Uncertainties in the evaluation of energy savings potential

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Abstract
The potential of energy savings in the EU has been evaluated in the recent years. On a technical basis, it is frequently said that the amount of energy services delivered could increase by a factor two while using 50 % less energy. The EU green paper for energy efficiency published in June 2005 and the resulting European Action Plan for Energy Efficiency indicate that the economic energy saving potential is higher than 20 % of the total energy consumption in the EU. On the same time, markets face barriers to fill the gap between this economic energy savings potential and the actual observed energy consumption. An investigation of the evaluation methods for assessing the energy savings potential at a global level introduces many assumptions. The paper reports the different issues to be addressed in order to evaluate the energy savings potential at a regional or national level. Results obtained at EDF/R&D on technical potentials of individual energy end uses in France are given. The aggregation and the accessibility of these potentials are discussed but not quantified, while it is considered at the present time that the uncertainty is still too high to enable a consistent quantification.

Introduction
In 1998, Amory Lovins from the Rocky Mountain Institute promoted the "Factor Four"[1] which means doubling the energy services with 50 % less energy. In the European Green Paper for Energy Efficiency entitled "doing more with less" and in the European Action Plan for Energy Efficiency, it is said that "the EU could save at least 20 % of its present energy consumption in a cost-effective manner, equivalent to EUR 60 billion per year". These results have been obtained through evaluations and scenarios that need to select assumptions on many technical and economical parameters. After a review of different types of savings potentials, and a reminder about the evaluation of energy savings and cost methodologies, this paper presents the different steps leading from individual end-use potentials to achievable potentials. The main assumptions that create uncertainties in the potential evaluation are described and discussed.

Background

TECHNICAL, ECONOMIC AND ACHIEVABLE POTENTIALS
The evaluation of the actual energy savings potential requires a progressive approach making the difference between several types of potentials. The World Energy Assessment proposes six definitions of potentials[2]: theoretical, technical, Business As Usual, economic, welfare, and political. These six levels create a complexity difficult to handle in the objective of decision

1. Ernest Von Weizsacker , Amory Lovins, Hunter Lovins, (1998), "Factor four: doubling wealth, halving resource use" (report of the Club of Rome)

2. World Energy Assessment: *Energy and the challenge of sustainability* , chapter 6: Energy End-Use Efficiency

making. For this reason the literature on potential studies frequently uses three types of potentials:

- technical potential, obtained by a direct substitution of existing end-use technologies by best available technologies. This substitution is operated on the whole stock of end use equipments. This potential does not include technological progress that would occur in the future. The cost of the equipments is not considered as a limiting factor as far as the technology is actually available on the market. Therefore it can also be qualified as the present technical potential.
- economic potential. Starting from the technical potential, the economic potential selects only the technologies for which the investment cost is lower than the price of the energy saved during the lifetime of the equipment. The economic potential depends strongly on the energy price assumptions and on the discount rates used for the investment costs.
- achievable potential: in order to integrate the market reality, additional accessibility conditions to economic potential must be included to obtain the achievable potential. These conditions concern the supply side and the demand side of the market delivering energy savings. The limiting factors are technical, economic or societal. At the same time, policy instruments can play a role to overcome the barriers limiting the accessibility of the economic potential. While the definitions of technical and economic potential are quite clear, the achievable potential is a well understandable concept but complex to implement, because it contains much more assumptions. However, policy makers are more concerned about achievable potentials than technical or economic ones, because it indicates a target that might be reached in the reality.

EVALUATION METHODS FOR ENERGY SAVING PROJECTS

The International Protocol for Measures and Verification Projects (IPMVP)[3] is an international reference used by Energy Service Companies (ESCOs) and public organisations for contracting on energy saving projects. At the level of individual projects (local level), this protocol enables contracting parties to evaluate in a common view the energy savings, reducing transaction costs and avoiding claims resulting from differences on calculation methods. This protocol is useful for the evaluation of saving potential at the level of a building (cases A and B of the IPMVP Protocol for each energy efficiency measure and cases C and D for the energy saved in the whole building). But it does not give any indication on the potential of savings at a more global level (city, region, state).

