Demand-Side CO_2 Reduction Using Advanced Power Meters

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Energy efficiency regulations in both the United States and the European Union require power billing to be carried out frequently enough to enable electricity customers to regulate their own energy consumption. Advanced electronic power meters are designed to provide the required billing data in real time. By diminishing energy demand in response to price signals, customers will be adding to the results of CO_2 reduction achieved by suppliers. Power meters might ultimately serve as accounting devices to allow participation in emissions trading.

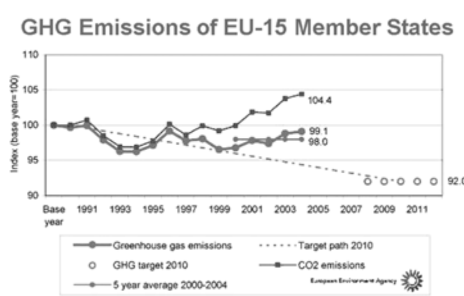
Two developments are poised to shape the 21st century in an unprecedented manner:

1. the precipitous warming of the Earth's atmosphere by greenhouse gas (GHG) emissions from fossil fuel combustion
2. the omnipresence of electronic computers for data processing.

Despite the ensuing threat to global existence by climate change, the immense computing power available to mankind is not yet being strategically employed to reduce and eliminate whenever possible the processes of energy usage that contribute to climate change.

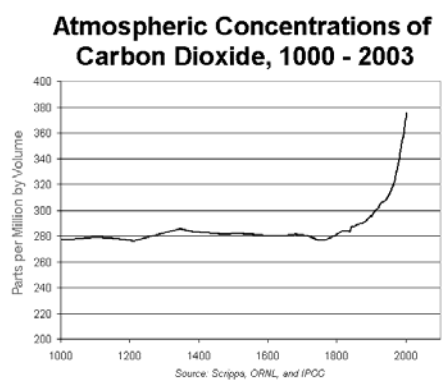
Insufficient Progress in Greenhouse Gas Mitigation

Since going into effect on February 16, 2005, the Kyoto Protocol to the United Nations Framework Convention on Climate Change has required 35 industrialized countries to reduce their greenhouse gas emissions by an average of 5.2 percent below 1990 levels by 2010/2012. In the European Union, for which an 8 percent reduction target applies, the progress to date has not been encouraging. Due to a 4.4 percent rise in carbon dioxide (CO_2) emissions from fossil fuel



use, greenhouse gas emissions in the EU-15 states are diverging from a linear reduction path arriving at 92 percent of 1990 baseline levels by 2010.[1] In evaluating the prospects for Kyoto fulfillment, the European Environment Agency has concluded: "Only two Member States – Sweden and the United Kingdom – expect that existing domestic policies and measures alone will be sufficient to meet or even exceed their burden-sharing targets. All others are projected to be significantly above their commitments with their existing domestic policies and measures."[2]

At the same time, extended risks are inherent to rising emissions levels. On January 10, 2007, the European Commission issued a communication stating that the EU “must adopt the necessary domestic measures and take the lead internationally to ensure that global average temperature increases do not exceed pre-industrial levels by more than 2°C”.[3] This objective tacitly reflects the inability to achieve more effective GHG restrictions, a situation in itself potentially hazardous for human existence. The Netherlands Environmental Assessment Agency notes in this regard that “climate change up to the present has already doubled the risk of heat waves, such as the European heat wave of 2003 and the resulting unusually large numbers of heat-related deaths”.[4]



In order to achieve the 2°C target with a probability of greater than 60 percent, it would be necessary to stabilize greenhouse gas concentrations in the Earth’s atmosphere at 450 ppmv (volumetric parts per million) CO_2 equivalent, or less.[5] In actuality, the continuing rise of carbon dioxide concentrations has resulted in an increasingly high risk of overshooting this level.[6] The greatest prospects for remediation of this trend lie in the application of advanced technologies combined with suitable alterations of human behaviour, preferably in the form of positive responses to the opportunity of conserving energy.

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1 "EU greenhouse gas emissions increase for second year in a row" (Copenhagen: European Environment Agency, June 22, 2006).

2 *Greenhouse gas emission trends and projections in Europe 2005* (Copenhagen: European Environment Agency, EIA Report 8/2005), p. 16.

3 *Limiting Global Climate Change to 2 degrees Celsius. The way ahead for 2020 and beyond* (Brussels: Commission of the European Communities, January 10, 2007), p. 2.

4 M.G.J. den Elzen, M. Meinshausen, *Meeting the EU 2°C climate target: global and regional emission implications* (Bilthoven: Netherlands Environmental Assessment Agency, Report 728001031/2005), p. 6.

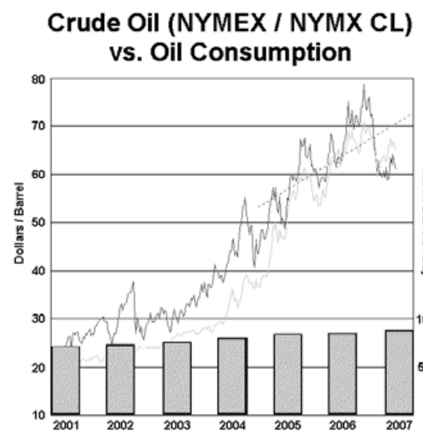
5 Ibid., p. 2.

