Bottom-Up methodologies and their possible application in Brazil

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Introduction

Energy Efficiency has become increasingly important in energy planning. As a key aspect in long term demand projections, saved energy – be it due to advanced technology or changes in consumption patterns – is treated as an important resource to dampen demand growth, with positive effects for the whole society.

Energy Efficiency is given such importance in energy planning that it was incorporated within the legal competences (law 10.847/04) of EPE (*Empresa de Pesquisa Energética*), the state owned company bound to the Ministry of Mines and Energy (MME) and responsible for energy planning studies.

EPE's modelling and forecast methodologies undergo a constant refinement. In the context of the technical cooperation program between Brazil and Germany, EPE and GTZ (*Deutsche Gesellschaft für Technische Zusammenarbeit mbH*) cooperate in order to refine EE related methodologies for energy planning.

Prior to the present work, EPE and GTZ have contracted a study to determine the current state of the art of energy efficiency with a top-down approach. The study resulted in a set of energy efficiency indicators and a description of data availability in Brazil.

Now, the information to determine the actual values of these indicators needs to be acquired. One, maybe the most important, approach lies within the application of bottom-up methods for energy modelling.

The objective of the present work is therefore to provide an overview (state-of-the-art) and insight on bottom-up approaches (methods and necessary data basis) for energy efficiency for selected countries. This shall provide a basis to assess their possible application in Brazil as auxiliary energy planning procedures. The methodologies shall further help to evaluate energy efficiency measures and better determine the costs of different future scenarios taking into account also demand side options.

The importance and role of energy efficiency

The Kyoto Protocol objectives and more recently, emerging constraints on energy supply have raised the importance given to energy efficiency policies. Almost all OECD countries and an increasing number of non-OECD countries are using new or updated instruments adapted to national circumstances. Apart from a major role of market instruments (voluntary agreements, labels, information dissemination etc), regulatory measures are also widely implemented where the market fails to give the right signals (buildings, appliances etc).

In developing countries, therefore, energy efficiency is an important issue, too but often with different driving forces compared to industrialised countries. In developing countries, the need to reduce greenhouse gas emissions and local pollution is less of a priority: alleviating the financial burden of oil imports, reducing energy investment requirement, and making the best use of existing supply capacities to improve the access to energy are more important drivers.

Energy efficiency improvements refer to a reduction in the energy used for a given service (heating, lighting, etc.) or level of activity. The reduction in the energy consumption is usually associated with technological changes, but not always since it can also result from better organisation and management or improved economic conditions in the sector ("non-technical factors").

Avoiding unnecessary consumption of energy or choosing the most appropriate equipment to reduce the cost of the energy helps to decrease individual energy consumption without decreasing individual welfare. Any cost related decision concerning energy efficiency is based, more or less, on a trade-off between the immediate cost and the future decrease in energy expenses expected from increased efficiency. The higher the energy price, observed or expected, the more attractive are the energy efficient solutions. Making a "good" investment decision, for domestic appliances or industrial devices, from the energy efficiency viewpoint, certainly relies on a sound economic rationale.

Clear price signals alone are not enough to achieve a rationalisation of energy use. Indeed certain conditions are required to remove the usual barriers to energy efficiency and to develop and structure the market for efficient equipment and devices:

- The availability of efficient appliances and production devices;
- The availability of good information for consumers about such equipment and devices; and,
- The availability of technical, commercial and financial services when necessary.

Policy measures are therefore necessary in market economies to reinforce the role of energy prices, firstly to create the appropriate market conditions for efficient equipment, secondly to drive consumer choice towards the most cost effective solutions.

Global estimates of potential for CO_2 emission mitigation in the buildings

For the IPCC AR4 global estimates of CO2 emission mitigation potentials were calculated based on the available country- or region-level literature (Levin et.al 2007). Only those studies were selected for analysis, which were based on a range of common criteria, such as following a bottom-up approach, covering demand-side measures and having a discount rate in the interval of 3 to 10 %. World potential figures were derived through the aggregation of the potentials they reported using the countries covered these studies as marker countries. The baseline was constructed based on the respective baselines used in the respective studies to preserve the integrity and consistency of the potential estimates with the baselines and to avoid double counting.

Countries/country groups reviewed for the region	Potential as % of national baseline for buildings[1]	Measures covering the largest potential
Developed countries USA, EU-15, Canada, Greece, Australia, Republic of Korea, United Kingdom, Germany, Japan	Technical: 38%–79% Economic: 22%–44% Market: 15%–37%	1. Shell retrofit, incl. insulation, esp. windows and walls 2. Space heating systems; 3. Efficient lights, especially shift to compact fluorescent lamps (CFL) and efficient ballasts
Economies in Transition Hungary, Russia, Poland, Croatia, as a group: Latvia, Lithuania, Estonia, Slovakia, Slovenia, Hungary, Malta, Cyprus, Poland, and Czech Republic	Technical: 26%–72% Economic: 24%–37% Market: 14%	1. Pre- and post-insulation and replacement of building components, esp. windows 2. Efficient lighting, esp. shift to CFLs 3. Efficient appliances such as refrigerators and water heaters
Developing countries Myanmar, India, Indonesia, Argentina, Brazil, China, Ecuador, Thailand, Pakistan, South Africa	Technical: 18%–41% Economic: 13%–38%h Market: 23%	1. Efficient lights, esp. shift to CFLs, light retrofit, and kerosene lamps 2. Various types of improved cooking stoves, esp. biomass, followed by LPG and kerosene stoves 3. Efficient appliances such as air-conditioners and refrigerators

Table 1: CO2 emissions reduction potential for the buildings stock in 2020

Table 1 (Ürge-Vorsatz, 2009) provides the results of the estimated CO_2 emission reduction potential in buildings as a function of world regions for 2020. Globally, approximately 9% of the projected baseline emissions by 2020 can be avoided cost effectively through mitigation measures in the residential and commercial sectors.

When the potentials are examined from a sectoral perspective, the worldwide review of a large number of bottom–up studies has shown that, by far, the largest potential for energy related CO_2 emission reduction is in the buildings sector; in essence, the economic potential in buildings is larger than in all other sectors combined (Barker et al. 2007).

[1] The **technical potential** is defined as the amount by which it is possible to reduce CO2 emissions by implementing already demonstrated technologies and practices without specific reference to costs although economic considerations might be applied;
The **economic potential** is a cost-effective potential for CO2 mitigation when non-market social costs and benefits associated with mitigation options are considered with market costs and benefits using social discount rates instead of private ones at particular levels of carbon prices;
The **market potential** is defined as the amount of CO2 mitigation occurring under forecast market conditions including policies and measures based on private unit costs and discount rates.

In general, there is a severe lack of robust, comprehensive, detailed and up-to-date bottom–up assessments of CO2 reduction opportunities and associated costs in buildings worldwide. Furthermore, the current reports often review a limited number of mitigation options, which makes the potential estimates lower than they may be in reality. In existing assessments of mitigation options, co-benefits are typically not included, while in general, there is an important need to quantify and monetize these so that they can be integrated into policy decision frameworks. Moreover, there is a critical lack of understanding, characterization and taxonomization of non-technological options to reduce CO2 emissions. These are rarely included in global CO2 mitigation bottom–up assessment models, potentially largely underestimating overall potentials.

Selected bottom-up approaches for identifying energy saving potentials

To set up policy measures addressing energy efficiency a sound database of energy saving potentials is necessary. To collect these data and to promote a better understanding of the current status of end-use energy efficiency energy audits, either walk-through or detailed energy audits, are essential for all sectors of the economy (including residential/tertiary sector buildings as well as industrial sector and transport companies).

The analysis of energy saving potentials can be differentiated by

- sectors (e.g., industry, commercial and public services, private households),
- fields of application (e.g., heating, cooling, lighting)
- fields of demand (e.g., housing, food, mobility)
- or technology areas (e.g., micro-CHP plants, condensing boilers, heat pumps).

First, it is recommended to estimate existing energy use in the respective sector, field of application, field of demand or technology area based on available statistics or empirical research. From this starting point, a baseline of the development of energy use for the time period focused on will be developed. Finally, energy savings are calculated against this baseline.

It should be noted that depending on the objective of analysis, the baseline can be determined differently, e.g.,

- As frozen efficiency: Comparing energy efficiency activities against the starting point.
- As business as usual (BAU) development: Comparing energy efficiency activities against a projected trend development
- As low-impact policy development: Comparing additional energy efficiency activities against existing policy effort (which may already entail some additional policies and measures).

Usually, BAU development is chosen as baseline. The determination of the (fictious) baseline development often is subject to controversial discussion. Therefore, every baseline choice should be well-founded. General market developments (number of products sold, price developments, etc.) have to be taken into account. Time frames of analysis have to be specified.

