Energy efficiency in an imaginary megacity

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New York's new subway monitoring and train control system enables more trains to travel faster through the network and thus use the infrastructure more efficiently.

Numerous energy efficient solutions are already available for use today with the potential to make considerable energy savings. These solutions are demonstrated here by presenting an imaginary megacity, incorporating real energy consumption figures for Germany as its basis. The megacity is a world champion in energy efficiency, reducing its primary energy consumption and carbon dioxide emissions by 50 per cent.

The combustion of raw materials such as coal, gas, and oil results in the emission of 26 billion tonnes of carbon dioxide (CO_2) annually. But what would happen if we used the most energy efficient technology? If we could start afresh, how much energy would an imaginary city of 10 million people require? This thought experiment leads to surprising conclusions.

ENERGY REQUIREMENTS FOR AN IMAGINARY MEGACITY

Germany, the sixth biggest energy consumer after the US, China, Russia, Japan, and India, consumes about 14,200 petajoules of primary energy (1 PJ equals 10^{15} joules). Its population is 82 million, which means an imaginary city of 10 million would consume around 1,750 PJ. The energy mix for the megacity consists of:

- Petroleum – 36 per cent
- Natural gas – 23 per cent
- Hard coal – 13 per cent and brown coal – 11 per cent
- Nuclear power – 12 per cent
- Renewables (water, wind, solar cells or biomass) – five per cent.

Converting this primary energy into usable energy will inevitably lead to losses. As a result, consumers only obtain 1,120 PJ of so-called 'site energy', of which industry and commerce consume 42 per cent, households 29.5 per cent, and transport 28.5 per cent.

ENERGY SAVINGS IN INDUSTRY AND BUILDINGS

In the imaginary city, the first issue to address is heat production, one of the biggest drains on energy. In Germany, 58 per cent of site energy is used to generate heat for buildings, hot water, and process heat for industry, eg in metal production. In private households, heating accounts for 80 per cent of energy use. Focusing on the imaginary city, some immediate savings can be exploited. Building renovation as well as intelligent building automation will reduce energy consumption by 40 per cent or more.

In industry, electric motors for drive systems, conveyor belts, and pumps account for more than two-thirds of its power consumption. Up to 60 per cent of the power used by an electric motor will be saved by using frequency converters and more efficient motors. Waste heat, for example in the glass, metal, and cement industries, will also be used for boiling a liquid to drive a turbine for generating electricity.

One way to finance efficiency-boosting measures ideal for municipalities such as the imaginary megacity is energy-performance contracting. The local government pays for the investment in instalments financed by the energy savings achieved. This puts no additional burden on local budgets, and once the contract expires after around 10 years, all savings flow directly into the municipal budget.

ENERGY EFFICIENT TRANSPORTATION

The megacity's second biggest energy guzzler is traffic. In Germany, 28.5 per cent of site energy is consumed in the form of fuels. The imaginary city's residents therefore often use the extensive public transport network, especially since taxes and toll fees have made it expensive to drive vehicles with high CO_2 emissions. The new buses and trains are not only comfortable and travel at short intervals; they also consume 30 per cent less energy than before, thanks to lightweight materials and braking energy regeneration systems.


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The world's largest and most efficient gas turbine produces enough electricity to supply the population of a city the size of Hamburg or Barcelona.

Those who still need a car drive hybrid vehicles, or use piezo technology to optimise fuel injection reducing fuel consumption by around 20 per cent. Internet-based information systems and traffic management systems prevent congestion and make it easier to find a parking space. This also considerably reduces CO_2 emissions, as studies have shown that the search for a parking space accounts for up to 40 per cent of city driving.

RESOURCE EFFICIENCY IN POWER GENERATION

The world champions of energy efficiency wouldn't be known as such if they hadn't also cut electricity consumption. Although electricity only accounts for 20 per cent of all site energy consumed in Germany, the electricity must first be produced in power plants, which convert only an average of about 40 per cent of primary energy into electricity. The megacity efficiency champions make better use of primary energy in facilities, such as combined cycle power plants, which convert more than 60 per cent of the energy contained in gas into electricity. By exploiting the heat produced, they bring the rating to over 80 per cent. Here, process steam and heat is sent via pipes to nearby factories and apartment buildings.

ONE GAS TURBINE FOR 1.8 M INHABITANTS

The imaginary megacity has invested in a 530 megawatt combined cycle power plant which will radically boost efficiency. At 444 tonnes, its gas turbine is as heavy as six diesel locomotives but has 100 times the output. Its output of 340 megawatts produces enough electricity to supply 1.8 million of the megacity's population. Replacing all coal-fired plants worldwide with such high efficiency plants would result in over four billion tonnes less of CO_2 being released into the atmosphere each year, equivalent to the total annual emissions from the whole of Europe. (Siemens is currently building such a plant for the energy supplier E.ON, due to go on line in 2008.)

Of course, renewables also reduce CO_2 emissions in the imaginary city. Solar cells can be found on top of public and private buildings and windmills provide their share of electricity, as do geothermal and biomass power plants. In addition, a large portion of household waste is converted into fuel for power plants. The city is also installing a fuel cell power plant in the megawatt class which, when combined with a gas turbine, will convert around 70 per cent of the energy into electricity. (Siemens and Energie Baden-Württemberg (EnBW) are developing such a fuel cell power plant which they plan to complete by 2012.)

THE POTENTIAL OF HOUSEHOLD APPLIANCES AND LIGHTING

Today, almost half of all electricity consumed in households is used by refrigerators, stoves, washing machines, and dishwashers. Purchasing new appliances whose consumption has been cut by 30-75 per cent since 1990 is the best investment here. Replacing all household appliances in the fictitious megacity would reduce electricity consumption by the amount used today by 600,000 people.

Lighting systems have been revamped in this city as well. Lighting accounts for more than 10 per cent of total electricity consumption in Germany and 19 per cent worldwide. Energy-saving lamps as well as LED lamps reduce electricity consumption by 80 per cent, compared to conventional lightbulbs. Some real cities are already making the switch. Budapest, for example, is replacing the lightbulbs in its traffic lights with LEDs. The financing model is similar to energy-performance contracting, as the monthly installments the city has to pay are lower than the savings generated from reduced power consumption and the elimination of traffic light servicing. This investment in sustainability pays for itself.

CONCLUSION

The combined potential for energy conservation in households, industry, transportation, and power plant technology enables the imaginary megacity to reduce both the consumption of primary energy and CO_2 emissions by 50 per cent. Nearly all of the described solutions already exist today. They don't have to be developed; they could be implemented immediately.

Author

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Organisation

Siemens (Berlin and Munich) is a global powerhouse in electrical engineering and electronics. The company has around 475,000 employees and provides innovative technologies to benefit customers in over 190 countries. Founded 160 years ago, the company focuses on fields such as energy and environment, industry and infrastructures and healthcare. In fiscal 2006, Siemens had sales of €87.3 billion and a net income of €3.033 billion.

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