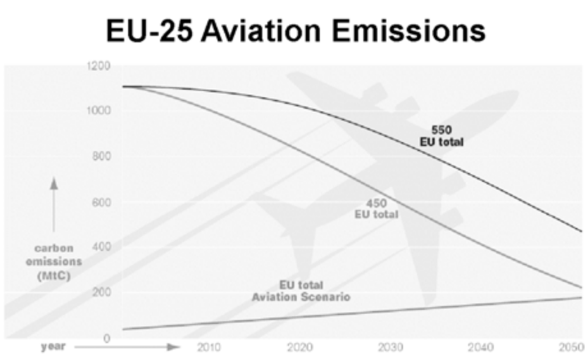
6 Ibid., p. 17.

Market Toleration of Global Warming

In its 1987 report *Our Common Future*, the World Commission on Environment and Development[7] called for a “safer and more sustainable energy future” using low-emission “renewables, energy-efficient industrial processes, transport vehicles, and energy-services”.[8] It was noted at the time that “positive energy developments world-wide that made sense with oil at $25” during energy crises had become harder to justify after oil prices had declined”. It appeared conversely logical to anticipate that rising prices would lower fossil fuel consumption.

Contrary to this expectation, however, the global demand for energy has continued to rise even as the cost of a barrel of oil tripled to $60. Price-driven efficiency technologies have lowered the energy input of many applications, but the number of applications has proliferated disproportionately. Greenhouse gas emissions are increasing in pace with this development, as a growing world population is availed of access to expansive living infrastructures, electrical appliances, motor vehicles, and aviation transport.





Current technologies often are not adequate to compensate for the emissions inherent to market expansion. This circumstance is illustrated by the aviation industry, in which the greater frequency of air traffic is compounded by longer flight distances and by increased airport congestion. An extrapolation of present trends in aviation indicates that virtually all greenhouse gas emissions in the EU would be emanating from this source by mid-century if the 450 ppmv requirement was simultaneously being fulfilled, because an 80 percent reduction of total emissions would be necessary by that time.[9] Since it is quite

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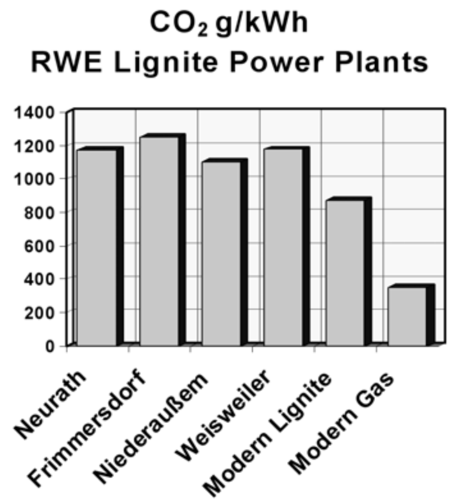
[7] Popularly known as the Brundtland Commission after its Chairman, Gro Harlem Brundtland.

[8] World Commission on Environment and Development, *Our Common Future* (Oxford: Oxford University Press, 1987), p. 201.

[9] *Decarbonising the UK. Energy for a Climate Conscious Future* (Norwich: Tyndall Centre for Climate Change Research, 2005) p. 49.

improbable that fossil fuel use in all other sectors could be eliminated entirely, the assumptions employed for this extrapolation will inevitably be modified by subsequent reality.

Excessive fuel consumption and thus inordinate contributions to global warming are often tolerated with persistent indifference to available technologies. The electrical power industry produces 40 percent of the energy-related carbon dioxide emissions worldwide – twice the greenhouse gas contribution of either the transportation or industrial sector.[10] Efficiency improvements would therefore contribute greatly to the fulfillment of climate protection mandates. However, since older power stations require no major expenditures besides fuel, their operation involves lower financial risks than new installations. This situation is exemplified by Germany's largest electrical power producer, RWE AG, which has kept 18 lignite (brown coal) power plants in service at four locations for over 40 years.[11] These outdated installations emit over three times as much carbon dioxide (CO_2) per kilowatt-hour as modern gas plants owing to a generating efficiency of only about 30 percent[12] and the high carbon content of lignite fuel. RWE power plants constitute the greatest single source of carbon dioxide emissions in Europe.



Confronting Climate Change with Distributed Computer Networks

Carbon dioxide produced from burning fossil fuels accounts for 59 percent of all anthropogenic greenhouse gases.[13] Many of the combustion processes involved on an industrial level are already being monitored and controlled automatically. Comparable techniques could be applied to improve efficiency in all sectors of the economy, as long as the expense of doing so did not

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10 "Energy Related CO_2 Emissions", in: *World Energy Outlook 2004* (Paris: International Energy Agency, 2004), p. 75.

11 *Neue Braunkohletagebaue durch Kraftwerkserneuerung?* (Düsseldorf: Parliament of North Rhine-Westfalia, DS 14/1040, January 11, 2006), p. 4.

12 The most recent RWE power station at Grevenbroich will exhibit a generating efficiency of 43 percent when it commences operation at the end of 2009. See: *Grevenbroich: Laserstrahlen sollen Baustelle ins rechte Licht rücken* (Westdeutsche Zeitung Newsline, December 27, 2006).