Benefit-cost perspectives

In general, benefits and costs of energy efficiency activities can be calculated from different perspectives (SRC International A/S 2001, p. 58ff.):

- User / building owner benefiting from the energy efficiency measure
- User / building owner not participating in energy efficiency measures
- Market actor producing, installing or planning the energy-efficiency measure
- Energy company loosing revenues, if energy efficiency measures are implemented, maybe differentiated by generation, transmission, distribution and supply
- Government (budgetary perspective)
- Society (national economy perspective, excluding or including external costs).

Net costs of energy saved

Benefits and costs can be calculated per year or cumulative. In principle, in the societal perspective, net costs of energy efficiency measures are calculated as follows:

Net costs =	
	Additional costs of technical or organisational energy efficiency measures (additional compared to the baseline case)
./.	Long-run avoided system costs for the supply of electricity and heating fuels (including or excluding external costs)
./.	Avoided maintenance costs of energy-efficient technology (or plus additional maintenance costs)

However, also more differentiated calculations are possible that include, e.g., changes in energy prices due to energy savings, or transaction costs of market actors.

The additional costs of technical or organisational energy efficiency measures in relation to a kWh saved are calculated from the annuity of the additional costs of an energy-efficient technology compared to the annuity of the costs of a baseline technology, thereby applying an adequate interest rate and lifetime of the energy efficiency measure. The costs of the baseline technology are the costs that arise when a ‚normal' reinvestment or refurbishment is implemented anyway, using technology that confirms to minimal standards or market average of not efficient technologies. Any investment in highly energy-efficient technology will immediately or later replace an investment in a less energy-efficient, business-as-usual technology – for which we use the term ‚baseline technology' here. The costs for that baseline technology will be incurred in any case and may thus not be counted towards the energy efficiency measure. In the case of thermal insulation, e.g. the additional costs are those for mounting a layer of insulation material, when the building's façade will be renovated anyway. Consistently, energy savings from baseline technology compared to the status quo before the investment (e.g., from a new but not so efficient refrigerator versus and old, inefficient model that is being replaced) will also not be counted. Only the additional savings of the energy-efficient technology (in the example, a super-efficient refrigerator) compared to new but not efficient baseline technology are compared with the additional cost.

Long-run avoided system costs for the supply of electricity and heating fuels are mainly generation costs or prices at border crossing, including avoided costs of CO_2 certificates in emissions trading schemes, and including or excluding external costs not covered by the CO_2 certificates. Furthermore, they include long-run avoided transmission and distribution system costs, avoided grid losses costs and avoided costs of reserve capacities. For the calculation of long-run avoided system costs, several assumptions have to be made. From the perspective of the users / building owners benefiting from energy efficiency measures, long-run avoided system costs for the supply of energy carriers are the variable part of the energy price, i.e., the part dependent on kWh, kW, MJ etc..

In many cases, maintenance costs of the energy-efficient technology are lower than those of the baseline technology. Therefore these cost differences are added.

If not only net energy costs, but also CO_2 abatement costs are calculated, benefits and costs will not only be put in relation to the kWh saved, but also to the CO_2 emissions reduced.

Cost-Potential Curves

The result of analysing all energy efficiency technologies in the different sectors can be presented in different ways. In order to define the ecological efficiency, it is reasonable to identify the particular CO_2 emissions reductions, thereby allowing a comparison between the different measures for electricity and heating fuel savings, and fuel switching. Cost-potential curves should not only focus on CO_2 abatement costs, but should also show net costs of conserved energy.

The curves can be produced both from the societal and the investor perspective. They will show the size of the potential that is cost-effective in principle but not implemented through market forces alone due to the plethora of market barriers and failures that exist. The following excursion presents an overview.

Excursion: Why are there cost-effective potentials for saving energy through energy end-use efficiency?

Cost effectiveness is only a **necessary, but not a sufficient precondition** for the decision to invest in an energy efficiency measure. Many factors are influencing the process from the first impulse, via the activition, and planning, to the final decision, and the implementation.

The main reason, why a big part of the cost-effective potential for energy end-use efficiency is not being harnessed, are manifold **structural, economic, and socio-psychological barriers**. Among the most important of these barriers are:

- a lack of motivation and information, not only with consumers, but also with providers of appliances, installations, and buildings (e.g. installation contractors, trade, engineers and architects, manufacturers). This barrier is aggravated by the fact that the energy efficiency potential is split into many small and medium-size measures;
- financial restrictions, be they a lack of capital in public and private households, be they a priority for investment into a company’s core business;

- split incentives – those who could invest would not reap the benefits of saved energy costs and vice versa, and
- risk aversion, again both on the demand and supply sides of technology markets.

All those market barriers contribute to the fact that the technology **markets** themselves only **realise a smaller part** of the **cost-effective potential of saving energy** through energy end-use efficiency. There remains an unused potential of additional energy conservation and CO_2 emission reduction, which is often cost-effective from the perspectives both of national economy and the consumer. The task for the preparation of cost-potential curves is to identify this part of the potential that will not be realised by the technology markets themselves.

Strength and Weaknesses of Cost-Potential Curves

Cost-potential curves were developed to describe and compare the different options for energy conservation in a transparent way. They show the quantity of conserved energy as well as the costs related to specific saving options and thus provide an indication of which options are to be preferred to ensure cost-effectiveness. Furthermore they play a key role in many energy and climate policy models.

The construction of CSC, however, is subject to several methodological issues that have an enormous impact on the slope and position of the final curve. Some of these issues are related to the assessment of costs for distinct saving options, the choice of “perspective”, the uncertainty related to the estimation of the relevant saving potential or the choice of parameters like energy price forecasts.

The **input data** are crucial for the quality of the final cost-potential curves and it is not surprising that the input variables have a considerable effect on the results Main input variables include discount rates for the investment calculation and energy prices as well as emission factors and CO2 emission certificate prices.

Furthermore when evaluating energy efficiency investments, an important issue is the differentiation between **additional and full costs**. Full costs refer to all the direct costs related to an energy efficiency investment. For an energy-efficient electric motor, for example, these costs comprise the motor price and the installation. Additional costs, in contrast, do not consider all the costs involved, but evaluate the energy efficiency investment compared with the investment in standard technology that would have been made instead.

Another methodological aspect for the cost assessment is the issue of **external costs** and whether they are considered in the modelling. The existence of external costs and benefits, i.e. costs incurred or benefits enjoyed by third parties not directly involved in the economic activity, has often been proved. Whether to consider external costs and benefits when constructing cost-potential curves is merely a question of the chosen perspective. If the perspective is that of the decision maker (i.e. the firm or the private person investing), external costs are not considered as they generally do not influence the decision. If the cost-potential curve is constructed to show the costs for society, external costs and benefits can be incorporated.

Another factor that influences the cost results of the cost-potential curves significantly is the often observed **reduction of unit cost of new technologies** due to experience and scale effects. Especially when the cost-potential curve is used for a long-term analysis the effect of cost degression has to be considered but unfortunately assessments of cost degression of demand side energy technologies are rare. Especially for emerging energy efficient technologies that still have a low market share and a high potential for learning and scale effects, future cost reductions have to be considered when constructing a cost-potential curve. Thus, not to consider cost-degression effects for emerging energy efficient technologies in cost-potential curves analyses with a long time horizon does produce results with a significant deviation from reality.

An often criticised weakness of cost-potential curves is their **stepwise character**, caused by the very common application of average values for all kinds of inputs. In reality, energy carrier prices and the costs of a conservation measure are depending on the region, the structure of the market, bargaining power, the energy provider, the quantity bought, the energy taxes, the time or the season or in the case of electricity even the connection power. In the case of a stepwise curve, the choice and the definition of distinct conservation options or bundles of conservation options affect on the results. Particularly when many options are combined to one large bundle the impacts might be huge and the curve might seem completely different.

However, while the consideration of heterogeneity is inevitable when the cost-potential curve is used to simulate investment decisions in the course of energy modelling, this is not so much the case when the curve is used as an instrument to visualise and compare policy options in the debate about energy conservation and climate protection. In this case, a stepwise curve might make it easier for the reader to differentiate between the distinct options and for the reader it is obvious that real life behaviour is not as stepwise as the curve indicates.

Another factor is related to the core methodology of bottom-up energy models and the construction of the cost-potential curve from distinct conservation options. To construct the curve mostly the described bottom-up approach is applied, in which every single technology option has to be assessed and distinctly included in the calculations; it is obvious that **further conservation options** do always exist, given the enormous complexity of the industrial production system. Particularly in the longer term when more and more new options become available that are not known initially and thus cannot be predicted. Therefore, the resulting potentials are to be interpreted as showing a possible efficiency improvement for a certain well defined set of conservation options, but additional options that might change the slope of the curve always exist.

Furthermore most **conservation options are not independent** but influence each other. This interaction always occurs, when several conservation options are related to the same energy flow. It is indispensable to consider these technical interactions in the construction of a cost-potential curve; otherwise the curve would only show a comparison of independent and alternative conservation options but would not allow showing the marginal costs of conservation for a chosen quantity of energy saved.

