Developing the energy supply of the future

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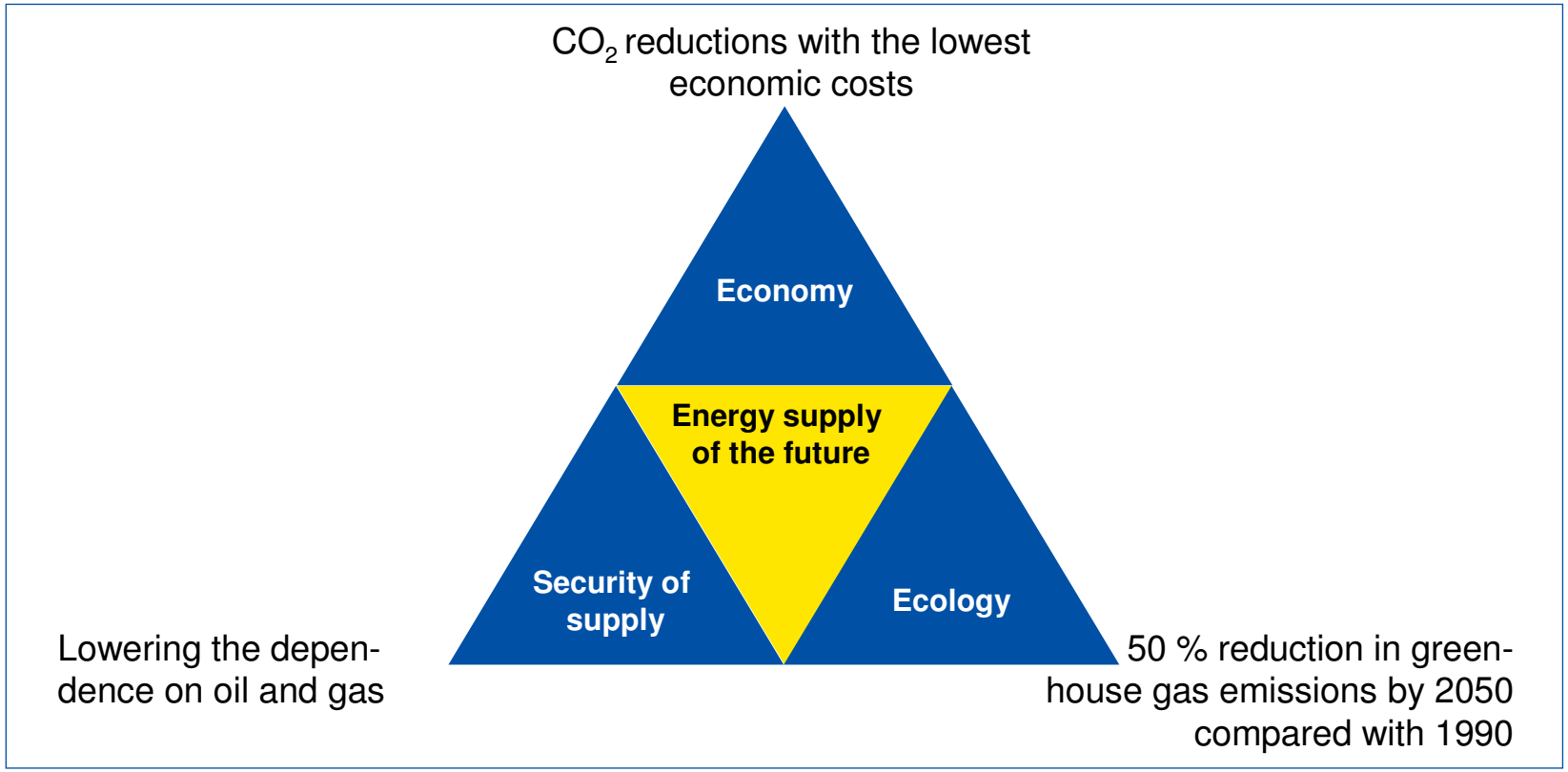
Executive summary – RWE shaping tomorrow's energy supply

