Energy gets smart.

e·on

Prof. Dr. Klaus-Dieter Maubach
E.ON AG Board of Management
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Dear Readers,

the world's energy appetite continues to grow. At the same time, there's an urgent need to tackle climate change which means deriving much less energy from fossil fuels. We also need to keep energy affordable and maintain a balanced energy mix. To meet these challenges successfully, we need a smarter energy system. At E.ON, smart energy is more than a vision of tomorrow. We're making it happen. By developing and deploying the technologies, products, and services that will have the most positive impact. Along with rapidly expanding our renewables capacity, we're devoting substantial resources to three key areas: energy efficiency, e-mobility, and smart grids. Smart solutions for homes and businesses will empower consumers to use energy more efficiently and to manage their usage more actively. More consumers will soon be able to use their mobile phone to control the heat in their home—so they can return to a warm living space without wasting energy while they're away.

Mobility will become smarter, too. Over the next decade, the arrival of millions of electric vehicles will make Europe's transport sector less carbon intensive and its cities cleaner and quieter. Moreover, the batteries of these vehicles will constitute a large distributed storage system that will enable us to manage the intermittent output from renewables more efficiently. The complex energy flows of an increasingly decentralized energy system will require a power grid that's been upgraded with sensors and information and communications technology. The smart grid will play a key enabling role in the transition to a low-carbon future.

This brochure describes some of the challenges we face, the smart solutions we're developing to meet them, the progress we've made so far, and the steps that are yet to be taken. We hope you enjoy reading it and that you'll join us in the journey to a smart energy future.

Yours sincerely,

Heat pump with heat storage

Micro CHP in testing operation

Efficient living and efficient buildings: energy efficiency

Three issues dominate the debate about energy: cost, security, and environmental impact. These issues—and their potential solutions—are often complex. But one simple solution—energy efficiency—is already available and will play an increasingly important role in the future. Smart meters and automation devices make it possible to manage energy use more effectively in homes and commercial buildings. Advanced insulation and low-energy lighting reduce overall consumption. Heat pumps consume less energy than standard gas or electric heating units, and millions of in-home combined heat and power (CHP) units will mean fewer new large-scale power stations will have to be built.

At E.ON, we're actively promoting energy efficiency as part of our effort to make tomorrow's energy cheaper for customers, less dependent on imported fossil fuel, and more sustainable.

What we're doing to make it happen

- conducting smart-home and smart-facility demonstrations, as part of the Thinking Energy Program, in Germany, the U.K., and Sweden to understand future home technology, its impact on customers, and its end-to-end benefits in real-world situations (page 6)
- funding field trials of heat pumps to study how human and environmental factors affect their performance (page 7)
- leading the way to bring the low-carbon benefits of micro CHP to residential customers (page 8)
- collaborating with leading companies and universities to understand the role, impact, and benefits of flexible demand management for heating and cooling commercial buildings (page 9)
- partnering to develop and install low-energy LED street lights that reduce cities' carbon emissions and electricity bills (page 10)

Field tests of electric vehicles are conducted for example in the U.K. and in Germany

Taking it to the streets: e-mobility

Transportation is responsible for 20 percent of Europe's man-made carbon emissions. So to tackle climate change we need to shrink our carbon tire print. E-mobility will play an important role. Electric vehicles are cleaner and quieter than conventional cars and trucks. They'll make mobility greener and one day could serve as a huge distributed energy storage system.

Many countries want to reap the benefits. Europe aims to have eight million electric vehicles on the street by 2020. E.ON actively supports the development of this promising technology through a company-wide e-mobility initiative.

What we're doing to make it happen

- conducting field tests of vehicles and charging points in Germany (page 11–12), the U.K. (page 13), Sweden, and Spain to learn more about driver behavior, resolve technical issues, and raise public awareness
- collaborating with universities in Aachen, Berlin, Coventry and Munich as well as with national research institutes to spur electric vehicle research and development
- testing technologies to make charging easy and efficient (page 14)
- studying how electric vehicles could comprise a smart, distributed energy storage system (page 12)
- exploring ways to provide electricity for recharging electric vehicles exclusively from renewable sources

