological change towards an electricity supply system completely based on renewable energies by 2050 is possible. By doing so, Germany's status as a highly industrialised country can be maintained, as can its subsequent ways of living, patterns of consumption and behaviour. This is shown in our simulation of the scenario "region's network scenario" as well as in several studies of other institutions like the German Advisory Council on the Environment (SRU), the German Enquête-Commission on sustainable energy supply or Greenpeace.

Our results should be regarded as one part of a level playing field needed to create a 100% renewable electricity supply system by 2050. Aside from the regional scenario, we also sketch two other scenarios: International large scale application of technology and Local Energy Autarky. For these two scenarios we intend to go more into depth within further studies as we expect them to provide further momentum towards achieving the level playing field.

A switch to an electricity supply system based on renewable energies will also be economically beneficial[2]. The costs of such a change in the energy supply are significantly lower than those of adapting to an unmitigated climate change we and future generations would have to otherwise face[3,4]. Germany could link a respective strategy to a successful economic development whilst creating important momentum for current international climate negotiations.

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** Full paper is given in terms of PowerPoint presentation.

[1] UBA 2010c

[2] SRU 2010, Enquete-Kommission 2002

[3] Stern 2007

[4] UBA 2010b

An electricity supply system completely based on renewable energies can provide the security of supply for today's high level of demand and at any hour of the year. The results of our simulations show that renewable energies can supply the demand for electricity and provide the necessary control reserve. Load fluctuations of the renewables can be safely compensated for at any time as the different forms of energy conversion, energy storage and intelligent load management complement each other sufficiently.

As an important condition for achieving this 100% renewable electricity supply, we have to tap the existing energy saving potential at the same time. This applies not only to the energy use of private households. Despite the expected economic growth, industry, trade and commerce also have to reduce their energy consumption by achieving the existing energy saving potential. If this is the case, renewable energies can provide the substantial additional electricity demand from new applications like electric cars or heat pumps for heating and hot water. To limit future electricity consumption for heating, a very good insulation of buildings is a basic requirement.

70% of the current primary energy consumption in Germany is based on the import of coal, natural gas or uranium. A complete supply of electricity from renewable energies could therefore dramatically reduce Germany's dependency on such imports and decrease vulnerability to fluctuating or rising oil- and gas prices.

The conversion of the electricity supply system towards the use of 100% renewable energies by 2050 is possible. Nevertheless, this is a very ambitious goal and requires decisive political support. The share of renewable energies in the German gross electricity consumption has increased in the past 15 years from less then 5% to 16% in 2009. However, there is still much work ahead if Germany wants to cover its demand for electricity in 2050 completely through renewable energies: It is not only necessary to accelerate the expansion of renewable energies but also to substantially convert the existing energy system to make it fit for an exclusive use of renewables in the future.

It is important to define intermediate goals, particularly for the period after 2020. Generally, it can be said: The earlier we start decisive actions the more time we will have to tackle the upcoming challenges of necessary technological and societal adaptation!

Overview

- Expansion of German Renewables since 1990
- German Climate Policy Roadmap
- UBA (2010): 2050: 100% - Energy Target 2050: 100% Renewable electricity supply
  - Model Assumption
  - I) Renewable Energy Potentials and Feed-In
  - II) Load Management and Storage
  - Summary
- Conclusion & Policy Recommendations

2050: 100% - Energy target 2050: 100% renewable electricity supply

Feed-in Legislation for Renewable Energies in Germany

- 20 years of German feed-in legislation:
  - 1990 first legislation passed [StrEG]
  - 2000 Renewable Energy Source Act [EEG] enters into force
- Development of electricity production from renewables [2009]:
  - Share in electricity consumption*: 16.4 % / 94 TWh / 46 GW
  - Feed-in compensation 2009: Ø14 €Cent/kWh
- Possible expansion trajectories**:
  - 2020: 35%*
  - 2050: 85%*

* Gross electricity consumption, Germany 2009: ~582TWh

** BMU (2009) Lead Scenrio 2009

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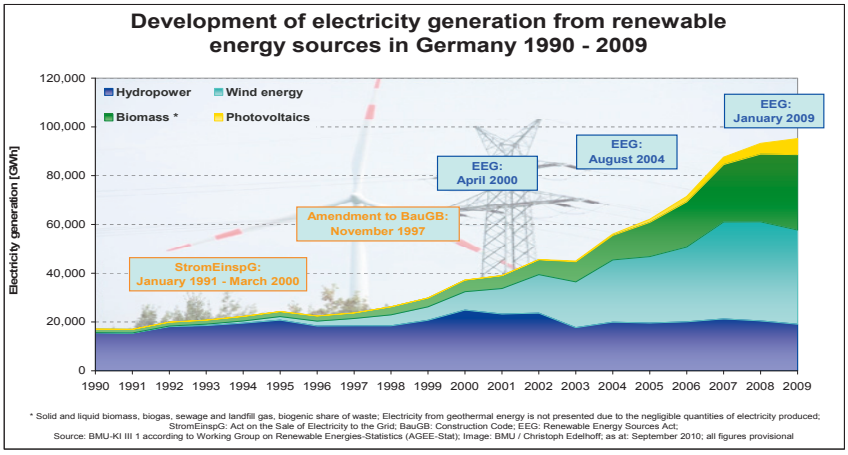