- RWE has produced a comprehensive study indicating a viable way ahead for the energy supply.
- In the study, RWE takes a look at the energy sector's technologies regarding their macro-economic, cost-optimal potentials to avoid CO_2 emissions, and gain more security of supply in Germany.
- The result: the targets of climate protection and security of supply are achievable by 2050 using measures that involve CO_2 avoidance costs of max. € 70/t, provided that three primary concepts are systematically applied:
  1. Low-CO_2 electricity mix consisting of wind, expansion of nuclear energy use, coal with CCS* and gas;
  2. Increased use of electricity, especially in mobility, but also in space heating and other sectors;
  3. Systematic exploitation of economic-efficiency potentials in all areas.
- The prerequisites are rationally underlying energy-management conditions able to help cost-optimal and innovative technologies achieve a breakthrough.
- The essential prerequisite is that these required steps are triggered now!

* CCS = carbon capture and storage

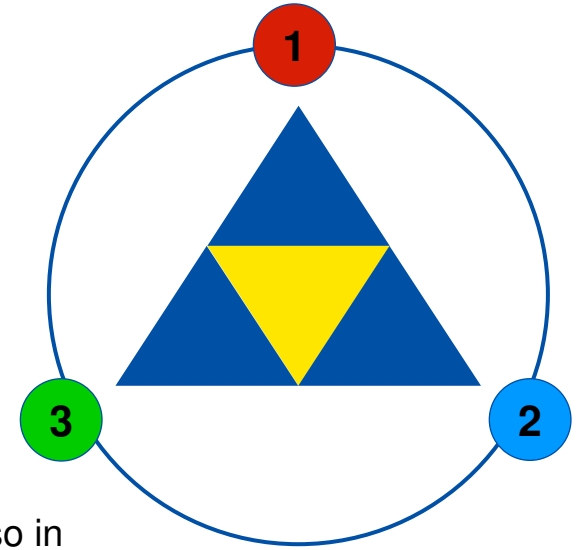
The energy-management triangle must be the yardstick for future energy-supply scenarios

Climate protection, economic efficiency and security of supply must be considered as framework conditions to ensure balanced developments in the future energy supply



For a climate-friendly, secure and economic energy supply, three levers must be used in equal measure

Low-CO_2 electricity mix of renewables, coal with CCS, nuclear energy and gas



Increased use of electricity, specifically in mobility, but also in space heating and other sectors

Systematic exploitation of economic-efficiency potentials in all areas

If all parts are implemented, it is possible to have 80%* lower CO_2 emissions in power generation by 2050

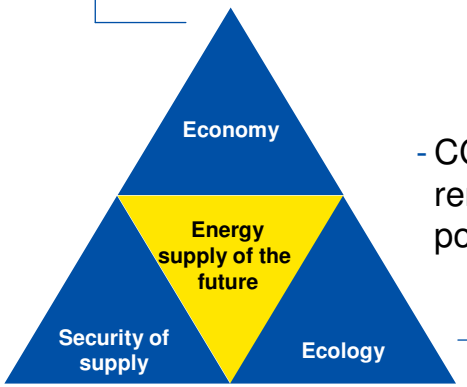
> Tripling of wind-power capacity (esp. repowering and offshore)

> Modernization and switch to CCS in coal-based power generation

> Lifetime extension (and later replacement) of nuclear-power stations

* compared with 1990

- Low-cost coal and nuclear energy
- Wind energy as the renewable with the largest potential



- CCS, nuclear energy and renewables are low-CO_2 power-generation options
- Coal and uranium availability secure in the long term
- Improved system integration of fluctuating of renewable energies

Wind energy with high expansion potential and relatively low CO_2-avoidance costs

Costs and potentials of renewables-based power generation, 2030+ (at suitable locations in Germany)

