Implementing Cost Potential Curves (CPCs) as an Energy Planning Method for Energy Efficiency in Brazil

Developed by:

gtz Brazilian-German Energy Program

Sebastian Schreier

For:
Agência de Cooperação Técnica Alemã – GTZ
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

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Coordination: Torsten Schwab (GTZ),
Ricardo Gorini (EPE)

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1 Introduction

In recent years, the Brazilian economy has been showing consistent growth rates and a society with an increasing standard of living, promoting further the growth of the commercial, service and industrial sector. As a consequence, the electric energy consumption has been growing and will probably continue to do so. The increasing electric energy demand has to date been met by the construction of new power plants.

Introducing energy efficiency measures in the end-use electric energy consumption of the different Brazilian sectors seems to be a good way to keep investment in new power plant at a reasonable level.

In the same way, implementing energy efficiency for saving energy from other sources is also from general interest of society.

Additionally, Brazilian politics recently joined the proactive global players for climate protection. Energy efficiency helps to maintain the outstanding low-carbon energy supply in Brazil and therefore contributes to climate protection.

In order to take the most promising measures to promote energy efficiency, the first step is to identify where energy saving potentials exist.

An instrument which has been gaining popularity for indentifying these energy saving potentials, as well as their related costs, is the so called “Cost Potential Curve” (CPC). CPCs have been calculated in other countries where enough empirical data had been gathered through bottom-up studies. The results were used as reference for implementing certain energy efficiency measures. Based on the positive experience with CPCs in other countries, they shall now be tested as a tool within the Brazilian energy planning toolset.

In this context, 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 modeling and forecast methodologies undergo a constant refinement. In the context of the technical cooperation program between Brazil and Germany, EPE and GTZ (*DeutscheGesellschaft für Technische Zusammenarbeit mbH*) cooperate in order to refine energy efficiency related methodologies for energy planning.

Prior to the present work, EPE and GTZ have contracted a study 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. On that study, was mentioned how identified energy efficiency potentials can be published with the help of CPCs.

The objective of the present work is to bring further the process of the possible implementation of CPCs as an additional tool for Energy Efficiency planning Methods in Brazil. Therefore a general description about CPCs was made, steps for the implementation of CPCs from the data gathering to the use of them were defined and described and finally a concrete and formal methodology for calculating different kinds of CPCs was formulated. The methodology describes formally which the needed INPUT parameters are and how those are used to calculate the OUTPUT parameters for constructing CPCs, so they can finally be published plotted on a chart. For better illustration of the methodology, a concrete example was given for each theoretically formulated step.

2 CPCs and their Calculation Methodology – Market Potential

(With an example for calculating CPCs for fluorescent lamps on EPEs 10th floor)

2.1 General description about CPCs

2.1.1 What are CPCs?

Cost Potential Curves (CPCs) are by now a common instrument for visualizing energy efficiency potentials and their marginal cost in an easy and understandable way. The energy efficiency potentials could be identified for a whole economy, a specific sector, specific applications or further segmentations.

Characteristic for CPCs is that the data used for calculating them is gathered with a bottom-up approach. That means, energy consuming appliances and systems are first identified, then energy efficiency measures are defined on a unit level and afterwards they are aggregated for a whole stock representing so the energy efficiency potentials for the segmentation done.

CPCs are plotted on a chart with two-dimensions. The cumulative energy efficiency potentials for all appliances or systems are given on the x-axis of the chart. On the y-axis the net marginal costs (or benefits if the cost are negative) for each potential unit of energy saved are given as a function of the specific parameters for each appliance and system.

The energy efficiency potentials of the analyzed appliances and systems are given on the chart following a marginal cost priority order, being the first one on the left the less cost intensive one (lowest marginal cost) and the last one on the right the most cost intensive (highest marginal cost)(Figure 1).

With the help of CPCs it is possible to recognize which energy efficiency potentials exist and which the costs (or benefits) for implementing them would be, as well as to which energy efficiency measures should be given priority because of its marginal cost advantage.

For calculating the energy efficiency potentials as well as their marginal costs needed for constructing CPCs, a specific methodology is to be applied. The methodology is described further in this document.

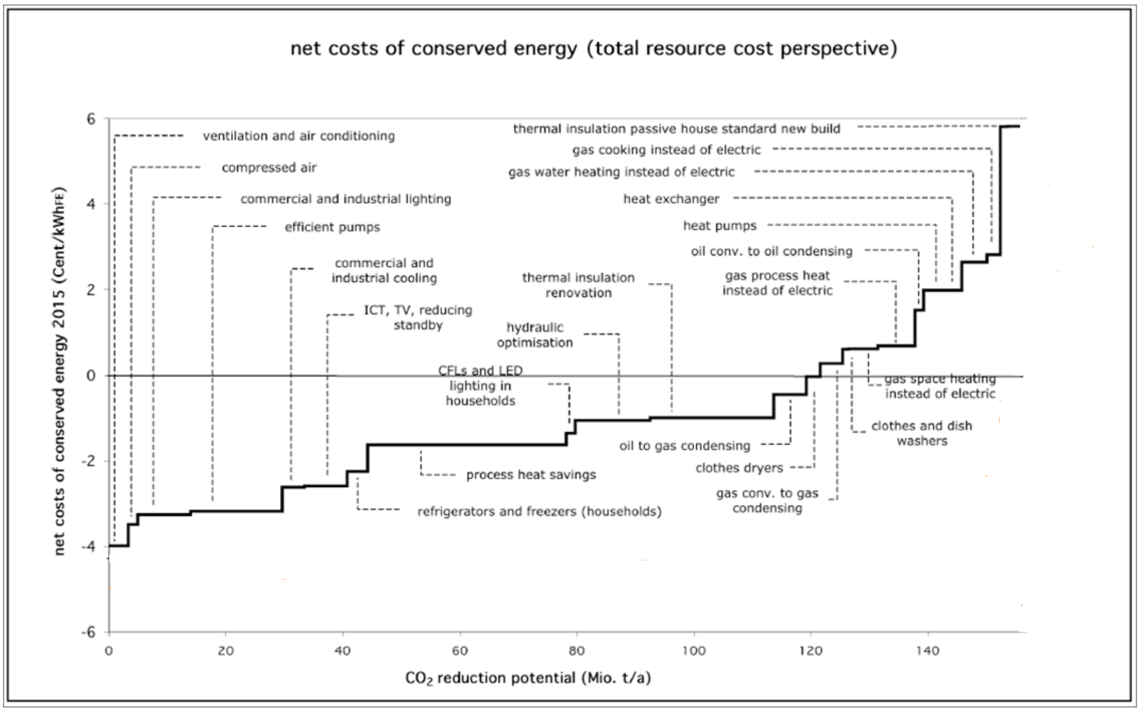

Figure 1: Example for a CPC (Fischedick, 2010)

2.1.2 Definitions for this document[1]

Technology

- Technology is the usage and knowledge of techniques, crafts or methods of organization. The word comes from *technología* (*τεχνολογία*) — *téchnē* (*τέχνη*), an 'art', 'skill' or 'craft' and *-logía* (*-λογία*), the study of something, or the branch of knowledge of a discipline. The term can either be applied generally or to specific areas: examples include *construction technology*, *medical technology*, *state-of-the-art technology* or *high technology*. Technologies can also be exemplified in a material product, for example an object can be termed state of the art technology.
- E.g. regarding CPCs: standard or baseline technology, energy efficiency technology.

Energy Consuming Appliance

- Electrical or mechanical elements which accomplish functions and offer a service to the user by consuming energy.
- E.g. regarding CPCs: household appliances, computer appliances.
- Remark: energy consumption is assigned to appliances as a single unit, since it is consider a single element

Energy Consuming System (and their Components)

- From Latin *systēma*, in turn from Greek *σύστημα* systēma, "whole compounded of several parts or members, system", literary "composition" is a set of interacting or interdependent entities (components or elements) forming an integrated whole. In this

[1] The definitions in this chapter are specific fitted for this document, i.e. for the use with CPCs. The general definitions of those terms were picked from (Wikipedia, 2010) and fitted for CPCs purpose by the author.

regard, the system as a whole with all its elements accomplishes a function and offers a service to the user by consuming energy.

- ⇨ E.g. regarding CPCs: energy consuming system, heating systems, cooling systems, lighting systems, and underground transport system.
- ⇨ Remark: the total energy consumption of a system results from the addition of energy consumption of their single components or elements. For CPCs purpose, a representative energy consumption value for the whole system is needed. Moreover, for gaining energy efficiency in systems, an analysis of their single components or elements should be done. Energy efficiency measures for single components added together would result in the energy efficiency potential for the whole system. It is important to well define the borderline of the analyzed systems (see also (Meier, 1982)).

