Electrical Engineering and Systems Technology

for the Use of Renewable Energies

and Decentral Energy Supply

Applications oriented Research and Development

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Das Virtuelle Kraftwerk - Kombikraftwerk

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Outline

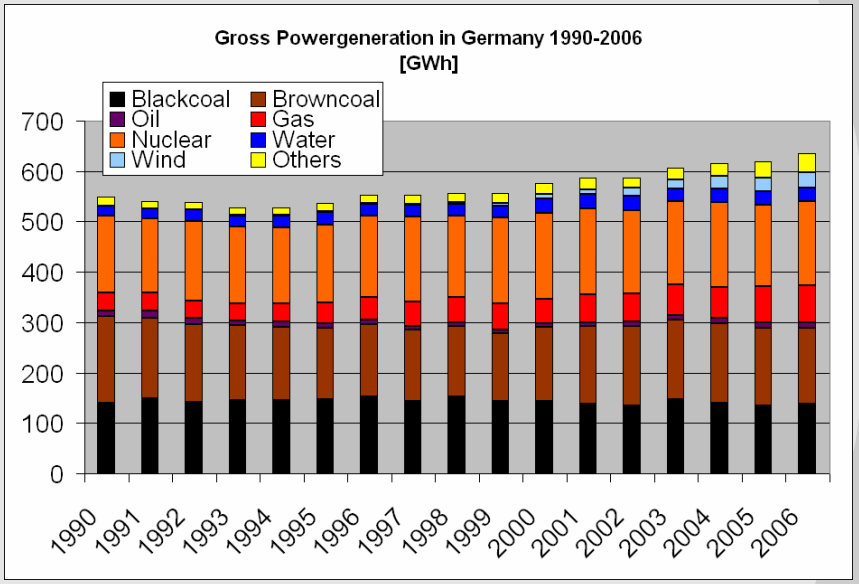
Kombikraftwerk

- Why renewable energies?
- The 100% renewables scenario
- The virtual power plant
- Critique
- Conclusion/Outlook

E-Energy - Regenerative Modellregion Harz

Why renewable energies? – The German situation

- Electrical power generation in Germany 540 TWh in 2006
- Over 60% of fuels have to be imported
- Prices for fossile fuels rise (e.g. price for oil rose to 250% compared to 2000)



Sources: Statistisches Bundesamt, EuroStat - Statistical Office of the European Communities 09.03.2008
Iea – 10.7.2008

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Why renewable energies? – The German situation

- Share of renewable energy sources about 14,2% in 2007
- Target for German share of renewable sources in 2020 is 30%
- Target for reduction of CO_2 emission compared to 1990 36% until 2020
- Additional phase-out of nuclear power until 2021

Source: Statistisches Bundesamt, EuroStat - Statistical Office of the European Communities 09.03.2008
BMU, Verbesserung der Systemintegration der Erneuerbaren Energien im Strombereich 5.2008

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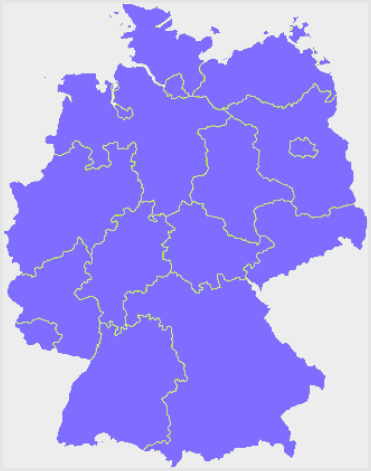
No limits for a full electricity supply by renewables



No limits means to supply Germany with 100% renewable energy.

Two main questions must be asked:

1. Potential: Is it possible to replace all conventional power generation with renewables?
2. Availability: Do renewables have the ability to meet the consumption anytime?