Technology	Production costs (in €/MWh_{el})		CO_2-avoidance costs (in €/t)		Expansion potential[1] (in TWh)	
Wind (onshore and offshore)	30 - 90	✓	0 - 70[2]	✓	~ 110	✓
Hydropower	20 - 70	✓	-50 - 50	✓	4	✗
Biomass (incl. heat credit)	55 - 150	o	20 - 150	o	3	✗
Geothermal (incl. heat credit)	140 - 200	✗	140 - 250	✗	0	✗
Photovoltaics	180 - 300	✗	210 - 400	✗	0	✗
Ocean energy	3)		3)		0	✗

✓ = Attractive costs or potential o = Depending on system design ✗ = Constraining factor

1) In the period from 2006-2030+ in Germany, at acceptable CO_2-avoidance costs (below € 70/t)
2) At wind speeds of more than 5 m/s
3) Very low potential at the German North Sea, none at the Baltic Sea

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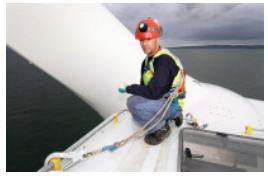
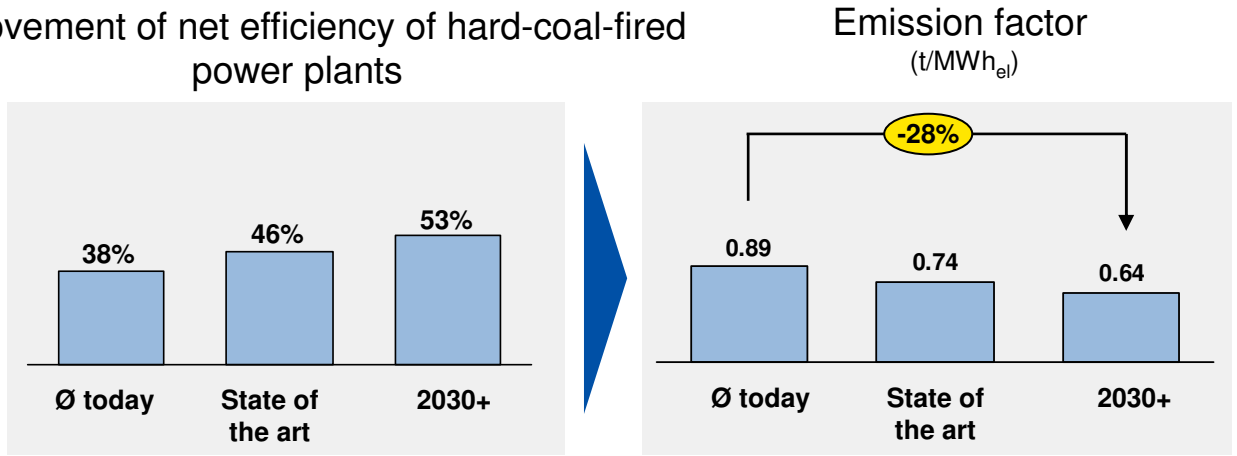
Wind is the renewable energy carrier with the greatest potentials in Germany



- Worldwide, the significance of renewable energies in power generation is rising. Electricity from wind, sun and biomass is representing high growth rates areas on an international level.
- By 2020, 20% of the EU's entire energy consumption is to come from renewable sources – possibly even 30% if a new, global climate-protection treaty is in place.
- Wind power will overcome the threshold of economic efficiency in the near future. In Europe, it offers attractive expansion potentials.
- Expansion of installed wind capacity is expected above all from repowering and offshore systems.
- Geothermal energy and photovoltaics in particular will depend on high public subsidies for a long time to come (photovoltaics is currently some 5-10 times more expensive than, e.g., wind energy or hydropower).
- Biogenic residues and energy crops are limited in their availability. The growing of energy crops (rapeseed, wheat, sugarcane) requires large surfaces and competes with food production. Cultivating short-rotation plants creates forests within the meaning of the law.