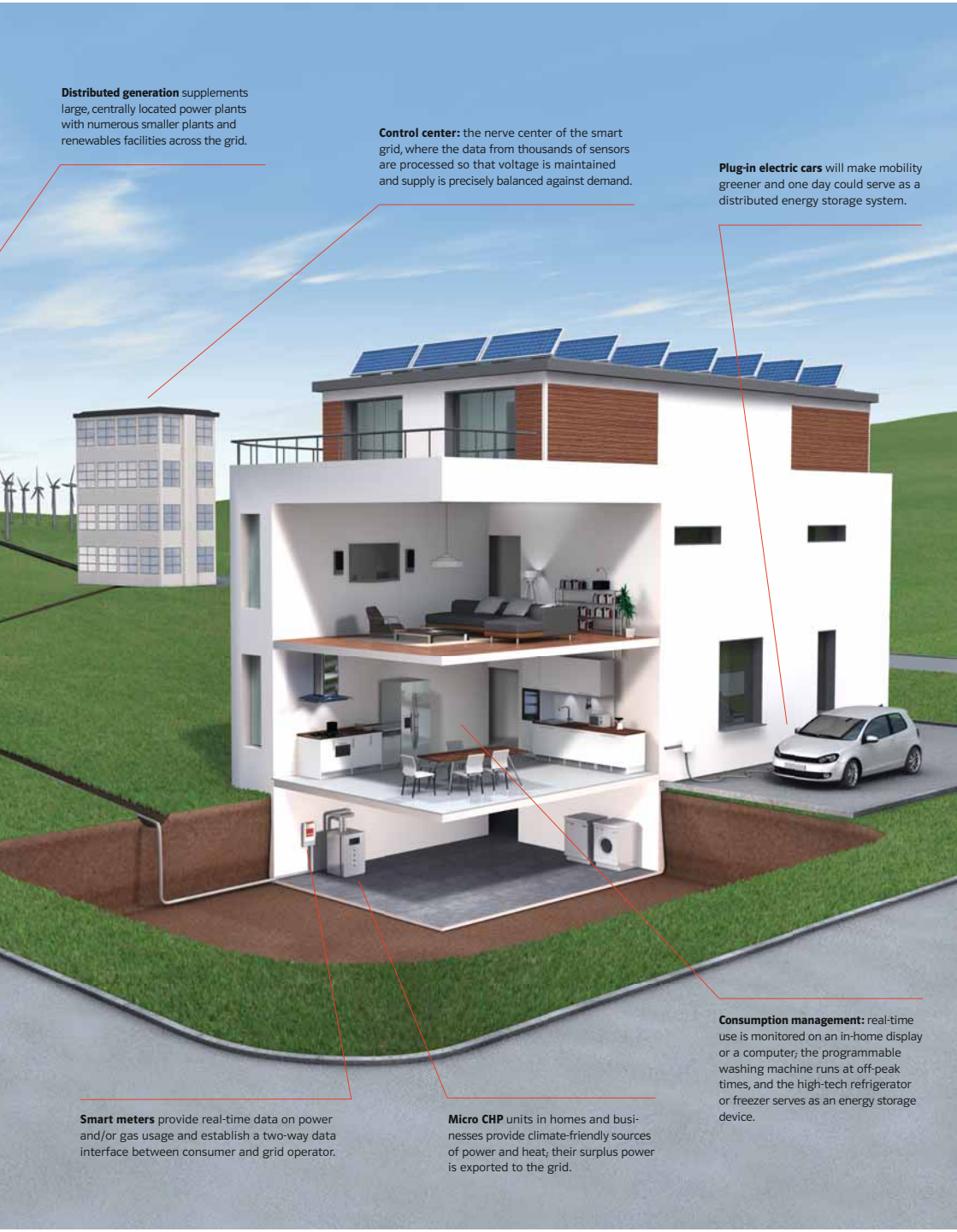
Watts with a byte: smart grids

A sustainable energy system will need more than low-carbon technologies. It will also need the right infrastructure: large-scale energy storage systems and smart grids so that we can fully utilize the intermittent power flow from wind and solar farms and integrate thousands of smaller, distributed energy generating units. Today's grid, built when electricity was generated at a relatively small number of big power stations, can't do all that. It needs sensors, data links, processing power, and automated controls. In short, it needs smart technology. When bytes of information flow with watts of energy, we'll have the ability to actively and efficiently integrate low-carbon technologies and to manage increasingly complex consumption and generation patterns. It's the energy infrastructure we need, to make a low-carbon future a reality.