METHODS AND UNCERTAINTIES FOR THE EVALUATION OF ENERGY SAVINGS AT A SECTORAL OR NATIONAL LEVEL

Methods used to evaluate total realized energy savings at a national or sectoral level have been recently analysed and discussed by Piet Boonekamp[4]. The author identifies issues that may introduce large differences in the resulting evaluation: the choice of the right aggregation level, the appropriate variables to construct a reference energy consumption trend, the energy quantities to be applied and interaction between various effects. He also stresses the fact that uncertainty margins are hardly discussed in most evaluations of total energy savings.

According to the Directive on Energy Efficiency on end-use and energy services, to be implemented by January 2008, evaluation methods for energy savings at the level of the member states are being developed, both in the EMEEES project [5] and in a CEN Taskforce recently engaged[6]. The methodology framework for this evaluation combines top-down and bottom-up methods.

COST EVALUATION FOR ENERGY EFFICIENCY PROGRAMS

The California Standard Practice Manual[7], related to economic analysis of demand side projects and programs, introduces four tests evaluating the balance between costs and benefits on different perspectives:

- the participant cost test, which refers to the consumer
- the rate impact measure test (RIM), which was previously named the non-participant cost test
- the total resource cost test (TRC), which contains a variant named the societal cost test
- the program administration cost test, which was previously named the utility cost test

The Societal Test differs from the TRC test in that it includes the effects of externalities (e.g. environmental, national security), excludes tax credit benefits, and uses a different (societal) discount rate.

RESULTS ON ACHIEVABLE ENERGY SAVINGS POTENTIALS

Several studies have evaluated the potential of savings in Europe and United States. The accounting unit of the savings vary from a study to the other: primary energy, final energy or CO_2 emissions. These differences create a difficulty to compare the results.

The "White and Green" Project completed under the EU SAVE Programme reviewed policies and measures to promote energy efficiency. Several of the policies and measures were simulated using technical-economic models of the MARKAL family[8]. The results suggested that by 2020 it is possible to increase energy efficiency by 15 % at no net cost without taking externalities into account. If externalities are considered, an increase of 30-35 % with respect to the business-as-usual

3. www.doe.gov/bridge

4. Piet Boonekamp, Evaluation of methods used to determine realized energy savings, Energy Policy 34 (2006) 3977 3992

5. EMEEES: Evaluation and Monitoring for the EU Directive on energy end-use efficiency and energy services, http://www.evaluate-energy-savings.org/

6. http://www.cen.eu/cenorm/businessdomains/businessdomains/utilitiesandenergy/latest+news+energy.asp

7. California Standard Practice Manual: economic analysis of demand side projects and programs. California Public Utility Commission, 2001, http://www.energy.ca.gov/greenbuilding/documents/background/07-J_CPUC_STANDARD_PRACTICE_MANUAL.PDF

8. Ugo Farinelli, Thomas B. Johansson, Kes McCormick, Luis Mundaca, Vlasis Oikonomou, Mattias Örtenvik, Martin Patel and Federico Santi, *White and Green: Comparison of market-based instruments to promote energy efficiency* , Journal of cleaner production 13 (2005) 2015-2026

scenario is justified. However, the modelling did not include transaction cost nor market imperfections.

The European Action Plan on Energy Efficiency (EAPEE), published in October 2006 by the European Commission presents estimates (in primary energy) for the "full energy savings potential" achievable in 2020 in each sector: 27 % for households, 30 % for commercial buildings, 26 % for transport and 25 % for manufacturing industry[9]. The EAPEE indicates: "on the basis of this full potential scenario for end-use sectors, the additional savings from new policies and measures and from strengthening existing ones are realistically estimated to be up to 20 % (1.5 % or 390 Mtoe per year) by 2020 (including savings in end-use sectors and at the level of energy transformation)".

Nadel & al. reviewed in 2004 the different studies of technical, economic and achievable energy efficiency potentials in the United States[10]. Savings potential across the 11 studies range from a 5 % achievable savings potential for natural gas throughout the U.S. over a ten-year period (Interlaboratory Working Group 2000) to a technical savings potential of 40 % or more in studies on Oregon and Washington State. In some states and sectors, the technical savings potential is as high as 69 %. Across all sectors, these studies show a median technical potential of 33 % for electricity and 40 % for gas, and median economic potentials for electricity and gas of 20 % and 22 % respectively. The median achievable potential after 20 years is 24 % for electricity (an average of 1.2 % per year) and 9 % for gas (an average of 0.5 % per year).