Coal remains a vital component with significant CO_2-reduction potential due to modernization of power-plant fleet



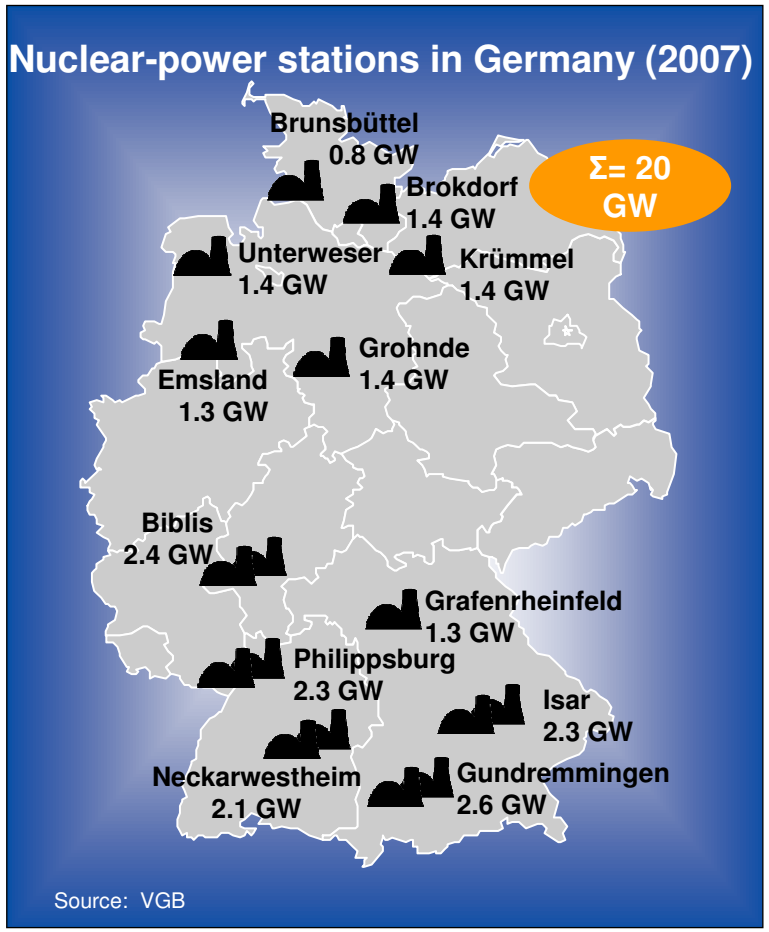
> Fossil energy carriers will continue to dominate power generation in most countries. According to the World Energy Outlook of the International Energy Agency, their share will rise slightly to 82% by 2030. Absolute coal demand will soar, since emerging markets like India and China are building more and more new coal power plants.

> To minimize the negative impact of coal power stations on the climate, it is necessary above all to further raise their efficiency (CO_2 reduction by 30% feasible).

> CCS even offers the possibility of lowering CO_2 by 90%, albeit at a higher cost and with loss of efficiency.

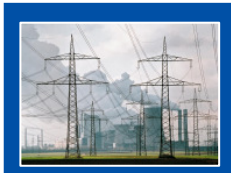
Nuclear energy's crucial contribution to climate protection, economic efficiency and security of supply

- Nuclear-power stations are contributing by 27% to Germany's power generation – virtually zero-CO_2 -emissions
- Safety standards meet very stringent and high requirements. Very long-term utilization is possible (reach of uranium >200 years).
- Nuclear phase-out withdraws 20 GW of low-cost and zero-CO_2 base-load power generation from the market.



All efficiency potentials available in generation, consumption and transport must be exploited

- Increase in economic efficiency for power plants thanks to steady rise in physical efficiencies.
- Information and communication technology (ICT) as cross-section technology enables efficient deployment and control of energy flows in all areas.
- Smart grids harmonize decentralized generation, wind feed-in and consumption.
- Smart meters enable thrifty consumption behaviour thanks to better consumer information.
- Smart homes offer solutions for efficient use of electric household appliances.
- More efficient appliances help to reduce power consumption.
- Improved insulation standards lower heat requirements. Modernizing all buildings takes time, however.
- Due to fluctuations in feed-in, the need for storage rises. Besides pumped hydro storage, compressed-air energy storage and the batteries of electric cars, too, may be suitable for this. Hydrogen (~75% loss, too expensive) is not suitable.