What we're doing to make it happen

- installing smart meters in millions of homes and businesses across Europe to give customers the information they need to use energy more efficiently (page 15)
- installing technology to increase the capacity of our existing power networks and make them more active and dynamic so that we can maximize the amount of power we draw from renewables (page 16)
- learn more about load situations in our distribution grids, especially with regard to the feed-in from photovoltaics into the low-voltage network (page 17)
- we simulate the impact of future consumer behavior on the network (page 18)
- developing prototype solutions for the sustainable city of the future that optimize the overall energy and transport system (page 19–20)

Smart grids will use sensors and data communications to increase distribution capacity, enhance efficiency, and manage power inflows from thousands of distributed sources as well as the timing of power demand.


Distributed generation supplements large, centrally located power plants with numerous smaller plants and renewables facilities across the grid.
Control center: the nerve center of the smart grid, where the data from thousands of sensors are processed so that voltage is maintained and supply is precisely balanced against demand.
Plug-in electric cars will make mobility greener and one day could serve as a distributed energy storage system.
Consumption management: real-time use is monitored on an in-home display or a computer, the programmable washing machine runs at off-peak times, and the high-tech refrigerator or freezer serves as an energy storage device.
Smart meters provide real-time data on power and/or gas usage and establish a two-way data interface between consumer and grid operator.
Micro CHP units in homes and businesses provide climate-friendly sources of power and heat; their surplus power is exported to the grid.

Promoting sustainable living: Thinking Energy Program

Homes are responsible for about one quarter of Europe's carbon emissions. For Europe to meet its climate-protection targets, homes need to become more sustainable and smarter. More sustainable means using energy more efficiently and conserving resources. Smarter means being able to integrate in-home generation technologies, electric vehicles, and active energy management and to function as part of a smart grid.

Showcasing the homes of tomorrow

We've initiated the Thinking Energy Program to showcase the homes and buildings of tomorrow in three countries: Germany, the U.K., and Sweden. The program's aims are to learn more about smart and efficient technology, raise public awareness of its energy-saving and climate-protection benefits, and promote its adoption. In Malmö, Sweden, we're partnering with other companies to construct a block of homes that incorporates cutting-edge technology and building techniques; combined with Malmö's existing smart-meter network, the project will result in one of Europe's smartest streets yet. In the U.K., where 80 percent of the projected 2050 housing stock have already been constructed, our focus is on identifying technologies and techniques that reduce the carbon emissions of existing homes while maintaining customer comfort and control. In Germany, we're examining both new and older homes and participating in projects to make commercial buildings smarter. We can take the lessons learned in all three countries and share them across our markets so that we can help our customers throughout Europe to find the best solutions for reducing their home's carbon footprint.

We all need to consider how best to manage energy use in our homes

Home is where the heat is: heat pumps

Except in the sunny South where the heating season is shorter, space and water heating account for a big share—usually more than 75 percent—of home energy consumption in Europe. So improving efficiency in this one area will make a significant contribution to climate protection. Heat pumps are a particularly promising option. Heat pumps extract heat from an outdoor source (the air, soil, or groundwater) and use it to help heat the home. This makes them much more energy efficient than typical home heating units. For instance, an air-source heat pump's average performance rating for space heating can be as much as 300 percent compared with about 90 percent for a modern gas boiler. Moreover, the increase in efficiency is affordable: heat pumps cost about the same to operate as the systems they replace.

Pump up the volume

The U.K. government estimates that the country could have 20 million new heat pumps installed by 2050. There's potential for expansion of the European heat pump market, too. To help customers tap into this potential, we're funding field trials of heat pumps in the U.K. and Germany to study the factors—such as installation techniques, usage habits, and local climate—that impact heat-pump performance. Our aim is to identify and continually refine best practices so that our customers—and the earth's climate—derive the maximum benefit from this low-carbon, renewable technology.