Lechtenböhmer et al. proposed in 2005 a policy and measure scenario[11] targeting an EU post-Kyoto strategy for the period 2012-2020. This scenario, mainly based on the large penetration of renewable energies and energy efficiency, indicates that "a reduction of EU-25 greenhouse gas emissions by more than 30 % by 2020 is feasible, reasonable and – to a large extent - cost effective".

Methodology and results for the evaluation of technical potential for end-uses in residential in France

WORK IN PROGRESS AT EDF/R&D ON SAVINGS POTENTIAL EVALUATION

EDF/R&D has engaged an internal study on potential evaluation in the residential, tertiary and industry sectors. The objective is to develop a knowledge enabling EDF to:

- have constructive interactions with policy makers
- address cost-effective measures for delivering energy savings
- propose suitable R&D issues on technologies for energy efficiency

The first phase was to assess the individual technical potential and the related cost of energy savings for the main energy end-uses in these sectors, using mainly public surveys and databases. The second step was to make an integration of individual potentials in order to obtain a global picture of the technical and economic energy savings potential in France. On that purpose, we had to solve the problem of aggregation linked to interactions between individual energy savings measures, and the heterogeneity of data availability for the different sectors. While the residential sector was quite well documented, the industry a little bit less, the tertiary sector was much more difficult to address.

BASELINE AND COST ASSUMPTIONS

In our study, the technical potential has been obtained by a direct substitution on the whole stock of existing end-use technologies by the Best Available Technologies. This potential does not include the technological progress that would occur in the future.

Three levels of energy performance are considered:

- low performance: average of the equipment stock
- medium performance: present average of market sales
- high performance equipments: Best Available Technologies (BAT)

A major issue is the selection of the technology for the baseline of the energy savings potential evaluation. For which products should the market sales average performance be selected or the stock average performance?

If we consider that the customer would have in any case bought the equipment at a given time, we are in a replacement configuration and the market sales average performance should be considered as the baseline. But when the customer has decided to invest in energy efficient equipment before the date of natural replacement, or when the investment was first driven by the energy savings, it can be considered that the baseline is the equipment stock equipment performance. When the baseline is the equipment stock, which means that customer's decision to invest was first driven by the expected energy savings, the cost selected in our study is the total cost of the equipment. In this configuration, we did not withdraw from the cost the co-benefit of the investment, for example comfort. When the baseline is the market average, then the cost is the difference between the Best Available Technology and the average market cost. In this evaluation of technical potential, the customer cost includes investment and installation, but transaction costs have not been included, nor co-benefits like innovation and employment. The table 1 presents the assumptions selected on our evaluation for each energy efficiency measure.

RESULTS OF TECHNICAL POTENTIAL FOR END-USE SAVINGS POTENTIAL IN THE FRENCH RESIDENTIAL SECTOR

The figure 1 gives an example of estimated technical potentials for selected energy saving equipments in the French residential sector. These results highlight the necessity to address energy efficiency measures on the reduction of energy needs by

9. European Commission, EU-25 Baseline Scenario and Wuppertal Institute 2005.

10. Steven Nadel, Anna Shipley and R. Neal Elliott:American Council for an Energy-Efficient Economy, *The Technical, Economic and Achievable Potential for Energy-Efficiency in the U.S. – A Meta-Analysis of Recent Studies*, Proceedings of the 2004 ACEEE Summer Study on Energy Efficiency in Buildings

11. Stefan Lechtenböhmer, Vanessa Grimm, Dirk Mitze, Matthias Wissner *Energy efficiency as e key element of the EU's post-Kyoto strategy: results of an integrated scenario analysis*, ECEEE 2005 summer study 203-212

Table 1. Proposed assumptions for the evaluation of energy savings and associated costs applied to selected end uses

End-use	Baseline	Total cost v.s. overcost	Comments
Loft, wall and ground thermal insulation	stock performance average	total cost	Induced by the energy efficiency measure
Double glazing	stock performance average	total cost	Mainly induced by the energy efficiency measure, but the comfort is also a strong factor of decision
Condensing boiler or high temperature heat pump	market performance average	overcost.	The policy aims at transforming the existing market
Solar water heater	stock performance average	total cost	Induced by the energy efficiency measure
CFL	market performance average	overcost	Difficulty on the lifetime assumption (years v.s. number of switches).
Refrigerators	market performance average	overcost	The cost difference includes non energetic functionalities like design or others