13 Kevin Baumert, Jonathan Pershing, *Climate Data. Insights and Observations* (Arlington: Pew Center on Climate Change, December 2004), p. 5.

exceed the benefits achieved. Millions of home and office computers already in service would be hypothetically available to assist in implementing this task.

Although every computer is electrically operated, only a very few are presently equipped to measure and control the consumption of electricity. A number of practical reasons have prevented the wide implementation of this application. If a home computer is operated continuously for managing energy in a private residence, its power consumption may easily exceed any savings realized. The attainable benefits then will not even offset hardware and installation costs. Furthermore, the integrity of data received from any indeterminate network of computers requires verification by a qualified agency. Even then, the results of energy saving strategies would only represent the usage habits of computer owners, necessitating inferences on the conservation efforts of all remaining segments of the population.

Power Meters with Computing Capabilities

Alternatively, the existing power meter infrastructure can be upgraded to implement a distributed energy monitoring and control system. By adding an electronic microprocessor to each meter, distinct advantages are achievable compared with the hypothetical network of home and office computers described above:

1. Every household and every business establishment is equipped with a power meter.
2. The electricity being measured likewise powers the meter.
3. The meter microprocessor operates continuously to measure power consumption.
4. Power measurements are performed with high accuracy according to utility industry specifications, making third-party data verification unnecessary.
5. Standardized design reduces hardware and maintenance costs.

For contributing to Kyoto fulfillment, an appropriate network of computing power meters must be made less costly than the environmental waste products it is intended to eliminate.

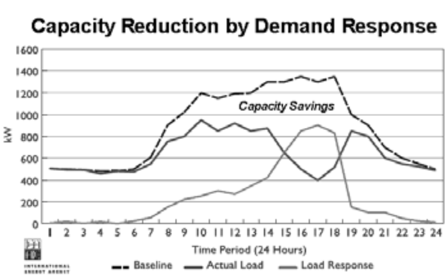
Emissions Trading as an Incentive to Fossil Fuel Efficiency

Although rising fossil fuel costs discourage energy wastage, years or even decades often intervene between the respective price increases and ensuing investments in fuel-efficient technologies, as has been shown for the electrical power industry. CO_2 emissions trading raises the incentive to make timely investments in lowering carbon fuel intensities. As world population rises, permissible emissions limits must be continuously reduced to fulfil the requirements of climate stabilization. The toleration of excessive CO_2 emissions thus ultimately becomes more expensive than their avoidance.

Article 17 of the Kyoto Protocol allows countries to participate in emissions trading for the purposes of fulfilling their commitments under Article 3. An appropriate Emissions Trading Scheme (ETS) has been implemented in the European Union for carbon dioxide allowances by Directive 2003/87/EC.[14] The traded emissions apply entirely to large stationary installations such as power and heat generators, oil refineries, and other major industrial facilities, while the transportation and private sectors are excluded. Consequently, only about 40 percent of all greenhouse gas emissions in EU-15 countries and 46 percent in the 10 new member states are covered by the trading scheme.

Demand Response for Carbon Emissions Reduction in North America

While the United States has not ratified the Kyoto Protocol, the Northeast and Mid-Atlantic States (Regional Greenhouse Gas Initiative RGGI), California, and Canada are likewise committed to the establishment of carbon emissions trading.[15] In contrast to Europe, furthermore, certain established practices have already effectively included the utility customer into carbon emissions reduction strategies.



The electrical power system of North America is subject to frequent service interruptions due to demographic expansion, the increasing prevalence of air conditioning, and the frequent neglect of investments in the grid infrastructure. Customer-side demand response techniques have therefore been

[14] *Directive 2003/87/EC of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC* (Brussels: European Parliament and Council of the European Union, October 13, 2003).

[15] The establishment of a Northeastern regional emissions registry for greenhouse gas trading was specified in 2001 by the "Climate Change Action Plan" of The Committee on the Environment and of the Conference of New England Governors and Eastern Canadian Premiers, New England Secretariat, New England Governors' Conference Inc. (Boston: August 2001), p. 18. www.massclimateaction.org/pdf/NECanadaClimatePlan.pdf

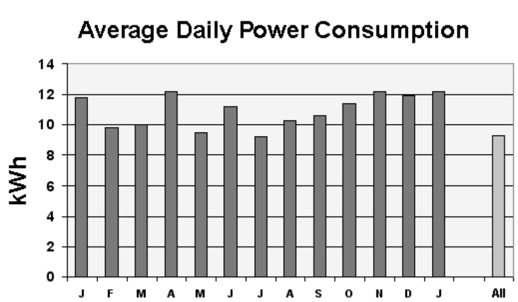
instated for pre-emptively shifting non-critical loads to more favorable rate periods, or for shedding predetermined loads whenever invoked by the utility company to avoid supply shortages. These measures reduce requirements for generating capacity reserves and provide a corresponding degree of CO_2 avoidance.