Table 2 summarizes the different determinants affecting the cost potential curves.

	Effect on conservation potential	Effect on specific cost of conservation
Input values		
Quality of input data	Both directions	Both directions
Higher discount rate	-	Higher
Higher energy prices	-	Lower
Longer technology lifetime	Lower: Slower diffusion of efficient technologies through the stock	Lower investment costs due to longer use of technologies
Technology data	Both directions	Both directions
Stronger growth in activity variables (production, value added)	Increasing absolute potential	-
Methodology – decisions		
Consider energy taxes (not VAT)	-	Higher
Considering heterogeneity	Both directions	Both directions
Relate conservation potential to an autonomous baseline development	Lower	-
Considering non-monetary costs	-	Higher
Additional instead of full cost assessment	Lower: Slower diffusion of efficient technologies through the stock	Considerably lower
Grouping of distinct options	Both directions	-
Considering external costs	-	Mostly lower costs due to reduced external costs (pollution), some options with higher costs
Methodology - deficiencies / shortcomings		
Considering interactions of conservation options	Considerably lower	Higher (for most options)
Scale and learning effects	-	Lower costs (in the long term)
Rebound effect	Overestimation of conservation potential	Higher
Considering co-benefits	-	Considerably lower costs
Omission of conservation options	Higher	Higher

Table 2: Summary of determinants and their impact on cost-potential curves (Source: Fleiter 2009)

Data acquisition procedures

The data requirements and the requirements for their quality, detailing degree and timeliness are directed generally to the purpose pursued by the respective users of the data. It must be a distinction between primary statistical data, collected data and derived, estimated data. The amount of data required significantly increases with the degree of disaggregation of analysis, forecasts and scenarios, especially if they are model-implemented. In addition to the most energy-related information for these purposes, economical, socio-economic and technical data become increasingly important. Against this background, the regular production of primary statistical sectoral data isn't a negligible problem, which with further division between sub-sectors, such as in the service-sector, will be strengthened.

The service sector is a very heterogeneous sector with a large share of medium-sized companies in the field of small business, trade, crafts, agriculture, construction and private services. In addition, all public buildings and facilities belong to this sector.

For the design, implementation and evaluation of energy policy measures for the rational use of energy among other the following data must be collected: direct energy data such as energy consumption by sectors, sources of energy and end-uses and consumption influencing factors such as information on housing stock, on device structure and use, information on energy conversion facilities, to heating and hot water systems.

Additionally for the country analysed and each sector, data on energy prices (and, if possible, long-run energy system costs), energy taxes and emissions certificate costs, and expected real price development and real interest rates applied need to be collected or estimated. Furthermore, data on conventional and energy efficiency technology costs need to be collected or estimated for each technology area selected in order to be able to calculate additional costs and net benefit or cost of the increase in energy efficiency.

Required data for end-use energy statistics addressing energy efficiency

For calculation of energy efficiency potentials and related costs a **sound database** is crucial. On one hand the database contains **basic data** as energy costs, CO_2-factors, CO_2-certificate costs and interest rates from the societal and consumer perspective on the other hand the database provides **data for each efficiency application** like stock numbers, age structure of stock, degree of equipment, specific consumption of the current technology and of the efficient technology, data on conventional and energy efficiency technology costs and overall consumption of sectors and kinds of appliances. All these data are needed **for the current status** and **estimations** have to be made **for the future status** the efficiency potentials should be calculated. The following tables 3 and 4 provide proposals for the collection of the required data for the database.

Basic data	today	in future
Electricity costs for households		
Electricity costs for the service sector		
Electricity costs for industry		
Thermal energy carrier (gas, light and heavy fuel oil, coal, lignite, district heat etc.) costs for households		
Thermal energy carrier (gas, light and heavy fuel oil, coal, lignite, district heat etc.) costs for the service sector		
Thermal energy carrier (gas, light and heavy fuel oil, coal, lignite, district heat etc.) costs for industry		
Interest rate from the consumers perspective		
Long term avoided costs of electricity from the societal perspective		
Long term avoided costs of thermal energy carriers from the societal perspective		
Interest rate from the societal perspective		
CO_2 certificate costs		
CO_2 factors for electricity and thermal energy carriers		

Table 3: Required basic data for calculating cost effective efficiency potentials

Data for each efficiency application	today	In future
Stock number (could also be fields of application as e.g. m^2)		
Energy consumption per application of the standard technology		
Energy consumption per application of the energy efficient technology		
Technical lifetime of the application		
Costs of standard technology		
Costs of efficient technology		
Market share of efficient technology (business as usual)		
Market share of efficient technology (highest technically possible)		
Share of stock of efficient technology		-

Table 4: Required data of each efficiency application for calculating cost effective efficiency potentials

Overview and insight on bottom-up approaches for energy efficiency

(state-of-the-art; methods and necessary data basis)

Germany

Both in terms of design as in degree of differentiation, the data from Eurostat and IEA energy balances are comparable to a large extent with the German energy balance. Slight differences exist among others in the sectoral structure within the large end-use energy sectors. While the household sector in all statistics is relatively similar, due to different allocations there exist deviations in the service sector and the industry.

Annual energy balances on energy consumption by sector are made in Germany since 1950 by the "Working Group on Energy (*Arbeitsgemeinschaft Energiebilanzen*)". These consist of a primary energy balance, a conversion balance and end-use balance; a further breakdown by energy end-use applications is not here.

The household's end energy consumption today amounts to third of overall end energy consumption in Germany. In contrast to this the currently available data base for making the energy balance is rather poor. A separate survey, which targets the collection of total energy consumption of households, is not currently done in Germany. What does exist are statistical surveys which provide consumption data for individual end-use energy consumptions directly or equivalent information from which those data can be derive. Similarly problematic is the situation with data in the service sector. In some cases findings from recent surveys and studies are included.

Another important data source for household's and the service-sector's energy consumption are the application statistics. A breakdown of the sectoral end-use energy on the various applications is based on information provided by the *AG Energiebilanzen*, which calculates the annual energy consumption separated by energy sources and consumption.

The application statistics include the following applications:

- Heating
- Domestic hot water
- Process heat (washing, dishwashing, drying, cooking, forging, hardening, welding)
- Mechanical Energy (Stationary and motor drives, compressors, pumps etc.)
- Lighting (at workplaces, homes and staircases, street lighting)
- Information, communications (television, radio, computer, controls, telephone, mobiles etc.)

Data sources that are used for the household sector:

- Building and housing census (census of 1987, several random sample counts)
- Micro-census 800,000 respondents per year, 100 questions

- Income and consumption survey (interviews with approximately 70,000 households in a five-year rolling)
- Household survey of the German Federal Association for Energy and Water (DBEW) (written surveys of about 140,000 households in a five-year rolling)

Figure 1 summarizes the different approaches in Germany for generation of statistical data for end-use energy of private households.

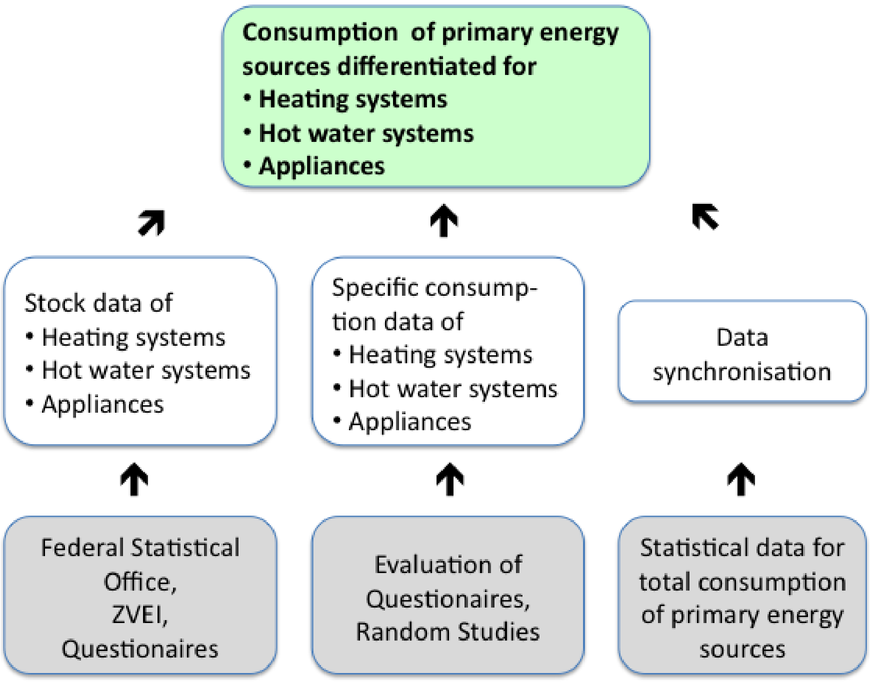

Figure 1: Bottom-up method for data evaluation regards structure of consumption of private households in Germany

Data sources for the service-sector:

Overall, the available energy data for this sector is in need of improvement. Currently used is following:

- Energy statistics of the *Arbeitsgemeinschaft Energiebilanzen* of the Federal Statistical Office, but no disaggregation into subsectors;
- Various association statistics, but they only rarely allow conclusions about the application and consumption shares by sector;
- Other statistics and national studies, for example DBU Detaillierungsstudie 1999 (Site inspections, metrological studies, questionnaires at 2800 companies) and IKARUS-Project

In summary, it can be stated for the end-use energy statistics in the household and service sector that a closed overall concept is missing and the sector boundaries are not sharp. In addition, the surveys have big time-lags, so that the compilation of time series is difficult.