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The 100% renewables scenario – Power generation

	2006	Future… (2050)
Electrical power generation in Germany [TWh/a]	536,1	573
Conventional powerplants	363,4	0
Wind onshore	30,5	168
Wind offshore	0	120
Biogas	18,6	100
PV	2,0	60
Hydro	21,6	25
Waste incineration, decentralized CHP	100	100

Source: Enercon GmbH, Schmack Biogas AG, Solarworld, ISET, July 2007

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The 100% renewables scenario – Energy production of renewables

Wind	Wind onshore		Wind offshore	
	2006	Future…	2006	Future…
Avg. capacity in kW	816	6000	0	6000
Number of plants	18685	10000	0	5000
Total capacity in GW	20,62	60	0	30
Full load hours	2000	2800	0	4000
TWh / a	30.5	168	0	120

Source: Enercon GmbH, ISET e.V. – 10th of July 2007

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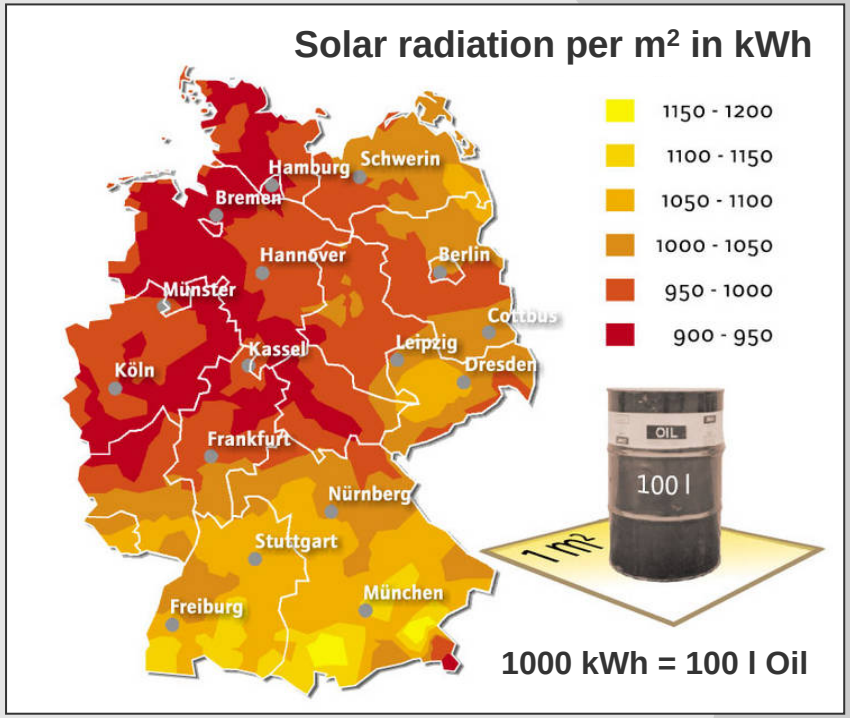
The 100% renewables scenario – Energy production of renewables

PV	2006	Future…
Rooftops in Mio. m²	3600	3600
% of Rooftops	0,58%	13,15%
Mio. m²	21	706
W / m²	120	150
Capacity in GW	2	71
Full load hours	950	850
TWh / a	2	60



Source: Solarworld AG, BSW Solar e.V ISET e.V. – 10th of July 2007

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The 100% renewables scenario – Energy production of renewables

Biogas	2006	Future…
Agricultural land in Mio. ha	17	17
% Agricultural land for el. power generation	5,47%	16,81%
Mio. Hektar	0,930	2,857
Mio. Ton	46,5	200
Tons of Corn / Hektar	50	70
m^3 Gas / Ton of corn	200	200
kWh / m^3	5	5
kWh_{el} / m^3	2	2,5
Gas Mio. m^3	9300	40000
TWh_{el} / a	18.6	100

Source: Schmack Biogas AG, ISET – 10th of July 2007

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The 100% renewables scenario – Installed capacities

Wind	60 GW onshore 30 GW offshore
Photovoltaic	70 GW (using 13% of the rooftops)
Biomass	40 GW CHP (using 16.8% of the agricultural area)
Storage capacities	10 GW
Import/Export	10 GW