Demand response capabilities require an adequate means of intercommunication to enable particular loads at each customer location to be switched manually or automatically in response to price changes or other supplier-side signals. Electromechanical dual-tariff power meters have been traditionally employed to allow domestic electrical heating storage ovens to be operated at lower rates during prearranged off-peak hours, therefore requiring only a written exchange of information. Most other conditions of demand are unpredictable, however, necessitating real-time communication between each power meter and the grid operator[16] for transmitting dynamic pricing signals and switching commands.

Although such intercommunicative demand response techniques are widely employed for industrial customers, the participation of smaller businesses and private households in similar programs has been voluntary. More favorable pricing is provided to those customers who consent to external intervention for switching off air conditioners and other major load devices whenever necessitated by grid capacity restrictions.

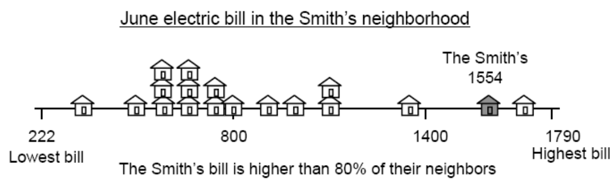
Demand-Side Efficiency Enhancements Using Information Feedback

Apart from real-time interaction with the grid operator, broad-based savings of energy resources and thus reductions of power plant emissions are additionally realized in the United States, Canada, Australia, and parts of Scandinavia by employing monthly meter readings. Each utility bill includes a graphical comparison between current and reference readings. Customers are motivated by this feedback of information to correct any conditions of excessive consumption, thereby exerting a demand-side influence on net generating capacities and



16 Intercommunication may be realized using either Powerline Communication (PLC) technologies, Wireless Wide Area Networks (WWAN), broadband cable networks, Internet via DSL, ISDN or analog telephone systems, or rudimentary dial-up services.

associated CO_2 emissions. Bar graphs containing historical data allow current demand to be compared with the consumption of previous billing months, indicating the aggregate influence of altered equipment usage, energy conservation measures, and seasonal variations. A separate bar indicates the average demand of all customers in the same billing category, thereby serving as a reference level for comparisons.



Cross-referenced data may be alternatively employed to compare the electricity bills of different customers in the same billing category for the current month. The use of symbols along a linear scale promotes intuitive assessments of electrical power costs with respect to absolute consumption and to prevailing differences with other customers. Rather than total usage, the consumption per square unit of living space will more accurately reflect owner attitudes toward energy conservation despite widely differing dwelling size.

The Centre for Sustainable Energy in the United Kingdom has determined that such monthly feedback of numerical and graphical data in the countries surveyed offers potential sustained energy savings of five to ten percent over the yearly billing practices that still prevail in most of Europe.[17] Indications of excessive consumption will prompt the consumer to lower power costs by correcting wasteful behavior and by employing energy-efficient appliances. The Centre notes that the feedback of historical and comparative information is most effective "when it is immediate, prominent, accessible, and specific to the consumer".

It follows that the greatest resource savings may be achieved by supplanting monthly or yearly manual billing by the continuous electronic measurement of electricity consumption. In this case, instantaneous feedback of data pertinent to usage can be provided to the consumer.

Electronic Meter Reading Capabilities

Of their innate nature, electronic power meters are capable of reading and transmitting data on electrical power consumption at any time. However, this technological potential is not always exploited. Automated Metering Reading (AMR) is often implemented only to replace pedestrian human meter readers with electronic data inquiry equipment that may be installed in a drive-by

[17] Simon Roberts, William Baker, *Towards Effective Energy Information* (Bristol: Centre for Sustainable Energy, July 2003), p. 4.

vehicle. The frequency of readings is not increased. The customer therefore detects no difference in his monthly power bill, so that no added motivation towards resource conservation results from this technological innovation.

By contrast, an intercommunicative Advanced Metering Infrastructure (AMI) is employed with the specific intention of sending real-time feedback information to the consumer at frequent intervals in order to evoke responsive adjustments of demand. Interactive efficiency improvements are thereby realized from three perspectives of energy usage:

1. **Feedback of metered demand.** Numerical readouts of current and cumulative power demand are provided at the meter on an LCD display. Customer awareness of electricity usage can be significantly enhanced by an additional display device located prominently within the living quarters that provides graphical indications of consumption and visual alerts triggered whenever preset energy or monetary budgets have been exceeded. This local feedback of information supports usage decisions and motivates the selection of power-efficient appliances in order to reduce ongoing demand. Utility billing charges also act as feedback information to influence the budget established by the customer.

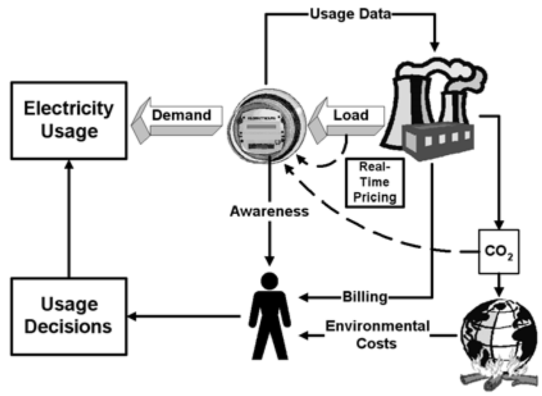
2. **Feedback of aggregate grid load.** Conventional monthly (or yearly) meter readings evoke only long-term customer responses. By contrast, AMI intercommunication enables the metered power demand to be read continuously by the utility company or grid operator. The aggregate demand of all customers constitutes the effective grid load. Dynamic real-time prices can then be returned to individual meter displays to prompt the shifting of demand by customers from peak to off-peak periods whenever warranted by grid supply conditions.