Function

- ⇨ Is interpreted as a specific process, action or task which an appliance or system is able to perform offering at the end a specific service with a specific quality.
- ⇨ E.g. regarding CPCs: a washing machine washes clothes running a process –the function is to wash following a procedure; an automated system produces items automatically – the function is to produce running a production procedure.

Service

- ⇨ An appliance or system accomplishing a specific energy consuming function serves in a specific way the user. To measure the service degree of the appliance or system, the end result (also called service) after having accomplished its function is decisive. The important question is to define what is the service performed and with which quality.
- ⇨ E.g.: the service of a washing machine is to clean clothes with a specific quality; the service of an automated system is to produce for the user with a specific quality or precision.
- ⇨ Remark: regarding the definition of energy efficiency technologies, it should be ensure that defined energy efficient technologies offer the same or a better service as the baseline technology! (see also (Meier, 1982))

Refurbishment

- ⇨ Process of maintenance or major repair of an appliance or system, either aesthetically or mechanically.
- ⇨ Remark: The time of a refurbishment, is a good time for improving the appliance or system towards energy efficiency.

Reinvestment

- ⇨ Acquisition of a new, modern appliance or system that offers the same or better service as the old one.
- ⇨ Remark: On a reinvestment, the new appliance or system might be the same or can be improved. The function for offering the service could be different, for example improved towards energy efficiency.

‘*Normal’* Reinvestment or Refurbishment

- ⇨ An investment on a new and modern energy consuming appliance or service arises not until the old one has reached the end of its useful lifetime. In other words, the consumer repairs the old item or acquires a new one when he is obligated to do so because the old one is broken or obsolete. With ‘normal’ it is refer to a replacement at the end of an appliance or system useful lifetime. (Wuppertal-Institute, 2010)

Useful lifetime

⇨ The time for which an appliance or system is normally used, before it is replaced. Reasons for a replacement can be damage or obsolescence. In this context, a technological and economical useful lifetime should be differentiated.

State of the Art

⇨ The state of the art is the highest level of development, as of a device, technique, or scientific field, achieved at a particular time. It also applies to the level of development (as of a device, procedure, process, technique, or science) reached at any particular time usually as a result of modern methods.
⇨ E.g. regarding CPCs: development or level of the end use energy consumption in a sector.

Base year:

⇨ Chosen reference year t=0 for which data can be realistically gathered. Based on that year, assumption can be done for future years.

Projection year:

⇨ A specific future point in time t=T for which the development of energy consumption is going to be analyzed.

Time Horizon

⇨ The time horizon, is the time interval from base year t=0 in the present until a fixed point in time t=T in the future, for which energy saving potentials are going to be estimated.
⇨ Assumptions for the time horizon are made and scenarios are build to estimate the existing energy saving potentials in the year t=T after elapsed time horizon.

State of the Art Energy Consumption Scenario

⇨ Energy consumption of current (in the basis year) used appliances or systems e.g. in a specific sector, region, etc.

Business-As-Usual (BAU) Scenario

⇨ Standard behavior when the time of a ‘normal’ reinvestment or refurbishment has arrived. Projected trend development for the use of energy consuming appliances or systems. (Wuppertal-Institute, 2010)
⇨ The BAU scenario is normally specified or analyzed for a specific time horizon.
⇨ Remark: In this scenario the consumer acquiring a new appliance or system at the time of a ‘normal’ reinvestment or refurbishment might, in average, not to prefer a new appliance with low energy consumption because those might be more expensive. However some consumer will do so, due to the awareness of energy efficiency advantages. (see below (chapter 2.3): “share of stock of the energy efficiency technology”)

Baseline Scenario

- ⇨ End use energy consumption scenario for the basis year t=0 (state of the art energy consumption scenario) or for the projection year t=T (BAU scenario[2]).

Energy Efficiency Scenario

- ⇨ Scenario in which the most energy efficient appliances or systems are implemented at once (static potential) or when the time of a 'normal' reinvestment of refurbishment has arrived (dynamic potential).
- ⇨ Remark: The energy efficiency technologies for this scenario are derived from the energy consumptions of appliances and systems defined for the baseline scenario.

Energy Efficiency Measures

- ⇨ All the actions (introduction of an energy efficiency policy, implementing the energy efficient technology, etc.) to be taken for developing towards the energy efficiency scenario.

Energy Saving Potentials

- ⇨ The resulting potential energy savings if energy efficiency technologies were implemented so that energy consumption would develop towards the energy efficiency scenario. The Energy Saving Potentials would result from comparing the energy consumption of the energy efficient scenario with that of the baseline scenario, being so the difference between both the Energy Saving Potentials.
- ⇨ Possible units for the potentials: [kWh/a], [tep/a], [J/a], [BTU/a], ([tCO_2/a]).

Marginal Costs for Energy Saving Potentials (also Net Costs per Unit Energy Saved)

- ⇨ Costs per UNIT of energy saved due to the implementation of an energy efficient technology instead of implementing the baseline technology.
- ⇨ It is important to remark, that these costs arise as the difference between the costs for the baseline and energy efficient technology. Hence, it is accomplished to evaluate solely energy saving potentials (and not the overall investment of one or the other technology) (see also 2.1.3).
- ⇨ They can be positive or negative.
- ⇨ Furthermore, they can also be considered as opportunity costs per unit of saved energy for not implementing the identified energy saving potentials.

Homogeneous Stock

- ⇨ A homogeneous stock of an appliance or system is characteristic for being uniform on its different parameters describing the appliance or the system through its whole stock. This means there is low variation between use intensities, power demand, prices and costs, types, etc. throughout the stock.
- ⇨ Normally the term homogeneous is used for describing something being completely uniform. In this document the term is used for classifying appliances and systems stock with a high degree of uniformity.

[2] Note: This scenario might be better to define for calculating the Dynamic Potential.

Heterogeneous Stock

⇨ A heterogeneous stock of an appliance or system is characteristic for being not uniform at all on its different parameters describing the appliance or system through the whole stock. This means that use intensities, power demands, prices and costs, types, etc. vary greatly throughout the stock.

2.1.3 Assumptions

`Normal' reinvestment or refurbishment assumption

Under the assumption that energy saving potentials only exist at the time of 'normal' reinvestment or refurbishment it is possible to consider potentials that can realistically be economically evaluated by comparing acquisition costs for baseline and energy efficient technologies. The assumption considers typical replacement rates of the baseline technology to estimate the amount of reinvestments and refurbishments that are going to happen in a specific time horizon[3].

Cost evaluation of energy saving potentials assumption:

Energy savings potentials are evaluated by their net marginal energy savings costs. They result by calculating the additional costs as the difference between the acquisition costs for the baseline and energy efficiency technology, further calculation of the annuity with a proper discount rate and dividing them through the annual energy savings. In a last step they are weighted with the costs for energy and a possible operation cost difference (see Equation 4) .

Only under this assumption of calculating additional cost, it is possible to evaluate the potentials itself and therefore justify the high acquisition costs for the implementation of energy efficient technologies.

This assumption is closely associated with the "'normal' reinvestment or refurbishment assumption".

'Heroic' assumption

The big challenge of constructing CPCs is to accurately represent a diverse stock of specific appliances or systems with a single 'average' case (average energy consumption and prices or costs for the baseline and energy efficient technology)!

This assumption is especially complex for the identified energy consuming systems, where overall energy consumption depends on the consumption of different elements of it. (See (Meier, 1982) for a description of this assumption)

Here we remark, that the quality and significance of CPCs depend on a good approach or methodology to estimate the values for the 'average' case. This depends on the stock for an appliance or system being homogeneous or heterogeneous and on how detailed the segmentation of data gathering was done[4].

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[3] See specially Chap. 2.3.3 Dynamic potential

[4] A stock of an appliance or system for a whole economy being heterogeneous, might be less heterogeneous if the stock is segmented in sectors, regions, states, cities, or other significant segmentations. E.g. the stock of public lamps for Brazil might be heterogeneous, segmenting the stock in regions or better in cities, can result in different homogeneous stocks.

2.1.4 Distinction between different definitions of CPCs[5]

Figure 2 shows the different kinds of potentials and their respective marginal costs for constructing CPCs. Potentials can be distinct by type, cost perspective and time horizon. By choosing one branch of the tree, the characteristics of the potentials and their marginal costs are established.

For the description of CPCs in this document, we are going to concentrate on the 2 branches marked in yellow, which is the market potential from end consumer perspective, for static total and dynamic potential.