Source:BMU – KI III 1

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German Climate Policy Roadmap

➢ Germany 2020

EU-target 2020: -20%[1]

- 40%-reduction target[1] (unconditional to international efforts)

➢ Germany 2050:

G8-target 2050: -80%[1]

- Government target (2010): *80-95% reduction*
- UBA suggests to choose a target at the top end of the IPCC suggestions of a 80-95% reduction
  - ✓ 1 t per capita (WBGU[2]) would equal to a German reduction of ~95%

1 Baseyear: 1990

2 WBGU: German Advisory Council on Global Change

2050: 100% - Energy target 2050: 100% renewable electricity supply

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Latest scenarios on 80-100% renewable energy systems:

2009 2010 2011

UBA (2010)

2050: 100%
Energy target 2050
100% renewable electricity supply

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Our Research Question:

Can a 100% renewable electricity system satisfy

I. Germany‘s total electricity demand
II. as well as any peak load throughout the year

2050: 100% - Energy target 2050: 100% renewable electricity supply

Our Framework Conditions:

- Technical optimisation Model SimEE of Fraunhofer IWES
  - Photographic impression of Germany in 2050
  - Feed-in data based on 4 metorological years
- 100% Renewable Electricity System
  - no CCS
  - no nuclear energy
- Exploitation of nationally available renewalbe energy potentials
  - Limitation of the use of bioenergy from waste and residue biomass as a last-resort energy source
- Exploitation of all energy efficiency potentials
  - - 58% reductions of final energy demand
  - -19% reduction of final electricity consumption

2050: 100% - Energy target 2050: 100% renewable electricity supply

Three Electricity Supply Scenarios

I. Region's Network Scenario [spring 2010]
- Germany exploits its nationally available renewable energy potentials
- Load management carried out in one national balancing zone
- Only minor imports from neighbouring countries

II. Local energy autarky Scenario [spring 2011]
- Self-contained electricity supply within small-scale, decentralized "island systems"
- Exclusive use of locally available renewable energy sources

III. International Scenario with large-scale Infrastructure
- Large-scale renewable energy generation scattered over Europe connected by a continental super grid
- Significant electricity trading with net-importing and net-exporting European countries

2050: 100% - Energy target 2050: 100% renewable electricity supply

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Our Methodology I:

- Assessing Germany's energy demand in 2050: 506 TWh
- Assessing the national renewable energy potential under environmental and social constraints

	Constrained German potential		Exploitation in the Region's Scenario	
	Capacity (GW)	Output (TWh)	Capacity (GW)	Output (TWh)
Photovoltaic	275	240	120	104
Onshore wind energy	60	170	60	170
Offshore wind energy	45	180	45	177
Hydropower	5,2	24	5,2	22
Geothermal energy	6,4	50	6,4	50
Waste biomass [biomethane]	-	23	23,3	11

2050: 100% - Energy target 2050: 100% renewable electricity supply

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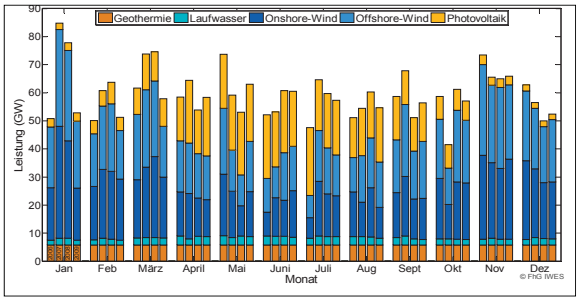
Our Simulation Results I: Feed-in from renewable energy sources

➢Overall our simulated renewable energy capacities generated excess supply: Ø534 TWh production versus 506 TWh consumption

Average **monthly** feed-in based on data derived from the meteorological years 2006-2009



2050: 100% - Energy target 2050: 100% renewable electricity supply

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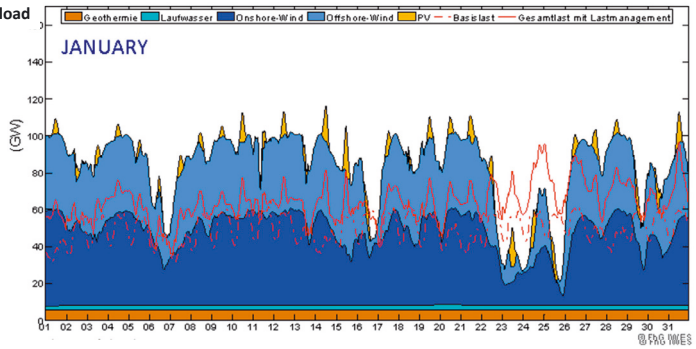
Our Simulation Results I: Example of a Summer and a Winter Month

- the load curve is adapted to feed-in by loadmanagement
- Solar and wind energy are a very good seasonal combination