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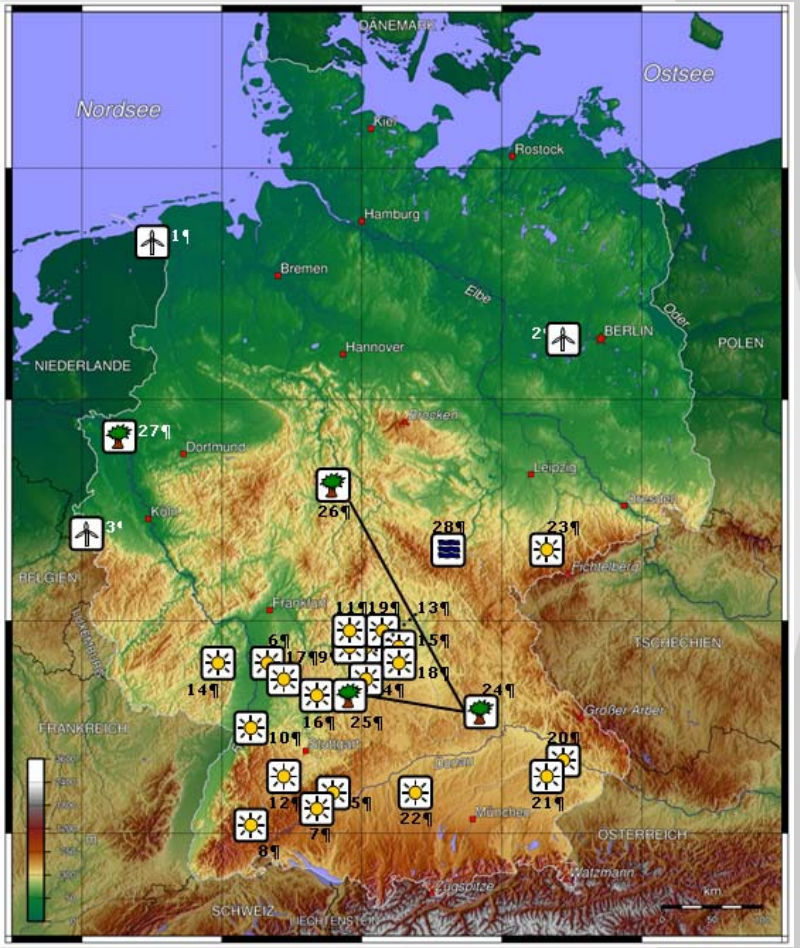
The 100% renewables scenario - The virtual power plant

- Virtual power plant - real energy.
- German Consumption 2006.
- Combination of wind, pv, biogas and pumped hydro.
- Scaling 1/10000.



Wind	Solar	Biogas	Hydro	Import /Export
12,6 MW	5,5 MW	4,0 MW	1,0 MW	1,0 MW

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The virtual power plant – Interfaces