EU

Households sector

With regard to reliable data in the household sector on end-use energy consumption by energy source and application within the EU, nine countries (Britain, Greece, Netherlands, Sweden, German, Austria, Spain, France, Italy) collect such data on annual basis (Odysee Database). Further details of energy consumption of households, including important consumption affecting factors are collected within the EU especially from Austria, France and Britain. Denmark has detailed building registers, both important in the household in the service-sector as basis for the calculation of energy consumption. In addition, in Denmark exist very detailed data on how households are equipped with electrical appliances.

Service-sector

Compared with the households sector, where a number of countries collect energy consumption data by energy source and application, for the highly heterogeneous service sector the available data regarding the direct energy consumption is significantly worse, especially considering data on subsectoral level.

Aggregated data of the whole sector are available for all countries on an annual basis. Additionally the statistical boundary of the service sector differentiates in the various countries which makes it difficult for international comparison. Especially the separation from the industrial sector is not uniform.

USA

The analysis of final energy demand of households, the service sector, industry and traffic are based on suitable statistics as well as on evaluations of the activities relevant for energy. These evaluations are mainly based on Zensus-surveys and backed up by sample testing.

Therefore most important is the availability of detailed statistical data relevant for energy, as for example building surfaces, degree of energy using equipment ownership of households and enterprises, energy demand after branches and kinds of energy use in the industry etc.

In addition, it is important for the production and evaluation of projections that the detailed data are given in good and consistent time series.

In the following a short overview over the US final energy statistics is given regards the background of these both main topics.

The hereby relevant energy application data originate from two main sources:

- The energy statistics for the Top-Down data are compiled using the monthly supply statistics of the energy utilities and f the sales statistics of the fuel suppliers. These data provide information at aggregated level about the actual energy use of the different energy sources and sectors. Weak points of these data lie above all in the fact that they deliver typically no information to where and for which purposes the energy is used.
- Since end of the 70s this topic is covered by bottom-up evaluations of the energy consumptions of the demand sectors.

With these statistics the US have very much detailed top-down and bottom-up energy statistics for households, the service sector and industry, which is classified in the international comparison as exemplary (Schlomann et.al. 2000, 61)

The elevations began for the households and the service sector in the end of the 1970s and were carried out predominantly every three years. Since 1986 corresponding data are also evaluated in the industry. For cost reasons since middle of the 90s the elevations have been carried out only every 4 years (Schlomann 2000, 61).

End use energy statistics in the household sector

In the households sector nine evaluations have been carried out since 1978 as representative evaluations each with approx. 5000 participating households. During the last years personal questionings have been substituted by phone interviews. Besides, not only numerous data relevant for energy consumption have been collected in the households, these data also have been compared with data of the energy supply companies or landlords where necessary to receive a more entire and more reliable picture of the energy end use (cf. Schlomann in 2000, 61).

In the framework of the Residential Energy Consumption Survey (RECS) households are asked about their kind of heating, about their general use of energy and about the degree of ownership of energy using devices. Moreover, numerous information about the energy costs of the households is also asked in the RECS. Additional statistical data as heating kinds of flats and residential buildings, are determined within the scope of the residential buildings census carried out every two years.

End use energy statistics in the service sector

The evaluations in the service sector refer to commercially used buildings (CBECS – Commercial Buildings Energy Consumption Survey, till 1986: Non-Residential Buildings Energy Consumption Survey). Above all energy applications are evaluated regarding energy sources, building surfaces, prevailing type of use of the building, energy use regards applications and energy costs.

Besides, the service sector evaluations provide exemplarily which problems can arise with the generation of time series. By a change of the classification system between different CBECS breaks in the time row – which also had influence on the exactness of the suitable energy projections – did arise.

Another weak point of the CBECS is the fact that the results are allocated according to prevailing applications, but not to branches or economic sectors.

End use energy statistics in the industry

In the industry sector Manufacturing Energy Consumption Surveys (MECS) have been carried out since 1986. Within these evaluations approx. 15,000 to 18,000 representative well-chosen industrial companies from all branches are questioned concerning their energy use according to energy sources as well as important applications and their energy costs. Base data serve annual turnover, added value and number of persons employed. The weighting of different branches occurs among other things after their energy intensity.

Fields of energy use are differentiated between indirect types of use in industry furnaces and cogeneration facilities and direct types of use in processes (process heat, power, electro-chemical processes, other process applications) and other nonspecific types of use like heating, ventilation, climate control, lighting, transport on the premises, electricity generation and others (AER 2003).

End use energy statistics in the transport sector

The data base for the transport sector deviates from those of the other sectors. Important base data are delivered by the Federal Highway Administration, which provides extensive traffic statistics, based on countings, questionings and numerous other regional databases. An important background is the breakdown of a share of the petroleum tax according the traffic volume in the federal states. For this purpose numerous statistic data are collected. The data relevant for the Annual Energy Review (AER) as the average kilometres travelled and the average consumption of passenger cars, pickup vans incl. the so-called sport Utility Vehicles (SUVs) and trucks are taken over from these statistics.

China

Role of energy efficiency and its measurement in China's energy policy

Saving energy in China is a national priority. The 11th Five-Year Development Plan requires a mandatory 20% energy intensity reduction by 2010, which has been allocated to the provincial and municipal levels. Ten key areas for energy savings have been identified, and 1,000 enterprises with intensive energy uses are now under tight supervision for EE enhancement.

In 2004, China launched its "Ten Key Projects" initiative, a billion dollar program that provides financial support for energy-saving projects ranging from the power sector to construction across the nation. Monitoring and evaluation systems are a core component of the plan to increase energy efficiency in China.

	Key Projects	11th FYP Stated Energy-Saving Goals	11th FYP Energy Savings (Mtce)	11th FYP CO_2 Emission Reductions ($MtCO_2$)
1	Renovation of coal-fired industrial boilers	35 Mt coal during 11th FYP	25	69
2	District level combined heat and power projects	35 Mtce/yr in 2010	85	244
3	Waste heat and pressure utilization	7 Mtce/yr in 2010	21	60
4	Oil conservation and substitution	38 Mt of oil	8	16
5	Motor system energy efficiency	20 TWh/yr in 2010	17	4
6	Energy systems optimization	Not stated		
7	Energy efficiency and conservation in buildings	108 Mtce	100	323
8	Energy-efficient lighting saving	29 TWh	12	25
9	Government procurement energy efficient products	Not stated		
10	Monitoring and evaluation systems	Not stated		
	TOTAL		268	743

Table 5: Ten key projects for energy savings in China (LBNL 2006)

Measurement, Reporting and Evaluation in China

The national climate change goals for China are outlined both in China's Five-Year Plan framework and in its specific climate change policy – the National Climate Change Program

(National Development and Reform Committee, 2007c), released in June 2007. As detailed below, both the national program itself and the various sector-specific programs within it have metrics associated with them, as well as reporting and in some cases verification procedures.

In general, our review of China's mitigation policies and measures finds that China has programs with targets attached that have supportive policies and measures and that these policies and measures are diverse in terms of their mitigation impact. Further our review finds that not all policies have stated metrics associated with them, in cases where they do exist, the set of metrics are both quantitative and qualitative in nature, and are both outcomes-based and process-based.

In many cases, China has provisions for reporting; however, these **differ greatly by policy and program**. In addition to reporting, China also has verification procedures, some of which involve crosschecking data, but most of which involve spot-check inspection systems. As these systems were introduced recently in most cases it is not yet possible to test the quality of the systems or the data they produce. Furthermore, it should be noted that some policy review and data collection processes are centralized, others are decentralized, leading to a very diverse MRV system for climate related policies and measures."

Central government energy efficiency initiatives with a focus on measurement and monitoring of energy efficiency

In the **Medium- and Long-Term Energy Conservation Plan** (2005, National Development and Reform Commission, NDRC) the central-government emphasizes the need for monitoring and measurement mechanisms for the evaluation of energy efficiency. Due to sectoral targets, the measurement adheres primarily to a top-down approach.

Energy efficiency performance evaluation: Beginning in 2008, the political and administrative abilities of local government leaders will be evaluated on the energy efficiency performance of their jurisdictions.

Cleaner Production Promotion Law: Article 28 says enterprises shall monitor resource consumption and generation of wastes during the course of production and provision of services, and conduct cleaner production audits with respect to production and service procedures according to need.