3. **Feedback of environmental costs. T**he costs of climate change are increasingly reflected in electricity prices owing to uncertain hydroelectric capacities, power plant cooling water limitations, ecological taxes, and the conduct or preparation of CO_2 emissions trading. Emissions-related information may be sent directly to an AMI meter to permit dynamic calculation of environmental costs. The respective pricing coefficients will lie at a lower level for gas power plants and be eliminated almost entirely for renewable energies. Coal or lignite power generation, by contrast, will generally incur the highest CO_2 emission costs per kWh. If the correlation of particular energy charges with respective ecological burdens is made apparent on the meter display, a greater

motivation will be created to purchase energy producing lower greenhouse gas emissions, thus ultimately reducing the costs of using electricity. Additional feedback on environmental costs is received from the world at large, of course, exerting diverse influences on consumer attitudes and usage decisions.

Enhanced Customer Awareness through Real-Time Data Feedback

The overlying objective of real-time data feedback in an Advanced Metering Infrastructure is to enhance the awareness of each utility customer to economically achievable electricity savings based on personal demand, the grid load confronting the utility company, and the environmental costs inherent to generating electrical power. This information enables usage decisions to be motivated by any combination of these parameters using appropriate price signals. The customer thereby becomes an interactive component of the power generation and supply infrastructure.



Without this capability, usage decisions can be based only on manual meter readings that have no direct relationship to available grid capacities or to greenhouse gas emissions. A portion of available energy resources will invariably be lost to ineffective consumer responses.

Neglected Opportunities of Demand Response

Although interactive functions are recognized as reliable determinants of grid operating efficiency, they continue to be neglected in many utility business cases. The Sacramento Municipal Utility District (SMUD) recently resolved to replace all 500,000 meters in its service area with AMR devices capable only of one-way data transmission to a drive-by vehicle.[18] With data pickup conducted at intervals several weeks apart, short-term responses for enhancing grid efficiency, peak-load remediation, and CO_2 reduction are barred from customer interaction.

The SMUD decision prevents the adoption of time-sensitive rates that would promote equitable and accurate billing.[19] The recommendation of the Energy Policy Act of 2005 has thus been

[18] *SMUD performing huge meter retrofit* (Sacramento: Sacramento Municipal Utility District, January 4, 2007).

[19] Veronica Irastorza, “New Metering Enables Simplified and More Efficient Rate Structures”, *The Electricity Journal* (December 2005).

ignored, “whereby customers are provided with electricity price signals and the ability to respond to them”.[20] According to the U.S. Department of Energy, customers should be expected to alter normal consumption patterns “in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized”.[21] Yet although SMUD is a customer-owned electrical utility, its ratepayers have been excluded from real-time interaction with the cost and environmental factors pertinent to power generation and transmission. This diminishment of consumer influence ultimately constitutes an impediment to Californian climate protection policy, according to which greenhouse gas emissions in the year 2020 are to be reduced to 1990 levels.[22]

The demand-side programs of most European utility companies remain similarly restricted to large industrial consumers. This persistent deficit in the metering infrastructure is due to:

1. business and regulatory practices persisting from former closed energy markets,
2. the low power requirements of households with no electrical climate control or water heating,
3. high grid reliability with few power interruptions of any significant duration,
4. inexpensive manual yearly billing procedures that preclude investments in a metering communications infrastructure, and
5. close alignment of the Emissions Trading Scheme toward existing power industry conditions, thus inhibiting any motivation to implement demand-side measures for the purpose of CO_2 reduction.

However, the necessity of achieving the mandatory targets of the Kyoto Ptotocol, and the dwindling prospects for reducing greenhouse gas emissions adequately by existing means, constitute an incentive to implement advanced metering capabilities in signatory countries.

Opening the AMI Market on the Path to Kyoto Fulfillment

Placed into a European context, demand-response techniques would contribute to Kyoto compliance in two essential ways:

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[20] *Energy Policy Act of 2005. Conference Report* (Washington: 109th Congress, July 27, 2005), p. 1160.

[21] *Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them* (Washington: U.S. Department of Energy, February 2006), p. 6.

[22] *Executive Order S-3-05 by the Governor of the State of California* (Sacramento: Executive Department, State of California, June 1, 2005).

1. The current reliance on CO_2-intensive power plants would be reduced, just as the need for certain generating capacities in the United States has been avoided.
2. The ability to align loads with available capacities would allow greater amounts of CO_2-free wind and solar power to be used despite intermittent availability.

In the European Union, a suitable legal framework already exists for AMI implementation. Article 13 of Directive 2006/32/EC on energy end-use efficiency and energy services[23] prescribes standards of "metering and informative billing of energy consumption" by which final customers are to be provided with "competitively priced individual meters that accurately reflect the final customer's actual energy consumption and that provide information on actual time of use". Billing is to be performed "frequently enough to enable customers to regulate their own energy consumption". In addition, "comparisons of the final customer's current energy consumption with consumption for the same period in the previous year" are to be provided, "preferably in graphic form", as well as "with an average normalised or benchmarked user of energy in the same user category".