Heat pumps are an efficient renewable source of energy

Increasing domestic production: micro CHP

Wouldn't it be nice, many governments think, if their country produced more energy at home and imported less from abroad. In the not-too-distant future, millions of homes will be doing just that: producing energy themselves and importing less from the grid. A single in-home unit varying from the size of a dishwasher to a frige or freezer will keep occupants warm, provide them with hot water, and meet most of their electricity needs. The technology is called micro combined heat and power (CHP). Because it does two things at once—generates both heat and electricity—micro CHP is highly efficient and thus climate friendly. And because the residential heating market is so big, micro CHP has great climate-protection potential.

Readying for the mass market

Take Germany for example, where about 700,000 families replace their gas boiler each year. Upgrading these boilers to micro CHP units would yield additional annual carbon emission savings of about one million metric tons every year. With 1.5 million heating systems replaced each year in the U.K. alone, on a European scale the savings could be enormous.

At E.ON, we're working with the world's leading micro CHP manufacturers (Whisper Tech, Energetix Group, Ceramic Fuel Cells Ltd) to make this technology ready for the mass market. Our research and development program includes tests of the WhisperGen, a gas-fired micro CHP unit, in customer homes. We're also participating in Callux, Germany's largest field trial of fuel-cell micro CHPs, which will involve installations in more than 800 homes by 2012.

eon.com/chp

In-home CHPs can reduce the reliance on large scale power stations

Matching consumption to supply: flexible demand management

Because electricity can't easily be stored in large quantities, generation must exactly match consumption every minute of every day. This requires accurate demand forecasts, careful monitoring of real-time data, and reserve capacity: power stations running below full output, ready to be turned up to meet spikes in demand.

Flexible demand management takes the opposite approach: reducing spikes by shifting demand—by a few minutes or hours—to meet supply. This offers several benefits. It puts less strain on aging power distribution networks. It helps maximize the use of wind and solar power by moving demand to windy or sunny times of the day. It can reduce annual carbon emissions by 300 to 700 metric tons for every megawatt of fossil-fueled reserve capacity rendered unnecessary. And it can save customers money by limiting their usage during peak-demand periods when electricity costs the most.

Demonstrating demand flexibility

In late 2010, an E.ON-led consortium have completed a large-scale, two-year project to demonstrate flexible demand techniques in commercial heating, ventilation, and air-conditioning systems at a number of sites in the U.K. and to determine what communications and metering equipment these techniques require. The consortium includes other utilities, leading academics, and forward thinkers and is funded by the U.K. government through its Technology Strategy Board. The data gathered from this project will enable us to calculate the potential of flexible demand management for the U.K. as a whole and for other European countries. The project is thus a significant step towards lowering carbon emissions and meeting the challenges facing the power industry.

Flexible demand management helps to maximize the use of wind power

Illuminating a path to the future: advanced LED lighting

Europe has over 90 million street lights. They help to prevent traffic accidents and discourage crime. But they also consume a lot of electricity which in turn costs money for city authorities. They also create what's known as urban light pollution. It's estimated that Europe's street lights consume about 70 terawatt-hours of electricity each year. That's about 2.5 percent of total EU consumption and three times Sweden's residential consumption. Advanced LED technology will soon make street lighting more sustainable by reducing its consumption.

Let there be light—but less carbon

E.ON is leading the way with the Marlin LED street light, developed in partnership with Coventry-based Advanced LEDs Ltd. The Marlin emits equivalent light levels but lasts up to ten times longer than a standard sodium light. It consumes 70 percent less electricity and at one third of the lifetime costs. Successful trials at E.ON sites in the U.K. demonstrated that the Marlin meets the U.K.'s high standards for street lighting and that its superior, whiter light improves overall visibility and the resolution of CCTV pictures, promoting public safety. LED lights like the Marlin, which already form the backbone of our public lighting business in the U.K., could reduce Europe's annual carbon emissions by 19 million metric tons. Our aim therefore is to help as many cities as possible to reduce their energy costs and carbon emissions by lighting their streets with LEDs.