Substituting oil and gas for electricity reduces CO_2, increases security of supply, and lowers CO_2 emissions

Levers for low-CO_2 energy application

Space heating	New heating systems	> Alongside building insulation, the modernization of heating systems is one major lever (e.g. high-efficiency gas boiler) > In today's electricity mix, electric heat pumps already emit less CO_2 than gas boilers > In very well insulated buildings, innovative electricity-based air-heating systems with heat recovery may be the future
Road traffic	Electric mobility	> E-mobility is on the threshold of becoming competitive and already involves lower CO_2 emissions than combustion engines > Using today's electricity mix, an electric car has about 20% lower CO_2 emissions than a comparable petrol or diesel vehicle > In addition to this, electric vehicles drive quietly, emit zero-emissions and reduce the dependence on energy imports > With innovative batteries, electric vehicles will have the range of petrol-powered vehicles in the near future

The path to implementation

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Tripling the installed wind capacity in Germany, especially offshore and by repowering

- We see further capacity increases in onshore wind energy mainly by repowering, i.e. replacing old wind turbines with modern, more powerful models. This requires no extra ground. In fact, repowering even reduces the number of wind turbines at a specific location. The offshore expansion potential is as great as onshore.
- In Germany, there is still quite a high technical/economic surface potential for expanding wind energy. Constraints to this are approval-law specifications/caps, and non technical or financial limitations.
- Compared to wind, other renewable energies are associated with high costs or, in Germany, with very low potential.
- Power generation from biomass is often criticized for competing with food production. One solution is offered by cultivating short-rotation crops in plantations, although it must be ensured that the legal framework is in place for plantations.

Measures required for implementation:

- Elimination of constraints by approval-law specifications
- Adaptation of the Federal Forest Law (*BWaldG*) so as to allow creation of short-rotation plantations without creating forests within the meaning of the Law

Worldwide, coal is indispensable as backbone of the energy supply

- Coal-based power plants will continue to be the backbone of electricity generation in the coming decades. Energy consumption is on the rise worldwide. Highly efficient, fossil-fired power stations will – despite all the progress made in renewables – have to secure a reliable electricity supply in the foreseeable future.
- In Germany, extensive substitution investment is still needed: power plants with a capacity of over 40,000 megawatts must be renewed due to age reasons by 2020.
- State-of-the-art power stations offer a higher capacity together with lower emissions and less resource consumption.
- In the long term, what matters is to implement the vision of a climate-saving coal-fired power plant with CO_2 capture and storage (CCS). This would be a significant contribution to solving the CO_2 problem.

Measures required for implementation:

- Promotion of research and development regarding coal-based power stations
- Adoption of an investment-friendly CCS law to enable the construction of demonstration plants in time
- Decision on the funding of CCS demonstration plants with EU emission-trading certificates
- Active support by policymakers and approval by authorities in planning and building the CO2 infrastructure

We need nuclear energy for security of supply and to achieve climate-protection targets as well.

- Germany's nuclear-power stations are exemplary regarding safety – irrespective of age and operating life.
- Nuclear energy dampens electricity-price developments. An expertise by the EWI* shows that wholesale electricity prices in 2020 will be 11% lower if the operating span is extended in contrast to a phase-out. An extension to 60 years would even prevent a price rise by 24%.
- Nuclear-power generation represents zero-CO_2 emissions: It is a cost-efficient option for reducing CO_2 emissions!
- The problem of final atomic waste storage is technically solved. However, final storage is already today necessary irrespective of a nuclear power station's operating span.
- Nuclear energy and renewables complement each other: nuclear energy and lignite/run-of-river underpin renewables in the base load.
- Nuclear energy is economically efficient: Its competitiveness is in fact growing with regard to CO_2-emissions trading and expected fuel-price developments. Low fuel costs and the absence of CO_2 costs overcome the higher investment costs of new nuclear-power stations.
- There is sufficient uranium: At current consumption levels, today's reserves will last some 200 years (OECD/NEA and IAEA).