These requirements confirm the improvement in energy efficiency that advanced metering can achieve in combination with progressive billing practices. The Directive notes, however, that implementation must be "financially reasonable". To insure that AMI is widely implemented, this provision may be effectively circumvented by providing additional services and features that reduce the specific costs of power metering itself.

AMI Cost Defrayment through Multiple Functionality

Multiple functionality realized by microprocessor control can be a decisive factor in achieving widespread AMI implementation, for two essential reasons:

1. The energy savings resulting from the feedback of usage information alone are often not sufficient to cover AMI equipment and operational costs, due to the low electricity consumption of the many households without air conditioning or electrical heat. European utility companies routinely argue against adopting monthly power billing on the same basis.
2. Unrealistically low component and installation costs are frequently claimed by the proponents of advanced power meters in order to promote their adoption. If these cost

[23] *Directive 2006/32/EC of the European Parliament and of the Council on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC* (Brussels: Council of the European Union, April 5, 2006)

expectations cannot be fulfilled, AMI implementation may be neglected. Power meters with enhanced functionality are invariably more expensive to manufacture, yet they will be capable of increasing the cost-effectiveness of deployment through additional subscriber services that produce greater revenues.

Owing to the voluminous data that will be collected by an AMI system, only the information required to improve energy efficiency should be filtered out for feedback purposes. There is usually no need to provide repeated data feedback if electrical power demand or CO_2 emissions always remain within a prescribed budget; in this case, occasional printed invoices will suffice for accounting purposes. Yet the utility customer must be informed immediately of excess consumption, which might be due to the careless operation of electrical appliances, but also possibly be caused by hazardous equipment defects. For this purpose, an AMI power meter should be equipped with a multiple alarm function capable of both on-premise alerting using visual or acoustical signaling devices as well as remote messaging via email and SMS.

Once this alarm capability is available, it can be used for additional emergency functions such as fire detection, burglary or intrusion alarms, central locking systems, emergency medical signaling, and disaster messaging. Water and heating energy usage may likewise be metered, both for tracking normal usage and to guard against water pipe breakage in unoccupied buildings due to winter freezing. The control of smart appliances can likewise be realized within the wireless meshed network used to implement these functions.

Cost benefits to the utility company will result from service outage/restoration reporting, remote service connect & disconnect, theft of power reporting, over voltage and under voltage reporting, power factor monitoring, emergency disconnect, and automated reporting to field service personnel.

Finally, the meter may include a “smart card” or memory card reader to allow prepayment of utility services. The card could be loaded with energy credits at a point-of-sale (POS) service terminal. Because of intercommunication with the utility company and the Internet, however, the entire accounting procedure could also be performed at the meter using either a banking or credit card, if no dedicated card had been introduced. The prepayment capability could contribute substantially reducing the effective cost of the metering infrastructure due to the elimination of late or defaulted payments. In the United Kingdom, a consequential fall in the disconnection of electricity customers from nearly 13,000 in 1992/3, to 1,084 in 1994/5 has been reported.[24]

The wireless interconnections that link in-home devices can be realized at little additional expense using miniature radio frequency transceivers complying with ZigBee or comparable wireless meshed network standards. Appreciable cost benefits will be realized in comparison with separate discrete systems, thereby dissipating the financial burdens of AMI over the additional services realized. The power meter assumes the function of a universal network gateway available to every household and business establishment.

Demand-Side CO_2 Reduction

The preamble of Directive 2006/32/EC emphasizes that improved energy end-use efficiency will contribute to the “reduction of primary energy consumption, to the mitigation of CO_2 and other greenhouse gas emissions and thereby to the prevention of dangerous climate change”. These objectives focus mutually on the reduction of fossil fuel use and inherent carbon dioxide emissions in satisfying energy requirements.

The usage decisions supported by an advanced power meter can therefore be directed toward eliminating either fuels or emissions containing carbon. While efficiency strategies usually focus on energy savings, CO_2 reduction may offer greater environmental benefits when made the lead parameter. For instance, the prospect of switching from a low-carbon to high-carbon electricity supplier becomes less likely when a limit is set on emissions rather than on final energy.

Private CO_2 Allowance Purchases

An advanced power meter equipped for the prepayment of utility services could be used for carbon emissions accounting, with CO_2 allowances bought and sold via the meter card terminal.

According to Article 12 of Directive 2003/87/EC on emissions trading, EU allowances (EUA) can be transferred between any persons within the European Community.[25] While the trading registration fee generally excludes private individuals from participation, the allowances may be

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24 Mark Scanlan, Walter Neu, *Study on the re-examination of the scope of universal service in the telecommunications sector of the European Union, in the context of the 1999 Review* (Bad Honnef: Wissenschaftliches Institut für Kommunikationsdienste GmbH, 2000), p. 27.

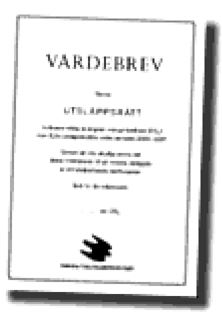
25 *Directive 2003/87/EC of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC* (Brussels: Council of the European Union, October 13, 2003).

bought by registered agencies and subsequently resold. Article 19 states that any person may hold allowances.