Beijing Energy Efficiency Center

Goal: To support a team of leading energy policy research institutes, led by the Beijing Energy Efficiency Center, to develop a **"bottom-up" modeling tool** in order to implement the National Energy Plan 2020 and help China achieve its 2020 development goals through sustainable energy development.

Data sources

Data on total production of energy and its composition is calculated on the basis of statistics on output of industrial products. Data on the total consumption of energy and its composition comes from the Association of Power Generation Enterprises. Moreover, energy data comes from energy balance sheets which are collected over the years.

Numbers for primary energy are compiled and reported by China's National Bureau of Statistics (NBS), which bases them on reports from provincial statistical bureaus and from corporations and government agencies in energy industries. NBS is the only source of comprehensive national statistics.

Gathering and assessing Energy Data in China

The main metric used is energy intensity of GDP, which is measured through an energy accounting system. The State Council to the NDRC and the National Bureau of Statistics (NBS) jointly set the standards and implemented a comprehensive system to review performance towards its goals. NBS collects the data and the NDRC leads a verification and inspection process. The NDRC has allocated energy conservation targets to every province, autonomous region and municipality. The regional governments have further allocated targets to cities, counties and key energy-intensive enterprises. All levels of government then report through their Statistics Departments. The Provincial and National levels of the NDRC then inspect enterprises to ensure compliance. The energy accounting system covers three areas: energy production; energy circulation (transmission and distribution) among different provinces; and energy consumption. The system is intended to collect energy data from specific sectors as needed to calculate the energy intensity of GDP as accurately as possible.

India

India’s energy efficiency policy has a long tradition. In 1978 the Indian government created the Petroleum Conservation Research Association (PCRA). Its main task has since then been the promotion of petroleum fuel saving strategies through programmes and campaigns. It also functions as a think tank to the government for proposing policies and strategies on petroleum conservation and environmental protection.

With the implementation of the Energy Conservation Act (ECA 2001) and the establishment of the Bureau of Energy Efficiency (BEE) the Indian government has further strengthened the energy efficiency institutions.

Beside the governmental level, industry plays a role that should not be underestimated. Indian industry associations have played an important role in promoting energy efficiency. The Confederation of Indian Industry (CII) and Federation of Indian Chambers of Commerce and Industry (FICCI) are engaged in capacity building. The Indian Green Business Centre is an example of an institution created by an industry association. It is engaged in facilitating energy efficiency improvement across industry. For instance an own rating system for sustainable buildings, the Leadership in Energy and Environmental Design (LEED-INDIA) Green Building Rating System, was setup by CII-Sohrabji Godrej Green Business Centre of the Confederation of Indian Industry (further information in Energy Efficiency Policies, Building Sector). A second rating system, GRIHA, was created by the Energy and Resources Institute (TERI).

The Energy Conservation Act 2001 (ECA 2001) and the role of the Bureau of Energy Efficiency

The most important regulation for energy efficiency policy in India is the Energy Conservation Act (ECA 2001) which was introduced in 2001. This act provides the legal framework, institutional arrangements and regulatory mechanisms at the Central and State level to upscale energy efficiency in various sectors of the Indian economy.

On the institutional level, with the ECA 2001 the BEE (Bureau of Energy Efficiency) was established. It is a statutory body under the Ministry of Power and became operational in March

2002 as the legal body in the Central Government. The overall task of the BEE is the development of policy and strategies with the primary objective of reducing energy intensity of the Indian economy.

The Central Government of India has identified nodal agencies or Designated Agencies in the different federal states to implement the EC Act. By now 30 of those state agencies are setup[2]. Some of these states have taken initiatives for awareness creation in energy efficiency, and a few have developed plans to implement demand side management programmes.

This will be achieved with active participation of all stakeholders, resulting in accelerated and sustained adoption of energy efficiency in all sectors.

For this purpose the BEE disseminates information and knowledge on energy efficiency and facilitates pilot and demonstration projects.

The Major Regulatory Functions of BEE include:

- Develop minimum energy performance standards and labelling design for equipment and appliances;
- Develop specific Energy Conservation Building Codes;
- Activities focussing on designated consumers;
- Develop specific energy consumption norms;
- Certify Energy Managers and Energy Auditors;
- Accredit Energy Auditors;
- Define the manner and periodicity of mandatory energy audits;
- Develop reporting formats on energy consumption and action taken on the recommendations of the energy auditors.

Another broad function of the BEE is to establish systems and procedures to measure, monitor and verify energy efficiency and conservation efforts and programmes.

General Energy Data Available in India and it´s collection

Energy Statistics (http://www.mospi.gov.in/cso_test1.htm) provided by the Ministry of Statistics and Programme Implementation gives a **sector-wise energy consumption at a national level**. They have outlined their Energy Data Collection Mechanisms for different sectors which are listed below:

Coal & Coal Derivatives

The statistics Division of the Coal Controller´s Organisation, a subordinate of the Ministry of Coal, is responsible for coal related statistics. They collect data from coal companies on a monthly basis on some major parameters. Annual surveys of coal and lignite industries based on complete enumeration, through mailed questionnaires, and sample check by physical inspection are carried out.

Petroleum and Natural Gas

[2] For further information see: http://www.bee-india.nic.in/designated.php

The Economic and Statistics Division of the Ministry of Petroleum and Natural gas is responsible. It collects data on a monthly, quarterly and annual basis from all public sector undertakings and private oil companies, including oil refineries.

Electricity

Central Electricity authority is responsible for collecting data from various Public and Private Entities/ Utilities/ Organizations/ Industries. Installation of electronic data collection system, called Information Management System, is underway. This will ensure that returns of electricity data will be directly furnished by concerned parties.

New and Renewable Energy

The Ministry of new and Renewable Energy (MNRE) compile basic data including year wise and month wise number of system installations, capacities, locations etc. from various stakeholders, such as the State Government Departments/ Nodal Agencies, NGOs, Private entrepreneurs etc.

Schemes, involving data collection, under the BEE Action plan for promoting energy efficiency in India during 2007-2012

Energy Efficiency in Small and Medium Enterprises (SMEs) Scheme

Realizing that "in quantitative terms, there is little reliable information and data available with respect to energy consumption and energy saving opportunities in SMEs." Therefore the BEE has proposed that it "in consultation with Designated State Agencies, will initiate diagnostic studies in 25 SME clusters in the country" by "conducting energy audits in these clusters".

Institutional Strengthening of BEE and other Energy Efficiency Institutions

Part of this scheme undertook the "setting up of Energy Conservation Information Center (ECIC) christened BEEnet as a web enabled online data collection and collation system. Web based online system that facilitates seamless filing of returns by the Designated Consumers as required under sections of the Energy Conservation Act. The returns will be required to be filed before the State Designated Agencies.

Projects covered by the BEE which deal with energy efficiency data collection

Energy end use study for residential electrical equipment

The project collected important information at selected sample of houses on patterns of actual baseline of electricity consumption, stock of electrical gadgets / appliances as refrigerators, air conditioners and electrical appliances such as geysers, electrical irons, mixtures, washing machines, computers, TVs etc.

It evaluates the degree of penetration of energy efficient appliances / devices and makes estimations of energy saving potentials with respect to energy efficient appliances

State-wise Electricity Consumption & Conservation Potential in India

The study focused only on estimation of the total electricity consumption and saving potential in the following sectors of each state / UT:

- Agricultural pumping;
- Municipal water and sewage pumping, street lighting;
- Commercial buildings like hotel/resorts, hospitals, shopping malls/multiplex, office buildings, public parks/monuments having connected load of more than 500 kW;
- Representative small and medium enterprises (SMEs) which have high saving potential.

The methodology applied by the National Productivity Council (NPC) for this purpose is as under:

- Data collection: Directly from the organisations in the state engaged in each sector by way of questionnaires designed for this purpose;
- Data collation and validation: By verification of data from third party sources like DISCOM, Industry Associations at the state level
- Data Verification: On a sample basis by field visits to facilities
- Assessment of Potential: By conduct of sample audit studies in certain facilities and by survey of similar audits conducted by the entities at the state level in the recent past.

The study also looks at the large industries and the household sector. The energy saving potential was assessed based on the experience gained in implementing programmes in industry and household sector by BEE and NPC.

Conclusions regarding energy efficiency related data in India
(drawn by experts)

No detailed national comprehensive energy statistics exist. This poses a major constraint and hinders efficient and effective energy policies. The situation has improved significantly in recent years based on the work of the Indian Bureau of Energy Efficiency, but further work is needed.

According to an IEA feasibility study, the driving forces of energy use are far from being clearly understood yet.

- More effective co-ordination of energy data collection and processing exercises across sectors and fuels is essential to improve the understanding of changes taking place in the Indian energy system and economy, allowing development of indicators and more informed policies.
- More capacity needs to be built in all statistical institutions involved in collecting and disseminating energy data in India.
- Methodologies to process energy data need to become more compatible with internationally accepted standards, such as the ones used by the IEA.