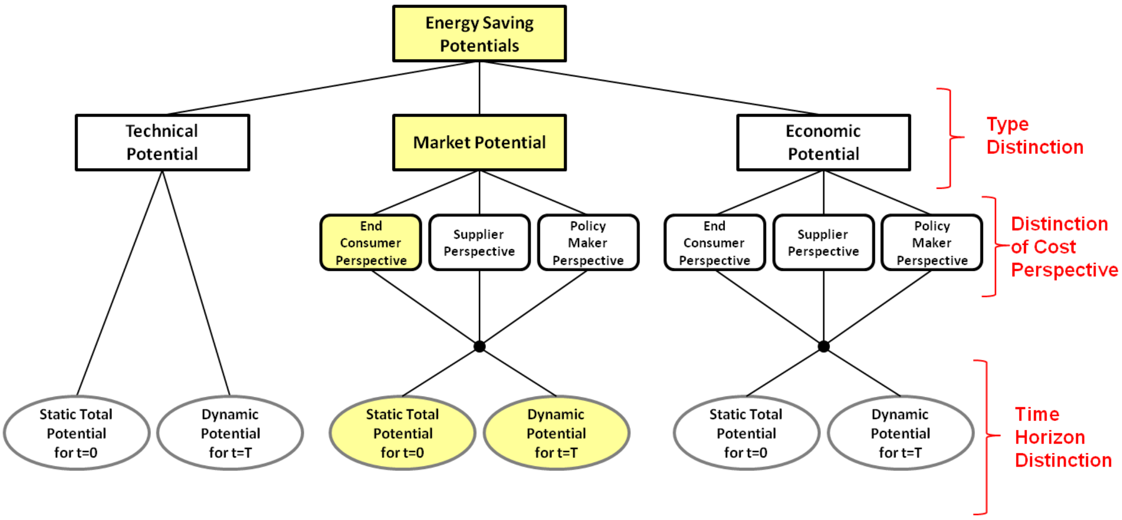


Figure 2: Distinction of potentials regarding type, cost perspective and time horizon

2.1.4.1 Distinction regarding types of potential

The Technical Potential[6]

The technical potential is defined as the amount by which it is possible to reduce consumption by implementing already demonstrated energy efficient technologies without specific reference to costs. (IPCC Working Group III, 2007)

The Market Potential[7]

[5] In this chapter we only differentiate between the general descriptive distinctions of different potential approaches. In Chapter 2.3 "Parameters distinction between CPCs definitions", we make the concrete distinction of them referring to which parameters are altered between them.

[6] The technical potential do not really fall under the category CPCs. CPC curves show in a chart energy saving potentials and its marginal costs per saved energy and the technical potential doesn't make a reference to cost.

[7] It is the most conceivable potential (no use of abstract parameters like social costs) and the best applicable to construct CPCs, because realistic data can be gathered through market statistical studies and the different cost perspectives (end consumer, supplier and policy maker) can be well distinguished.

The market potential is defined as the amount of savings occurring under forecast market conditions including policies and measures in place at the time. It is based on private unit costs and discount rates, as they appear in the base year[8] and as they are expected to change in absence of any additional policy or measures[9].

In other words, the market potential is the conventional potential assessment of the energy saving potential at current market prices, with all barriers and hidden costs, etc. in place at the time. (IPCC Working Group III, 2007)

The Economic Potential[10]

The economic potential is a cost-effective potential for energy savings when non-market social costs and benefits associated with energy efficiency options are considered with market costs and benefits using social discount rates. The potential includes externalities (i.e. non-market costs and benefits such as environmental co-benefit). (IPCC Working Group III, 2007)

In other words, the economic potential has a similar approach as the market potential, but includes furthermore externalities like non-market cost and benefits (e.g. social and environmental costs or benefits).

2.1.4.2 Distinction regarding the cost perspective

Especially two parameters are differentiated in this distinction: the discount rate and the costs for energy. Both are in each case considered from the 3 different perspectives.

End consumer perspective

The end consumer perspective uses general economic parameters for evaluating and comparing the costs (or benefits) of appliances or systems that are typical for the end consumer. That means, typical end consumer discount rates are used, as well as typical energy prices paid from end consumers for using energy.

Supplier perspective

The supplier perspective uses general economic parameters for evaluating and comparing the costs (or benefits) of appliances or systems that are typical for suppliers of energy. That means, typical suppliers discount rates are used as they are used by suppliers for evaluating their investments. Especially for the costs from the supplier perspective is important to consider the marginal costs for each extra unit of energy that is needed to be produced or supplied.

Policy maker perspective

The policy maker perspective should consider also discount rates and cost for evaluating and comparing the costs (or benefits) of appliances or systems that are typical for policy makers.

[8] Primarily needed for the Total Static potential

[9] Needed for the Dynamic potential

[10] This potential requires gathering more data and abstract parameter specific for Brazil that might be difficult to estimate, e.g. social and environmental social costs or benefits. NOT recommended to calculate this potential in the beginning!

The definition of this perspective can be kind of abstract and tedious. But, it might be possible to find a proper discount rate typical for policy makers. For the cost of energy it could be an approach using energy taxes or further investments in energy infrastructure which can truly evaluate the cost of potentials from the policy maker perspective[11].

2.1.4.3 Distinction regarding time horizon of potentials

The Static Total Potential

It is defined as the energy saving potential and its associated marginal costs (opportunity costs) that would arise by replacing the entire current stock of appliances or systems (baseline technology) in t=0 entirely by the energy efficient technology at once. (Fischedick, 2010)

The Dynamic Potential

The Dynamic Potential is the energy saving potential and its associated marginal costs (opportunity costs) for a point in time t=T years into the future, considering typical exchange rates of the baseline technologies. This is a function of the age structure of the current stock and the appliances or systems' lifetimes. (Fischedick, 2010)

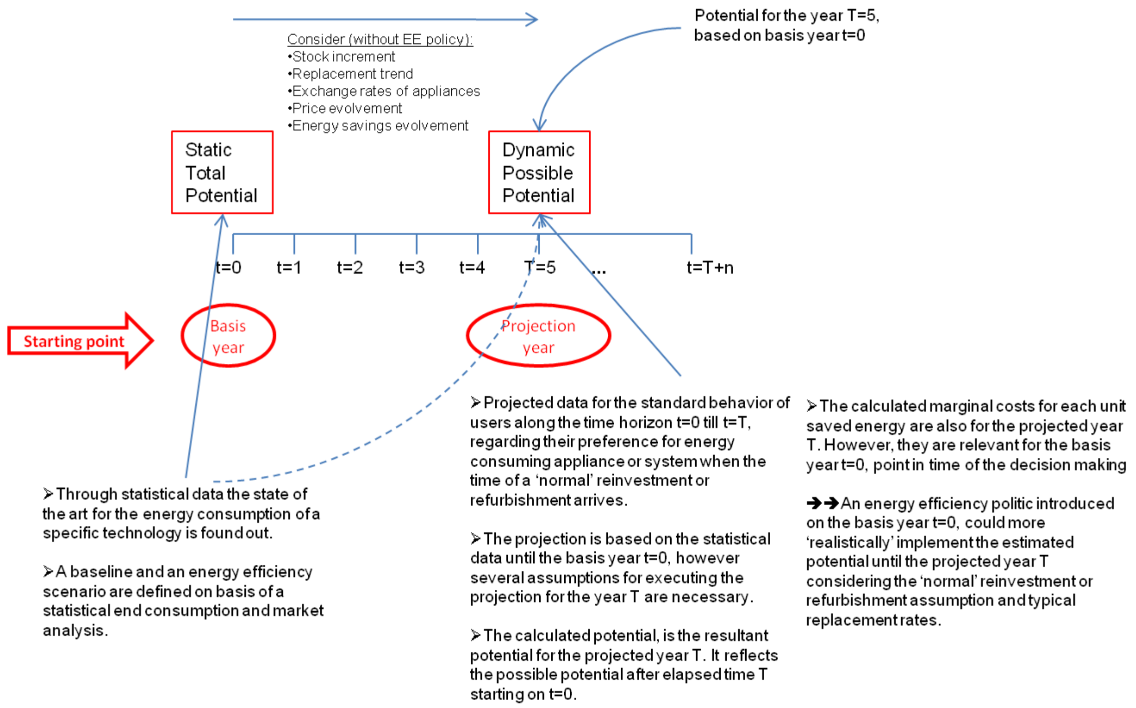


Figure 3: Difference between Static Total and Dynamic Potential

[11] We leave it to the reader to distinguish the right approach for accomplishing this cost perspective.