At present, two institutions in Europe offer EU allowances for sale with the specific intention of removing them from the market.

1. **TheCompensators** (www.thecompensators.org) is an association in Potsdam, Germany, specifically established to delete emission allowances from the EU Emissions Trading Scheme. The allowances are sold with the understanding that they will be retired from trading by the purchaser. By decreasing the number of allowances available on the emissions market, the cost of carbon will be increased, thereby contributing to a more rapid deployment of climate-neutral technology. The price of the allowances is oriented toward the trading price on the European Energy Exchange (www.eex.de), which had fallen to below 4 euros/ton at the beginning of 2007. At this price level, emissions trading presents no significant obstacle to the use of high-carbon fuels, thus substantiating the necessity of purchases by third parties in the interest of climate protection.

2. **Svenska Naturskyddsföreningen (SNF),** the largest environmental organization in Sweden, offers emissions certificates on its website (skarv.snf.se/snf/co2/index.asp) for 350 Kroner (about 39 euros, or 50 dollars) per ton. By the end of 2006, over 6000 people had purchased allowances to eliminate them from trading.[26] The relatively high certificate cost reflects the inability to predict later trading price declines when the program was instituted a year ago.



Compared with the total yearly CO_2 emissions assigned to Germany (453.1 million tons) and to Sweden (22.8) under the Emissions Trading Scheme, the allowances retired by these programs may exert only minimal effects on trading prices.

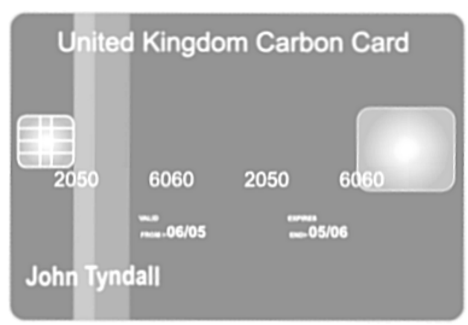
[26] Bernd Parusel, *CO_2-Zertifikat zu Weihnachten* (Berlin: Neues Deutschland, December 21, 2006).

By contrast, the hypothetical but legal ability to withdraw ETS allocations from circulation using a smart card terminal at each power meter would allow the public at large to exert a continuous, potentially massive influence on the climate-related pricing of electricity. The installation of this capability would increase the commercial risks inherent to planning and operating fossil fuel power plants. Investments in renewable energies, on the other hand, would become more secure, reducing the need for public subsidies and fixed feed-in tariffs to promote their use.

Tradable Quotas for Energy and Emissions

Since emissions trading in the European Union is restricted to the industrial users of energy, the CO_2 reductions it is capable of achieving may possibly be offset by increased emissions in other areas of the economy, particularly by the transportation sector. To overcome this problem of inequity, a system of Tradable Energy Quotas (TEQs) is currently under discussion in the United Kingdom. Originally proposed by the London-based policy analyst Dr. David Fleming in 1996, a similar system of Domestic Trading Quotas (DTQs) has been more recently investigated at the University of Manchester with funding from the Tyndall Centre for Climate Change Research.[27]

DTQs (or TEQs) are intended to reduce greenhouse gas emissions from energy use by requiring anyone purchasing fuel and electricity to surrender emissions rights along with payment. The rights are distributed free to all adult individuals on an equitable basis, while organizations are obliged to purchase the emissions rights they require on a national carbon market. Individuals who surrender fewer rights than allocated can sell their surplus rights on the national market; individuals who require additional rights must purchase them on the same market.



The British government has initiated a pilot program to test the viability of the proposal.[28] Smart bank cards ("swipe cards") can be employed for storing personal carbon usage, while advanced power meters may be

[27] Richard Starkey, Kevin Anderson, *Domestic Tradable Quotas: A policy instrument for reducing greenhouse gas emissions from energy use,* Tyndall Centre Technical Report No. 39 (Norwich: Tyndall Centre for Climate Change Research, December 2005), p. 1.

[28] David Adam and David Batty, *Miliband unveils carbon swipe-card plan* (London: Guardian Unlimited, July 19, 2006); Charles Clover, *Labour plans carbon cap on household energy use* (Daily Telegraph, July 20, 2006).

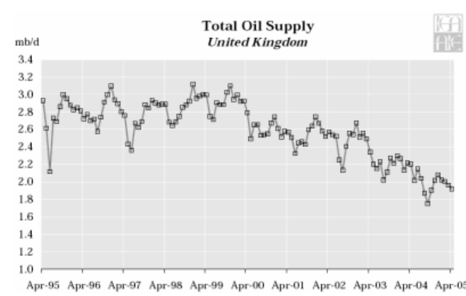
used to calculate the carbon burden of household energy consumption in the course of regular billing routines for electricity and gas or heating oil.