LED street lights help to reduce energy and lower carbon emissions

E-mobility in Munich

In July 2010, we completed a one-year field test of 15 battery-powered BMW Minis in Munich. To conduct the test, we set up a network of E.ON installed home charging stations. Much of the electricity for the charging points came from E.ON hydroelectric stations. The 15 Minis logged an average of 10,000 km each during the trial. And being charged largely with hydropower made them almost as climate friendly as bicycles. The trial has given us valuable insights into drivers' needs and expectations. For example, while some drivers found no inconvenience in plugging in their car to recharge it, the majority expressed a desire for cable-free charging technology (for more on what we're doing to refine such a technology, see page 14). The trial also provided us with data we can use to help predict the impact a large number of electric vehicles would have on the power system.

Munich is also the site of eFlott, a one-year trial with 20 Audi A1 plug-in hybrids which started in September 2010. From mid of 2011 the Audis will be driving on the streets. As the name suggests, the hybrid veicles have both, an electric motor (for short trips around town) and an internal-combustion engine (for longer trips). The objective is to make the switch to clean, efficient, battery-powered cars as simple as possible.

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The A1 e-tron will be driving on the streets of Munich starting mid of 2011

Part of a network: fleet trial in Wolfsburg and Potsdam

Since June 2008, E.ON, along with Volkswagen and other partners, has been part of an "E-mobility fleet trial". Starting in 2011, 20 Golf Twin Drive vehicles will be out and about, testing hybrid technology in daily life. One of the project's objectives is to use smart charging of the cars to incorporate renewable energies into the grid as smoothly as possible, which will help make zero-emissions driving an affordable experience. The Twin Drive marks the first practical test in Germany of time-variable controlling of charging with feed-in of electricity back into the network (vehicle-to-grid), with charging controlled by means of a Smart Meter. The variable electricity prices used in the project reflect the situation as it will be in the future, when the energy mix will contain a high proportion of renewables. Prices are updated hourly and transmitted to the Smart Meter a day in advance. Users can retrieve the currently valid prices and charge times at any time via a protected area in the internet or on their smartphone, giving them the opportunity to make informed decisions on their charging behavior.

The trial's participants receive a monthly statement of how much they have 'earned' through these decisions over the past month. The savings they make are paid to them, creating a real incentive for energyefficient behavior. For E.ON, the fleet trial is an opportunity to push the development of its technology for charging electric vehicles, which will result in the debut of a fast charging point using DC electricity, making it possible for the Twin Golf's battery to be fully recharged within a very short time. As the effects of this procedure on the battery have not yet been studied in detail, the test will provide important insights in this regard. The German federal government recognizes the potential this concept has to offer and is supporting the fleet trial.

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E.ON is one of the partners of the "E-mobility fleet trial"

Charging ahead in the English Midlands

The Midlands, the birthplace of British carmaking, is now leading the way in eco-motoring. It's the site of Britain's first large-scale trial of electric vehicles: the Coventry and Birmingham Low-Emission Vehicle Demonstrator (CABLED). CABLED, made up of 13 organizations (E.ON, the two city councils, three local universities, an engineering consultancy, and six vehicle manufacturers), is the largest of eight consortia participating in a £25 million government-sponsored, U.K.-wide demonstration program for low-carbon vehicles.

In CABLED's trial, which started in December 2009, real-world users will test a total of 110 vehicles of several types (electric cars, electric vans and plug-in hybrids). The project will gather data on how the vehicles are used, when they need charging, and how drivers' respond to different vehicle technologies. The ultimate aim is to help remove barriers to the wider adoption of low-carbon vehicles, which are essential to the U.K. achieving its target of reducing carbon emissions by 80 percent by 2050.

Hooking up CABLED

E.ON is the exclusive energy partner for CABLED and is providing charging infrastructure consisting of 90 at-home, 36 public charging points and for 18 workplace locations. And by analyzing usage of these points, we'll gain vital insights into how many points will be needed and where they should be located so that we can prepare for the day when millions of electric vehicles are humming down British roads.

The electric car Mitsubishi i-MiEV has a range of up to 140 kilometers

Cable-free charging

If electric vehicles are to go from novelty to ubiquity, they'll need a safe and easy-to-use charging infrastructure. Drivers won't be content to charge their electric vehicles at home. They'll expect the convenience of being able to top up the battery at convenient places—while parked in the garage at home, at work, or while out and about in the city—charging means parking.They'll also want recharging to be simple and safe.