Agents

Load

Wind

Biogas

PV

Hydro

Import/Export

Calculationalgorithm

Results

Control

System is running operationally since 3rd of July 2007

Webservice **Webservice**

Powerproduction **Calculationserver** **Graphical Interface**

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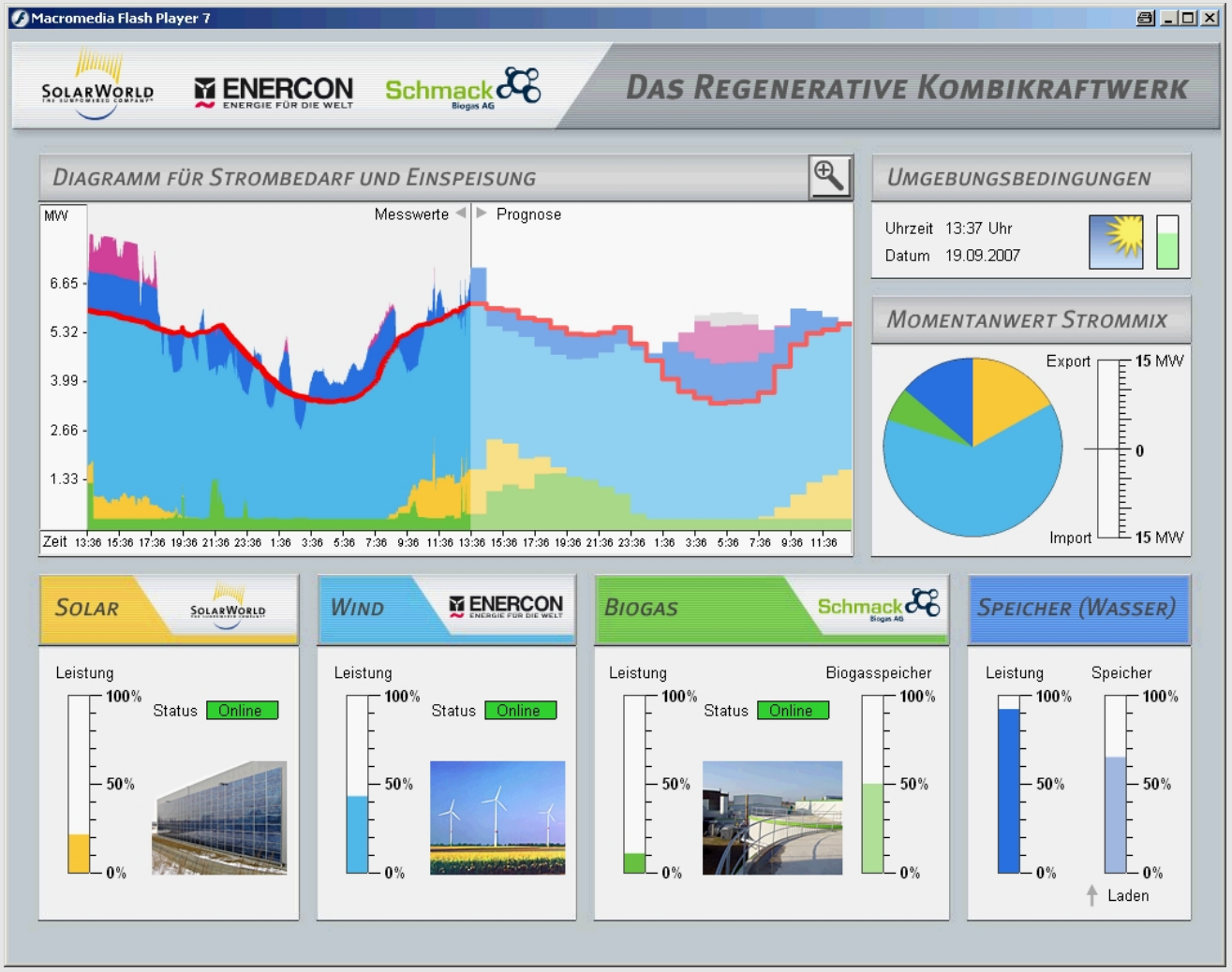
The virtual power plant – Graphical user interface



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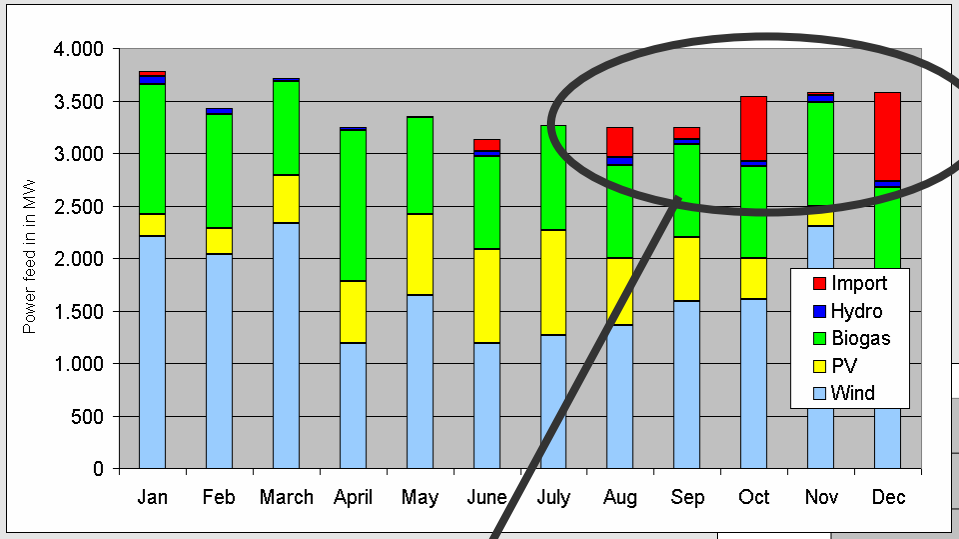
The virtual power plant - Results