Measures required for implementation:

- Repeal of the phase-out decision
- Setup of a final-storage facility

* Institute of Energy Economics, University of Cologne

Efficiency increase as basis for boosting the use of low-CO_2 electricity

- Energy efficiency can be increased above all by using more efficient technologies. The less primary energy is needed for the same energy service, the more efficiently the energy is being handled.
- Intelligent modernization of existing buildings can lower heat requirements by more than 50%.
- Taking account of incoming daylight during construction planning, together with energy-saving light bulbs, the electricity efficiency of lighting can be considerably increased.
- An intelligent infrastructure harmonizes generation and consumption, while smart meters help us learn more about our consumption behaviour.
- Better insulation standards lower heat losses.
- Due to fluctuations in feed-in, the need for storage rises. Besides pumped hydro storage, compressed-air energy storage and the batteries of electric cars, too, may be suitable for this. Hydrogen (~75% loss, too expensive) is not suitable.

Measures required for implementation:

- Promotion of the use of energy-efficient appliances
- Provision of more information on energy efficiency and energy advice
- Further promotion of research into intelligent infrastructure
- Provision of consumer information on appliances' stand-by mode
- More research into storage technologies

Increased use of electricity in the heating systems of well-insulated buildings

- Heat pumps predominately use environmental heat and add a residual electricity quantity
- Electricity-based heating concepts (e.g. direct heating in ventilation heat recovery) are potentially attractive in buildings with high insulation standards (e.g. passive houses)
- The system load associated with fluctuations in the feed-in from renewable energies might be homogenized in future due to electricity-based heating concepts

Measures required for implementation:

- Promotion of heating system modernization
- Provision of energy counselling for consumers, industry and public buildings
- The ban on night-storage heating should be reassessed
- Promotion of heat pumps

Making e-mobility mass-marketable requires joint efforts

- E-mobility is an important innovation with high growth potential. The number of vehicles worldwide is expected to rise from 700 mill. today to some 1bn by 2020.
- If implemented on a broad basis, e-mobility can make a crucial contribution to the security of supply and environmental protection at competitive costs.
- Crucial advantages in cities and conurbations are lower CO_2 emissions, less inner-city fine-dust and noise nuisance, as well as the option of new traffic concepts.
- Ongoing pilot projects are not enough to help e-mobility to achieve a breakthrough. The political support is essential for a rapid market development.

Measures required for implementation:

- Creation of ground-covering and standardized charging infrastructure
- Attractive offers of electric vehicles
- Improved battery technology
- CO_2-based car tax
- Onetime bonus for buying electric cars

RWE takes responsibility for implementing the targets

RWE has launched the biggest investment programme in its corporate history. For the upcoming ten years, we are planning to invest 70 to 80 billion Euros.

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RWE generates power from wind, water and biomass and is contributing actively to the expansion of renewable energies throughout Europe

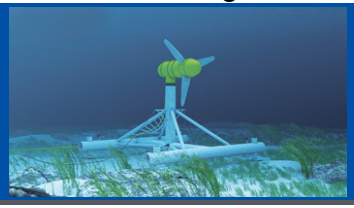
RWE Innogy, set up in 2008; 2,200 MW installed power-plant capacity, 1) target: renewables: 30% of installed power by 2025, Average investment € > 1bn per year
Examples:

	Offshore wind Gwynt y Môr	Start of construction: 2011 Final commissioning: 2014	Electrical output:	576 MW
	Offshore Wind North Sea East	Start of construction: 2011 Final commissioning: 2013	Electrical power:	288 MW
	Run-of-river power plant Total >60 run-of-river power plants, incl. 45 in D	Currently rebuilt: Rheinkraftwerk Albbruck-Dogern AG (majority shareholding of RWE Innogy) Commercial operation end 2009	Investment: Output increase	€ 70m of 24 MW to 104 MW
	Biomass CHP plant Siegen-Wittgenstein	Pure virginwood-plant Trial operation 2009 Commercial operation Q1 2010	Investment: Electrical output: Thermal Power	€ 20m max. 7MW 25 MW

1)Incl. Essent-Units. State Q4 2009. Accounting View & Power Purchase Agreements. Plants are in operation.