Inductive recharging, already used in millions of electric toothbrushes and shavers, is a particularly attractive option. It transfers energy using electromagnetic fields without the need for a cable. In the future, drivers will simply park their electric vehicles in a parking spot that has an inductive-recharging unit embedded in its surface.

Testing technology, setting standards
E.ON is actively involved in developing and testing efficient cable-free charging solutions. We're also partnering with TÜV Süd, a globally recognized testing and certification institute based in Munich, to establish strict minimum safety standards for inductive-charging systems. And to ensure that in tomorrow's energy world, vehicle recharging is cable-free and hassle-free.

eon.com/inductivecharging

Inductive charging: supplying power to electric vehicles without cables

Smartening up homes across Europe

An energy bill can only tell customers how much energy they've used in the past. Smart meters provide immediate feedback, enabling customers to understand, manage, and optimize their usage. Independent studies and our own experience suggest that smart metering can help residential customers reduce their energy usage by 3 to 10 percent. On a European scale, that's a massive savings in both energy and carbon emissions. Smart meters can also store customers' consumption data, information that will help us develop new products and services that are better tailored to our customers' needs, daily routines, and lifestyles. And smart meters can be read remotely, which makes billing more accurate, informative, and timely. Smart metering is not only a valuable energy-saving tool; it's a technology that enables E.ON to partner with our customers on the road to a low-carbon future.

Multi-million-meter rollout under way

We're a European pacesetter in smart metering. We've already installed more than one million smart meters in Sweden and 130,000 in Spain (where 620,000 more are due to be installed by 2018). As smart meters are rolled out in our other markets, we'll use this experience to help our customers realize this technology's full energy-saving potential. At the moment preparations are under way for the mandated rollout of smart gas and electricity meters to around five million customers in Britain.

eon.com/smartmeter

Installation of smart meter technology

Increasing network capacity to harness more wind power

We operate power networks in breezy northern Germany, which is also home to lots of wind farms. There are so many, in fact, that on blustery days they sometimes have to reduce their output because it exceeds the capacity of the network, which was built about 50 years ago. Our challenge is to find innovative ways to move as much renewable power as possible using our existing lines. One way is called dynamic thermal circuit rating (DTCR). As more power flows through a line, the line gets hotter, expands, and eventually begins to sag. If a line sags too low, it's unsafe. Power lines are cooled by air and wind, so their capacity is higher on a brisk, breezy day. But to ensure network reliability, a line's assigned capacity (known as its static rating) is based on a worst-case scenario: an unseasonably warm, windless day.

Dynamic rating: a wind-wind solution

With DTCR, smart technology is applied to existing lines so that their capacity utilization is based on actual—not worst-case—air temperature and wind speed. Sensors along the lines transmit weather data to a computer at our control center, which calculates exactly how much each line can carry and remotely controls wind farms' output so that our network can operate at near its maximum safe capacity. DTCR has increased capacity on 1,000 km of our lines in Germany by up to 70 percent. Over the next five years, we're upgrading an additional 10,000 km of lines with DTCR. Going forward, we also intend to increasingly apply this technology in the U.K., Sweden and Spain. More wind means more green power and, thanks to smart technology, more capacity to bring it to customers. A true win-win solution.

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Upgrading the overhead-lines

Meeting the challenges of decentralized generation in Bavaria

If often-overcast Germany has a sunbelt, it's Bavaria. On average, Bavaria enjoys the most hours of sunshine per day of any region in Germany. Thanks to clear skies and favorable subsidies for renewables, Bavaria's photovoltaic (PV) capacity is rising sharply. On sunny days, 3.5 GW of PV power is fed into the Bavarian network. That's roughly the output of three nuclear power plants, and more is being added all the time. The difference is that 3.5 GW of solar power isn't generated centrally at a few big plants but decentrally at more than 100,000 different sites. These range from small rooftop PV arrays to large solar farms (Bavaria's biggest, Straßkirchen, has 54 MW). Because solar power enters the grid at so many different points—and fluctuates at each—it creates challenges for network operators like our subsidiary E.ON Bayern.