Remarks to the dynamic potential for reaching good quality CPCs:

- ⇨ The shorter the time frame chosen for the projection, the better the quality of the Dynamic Potential (due to the amount of values that have to be projected, it is realistically to choose short time horizons). The author recommends a five year horizon for feedback purposes (see "idea" below), and 10 year horizon in order to use CPC in PDE.
- ⇨ The shorter the time horizon for the projection and the longer the useful lifetime of the considered appliance or system, the smaller the Dynamic Potential. The Dynamic Potential considers typical replacement rates, so if the lifetime of an appliance or system is long and the analyzed time horizon is short, it would result in small replacement rates and hence in a small dynamic potential.

Idea:

- ⇨ Each CPC is recalculated at the end of its prediction horizon with the **SAME** assumptions, however, with the real development in order to make the comparison between baseline (for example, CPC of 2010 with horizon 2015) and real progress (represented in CPC 2015 "retrospect").

  In other words:

  Calculate a CPC in 2010 with horizon 2015, record all parameters used for this and in 2015 recalculate CPC with recorded values, then compare to original CPC.

  Keywords: measuring energy efficiency and policy impact monitoring (see chap. 2.2 Steps 10 and 11).

2.2 Steps to follow: from the Bottom-Up study to the CPC

The steps presented below should be considered as a roadmap to implement CPCs as an instrument for identifying and evaluating economically energy saving potentials, as well as to use CPCs for a well founded implementation of energy saving policies for achieving energy efficiency gains.

In the chapter above 3 different types of CPCs and their costs perspectives were described (technical, economical and market potential). These steps are in generally applicable for all 3 types[12]. However, since there should be some variations between each kind and describing all of them would go over the scope of this work, from now on the following explanations will only refer to the market potential from an end consumer perspective. Moreover, the author recommends applying the CPCs methodology initially only for the market potential – easier to gather needed data for it – and doing so, evaluate the potentials from different perspectives – consumer, supplier, policy maker. (See also Figure 2 highlighted boxes)

The collected data for estimating one of the potentials would be nearly the same needed for all 3 types of potentials (specially the data specific for the appliances and systems –see 2.3.1.2 and 2.3.3.2). Because of this, part of the data gathered for one could be further used for the others too!

Regarding the distinction of the time horizon, the steps would only differ on the quantity of data needed, since the dynamic potential should require more data (data from the past) to be able to make projections. Furthermore, the data used for the dynamic potential is based on or derived

[12] Except that for the Technical Potential no reference to cost is needed.

from the data for the static total potential. Considering several assumptions for each appliance or system the data can be projected for the projection year t=T.

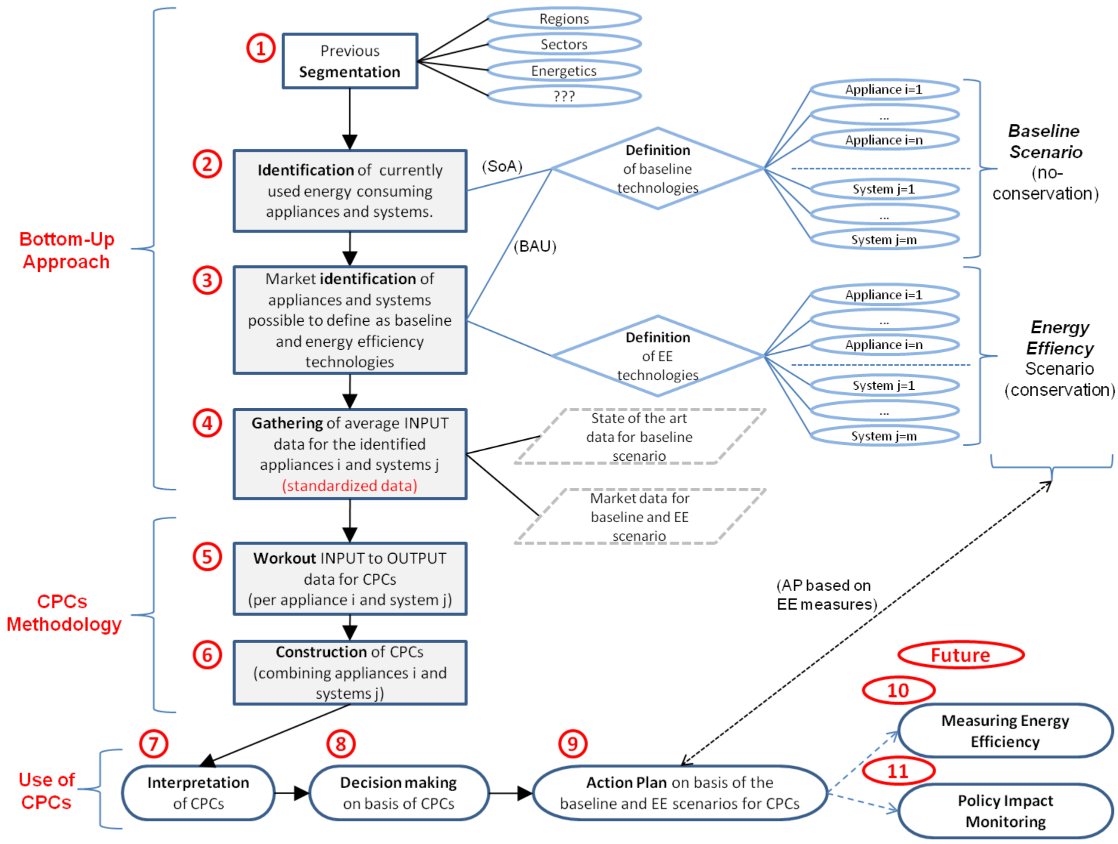


Figure 4: Steps to follow from the Bottom-Up approach to the use of CPCs[13]

Step 1: Initial **segmentation**[14] for the statistic study

- Decide what segmentation is meaningful in terms of be able to carry on a methodological analysis for energy efficiency. This step is critical, since it establishes the frame of the field study approach and the afterwards resulting publication of CPCs (e.g.: CPCs for a whole country vs. CPCs for a sector in a state Brazils[15]). It could even be helpful to make a very detailed segmentation for the field study approach and then by aggregation of smaller segments in bigger ones, construct the general CPCs.
- Possible segmentations are:
    - Segmentation in sectors (residential, industrial, public, commercial, transport, transformation (energy), agricultural)

[13] The abbreviations (SoA) and (BaU) refer to "State of the Art" and "Business as Usual" and mean that depended from what scenario is selected to be the baseline scenario, definitions are made in step 2 or 3.

[14] For the segmentation it should be clear if it is going to be the demand side or the supply side energy efficiency approach (demand side -> How to save energy on the consumption side by using efficient appliances or systems or by changing habits?; supply side -> How to make the supply of energy more efficient by achieving higher efficiency ratios for transformations and transport?). Although initially the energy demands side should be from interest!

[15] It might be better for Brazil, not to construct general CPCs for the whole country. Moreover, it would be more significant to construct different CPCs for a greater segmentation!

  - Segmentation in regions, states, cities, areas (urban and rural), etc.
  - Further segmentations are also possible!

- Important: the goal is to be able to gather representative average data per unit applicable for a whole stock! Here we refer to the difference between homogeneous and heterogeneous stocks and to the 'heroic' assumption.[16]

> Example:
>
> The following segmentation was made:
>
> - Commercial sector
>
> - One floor of EPE's office.

Step 2[17]: **Identification** of **energy consuming appliances and systems** for the above chosen segmentation through statistical studies with a bottom-up approach[18]

- Information should be gathered for the selected segmentation about energy consuming appliances and systems. Thereby it is necessary to estimate their stocks and distinguish them in homogeneous or heterogeneous stocks.

- Data describing the state of the art for levels of energy consumptions, use intensity, consumption pattern for each appliance and system has to be found out through closer analysis, for example statistical studies.

- For this step taking the top-down energy consumption as starting point reference can be helpful, so the bottom-up and top-down are interfaced.

- In this step the service and its quality offered by appliances and systems should be described. This is needed later for the definition of the energy efficiency technologies, since those should offer at least the same service and quality by lower consumption of energy.

- Remark:

  This is the first analysis needed to identify which items consume energy; consequently for which energy efficient technologies should be defined. It is the starting point before searching for energy efficiency energy efficient technologies.

- The end result of this step is to have a list with the included appliances and systems consuming energy, as well as fact sheets describing the state of the art (use intensity, function, service, consumption, etc.) for each item of the list (see Annex A).

> Example:
>
> Floor lighting was identified as one energy consuming appliance (among others like computers, air conditioning, printers, etc.). Following our example, the current stock of

[16] Most important clue of the resulting significance of CPCs relies in a good segmentation!