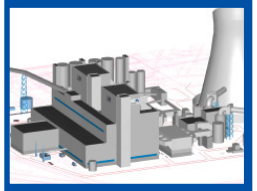
New technologies for renewable energies are being developed and introduced into the market

Innovation regarding renewable energies by means of R&D, demonstration power plants or venture capital – Examples:

Geothermal energy	Ocean energy	Decentralized wind power	Biomass
> In two large depth geothermal-energy projects in southern Germany, the geothermal potential of a round about 100 km^2 – surface area per project is investigated through the next three years. > Deep geothermal energy can generate base-load-capable electricity	> Marine current turbine planned in northern Scotland > Full size Prototype 1MW in cooperation with developers and manufactures > Objectives: test and operational experience > Wave power plant Siadar 4MW in north Scotland approved > Commissioning 2013	> RWE Innogy holds a minority share in Quiet Revolution Ltd. > Main product: vertically aligned, spindle-shaped micro-wind turbines with 6 kW output > Roof installation possible	> Shareholding in Topell: company with ground-breaking process for converting biomass into bio coal pellets > Biogas plant Güterglück: upgrade of biogas to natural-gas quality and feeding into a natural gas grid (in operation since Q3 2009)
			

By 2012, with investment of some 7bn Euros in modern power plants, RWE is tapping a CO_2 reduction potential of 25-30%

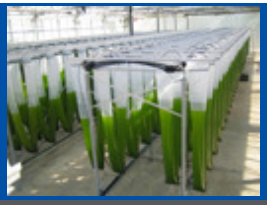
CO_2 emissions of fossil-fired power stations can be lowered significantly thanks to modern power-plant engineering – Examples:

					Spec. CO_2 reduction*
	*BoA* 2&3 Neurath	Construction phase Comm. operation after 2010	Investment: Electr. output: Efficiency:	€ 2.2bn 2,100 MW_n > 43%	> 30%
	Hard-coal-fired power plant Westfalen	Construction phase Comm. operation after 2011	Investment: Electr. output: Efficiency:	€ 2.0bn 1,530 MW_n 46.0%	> 25%
	Hard-coal-fired power plant Eemshaven	Approval phase Comm. operation after 2012	Investment: Electr. output: Efficiency:	€ 2.4bn 1,560 MW_n 46.5%	> 25%
	Gas and steam turbines CCGT-plant Lingen	Construction phase Comm. operation since 2010	Investment: Electr. output: Efficiency:	€ ~500m 876 MW_n 58.6%	> 25%

* compared to existing plants

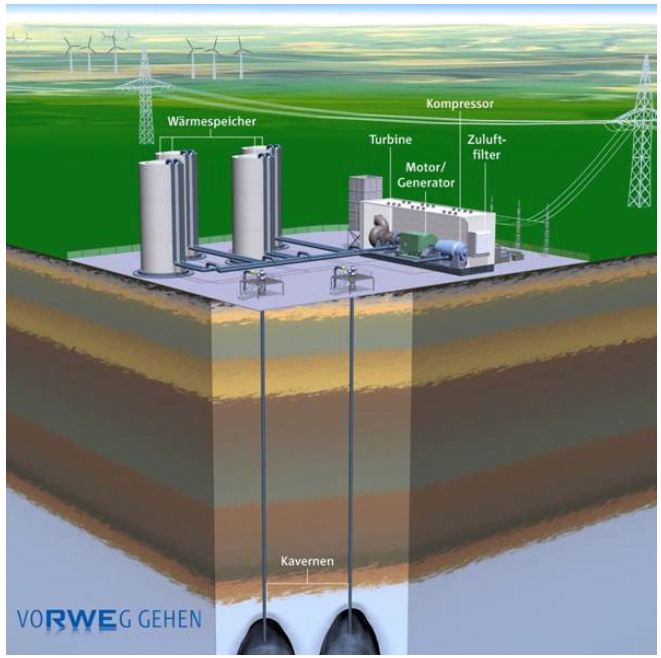
The Coal Innovation Centre is engaged in various research projects making coal fit for the future