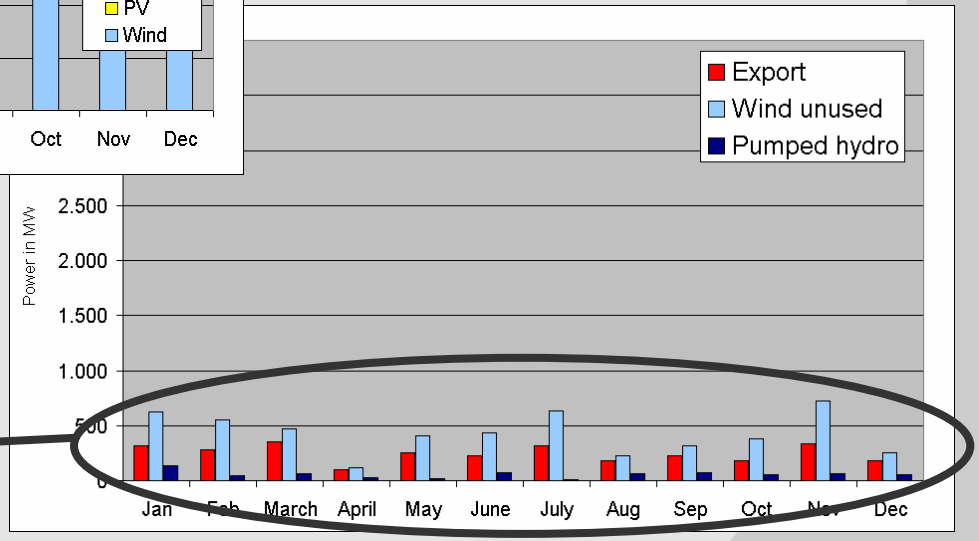
Simulation with lower wind feed-in – 90% compared to avg. wind year



Demand	41.124 MWh
Wind	20.338 MWh
PV	6.153 MWh
Biogas	12.043 MWh
Hydro	522 MWh
Import	2.067 MWh

Higher imports during winter

Smaller portions of unused wind



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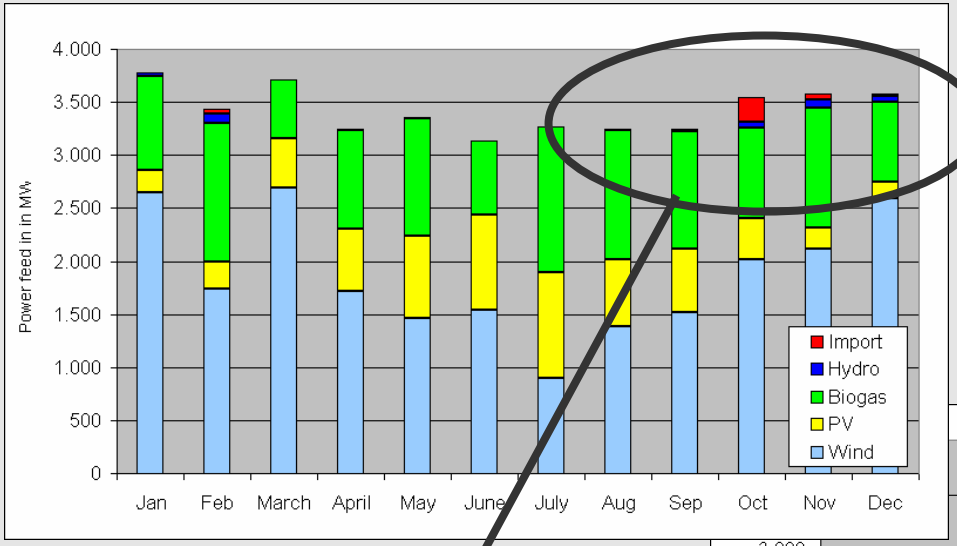
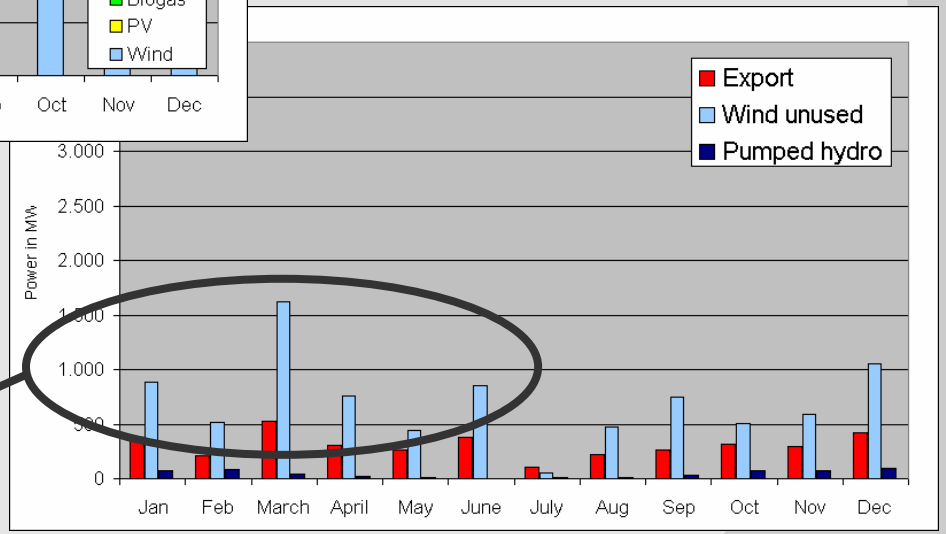
The virtual power plant - Results