RE-feed-in and load



2050: 100% - Energy target 2050: 100% renewable electricity supply

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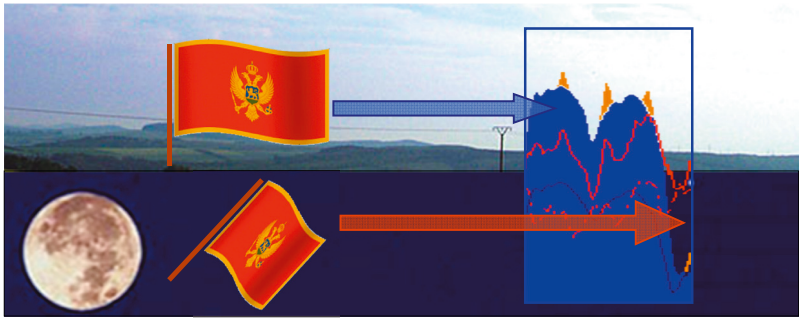
Our Methodolgy Part II: Load Management & Storage

- Dealing with the fluctuating feed-in from renewable energy sources solving the „calm night problem“: *periods with little wind power or photovoltaic feed-in*



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Our Results Part II: Load Management & Storage

- In periods of supply shortages stored electricity was reconverted:

A) Short-term storage and load management with frequent loading and reconversion: pump storage

B) Long-term/ Seasonal Storage: Renewable Power Hydrogen/ Methane (comparison of both cases) re-generation in combined cycle power plants or other use (possibly as fuel)

2050: 100% - Energy target 2050: 100% renewable electricity supply

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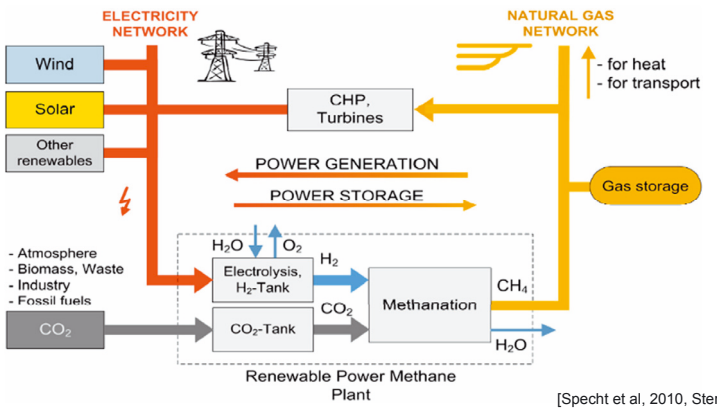
Chemical Energy storage: linking the power grid to the natural gas grid



[Specht et al, 2010, Sterner, 2009]

2050: 100% - Energy target 2050: 100% renewable electricity supply

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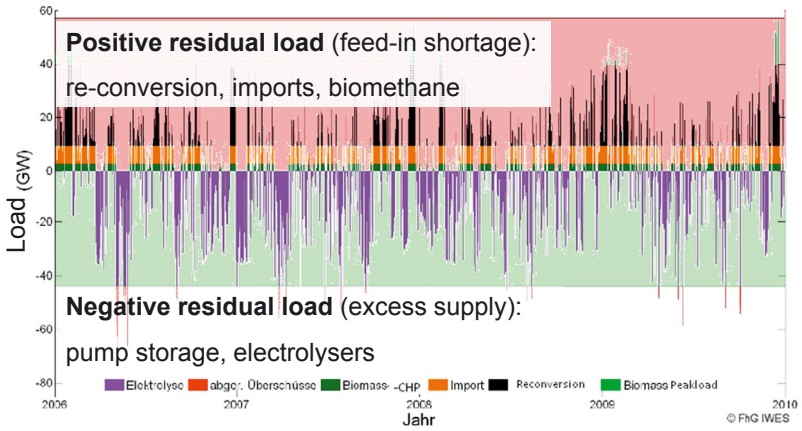
OUR RESULTS II:

- Satisfying load at any point throughout a year



2050: 100% - Energy target 2050: 100% renewable electricity supply

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Summary

- Successful Simulation of a 100% renewable electricity sector:

  Under the premises that energy storage and demand management were utilized, 260 GW installed renewable electricity generation capacity could satisfy a total German electricity demand of 500 TWh at any hour of the year.

2050: 100% - Energy target 2050: 100% renewable electricity supply

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Our Policy Recommendation:

What policy makers need to do…

- **Give** planning security by formulating binding emission reduction and renewables targets
- **Create** incentives for the efficient and intelligent use of energy
- **Enable** the construction of necessary infrastructure and adapt spatial planning
- **Start** the transformation prcess of the existing energy production fleet
- **Support** R&D in energy technologies
- **Generate** social support and communicate change in a transparent policy process

2050: 100% - Energy target 2050: 100% renewable electricity supply

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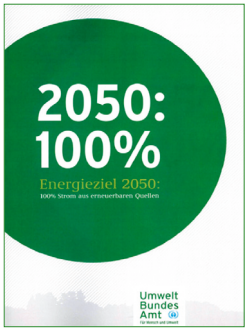

this is only the beginning…

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More information:
UBA: www.uba.de/uba-info-medien/3997.html
Ministry of the Environment: www.erneuerbare-energien.de/inhalt/3860