Specifically in rural areas data collection on consumption is primarily recall-based and local-level supply and demand is difficult to capture. Hence, there is an inherent problem of data availability and authenticity. Micro-level experiences are at times contrary to the macro assessments provided. The majority of rural energy data especially on the household energy is derived from national (NCAER & NSSO) surveys. Currently, the majority of other agencies and institutions do not have on their basic mandate rural energy related data collection.

It is desirable to allocate the responsibility of data collection to one agency and it will also be necessary to evolve a system of continually updating the information. The need is to evolve a system to capture the data on an area basis, focusing on a synergetic approach involving patterns and trends in traditional and commercial energy consumption, and economic, social and environmental indicators of rural development.

Examples

Energy end-use efficiency cost-potential curves in Germany

In a study on behalf of the energy company E.ON AG, Wuppertal Institute (2006) estimated energy end-use efficiency potentials in Germany. First, the current (2003) energy consumption was differentiated by the three sectors – residential sector (private households), commercial and public services, and industry – and the relevant end uses. The analysis showed 18 fields of end use with high energy consumption. As the second step, around 70 energy efficiency technologies and measures able to provide major energy efficiency improvements for these 18 fields of end uses were selected for the analysis. The third step was the analysis of the energy saving potential of these 70 energy efficiency technologies.

The analyses were made for 2005 as the starting point, 2010 and 2015, and consider the interactions between individual measures, such as thermal insulation and the replacement of a heating system. The energy saving potential was calculated on the basis of normal reinvestment cycles, since in most cases, the decision for the most efficient technical alternative will only be cost-effective, if modernisation or renovation works have already become necessary. At the same time, a possible increase in the stock of developed building areas, appliances and units was taken into consideration.

For example, for dryers in private households, it was assumed that the number of dryers develops from 12 million units in 2005 via 18 million units in 2010 to 20 million units in 2015, according to existing market analyses. Two energy efficiency technologies were considered, which are hardly used today and will – according to our estimate – not be used in future BAU development: gas-fired dryers and heat pump dryers. For the baseline, it was furthermore assumed that on average, a conventional dryer, with average use in German households, consumes 407.5 kWh_{el}/year. In the energy efficiency scenario, gas-fired dryers will have a market share of 60% in 2015, heat pump dryers a market share of 40%, i.e. no conventional dryers are sold anymore. The assumed lifetime of 12 years leads to the yearly replacement rate of 8.3%, i.e. that in 2015, more than 50% of the existing dryers are heat pump ones, more than 30% gas-fired ones. In total, the replacement of conventional dryers by gas-fired ones will lead to electricity savings of 2.9 TWh in 2015 compared to the baseline, and additional gas consumption of 3.4 TWh. The replacement of conventional dryers by heat pump dryers will lead to electricity savings of 2.2 TWh in 2015 compared to the baseline.

Net cost of energy end-use efficiency potentials in Germany

For example, for the above-mentioned example of gas-fired dryers, it was assumed that additional costs are 220 Euros/unit today, 132 Euros/unit in 2010, and 88 Eurso/unit in 2015 compared to the baseline technology, thereby assuming a learning curve and economies of scale. It should be noted that such estimates are always average values for additional costs, derived from the analysis of an average case. For the planning of an investment decision, however, the individual case should always be taken as the basis, particularly for more complex measures. The estimates for the average additional costs were based on manyfold references in the literature, research on technologies and market data, and experiences of the Wuppertal Institute from own pilot projects; these estimates were intensively discussed with E.ON AG and E.ON Energie AG staff. In particular, the estimates for the areas of space heating, water heating, cooking, and, in the residential sector, for clothes washing and drying, dish washing, and circulators for heating systems were fixed in joint discussions with the division ‘end use technology’ (*Anwendungstechnik*) of E.ON Ruhrgas AG. Furthermore, it should be noted, that for a number of measures, there is a large bandwidth of additional costs. As an example, the additional costs for thermal insulation according to the passive house standard (i.e. achieving a heating energy performance of only 10 to 20 kWh/m^2/year) can vary a lot between suppliers. Sources show a variation in additional costs between 15 and 130 Euros per m^2 of living space. Another reason for wide variations in additional costs can be that measures differ not only in energy efficiency, but also in other features that are difficult to monetise. Subjective valuations for such features were not taken into account within our quantitative assessment. An example is the additional space in the basement that may be gained through replacing an oil-based heating system by another heating system. However, such additional benefits, and the value given to them by consumers, may be decisive for an investment decision in practice.

For the calculation of the annuity in the case of gas-fired dryers, a real interest rate of 4% was applied for the calculation from the societal perspective, and 8% for the calculation from the perspective of the user and the energy company. Long-run avoided electricity system costs were estimated as 5.15 $EuroCents/kWh_{el}$ saved over the whole period considered (2005 –

2015), long-run marginal costs of gas supply assumed to be between 1.75 and 1.89 EuroCents/kWh, increasing between 2005 and 2015.

The resulting net costs in the case of gas-fired dryers were positive in 2005 (i.e. the energy efficiency measure is not yet cost-effective from the societal perspective and causes additional costs even after deduction of the avoided energy system costs), about zero in 2010, and slightly negative (i.e., the energy efficiency measure is economical from the perspective of the society) in 2015. At the same time, from the perspective of the customer, the measure is always profitable (always negative net costs), with a pay-back period of 6.0 years today, 3.3 years in 2010 and 2.2 years in 2015.

Cost-potential curve for end-use efficiency potentials in Germany

In the above-mentioned study on behalf of the energy company E.ON AG, (Wuppertal Institute 2006), finally, the following cost-potential curve was developed for the year 2015, starting from the beginning of 2006.

The total CO_2 reduction for all reduction technologies and for all sectors except transport in Germany, which was available within 10 years starting from the beginning of 2006, is shown in the figure above. Here, based on the 70 energy efficiency technologies analysed, measures which aim at the same end-use and which are implemented in the same technology markets, have been summarised. For this, the CO_2 reductions of each individual measure were added together, for the costs of conserved energy and the costs of CO_2 abatement, the weighted averages were calculated. Thus, it is possible to compare the CO_2 reduction potentials and the net costs of saved energy resulting from different end-uses and technology markets. The technology markets are partially overarching different sectors.

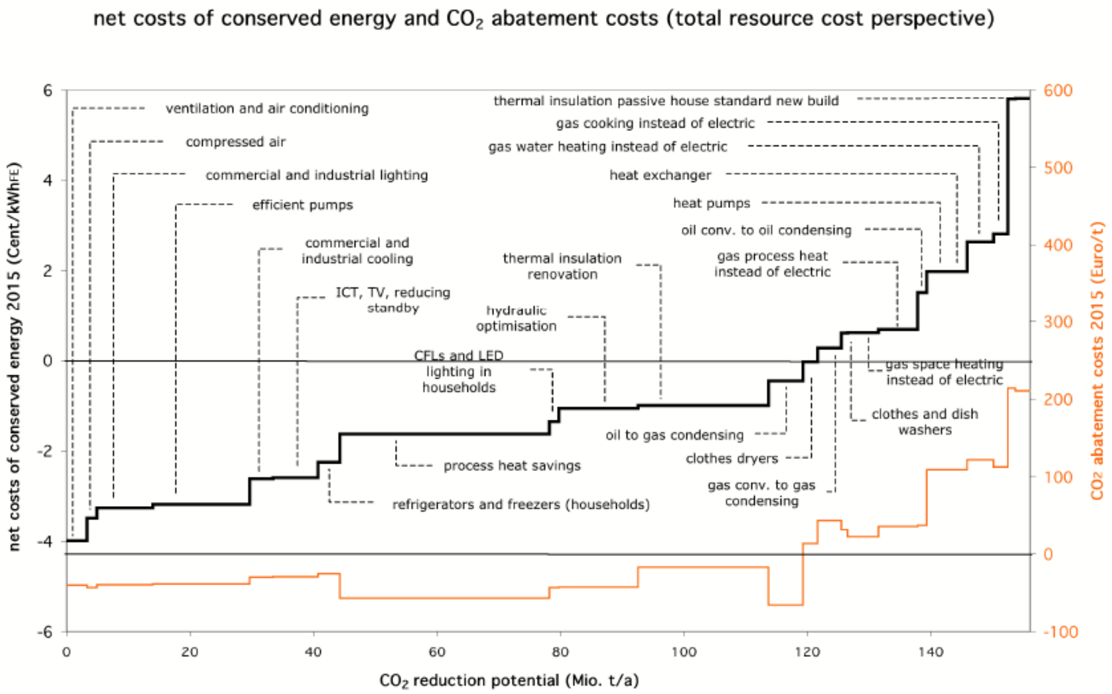

Figure 2: Cost-potential curve for end-use efficiency potentials in Germany (Source: Wuppertal Institute 2006)

In the figure above, the curves of net costs of conserved energy (bold line) and of net costs of CO_2 reduction (thin line) represent, from a macroeconomic view, the measures in an ascending order relative to the average net costs of conserved energy in Euro per kWh of conserved or substituted energy (electricity or heating fuel).