Simulation with higher wind feed-in – 116% compared to avg. wind year



Demand	41.124 MWh
Wind	22.328 MWh
PV	6.153 MWh
Biogas	11.907 MWh
Hydro	385 MWh
Import	352 MWh

Low imports in total



Higher portions of unused wind

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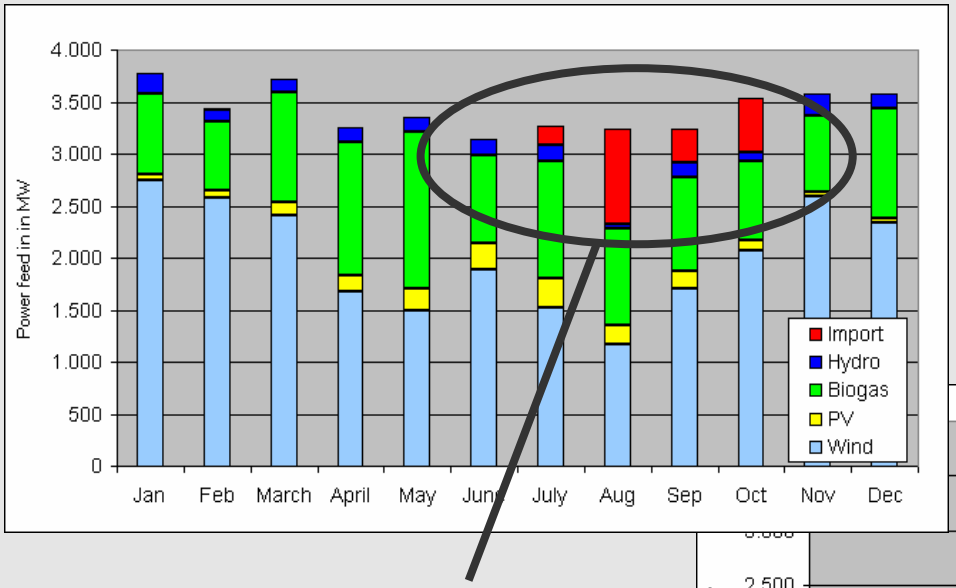
The virtual power plant - Results

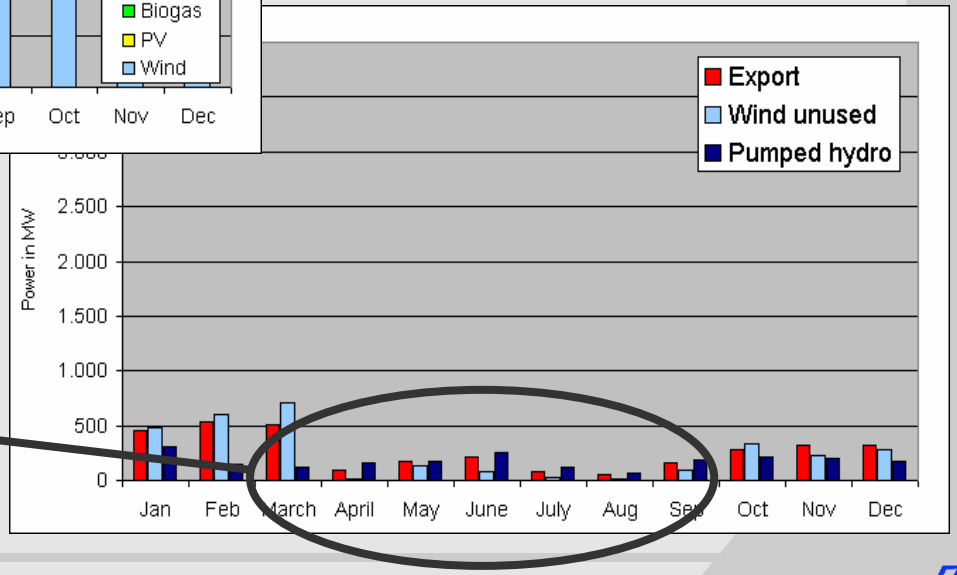
Simulation with avarage wind and lower pv feed-in