[17] Step 2 and 3 can be realized with the help of the Fact Sheet 1 in Annex A.

[18] Step 2, 3 and 4 require a bottom-up approach. A description about bottom-up studies can be found in (Wuppertal-Institute, 2010). This document contains information about bottom-up data gathering with examples of bottom-up practices in other countries.

lighting elements was analyzed. Analyzed was on one hand the service provided by the lamps, this can be described by a technical description. On the other hand, the use pattern of the lamps was analyzed to be able to estimate the overall energy consumption. Finally to be able to estimate replacement rates, the age structure of the lamps was established. The stock of lamps can be characterized as very homogeneous: all lamps are the same!

Description of the currently used lighting technology and its consumption pattern:

Stock:	200 lamps
Technology:	Osram T8 fluorescent lamps, model 640 comfort white, 120 cm long, lighting flow of 2400 lumen, color of 4000 K
Useful life:	7500 hours
Power demand:	32 [W/unit]
Use intensity:	14 hours/day, 5 days/week, 52 weeks/year
Unit yearly Energy consumption:	116, 48 [kWh / (unit x a)] (32 W x 14 h x 5 d x 52 s / 1.000 (1/k))
Total yearly energy consumption:	23,296 [MWh/a] (200 units x 32 W x 14 h x 5 d x 52 s / 1.000.000 (1/M))
Age structure:	50% of stock is new, 50% of stock is 1 year old (assumed for modeling reasons – see chapter “difference between dynamic and static potential”)

Inserted in a table:

Iluminação no Andar:

Descrição da tecnología atual: **Baia**

Caracteristicas:	Flourecent Osram 32W/640/comfort white	
Potencia:	[W/unidade]	32
Fluxo luminar:	[lumen]	2400
Cor:	[K]	4000
Tempo de acendido:	´[h/dia]	14
Consumo anual:	[kWh/(ano x unidade)]	116,48
Stock:	[unidade]	200
Estrutura de edade:	[ano]	1
Vida util técnica:	[h]	7500
	[ano]	2

Table 1: Example for identified characteristics of an appliance

Remarks:

- The overall consumption values per year are given here as a reference. For this step, more important are characteristics and consumption pattern of appliances and systems.
- This is the starting point for searching and defining a baseline and an energy efficient technology.

Step 3: **Market study** to identify and establish the **baseline** and **energy efficiency scenarios**[19]

- Baseline and energy efficiency technologies are defined in this step, by evaluating energy efficiency possibilities found on the market.
  - The energy efficiency options can also be defined by taking as reference previous works found in the literature; its applicability should be proven with up to date market information.
- This step is accomplished for each appliance or system individually, defining for each one a baseline and an energy efficient technology.
- All the defined baseline technologies constitute the baseline scenario.
- All the defined energy efficiency technologies constitute the energy efficiency scenario.
- Remarks:
  - Not every appliance or system may be suitable to increase the energy efficiency. For the ones which are suitable, a baseline and energy efficient technology should be defined and described in this step.
  - This step is more an engineer and feasibility (technical and economical data – which is found on the market) approach for defining the baseline and energy efficiency scenario.
- This step compliments step 2 and makes also part of the results given on the fact sheets (Annex A) per identified appliance and system.

Example:

Through research on the internet it was analyzed what kind of technologies could be chosen as baseline and energy efficient technology. The currently used one was chosen as baseline, since the normal attitude would be to replace the broken fluorescent lamps by new ones from the same technology. Modern T5 energy efficient fluorescent lamps were chosen as the energy efficient technology.

Remark on defining baseline and energy efficiency technologies:

On EPEs floors energy efficient technology for lighting is already being used. Considering the residential sector in Brazil in general, the baseline might be incandescent light bulbs.

Definition of baseline technology:

[19] We remember that this step is needed to define baseline and energy efficient technologies, as well as to be able to establish prices and costs!

Technology:	The same as the ones actually used! (Best possible data quality) T8 fluorescent lamps, 120 cm long, lighting flow of 2400 lumen, color of 4000 K
useful life:	7500 hours
Power demand:	32 [W/unit]

Definition of energy efficient technology (static perspective):

Technology:	T5 fluorescent lamps, 120 cm long, lighting flow of ~2600 lumen, color of 4000 K
Useful life:	20 000 hours
Power demand:	28 [W/unit]

It was identify, that LED tubular lamps are going to gain energy efficiency importance in the near future. Information about them was gathered for a precise calculation of the dynamic potential.

These lamps are already known in the basis year and are even slowly being introduced into the market. This technology could also be considered as an energy efficient one. However, due to the extreme high unit price it is not yet a real alternative. Defining LED as the energy efficiency measure is though a definition question that should be carefully evaluated!

For the fluorescent lamps example, LED tubular lamps are considered as a future energy efficient technology.

Definition of further possible energy efficient technologies (needed for the dynamic perspective):

Technology:	T8 LED lamps, 120 cm long, lighting flow of 2400 lumen, color of 4000 K
Useful life:	50 000 hours
Power demand:	22 [W/unit]
Unit yearly Energy Consumption:	80,08 [kWh / (unit x a)] (22W x 14h x 5d x 52s / 1.000)
Average price:	R$ 261,27

Step 4[20]: Gather **standardized average INPUT data** for each defined appliance and system in order to calculate OUTPUT parameters for the CPCs

[20] In Annex B we give a proposal for how Fact Sheets can be designed to estimate standardized average INPUT parameters for the selected segmentation as well as for each appliance and system. Methodological approaches for that process should be described!

- Representative standardized average INPUT parameters have to be estimated for the baseline and energy efficient technology, in order to be able to calculate the OUTPUT parameters for the construction of the CPCs.

- This standardized average INPUT parameters are the result of a vast field study for end consumption (step 2) and vast market analysis (step 3), by which different brands, suppliers, models, etc. are analyzed to be able to estimate average data (technical and economical).

- This step is also accomplished separately for each appliance or system.

- For methodological and standardization reasons, from now on we refer to appliances i and systems j to be able to order the standardized INPUT data.

- Remarks:

    - This standardized data is collected regarding the baseline and energy efficiency scenarios defined in the step before.

    - The difference between both steps is that step 3 relates more to the engineer approach for identifying and specifying possible energy efficiency measures and step 4 accomplishes a statistical study for gathering standardized energy consumption and price/cost data based in average values for each appliance i or system j.

    - In this step the 'heroic assumption' gains importance that is to accurately represent a diverse stock for a specific appliance or system with a single "average" case (average energy consumptions for the baseline and energy efficient technology and its economical evaluation)! (Meier, 1982)

    - Since markets are very heterogeneous (this in combination with stocks of appliances i and systems j also being heterogeneous), there is a need to make an exhaustive market analysis for each appliance i and system j and for each baseline and energy efficiency technology. These market studies are made to analyze different brands, models, suppliers, and others with reference to energy consumptions and prices/costs data.

    - It must be kept in mind for carrying out the market study that the baseline and energy efficiency scenarios are defined for specific services and qualities offered by the appliance i or the system j.

Example:

The standardized average energy consumption and economical data for this step resulted from the following table[21]:

[21] Note that for this simple example less data is significant. For analyzing a whole economy extensive research needs to be carried out to achieve representative values.

Analesis de technologia standard energética:

						Média:
Fonte de Informação:		rimoeletrica.com	rimoeletrica.com	rimoeletrica.com	rimoeletrica.com	
Marca:		Osram	Sylvania		Osram	
Modelo:		FO 32W/640/T8	LD plus 30W	T8 DS 5,0 K 32 W	FO 32W/640/T8	
Potencia:	[W/unidade]	32	30	32	32	31,5
Fluxo luminar:	[lumen]	2400	2900		2400	
Cor:	[K]	4000	4000	5000	4000	
Vida util:	[anos]	7500	7500	7500	7500	2
Tempo de acendido:	´[h/dia]	14	14	14	14	14
Consumo anual:	[kWh/(ano x unidade)]	116,48	109,2	116,48	116,48	114,66
Preço:	[R$/unidade]	5,26	5,34	7,03	3,47	5,28
Base:		G13	G13	G13	G13	
Preço base e servicio:	[R$/unidade]					

Analesis de technologia efficiencia energética:

						Média:
Fonte de Informação:		rimoeletrica.com			rimoeletrica.com	
Marca:		Osram	Phillips	Sylvania	Ourolux	
Model:		FH 28W/865	TL5-28W-HE/840	T5	T5	
Potencia:	[W/unidade]	28	28	28	28	
Fluxo luminar:	[lumen]	2400	2900	2900		
Cor:	[K]	4000	4000	4000	500	
Vida util:	[anos]	18000		24000		6
Tempo de acendido:	´[h/dia]	14	14	14	14	14
Consumo anual:	[kWh/(ano x unidade)]	101,92	101,92	101,92	101,92	101,92
Preço:	[R$/unidade]	15,44	6,58	7,5	8,12	9,41
Tipo de base:		G5	G5	G5	G5	
Preço instalação:	[R$/unidade]	0,6	0,6	0,6	0,6	0,6
Preço base:	[R$/unidade]	0,2	0,2	0,2	0,2	0,2
Preço Total:	[R$/unidade]					10,21

Table 2: Example for defining standardized average INPUT data for an appliance

There were different suppliers, different brands and models analyzed and average consumption and costs were calculated. The results are the following:

Standardized average values for the baseline technology:

Useful life:	2 years
Unit yearly Energy consumption:	116, 48 [kWh/(unit x a)] (32W x 14h x 5d x 52s / 1.000)
Average price:	R$ 5,28

Standardized average values for the energy efficient technology:

Useful life:	6 years
Unit yearly Energy consumption:	101,92 [kWh/(unit x a)] (28 W x 14h x 5d x 52s / 1.000)
Average price:	R$ 10,85

Remarks:

- For the simplified example of EPEs floor, such a study would not be necessary needed because a specific and concrete energy efficiency measure could be possible to define. However, for illustration reasons this example was accomplish like this and can serve as a model to do a similar study for a whole economy.

Step 5: Calculate **output parameters** for the construction of CPCs for each appliance or system individually[22]

- The standardized average INPUT data from step 4 is used by applying the methodology for calculating OUTPUT parameters for the CPCs (see chapter 2.3 Methodology for static and dynamic CPCs).
- Once more, this step is accomplished for each appliance i and system j individually.

Example:

The input data gathered was used by applying the methodology for the CPCs. The calculations are described in detail further on in this document (chapter 2.3) and the following two parameters for the construction of CPCs were estimated for each approach, Static Total Potential and Dynamic Potential:

Static Total Potential approach:

Static Total Potential:	2548 [kWh/year]
Net Costs for Saved Energy:	-0, 32 [R$/year]

Dynamic Potential approach:

Static Total Potential:	1382,4 [kWh/year]
Net Costs for Saved Energy:	-0,34 [R$/year]

Remark:

- According to Figure 1, these two potentials (Total Static and Dynamic) are Market Potentials from end user perspective!

Step 6: **Construction of CPCs**, combining the chosen appliances i and systems j[23]:

- CPCs have to be constructed, combining the appliances i and systems j, plotting the results in a chart.
- Only two output parameters per appliance i and system j are needed to construct the CPCs. These are energy saving potentials for the whole stock (given on the x-axis) and the corresponding marginal costs (net costs) for the saved energy (given on the y-axis) (as calculated in step 5).
- With a specific methodology[24] (see chapter 2.3.4), the two parameters for each appliance i and system j are plotted in a chart to construct the CPCs.

Example:

For the example, CPC parameters were calculated for only ONE appliance. Because of this, the 2 parameters for this appliance were plotted in the chart which gives the following chart as

[22] To describe the methodology for calculating OUTPUT parameters to construct CPCs and the definition of the INPUT parameters needed is the main purpose of this document!

[23] Combination of appliances i and systems j are special for a specific segmentations (e.g. sector, region, city, etc.)

[24] Order all appliances i and systems j by prices and plot them on the graphic starting with the one with lowest cost and given the potentials cumulative.

result:

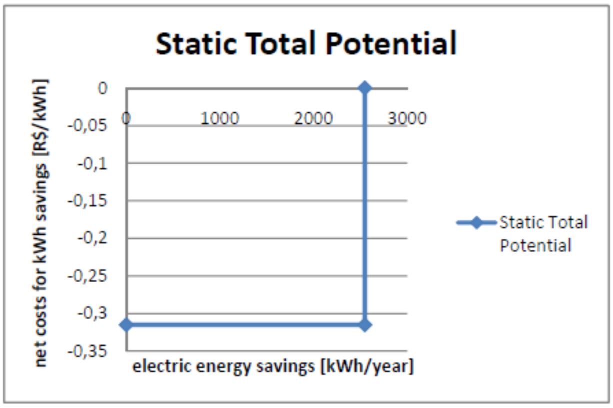


Figure 5: Example for CPC for Total Static Potential of one appliance i (fluorescent lamps)

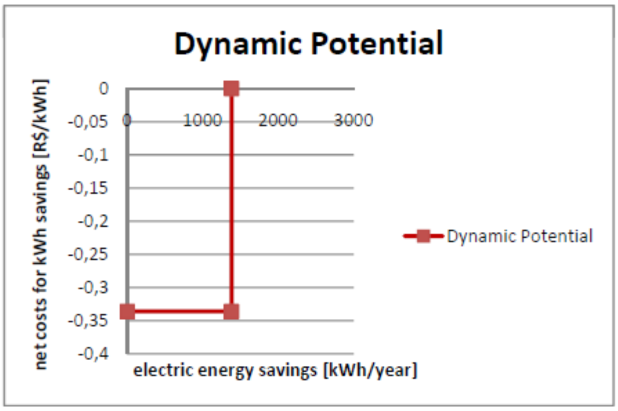


Figure 6: Example for CPC for Dynamic Potential of one appliance i (fluorescent lamps)

Remark:

- Normally it makes no sense plotting the results for only one appliance or system. Since our example only analyzes fluorescent lamps, we still plot the results for illustrative reasons. (see chap. 2.3 “Plotting CPCs for a whole sector, region, etc.” for correct and methodological realization of this step for more than one appliances i)
- We notice here, that there is a difference between the Total Static and the Dynamic Potential in both the Energy Saving Potential and the Marginal Net Cost for the Unit Energy Saved! (see chap. 2.3 “Dynamic Potential” for the explanation)

Step 7: **Interpretation and plausibility check**

- Once the CPCs have been constructed, the graphic has to be interpreted. Many aspects should be considered:
    - What is the general energy efficiency approach? What type of energy should be saved? Or is it of interest to reduce GHGs?
    - For which appliances i and systems j were energy efficiency potentials identified?

  - How high is the overall energy efficiency that would be achieved by implementing all the energy efficient technologies for each appliance i and system j?
  - How high is the energy efficiency potential for each appliance i or system j?
  - Regarding the costs, which appliances i or systems j should have priority for increased energy efficiency?
  - Interpret the costs, what are the units and the amount?
  - Get back to the “roots” and analyze the assumptions made for each appliance i and system j and INPUTs that lead to the plotted CPCs!
- A plausibility check is indispensable to reassure that the resulted CPCs are meaningful!
  - E.g. is the cost order compatible with the possible implementation order?
  - Is the resulting CPC meaningful?

Step 8: **Decision making**[25]

- From decision making perspective the goal is probably to implement as much energy saving potentials as possible to affordable costs! And the best way therefore is implementing well founded energy efficiency policies that give incentive to the users to contribute with gaining energy efficiency.
- At the beginning there should the magnitude of the budget for energy efficiency be established. Then, following the structure of CPCs, less cost intensive energy saving potentials are going to be given priority to be implemented through specific incentives (through policies and subventions). Therefore, the decision making procedure will be to implement the energy saving potentials one after another starting by the less cost intensive (i.e. the first appliance i or system j on the left of the chart) until the budget is gone!
- From decision making perspectives CPC curves are very helpful, because they show a good relation between energy saving potentials and their costs. Especially considering that costs are a common barrier for implementing energy efficiency technologies, knowing the relation of potentials and its costs (or benefits) give a big motivation for moving towards the energy efficiency scenario.

Step 9: **Action plan**

- One effective approach for achieving a goal is planning. Therefore, after having taken a decision based on a CPC, it might be suitable to draw up an action plan with the strategy for implementing the energy saving potentials as effectively as possible.
- For this step, going back to analyzing the defined energy efficiency measures (steps 2 to 4) might be needed. On this 3 steps the ‘source’ for gaining energy efficiency is analyzed. A CPC only shows in a chart the identified potentials and their respective marginal costs, but doesn’t give much information about the energy efficiency definitions. Therefore, CPCs are good for taking decision about energy efficiency regarding cost, but for the Action Plan the previous work needs to be analyzed again!
- So, knowing the gaps for gaining energy efficiency, it is possible to create institutions, programs, indicatives, etc. that that make the society aware of energy efficiency potentials and help and motivate society to implement them.