The selection of emissions as the lead parameter of energy usage reflects the growing uneasiness of many Europeans over detectable, enduring changes in meteorological and biological phenomena. The United Kingdom is commensurately pursuing the establishment a transatlantic market for carbon dioxide emissions and has already signed a climate pact with the State of California toward this end.[29]

In the preamble of his latest treatment *Energy and the Common Purpose,*[30] Dr. Fleming categorizes the objectives of TEQs as:

- Climate change: to reduce the carbon dioxide released into the air when oil, gas and coal are used.
- Energy supply: to maintain a fair distribution of oil, gas and electric power during shortages.

The reduction of CO_2 emissions would provide additional impetus to reducing dependency on fossil fuels from the North Sea, where dwindling reserves do not allow the energy independence of earlier years to be sustained. The potential threats to the British economy are reminiscent of the submarine blockades experienced during two world wars. A collective historic consciousness thus already prevails for precluding material need.



The British climate change researcher Mark Lynas, who terms an appropriate strategy of economic discretion “rationing the future”, sees a direct analogy between the Second World War and current priorities: “Defeating Hitler was our number-one aim in 1940: it ranked above health, education, crime and all the other day-to-day concerns of government, requiring a supreme effort of mobilisation. Defeating global warming must be our priority today, or we will lose this war, and with it our very existence as a civilisation.”[31]

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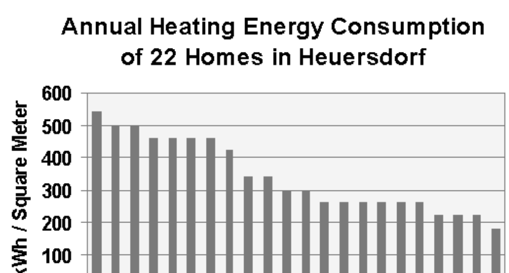
[29] Patrick Wintour, *Blair signs climate pact with Schwarzenegger* (The Guardian, August 1, 2006).
[30] Richard Fleming, *Energy and the Common Purpose. Descending the Energy Staircase with Tradable Energy Quotas (TEQs)* (London: The Lean Economy Connection, 2006).
[31] Mark Lynas, *Why we must ration the future* (London: New Statesman, October 23, 2006).

Successive reductions in resource deployment are foreseen in Dr. Fleming's proposal using a 20-year "staircase" budget,[32] which is intended to promote efficiency in pre-established descending steps. The feasibility of this scheme presumes not only further technological progress, but also a growing public appreciation of the need to reduce requirements for energy.

It appears probable that the use of tradable quotas would already be acceptable to a majority of the population due to the prospect of wealth transfer that it presents. People with a modest living standard having only limited possibilities for personal consumption would surrender their own surplus emissions rights against added income, which would have been received on the national market from affluent consumers and from organizations with above-average requirements for fossil fuels.

CO_2 Reduction Networks

Advanced power meters allow persistent shortcomings of coordination and correlation inherent to conventional energy efficiency strategies to be overcome. AMI intercommunication capabilities allow energy data to be transmitted to the utility company, but likewise to be exchanged with other consumers for compiling aggregate measurements in neighborhoods and entire regions. The required data transfers take place over the Internet. The resulting enhanced transparency of energy data can reveal additional CO_2 mitigation potentials that would not otherwise have been apparent.



As a case in point, comparative measurements of 22 unrenovated homes in the German village of Heuersdorf[33] in 1997 revealed high unsuspected variations in heating consumption for comparable levels of human comfort. Energy expenditures varying by up to a factor of three were determined, ranging from 180 to 540 kilowatt-hours per square meter and year (kWh/m^2*a). Since one liter of heating oil supplies about 10 kWh of thermal energy, up to 50 liters of oil per square meter of floor space were being employed annually in some dwellings, corresponding to an excessively high carbon dioxide emission level of 130 kg/m^2*a. The

32 Ibid., p. 13.
33 Heuersdorf is located near the city of Leipzig: www.heuersdorf.de.

heating energy consumption of new and renovated buildings generally lies below 100 kWh/m^2*a, with corresponding CO_2 emissions of less than 30 kilograms per square meter. Highly insulated homes achieve values of 30 (“three-liter homes”) to 80 kWh/m^2*a, or less. Since the entire population of Heuersdorf is now being relocated by a local mining company, this information can be used in developing a low-energy residential settlement equipped with cross-correlative AMI energy monitoring.

Starting on July 1, 2007, utility customers in Germany will be able to contract the installation of their own power meters according to the Electricity and Gas Supply Act of 2005,[34] which also allows billing information to be collected by qualified third parties. Metering service companies could therefore use AMI metering to establish energy efficiency networks for their customer base. The subsequent reduction of power demand would constitute a CO_2-free virtual power station that had supplanted physical generating capacity. Greenhouse gas avoidance could be realized most effectively by reducing CO_2-intensive coal and lignite power generation proportionately.

Data linkage of solar feed-in power meters would reveal differences in performance between individual photovoltaic installations. More significantly, regional contributions of load shedding and CO_2 emissions reduction could be determined. This dedicated metering infrastructure would represent a distributed solar power plant for diminishing peak grid loads on warm sunny days, when conventional generation capacities are in greatest demand.

[34] *Gesetz über die Elektrizitäts- und Gasversorgung* (Cologne: Bundesanzeiger Verlagsgesellschaft mbH, BGBl I 2005, 1970 (3621), July 7, 2005).