Demand	41.124 MWh
Wind	24.176 MWh
PV	1.682 MWh
Biogas	11.626 MWh
Hydro	1.663 MWh
Import	1.977 MWh

High imports during summer

Smaller portions of unused wind



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Critique

- **Storage Capacity is to big**

Big potential for AA-CAES (2,5 – 3,7 TWh)

- **Too much PV**

Dirty silicium (Q-Cells wants to produce 1 GW in 2010)

Only technical aspects were considered

- **Too much Biogas**

Study BMU – 4,4 m ha for energy plants

Ulf Ehlers, Windenergie und Druckluftspeicher, Diplomarbeit, Uni/FH Flensburg

Öko-Institut u.a.: Stoffstromanalyse zur nachhaltigen energetischen Nutzung von Biomasse. Endbericht. Verbundprojekt gefördert vom Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit. Darmstadt 2004.

Conclusion/Outlook

Conclusion :

- It is possible to supply an area like Germany with renewable energy.
- Fluctuating power feed-in raises the need for storage devices and cogeneration.
- Further possibilities for storing energy have to be found.
- Systems like the regenerative power plant have to balance between storage and energy imports/exports.

Outlook:

- In future smaller regions will switch to a larger share of renewables
- To use energy effectively, systems of electical power supply, heat and mobility have to be examined in context

Thanks for your attention – Visit ISET at Stand 7A316

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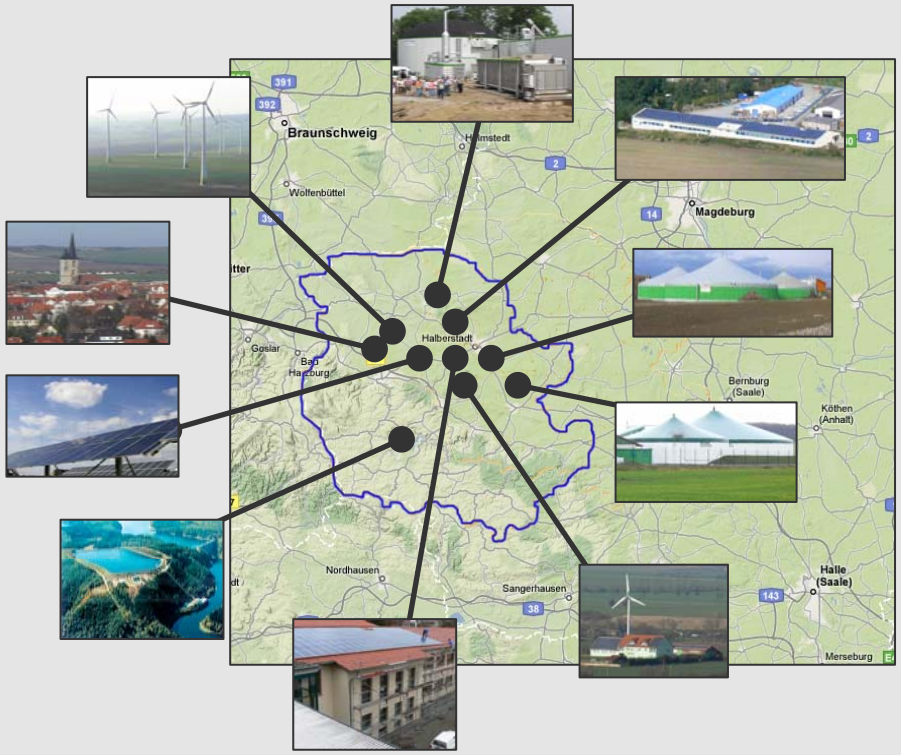