Step 10: **Measuring Energy Efficiency**

- Looking far ahead, it would be possible to recalculate CPCs after the elapsed time horizon (in case of the Dynamic Potential), i.e. at time t=T, under the same assumptions

[25] For decision making regarding CPCs that identify GHG reduction see (Kesicki, 2010). The work describes the MAC Curves very well. However the report hasn´t been officially published.

and conditions as in the base year t=0, but using real data. In this way it might be practicable using CPCs (or its methodology) also as an instrument for measuring energy efficiency. Further work for this purpose is needed!

Step 11: **Policy Impact Monitoring**

- This step is closely related to the previous one. Having measured the energy efficiency gained, it might be possible to evaluate the impact of an energy efficiency policy introduced based on a CPCs. How to use the CPCs methodology for this purpose requires also further work!

2.3 Methodology for static and dynamic CPCs

In this chapter we depict in detail the methodology of calculating the Static Total and the Dynamic potential for one of the 3 types (technical, market and economic) of potentials. To simplify, the description will refer especially to the Market Potential, because, compared with the Technical Potential, it makes a reference to costs and, compared to the Economic Potential, the necessary data can be objectively found on the market by accomplishing a vast statistical study. For those reasons, the Market Potential is maybe the most appropriate type to illustrate the methodology. Moreover the description is made from an end user perspective (see Figure 2). We assume for the following description, that the needed standardized average INPUT data for calculating CPCs is already given[26].

Furthermore, once the standardized average INPUT data for one appliance or system has been collected, the methodology for calculating the Static Total and the Dynamic Potential for each type should be the same. Although, the requested INPUT parameters for each type (see Fact Sheets 1 and 2 in Annex A and B) of potential might defer between types.

However, the methodology should be applied for each type of potential (technical, market and economic) individually. Each type of potential, and for each, the static and dynamic potentials, should be published in different charts. It is not suggested to plot them in the same chart since each one is calculated with different assumptions and conditions, therefore they are not comparable.

In general, the Static Total Potential, as its name says, requests static data for an appliance i or system j and shows Energy Saving Potentials for the basis year t=0. The Dynamic Potential, requests in a certain time horizon projected data for the appliance i or system j and shows the Energy Saving Potential for the year t=T after the elapsed time horizon.

This methodology, that calculates the collected standardized average INPUT data to estimate the two OUTPUT parameters needed for the CPCs for each, Static Total and Dynamic Potential, should be applied for each analyzed appliance i and system j individually. Afterwards combining all the appliances i and systems j for the selected segmentation, the final CPC is plotted in a chart.

From the steps described in the previous chapter (Figure 4), the methodology belongs to step 5[27]. In Step 6[28], all the output parameters calculated in step 5 for each appliance i and system j for the selected segmentation are combined to construct the proper CPCs and plot it in a chart. (See below chapter 2.3.4 Plotting CPCs for a whole sector, region, etc)

[26] Fact Sheets 1 and 2 in Annex A and y B help to estimate the standardized INPUT data and in chap. 2.2 it is generally described how to gather and estimate the needed standardized INPUT data!

[27] Step 5: "Calculate **OUTPUT parameters** for the construction of CPCs for each appliance i or system j individually"

[28] Step 6: "**Construction of CPCs**, combining the chosen appliances i and systems j for the segmentation done"

For a better overview of the different potentials we refer to Figure 2 and Figure 3.

Here we describe a methodological procedure that takes for granted that standardized INPUT parameters were established and those are used in the calculation as INPUT. Therefore, we describe the following parameters and formulas very formal with describing indexes and variables. There is a specific methodological procedure for establishing the INPUT parameters assumed (once more we refer to the Fact Sheets 1 and 2 on Annex A and B).

Description of indexes and variables:

Indexes are used to characterize the used parameters.

- kWh = kilo Watt hour
- toe = tone of oil equivalent
- BTU = British Thermal Unit
- EE = Energy Efficiency Technology
- BL = Baseline Technology
- tech = technical perspective (Technical Potential)
- p = private perspective (Market Potential)
- s = societal perspective (Economic Potential)
- stat = Static Total Potential
- dyn = Dynamic Potential
- net = opposite of gross
- endc = end-consumer perspective
- sup = energy supplier perspective
- pol = energy policy maker perspective

Running Indexes are used to characterize the different appliances i and systems j[29] for the selected segmentation.

- i, j = appliance i or system j [30] for i,j ={a,…,n or A,…,m}

There is only one variable used, the time variable t [31].

- t=0 Refers to data specific for the base year. This data is specially used for the Static Total Potential
- t=T Refers to data for the year T. The interval t = {0, T} describes the time horizon used for the Dynamic Potential.

[29] We used an index instead of a variable, because it only characterizes appliances i or systems j to be differentiated between each other. In other words, the parameters are not a function of the value of the index. These indexes can, but must not be numbers!

[30] In order to not saturate the parameters with indexes, for our description of the methodology we use only indexes i, but they can also be indexes j that we used to describe the systems. Although the INPUT parameters for appliances i and systems j should be used the same way in the methodology (in the calculation), we described them with different indexes because the approach to estimate them is different. (see also definition of “appliance” and “systems” in chapter 2.1.2)

[31] The parameters used in the methodology are stochastic functions of the time t. For the point in time t=0 the parameters might have a background in real values gathered. For another point in time t, projected parameters based on assumptions as a function of t are established.

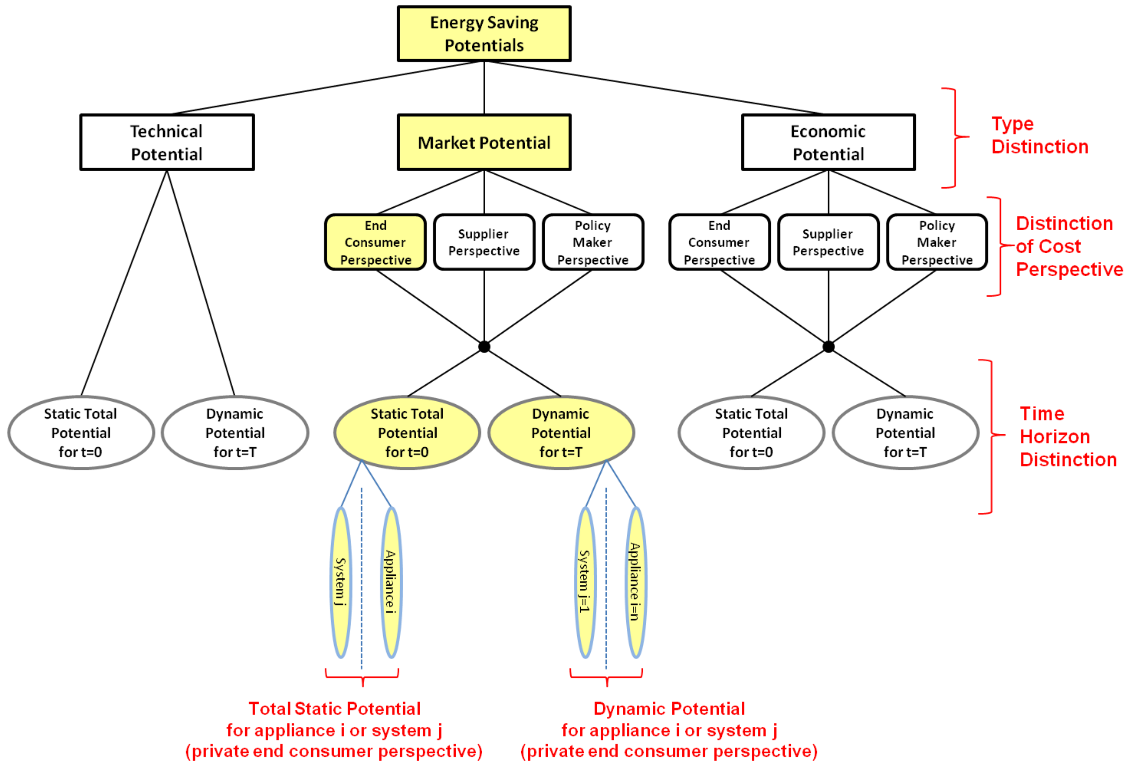


Figure 7: Illustration of the methodology for one appliance i or system j for a specific type and from a specific perspective

2.3.1 Static Total Potential

It is defined as the energy saving potential and its associated marginal costs (opportunity costs) that would arise by replacing the entire current stock of appliances i or systems j (baseline technology) by the energy efficient technology at once. (Fischedick, 2010)

Example:

For the fluorescent lamps example, the Static Total Potential results by considering a replacement of all 200 fluorescent lamps by the T5 fluorescent lamps technology at once in the base year.