For a number of measures, there is a large bandwidth of additional costs of energy efficiency investment. Therefore, it should be noted that the net costs presented in the figure always include average values for additional costs, derived from the analysis of an average case.

All measures with net costs of saved or substituted energy below zero are cost-effective from the perspective of society. Measures with net costs above zero, in turn, cause additional costs even after deduction of the avoided energy system costs.

Thus, in this case of Germany, it will be cost-effective from the perspective of society to apply the examined efficiency technologies and measures for saving more than 120 million tons of CO_2 per year until 2015. Especially insulation of buildings, the hydraulic optimisation in the residential, commercial, public and industrial sector as well as the savings of process heat and the installation of pumps with frequency converters in the commercial, public and industrial sector can considerably contribute to cost-effective energy savings and CO_2 reductions.

Additionally, the net costs of CO_2 reduction in Euro per ton for each individual technology are shown from a total resource cost perspective (thin line in figure 1). Applying this indicator, most of the analysed potentials are cost-effective, too, i.e. the costs of CO_2-abatement are below the expected price per certificate of 10 Euro per ton of CO_2 or more.

Wuppertal Institute also calculated the costs of conserved energy from the customer's perspective. Generally, the picture is quite similar to the perspective of society, i.e. measures that are cost-effective for society will also be so for the customers. Usually, the net cost savings are even higher despite using a real discount rate of 8 % instead of 4 % for the societal perspective, since the customer also saves taxes on energy. Therefore, a number of measures that on average are bearing net costs for society, are cost-effective for the consumers. These are gas condensing boilers, efficient clothes and dish washers, and fuel switching from electricity to gas for space and water heating. Recently, energy prices have even increased above the levels assumed for the calculations within this project, which makes investments in energy efficiency even more profitable for the consumers in Germany.

Building Models

Energy used in buildings is responsible for more than 40% of energy consumption and GHG emissions of Germany and the EU and the sectors share of the cost efficient GHG mitigation potentials is estimated to be even higher. In spite of its huge savings potential up to 80% achievements are very slow in the building sector and much stronger political action seems to be needed.

In order to directly improve political action bottom up simulations of residential buildings are being conducted by different institutes and consultancies for Germany and for parts of the country (e.g. federal states or municipalities).

For the analysis a differentiated database of the building stock by construction periods, building types, as well as typical building sizes is used. Based on this a simulation of the thermal quality and costs of the components of the building shell for new buildings as well as the refurbishment of the existing building stock are modelled.

Based on this differentiated analysis relatively precise estimates of the potentials to be targeted by particular policies can be derived. By also providing estimates of the full costs related to certain strategies a major obstacle to accelerated energy-efficient building renovation and construction can be identified.

The Wuppertal Institute has developed and frequently used the “HEAT” model for such purposes. Its basic structure and features will be described in the following.

- The basic internal structure of the HEAT-model is the **heat demand planning.** For this calculation typical energetic characteristics of the relevant building shell components – such as outer walls, windows, cieling/roof and cellar –, the geometry and the size of every single building type are taken into account. Also factors like orientation of the building and its windows and shading from trees and neighbour buildings as well as internal gains from inhabitants and appliances are taken into account. For those typical values derived from empirical studies are used. The energy demand for heating is calculated using a static calculation model comparable to the Swiss norm SIA 380 (2009). In this context a full compliance to the respective standard is assumed. The fact that not all refurbishments or new buildings meet the standards can be taken into account for in the definition of scenarios.
- The building stock of Germany is represented by a number of 64 representative types of residential buildings. Their respective properties have been defined based on numerous empirical analyses as are used for several models in Germany. The types are basically characterised according to the ‚building-age‘ and the ‚building-size‘ because these two indicators are statistically available and appropriate to describe the energetic properties of typical building periods. Those periods are defined by the breaks in building tradition by the two world wars, the post-war period after the second world war and later periods mainly defined by strengthened building standards.
- Based on the heat demand calculation for each of the building types further energy uses are simulated:
    - Heating-systems (12 conventional systems, plus future-technologies) are simulated including their heat losses and auxiliary energy demand;
    - Hot water (demand calculated from the number of inhabitants and typical sanitary hot water usage, supplied from the heating system or from separate electric systems).
- Based on the technical simulation a differentiated simulation of the respective investments in energy saving measures and/or other alternative technologies are carried out.

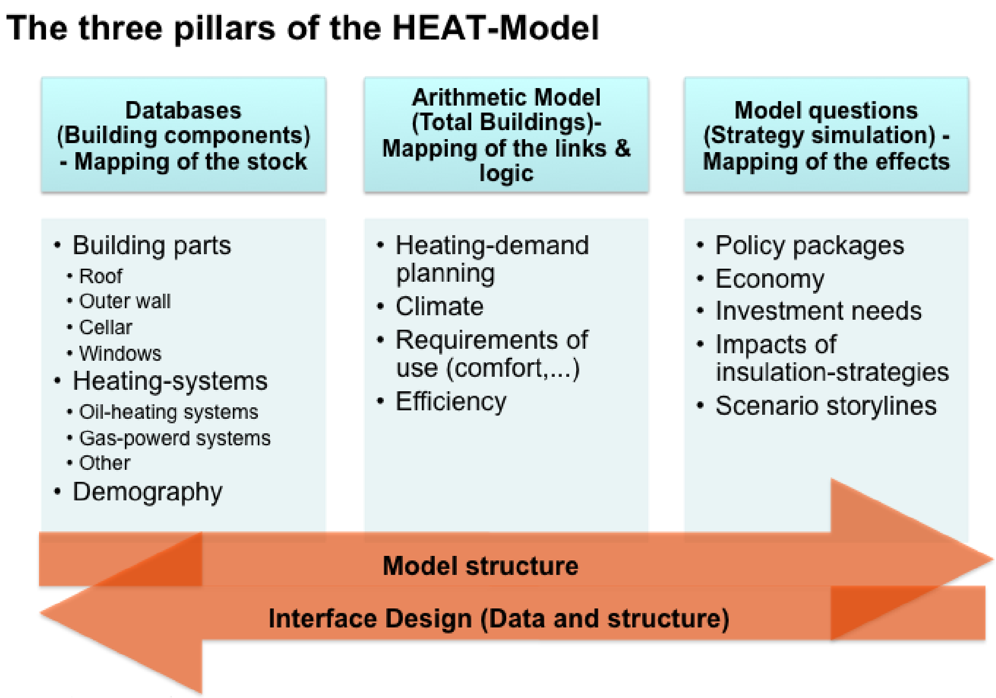

Figure 3: The three pillars of the HEAT-Model

Figure 3 summarises the components of the HEAT-model as three main pillars:

- The first pillar are intensive databases on the relevant components of all residential buildings, which are regularly updated according to recent technical and market developments. For all those components current and future energetic characteristics, potential application and typical cost values are fed into the model. Data for the model are derived from own field analyses and an extensive survey of secondary grey literature on technologies and costs.
- The second pillar is the calculation of the building as such. Here – for every one of the 64 typical buildings – heat demand and energy use is modelled. Based on this model different standards and various energy efficiency measures are designed and calculated and their effects and costs are balanced.
- The third pillar groups the efficiency measures per building to national strategies and scenarios. Here different philosophies for the selection of measures to be implemented over time can be selected. Here different assumptions according to the needed payback times for measures, certain barriers on implementation and/or market constraints can be taken into account. Further total effects on the national level are aggregated.

All pillars interact. This holds for the model structure and for the interface design. While the questions to be answered on the scenario and strategy level determine the detail of the model, the detail of the database predetermines the answers that can be given by the model.

Among other results the HEAT-model is capable of generating very detailed and well founded cost potential curves for the residential building sector.