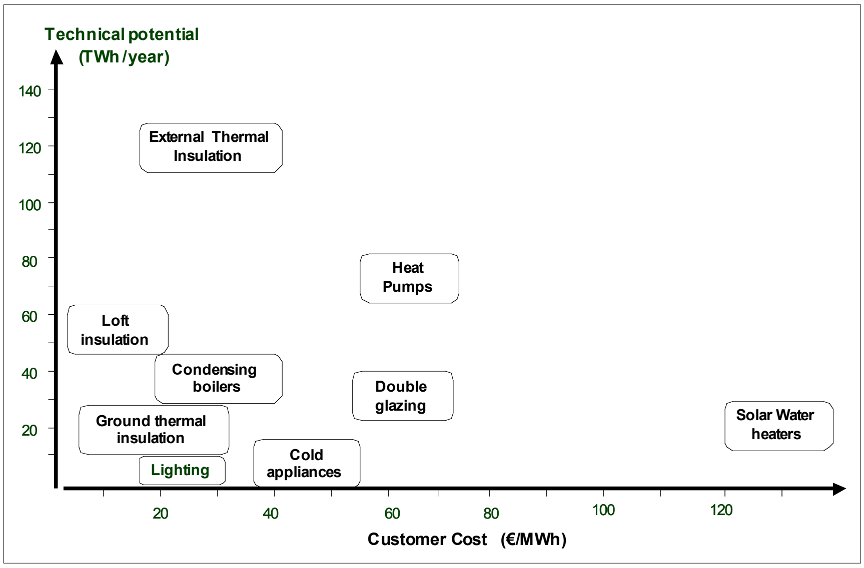

Figure 1: Technical final energy savings potential in France for the residential sector *– source EDF/R&D, customer cost corresponds to the cumulative energy saved during the lifetime of the efficient equipment, with a 4 % discount rate, the potential refers to annual final energy savings.*

thermal insulation of households. While the market already delivers loft insulation measures, external thermal insulation is an emerging technology in France that still needs to be implemented on a large scale. For heat and hot water generation, condensing boilers and heat pumps present a high potential of savings.

Discussion on methodologies and uncertainties for global evaluation of technical, economic and achievable potentials

AGGREGATION METHODOLOGY FOR THE EVALUATION OF TECHNICAL POTENTIALS

The energy savings potential of the residential sector in France arising from the technologies indicated in Figure 1 cannot be obtained by the addition of individual savings potential. On one hand, there is an overlap between the efficient technologies that might compete each other on the same use: condensing boilers and high temperature heat pumps can both be selected for the replacement of a standard boiler. On the other hand, the value of the energy saved with energy efficient thermal insulation equipments and heating systems cannot neither be added when they are combined. A correcting factor must be included in the model. An option is to consider first the potential related to the reduction of energy needs. Then, the potentials for heat generation in the whole sector are applied on the energy consumption obtained after this first reduction. Nevertheless, this method applied on average values of two energy efficiency measures does not integrate the heterogeneity of improvements resulting from each measure which creates an uncertainty when the two measures are combined for the whole stock of buildings.

REBOUND EFFECT

Usual environmental evaluation methods like Life Cycle Analysis (LCA) do not change the functional unity when different solutions producing this functional unity are compared. The rebound effect, usually considered as a correction factor in the evaluation method for energy savings, describes the difference of customer behaviour before and after the energy saving measure implementation. If a life cycle approach is used for the evaluation method comparing a policy scenario to a BAU scenario, we suggest that the rebound effect as a correction factor would be considered as an exogenous parameter and not included in the evaluation process.

ASSUMPTIONS REQUIRED FOR THE EVALUATION OF ACHIEVABLE POTENTIALS

Starting from the technical potential, the economic potential selects only the technologies for which the investment cost is lower than the price of the energy saved during the lifetime of the equipment. In order to evaluate the achievable potential, additional accessibility conditions must be included, that integrate the market reality, on the supply side and on the demand side. These conditions concern technical, economic or society related limiting factors, which change itself with time. First, the actual number of equipments concerned by the possibility of applying a best available technology must be considered. For example, retrofitting can hardly be realized on an household that was built less than five years ago. Also, floor thermal insulation has an accessible potential only on households in which this will not need to turn the building upside down. Then, the economic limitation should not come only from the investment cost of the equipment. The supply side of the market is not always able to deliver the technology or the service to the whole market on which it could be applied technically. Industrial and distribution structures of product manufacturers or service providers are often not adapted to address their offers to all the customers.