project partners

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Stadtwerke Quedlinburg
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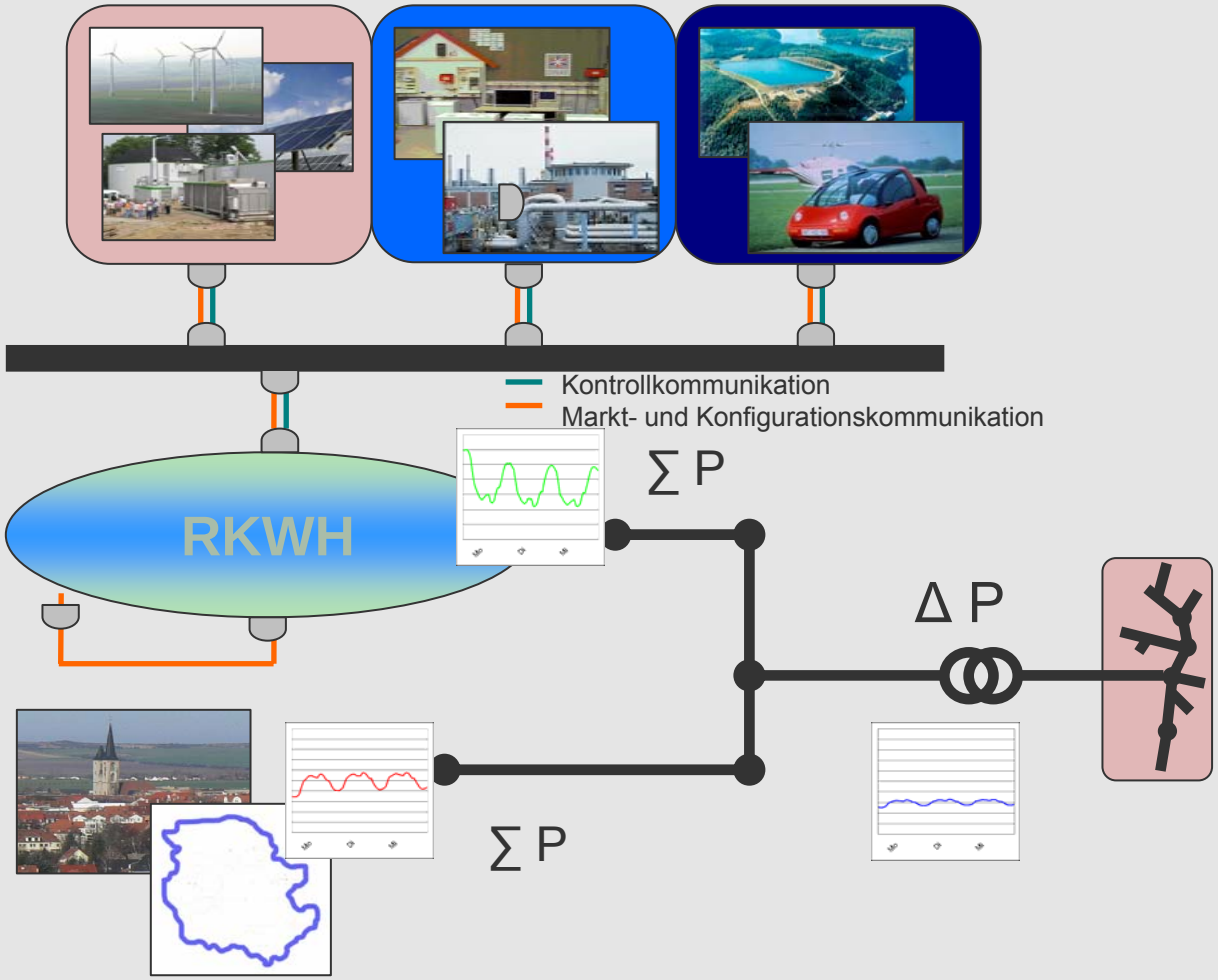

Different control possibilities for the virtual power plant

- Indirect control by price mechanisms
- Direct control by the virtual power plant to offer ancillary services
- Direct control by the system operator in an extreme case

Prerequisite: ICT

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Primary objectives

Climate protection: expansion of renewable energies

Security of supply: supervision of the grid,
active contribution of the power generators, accumulators and consumers

competition: support of the liberalisation process

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Thanks for your attention!

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