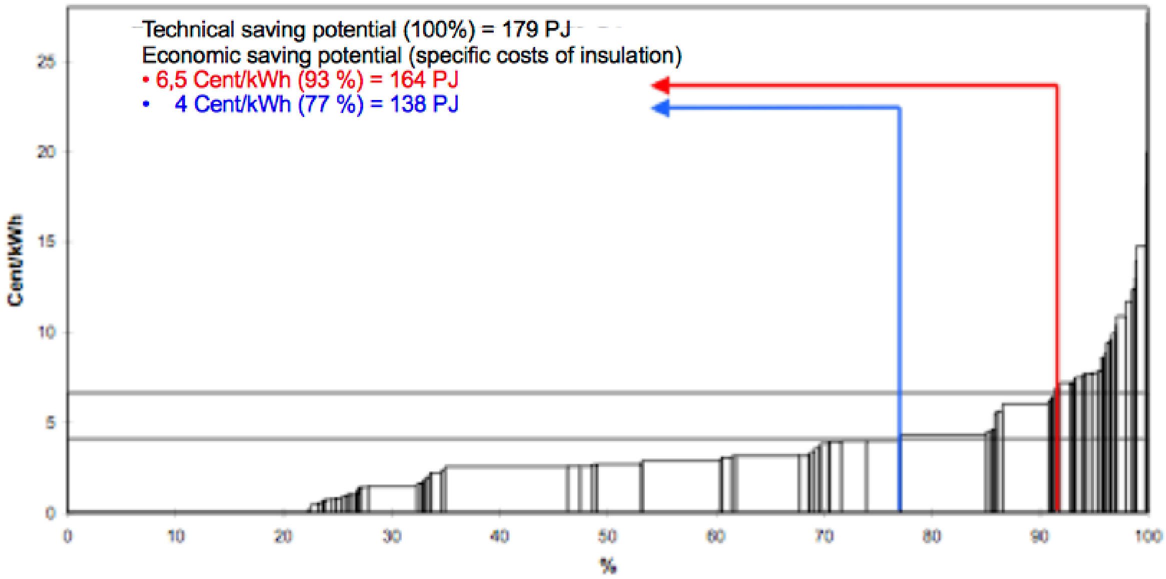

Figure 4: Cost potential curve of energy saving potentials from building shell improvements in existing buildings and specific costs of measures (Cent/kWh)

Figure 4 gives the results of a model run of the HEAT-model for Germany. It focuses on the heat demand savings from various renovation measures and different standards for new buildings. Details to the figure are given in table 6 below. Unlike other variants of such curves here only the costs of the energy savings are given. It can be shown that more than 20% of achievable savings come at zero or almost zero costs. 77% of the potential or 138 PJ are available below 4 Cent/kWh, 93% below 6.5 Cent.

		Percentage share of the (technical) energy-savings					Specific Costs of the energy-saving [€ Cent/kWh$_{th}$]				
Building size	Building age	Roof	Outer-wall	Celar	Window	Sum	Roof	Outer-wall	Celar	Window	Total Building
Single-family houses	before 1918	4,0%	5,6%	1,1%	1,3%	**12,0%**	2,7	4,0	1,9	6,7	**3,7**
	before 1948	4,5%	4,1%	1,2%	1,6%	**11,4%**	2,7	4,9	2,0	5,9	**3,9**
	before 1957	1,4%	5,3%	1,2%	1,3%	**9,3%**	8,1	3,3	1,4	4,2	**4,0**
	before 1968	3,4%	4,3%	2,4%	1,8%	**11,9%**	3,6	4,4	1,6	4,3	**3,7**
	before 1978	2,1%	3,6%	0,9%	2,8%	**9,4%**	10,1	8,8	2,9	4,2	**7,3**
	before 1983	0,8%	2,5%	0,9%	0,7%	**4,9%**	8,0	6,2	1,7	7,2	**6,0**
	before 1987	0,0%	0,0%	0,0%	0,0%	**0,0%**	9,7	13,7	2,9	5,1	**9,4**
	before 1995	1,1%	3,8%	0,9%	1,4%	**7,2%**	13,6	8,6	4,1	4,5	**8,2**
multi family buildings 3 - 6 dwellings	before 1918	0,8%	2,4%	0,2%	0,9%	**4,3%**	2,7	3,2	1,4	4,6	**3,5**
	before 1948	0,5%	1,6%	0,5%	0,7%	**3,3%**	2,6	3,1	1,5	4,6	**3,3**
	before 1957	1,5%	2,4%	1,0%	0,8%	**5,7%**	3,7	4,1	1,5	4,6	**4,1**
	before 1968	2,4%	3,4%	0,5%	1,3%	**7,6%**	3,9	3,0	1,8	5,4	**3,6**
	before 1978	1,0%	2,1%	0,5%	0,8%	**4,3%**	3,1	3,4	1,8	4,6	**3,7**
	before 1983	0,1%	0,8%	0,1%	0,4%	**1,4%**	0,0	0,0	0,0	0,0	**0,0**
	before 1987	0,0%	0,0%	0,0%	0,0%	**0,0%**	0,0	0,0	0,0	0,0	**0,0**
	before 1995	0,2%	0,7%	0,3%	1,4%	**2,7%**	0,0	0,0	0,0	0,0	**0,0**
mulöti family buildings with 7-12 dwellings	before 1918	0,1%	0,1%	0,0%	0,1%	**0,2%**	0,0	0,0	0,0	0,0	**0,0**
	before 1948	0,0%	0,1%	0,0%	0,0%	**0,2%**	0,0	0,0	0,0	0,0	**0,0**
	before 1957	0,1%	0,7%	0,1%	0,3%	**1,2%**	0,0	0,0	0,0	0,0	**0,0**
	before 1968	0,1%	1,0%	0,0%	0,3%	**1,4%**	0,0	0,0	0,0	0,0	**0,0**
	before 1978	0,2%	0,9%	0,1%	0,3%	**1,5%**	0,0	0,0	0,0	0,0	**0,0**
> 12 dw.	before 1968	0,0%	0,0%	0,0%	0,0%	**0,1%**	10,1	6,9	6,0	0,0	**7,6**
	before 1978	0,0%	0,0%	0,0%	0,0%	**0,1%**	13,6	8,6	3,1	4,5	**6,8**
	Sum	**24,2%**	**45,4%**	**12,0%**	**18,4%**	**100,0%**					

Table 6: Savings in residential buildings (costs and share of potential)

Possible roadmap for implementation in Brazil

Decisions regarding energy efficiency activities in Brazil require a sound database of cost effective efficiency potentials. Furthermore monitoring and evaluation tools have to be developed to assess the success of efficiency programmes and politics. The main steps to achieve this are summarized in the following points:

- **Cost-potential curves**: EPE may develop a methodology to generate cost-potential curves. Therefore according data (see above) have to be collected and processed in a database.
- **Database and data processing** tools need to be developed.
- **Scenario tools** need to be developed: definitions of targets, storylines, energy efficiency aspects.
- **Methods to monitor the impact of efficiency measures** are crucial and need to be developed (where appropriate together with partner organisations) and implemented.
- **Networking** with other institutions **in Brazil** during the whole process is very important for the success. Feedback, support and collaboration can be necessary and helpful during different phases of implementation. Decision makers, possible initiators of efficiency programs, regulatory authorities, national standards organisations and others should be linked to the activities as early as possible.

  On the **international level** cooperation should be intended with institutions which already have experiences with implementation and evaluation of efficiency programs in comparable countries.

Literature

AER (2003): Annual Energy Review 2003, IEA/DOE, 2004, Washington DC

Barker, T., Bashmakov, I., Bernstein, L., Bogner, J. E., Bosch, P. R., Dave, R., et al. (2007). Technical summary. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In R. D. B. Metz, P. R. Bosch, R. Dave, & L. A. Meyer (eds). Cambridge: Cambridge University Press.

Fleiter, T., Hagemann, M., Hirzel,S., Eichhammer, W., Wietschel, M.: Costs and potentials of energy savings in European industry – a critical assessment of the concept of conservation supply curves. In: Broussous, Christel (Hrsg.): Act! Innovate! Deliver! Reducing energy demand sustainability : ECEEE 2009 Summer Study ; conference proceedings ; 1-6 June 2009, La Colle sur Loup, France; Europ. Council for an Energy Efficient Economy, 2009, Stockholm

LBNL estimates and calculations based on National Development and Reform Commission (NRDC), 2006. Implementation Suggestions of Ten Key Energy-Conservation Projects during the Eleventh Five-Year Plan, NDRC Department of Resource Conservation and Environmental Protection Document: 2006

Levine, M., Ürge-Vorsatz, D., Blok, K., Geng, L., Harvey, D., Lang, S., et al. (2007). Residential and commercial buildings. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In O. R. D. B. Metz, P.R. Bosch, R. Dave, L.A. Meyer (Eds). Cambridge: Cambridge University Press.

Schlomann B. et al. (2000): Erarbeitung kostengünstiger Erhebungsformen zur Erfassung des effektiven Energieverbrauchs im Bereich Haushalte und Kleinverbraucher, im Auftrag des BMWT, Fhg-ISI, DIW, TUM, Berlin, Karlsruhe, München

SRC International A/S; et al. (2001): A European Ex-Post Evaluation Guidebook for DSM and EE Service Programmes. Birkerød

Ürge-Vorsatz, D., & Novikova, A., Köppel, S., Boza-Kiss, B. (2009): Bottom-up assessment of potentials and costs of CO2 emission mitigation in the buildings sector: insight into the missing elements. Energy efficiency, Springer Science + Business Media B. V. 2009

World Energy Council 2008: Energy Efficiency Policies around the World: Review and Evaluation, published by World Energy Council, London 2007

Wuppertal Institute (2006): Options and potentials for energy end-use efficiency and energy services. Summary. Final report by Stefan Thomas et al. on behalf of E.ON AG. Wuppertal