THE IMPORTANCE OF TRANSACTION COSTS

Referring to the Standard Practice Manual definitions for addressing cost evaluation, the costs to be considered in the evaluation of potentials are:

- the program administrator cost. This includes the cost incurred by the administrator of the program and the incentives received by the customers from this administrator.
- the participant cost. This is what the customer must pay to implement the measure: investment and installation cost of the energy efficient equipment. (The incentive received from the administrator of the program is not included in the cost. The energy bill change (higher or lower) generated by the energy efficiency program has also to be included.

The cost structure of the program administrator can be described more precisely:

- cost for the promotion of the energy efficiency measure
- resources for delivering the measures: audits, partnership contracts with installers,…
- resources for evaluation and registration of energy savings. When the energy efficiency programs are organized by the public authority but implemented by other parties, for example energy suppliers or distributors in the white certificates systems, these costs exist in both sides.

The share of these transaction costs in total cost will depend on the policy and measures that are implemented. For instance, they are higher in a white certificate system than in a mandatory requirement on performance of building or equipments[12]. Up to now, many studies on potential evaluation have not considered the transaction costs, which are difficult to address for a quantitative assessment. Introducing transaction costs in the saving potential evaluation reduces significantly the achievable potential, and the impact of transaction cost requires a policy scenario to be addressed.

THE INFLUENCE OF THE FACTORS DRIVING THE CUSTOMER DECISION

An energy efficiency policy induces a transformation of consumer behaviour on purchasing, but the dynamics of this policy induced market transformation is not well known. For example, would a recent householder owner buy a new efficient boiler saving much energy compared to the existing one after only the midterm of its lifetime? If we consider that the policy will accelerate the replacement market, we should then consider the baseline as the performance of the stock average. If we consider that the policy has no influence on the rate of boiler replacement, we should take the sale market performance average as the baseline. The resulting energy savings value differs significantly for one assumption compared with the other.

When a global assessment of savings potential is sought, many end-uses in different sectors are considered. The assumptions selected for this evaluation may vary strongly from one sector to the other. The decision making for saving energy is not the same for private customers in their household and for industrial managers. While a rational economic behaviour can be assumed for a business activity, the experience shows that it is not the same for the residential sector where other drivers exist as explained before. As a consequence, the weighting by experts of the accessibility parameters necessarily introduces a large uncertainty on the resulting evaluation of the achievable energy savings potential.

CO-BENEFITS OF ENERGY EFFICIENCY MEASURES

While investigating the market of energy savings, one faces a difficulty to provide an accurate metrics. In most cases, the savings constitute only one part of the product or service benefits. The customer does not buy energy savings, but a product delivering a service that holds its own utility: lighting, cooking, travelling, watching TV, heating, cooling. If he buys an efficient product, he will save energy compared to a standard product delivering the same utility. The energy savings cost in this case is the difference between the standard and the energy efficient product cost. However, in many case both products do not deliver the same utility.

12. Louis-Jacques Urvoas, Dominique Glachant, Luc Lorge, Paul Baudry, "*the action of EDF in end-use energy efficiency*", eceee 07 summer study, paper ID 2344

THE RATE OF MARKET TRANSFORMATION

This potential resulting from a static analysis of technical and economic conditions does not give any indication on the market dynamics needed to meet the target. A roadmap consistent with a realistic market evolution is necessary to propose a path filling the gap between the present situation and the objectives given by the policy. The rate of market transformation will be a critical issue on this purpose. Present market transformation rates result from previous market conditions and policies. Assumptions on rates of market transformation for the future are still hypothetical, depending not only on energy efficiency policies but also on the strategies of the equipment manufacturers on the supply side, and on the change of the consumers on the demand side, arising from societal evolutions.

Conclusion

The evaluation of a global energy savings potential requires a data collection on all energy uses. The process leading from individual energy savings of end-uses to the global achievable potential at a given time requires a progressive approach, introducing many assumptions. Results obtained at EDF/R&D on technical potentials of individual energy end uses in the French residential sector confirm that priority should be given to thermal insulation measures, and efficient heating systems. Key issues introducing uncertainties in the evaluation of achievable potentials have been identified and discussed. At the present time, we estimate that the uncertainty associated to the combination of these key factors are high and that the results on achievable potential evaluations should include uncertainty by providing range values. EDF/R&D is working on producing a scenario for France. The scenario approach enables to overcome the problem of uncertainties by delivering a proposal, which is different from a strict ex-ante evaluation.