Under the motto "The region does the research, the world reaps the benefits", four major projects are being implemented in the Coal Innovation Centre at the Niederaussem location:

Fluidized-bed drying	CO_2 scrubbing	*REAplus*	Pilot plant for algae breeding
In the prototype plant, RWE Power is constructing the pre-drying of lignite, a self developed process, using the fluidized-bed method, to commercial-scale maturity. The aim is to increase the efficiency by a further four percentage points.	The pilot CO_2 scrubbing plant Niederaußem is already successfully testing the capture of carbon dioxide from the flue gas.	The research project "High-performance scrubber *REAplus*" is designed to open up options for further emission reductions.	RWE's algae project, which is unique worldwide, researches options for binding CO_2 from power-station flue gases within useful plant substance.
			

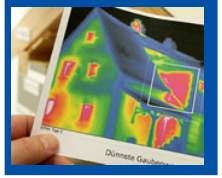
RWE is engaged in the further development of adiabatic compressed-air energy storage

- Due to the expansion of renewable-power generation, especially regarding offshore wind, and the intended expansion of electricity production via combined heat and power, the amount of not demand-correlated power production will rise. This requires intelligent solutions to ensure a reliable power supply around the Clock. Thus power storage units will gain more importance in future.
- ADELE (Adiabatic compressed air energy storage for electricity) recovers heat that was generated by compressing the air, uses it and achieves an efficiency of up to 70% (up to now approx. 50%).
- This process, referred to as advanced adiabatic compressed-air energy storage (AA-CAES), means heavy duty requirements on various system components, which are not yet available nowadays.
  Therefore RWE Power, jointly with General Electric, Züblin and the German Aerospace Center is investigating the feasibility of such an innovative power plant providing the basis for a corresponding development program. Construction and operation of a first demonstration plant are scheduled to follow after 2013.



Energy-efficiency within the whole picture: RWE investing 150 million Euros in energy efficiency at customers' premises

Reaching for less raw-material consumption and better climate protection, R&D work is of great importance. Households and commercial customers benefit from another experimental RWE research project

 100,000-meter programme	RWE launches the first large scale installation of smart meters in Germany. It includes 100,000 modern electricity meters in Mülheim a.d. Ruhr and means higher energy efficiency and cost transparency for customers
 E-energy	Development of an e-energy "Market place of the future". Using and linking innovative technologies from energy, information and communications will in future enable completely new offers and services for utilities and electricity customers.
 Innovative heat efficient products	RWE will introduce more heat efficiency into private dwellings: Radiators will be controlled using a central display, a personal computer or even remotely by a cellular telephone.
 5,000-town-hall programme	Applicants are offered an energy-saving check including an energy passport for the building. The buildings are usually public property. The funding budget concerned depends above all on the size of the municipality, but is at least 1,000 Euros.

* Cooperation of RWE Energy, Siemens Energy, ef.Ruhr (collaboration of the energy-technology chairs of the universities of Duisburg/Essen, Bochum and Dortmund), Miele, Stadtwerke Krefeld and ProSyst.

"E-mobility Berlin": Daimler and RWE launch the age of electric mobility

- RWE is working on establishing technical standards and on the rollout of a charging infrastructure. Already more than 200 charging points have been built with emphasis on Berlin and the Ruhr conurbation along the A40.
- RWE has already registered more than ten patents.
- To accelerate infrastructure installation collaborations were set up with different established partners. Thus e.g. RWE has made an agreement with Renault for the promotion of zero emission mobility in Germany.
- *e-mobility Berlin* is the world's largest joint project for climate-friendly electric cars involving more than 100 electric vehicles - provided by Mercedes-Benz and Smart - as well as 500 charging points from RWE.
- Specific offers: e-package containing electric car + charging points + RWE electricity in NRW; RWE car electricity road show in Germany, public charging points in Berlin, Essen, Mülheim, Dortmund and other cities.
- Among the most important vehicle-related innovations is the lithium-ion battery specially developed for automotive use.
- When suitable batteries are available, re-feeding the stored energy from the vehicle into the grid (vehicle-to-grid) will also be possible.

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