Designing tomorrow's grids today

E.ON is committed to supporting a sustainable energy mix and providing the network infrastructure to connect decentralized renewable generation. In 2010, E.ON Bayern launched a two-year project called the "Grid of Tomorrow". To gather data on the changing dynamics in the grid, smart meters will be installed for all customers who produce energy, and over 100 substations will be equipped with advanced information and communications technology. The data will help us explore the implications of increased decentralized generation and identify where our grids need to be upgraded with new technologies. It's one of the ways we're taking action today to design the smart infrastructure for tomorrow's low-carbon energy world.

eon-bayern.com/netz (website available in German only)

PV installation in rural area of Bavaria

Energy project 2020 and smart local networks

Solar panels, smart metering, electric vehicles and other new technologies are going to change residential consumption patters. How much electricity will a home of tomorrow need and at what times of the day? How much will it deliver back onto the network and when? To help find answers to these questions, E.ON Avacon equippes around 30 homes with innovative technology. The idea is to simulate how a typical home will consume (and produce) energy in 2020, when many of these technologies will be standard. The project's main focus is to learn more about homes' usage and feed-in patterns and to determine whether and how this information can be used for smart grid management.

The low-voltage network is also being upgraded with innovative technology like self-regulating substations that automatically correct dramatic voltage fluctuations and thus maintain network stability. This technology has already been proven at intermediate-voltage level. Now we're testing a low-voltage prototype in north-central Germany.

Smart local networks
The simultaneous feed-in of electricity from numerous solar panels can cause voltage to fluctuate. That's why today E.ON Westfalen Weser is installing the standard equipment of tomorrow's networks by equipping 100 substations with smart technology that can automatically regulate voltage fluctuations.

Smart grid model at E.ON's Annual Shareholders Meeting 2010

The Västra Hamnen district in Malmö is an excellent example of a sustainable city

Sustainable city: Malmö

Half of the world's population lives in cities. This figure is projected to increase in the years to come. Urbanization results in a high concentration of energy use and waste production in a limited area. This makes the transition to sustainability particularly challenging for cities. At E.ON, we're using our energy expertise to help cities meet this challenge by working with them to design and implement green, climate-friendly infrastructure solutions. Our first partnership was with Malmö, Sweden's third-largest and fastest growing city. The partnership demonstrates that by putting it all together—innovative technology, energy efficiency, and e-mobility—cities can achieve both a high quality of living and true sustainability.

Västra Hamnen

A decade ago, Malmö's Västra Hamnen (West Harbor) was an industrial wasteland of dilapidated docks, empty warehouses, and an abandoned shipyard. Today it's a modern, vibrant part of the city, home to nearly 3,000 residents, dozens of businesses, a convention center, and an already iconic piece of contemporary architecture: the Turning Torso tower. Västra Hamnen is an outstanding example of innovative, sustainable urban development. Its buildings incorporate cutting-edge materials, technology, and designs that maximize energy efficiency. The entire district is powered, heated, and cooled using 100 percent locally produced renewable energy: wind, solar, biomass, and a large groundwater heat pump. Even refuse is put to use: city buses run on biogas produced at the local landfill.

Västra Hamnen – a district with 100 percent locally renewable energy

E-mobility and sustainability

We're now working with Malmö to show how e-mobility can be integrated into the city's sustainability paradigm. A multi-year field test, which will be fully operational in 2012, will involve 70 electric and hybrid vehicles from several manufacturers and 250 recharging stations in and around Malmö. The recharging stations will be at a range of sites, from garages at people's homes to parking facilities at apartment buildings, businesses, shopping centers, and entertainment complexes. The test will also have a strong intermodal component: recharging points will be set up near train and bus stations so that e-mobility complements public transport. The field test will help us to learn more about users' behavior with regard to vehicle technologies and recharging options and about which e-mobility business models work best for us as an energy supplier.

What's ahead

E.ON's partnership with Malmö demonstrates how companies and communities can work together to combine economic growth with environmental protection and decarbonization. Planning is now under way to develop another section of Malmö (Hyllie) by adopting a comprehensive sustainability approach that also incorporates smart-grid solutions. There's also a growing list of cities implementing the Malmö paradigm with help from E.ON. They include Mora and Norrköping (both in Sweden) as well as Copenhagen (Denmark), whose North Harbor is being transformed into a sustainable residential area for 40,000 people. In Germany, we're exploring ways to adapt the Malmö paradigm to a city in the country's Ruhr region.

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