This potential is helpful as reference for the maximum energy efficiency potential which could be reached, but is not realistic to implement. The currently used appliances i or systems j might not be at the end of their useful lifetime and thus do not need be replaced yet. Replacing still working appliances before they have reach the end of their useful lifetime would even result in a less beneficial marginal costs for each unit of saved energy because the cost for not using the current appliance i or system j till the end of its useful life should be included into the cost calculation.

2.3.1.1 General INPUT and INTERMEDIATE data specific for a type of potential:

The general data is characteristic on one hand for the type of potential (technical, market, economic) and for the perspective from which the potential is economically evaluated (end user, supplier, policy maker, etc.), and on the other hand characteristic for the sector, region, etc. (further segmentation done) chosen for the analysis.

It is used to accomplish the economic evaluation of the potentials estimated for each appliance i and system j that are being analyzed. The same general data is used for each appliance i and system j, to be able to economically compare the marginal costs of potentials between appliances i and systems j after they were combined to construct the CPCs (step 6 [32]).

This data is gathered from market analysis or taken from the literature on market data for those parameters[33].

Parameter	Measure Unit	Description
$r_{p,\ endc}(0)$[34]	[%]	Discount interest rate in t=0 (private end consumer perspective)
$p_{kWh,\ p,\ endc}(0)$	[R$/kWh][35]	Price of Energy (for kWh) in t=0 (private end consumer perspective)
$c_{kWh,\ p,\ endc}(0)$	[R$/kWh]	Long-run avoided system costs for Energy (for kWh) in t=0 (private end consumer perspective)

Table 3: General INPUT and INTERMEDIATE parameters for the Static Potential

Remarks:

- These values are important mainly for the economic evaluation of potentials. Furthermore, they define the type of the calculated Potential (market, economic) and the cost perspective (end consumer, supplier, policy maker)
- Example 1: for the Market Potential and end consumer perspective, the avoided long-run energy costs are the price for electricity paid from an end consumer.
- Example 2: for the Market Potential and energy supplier perspective, the avoided long-run costs are the marginal costs for producing more units of energy.
- The resultant CPCs are sensitive to these parameters (See (Wuppertal-Institute, 2010) chapter “Strength and Weaknesses of CPCs” for a detail description of sensitiveness).

Example:

We attempted to calculate the Market Potential from the end user perspective (Commercial sector). We chose the general INPUT parameters for those potential criteria from the found

[32] Step 6: “**Construction of CPCs**, combining the chosen appliances i and systems j”

[33] Once again we refer to: Fact Sheets 1 and 2 on Annex x and y

[34] We use here the index “p” to characterize the market potential and “endc” the end user perspective.

[35] We use here the unit kWh for measuring energy, but a different unit can also be used (toe, BTU, etc.) depending on which unit needs to be measured. For the monetary unit we used R$, because this document is directed for Brazil, but a different one can also be used. We use the energy unit kWh and R$ for the further description of this document.

literature (see argumentation).

Parameter	Measure Unit	Values	Argumentation
$r_{p,\ endc}(0)$	[%]	12	Taken from (Garcia, 2010)
$p_{kWh,\ p,\ endc}(0)$	[R$/kWh]	0,41194	Taken from an electricity bill for a household (May 2010)
$c_{kWh,\ p,\ endc}(0)$	[R$/kWh]	0,41194	The long-run voided system costs are equal to the price paid by the end user for electricity

Table 4: Example for the general INPUT and INTERMEDIATE parameters of the Static Potential

2.3.1.2 Standardized average INPUT, INTERMEDIATE, OUTPUT data needed specifically for an appliance i or system j:

In this section we describe in detail the needed standardized average INPUT parameters and the formulas to calculate the OUTPUT parameters for CPCs.

We assumed again, the previous steps for estimating the standardized average INPUT parameters were already carried out!

Standardized average INPUT parameters for an appliance i or system j:

For each technology i and system j, the standardized average INPUT parameters refer to stock, share of stock, yearly energy consumption, different prices and costs, and useful life. Most of them are needed in each case for the baseline and energy efficient technology.

Parameter	Measure Unit	Description
$N_i(0)$	[units]	Current stock for a specific appliance i[36] in t=0
$\text{maxpN}_{EE\,i}(0)$	[%]	Maximum possible share of stock of energy efficient technology i in t=0 (normally 100%, since it is theoretically possible to replace the whole stock by the energy efficient technology)
$N_{EE\ i}(0)$	[%]	Share of stock energy efficient technology i in t=0
$EC_{BL\,i}(0)$	[kWh/unit x year]	Energy consumption baseline technology i per unit per year (average values)
$EC_{EE\,i}(0)$	[kWh/unit x year]	Energy consumption energy efficient technology i per unit per year (average values)
$t_{EE\ i}$	[year]	Useful life energy efficient technology i
$p_{BL\,i}(0)$	[R$/unit]	Price baseline technology i at t=0
$p_{EE\,i}(0)$	[R$/unit]	Price energy efficient technology i at t=0
$ic_{BL\,i}(0)$	[R$/unit]	Installation costs baseline technology i at t=0
$ic_{EE\,i}\ (0)$	[R$/unit]	Installation costs energy efficient technology i at t=0
$exc_{BL\,i}(0)$	[R$/unit]	Extra costs baseline technology i by the time of acquisition in t=0

[36] Again we remember, that to simplify we refer only to appliances i. The same methodology is equally applicable to systems j.

$exc_{EE\,i}(0)$	[R$/unit]	Extra costs energy efficient technology i by the time of acquisition in t=0
$oc_{BL\,i}(0)$	[R$/unit x year]	Operating costs baseline technology i per year t (maintenance, spare parts, salaries, etc)
$oc_{EE\,i}(0)$	[R$/unit x year]	Operating costs energy efficient technology i per year t (maintenance, spare parts, salaries, etc)

Table 5: Standardized average INPUT parameters for an appliance i or system j

Remarks:

- The INPUT parameters of energy consumption and costs are representative for a whole stock. We remark here again, how important it is to estimate significant average values for them. We remember here to the exhaustive work that has to be done in step 4 to estimate them under the 'heroic assumption'!

Example:

After step 4 of our example, the INPUT parameters can be given as follows:

Parameter	Measure Unit	Values	Argumentation
$N_i(0)$	[units]	200	Stock counted for fluorescent lamps
$\mathrm{maxpN}_{EE\,i}(0)$	[%]	100	
$N_{EE\,i}(0)$	[%]	0	Defined energy efficient technology is not been used (normally this parameter is find out through statistical data)
$EC_{BL\,i}(0)$	[kWh/unit x year]	114,66	Average data from above
$EC_{EE\,i}(0)$	[kWh/unit x year]	101,92	"
$t_{EE\ i}$	[years]	6	"
$p_{BL\,i}(0)$	[R$/unit]	5,28	"
$p_{EE\,i}(0)$	[R$/unit]	9,	"
$ic_{BL\,i}(0)$	[R$/unit]	-	
$ic_{EE\,i}(0)$	[R$/unit]	0,6	Costs for installation service. The sockets are different and have to be exchanged.
$exc_{BL\,i}(0)$	[R$/unit]	-	
$exc_{EE\,i}(0)$	[R$/unit]	0,2	Price for the sockets
$oc_{BL\,i}(0)$	[R$/unit x year]	-	
$oc_{EE\,i}(0)$	[R$/unit x year]	-	

Table 6: Example for the standardized average INPUT parameters for an appliance i (fluorescent lamps)

Calculation of INTERMEDIATE parameters for an appliance i or system j:

There are some previous calculations to estimate some INTERMEDIATE parameters needed for the final calculation of the OUTPUT parameters for CPCs.

There are defined as:

Parameter	Measure Unit	Description
$ES_i(0)$	[kWh/unit x year]	Energy savings per unit per year due using the energy efficient technology for appliance i in t=0
$aqc_{BL\,i}(0)$	[R$/unit]	Acquisition costs baseline technology i at t=0
$aqc_{EE\,i}(0)$	[R$/unit]	Acquisition costs energy efficient technology i at t=0
$adc_i(0)$	[R$/unit]	Additional costs per unit due to introducing the energy efficient technology instead of the baseline for appliance i in t=0
$adc_{\boldsymbol{p},\ \boldsymbol{endc},\ i}(0)$[37]	[R$/unit]	Additional costs per saved kWh[38] due to introducing the energy efficiency technology for appliance i in t=0 (private end consumer perspective)

Table 7: INTERMEDIATE parameters for an appliance i

Example:

Using the INPUT parameters, the INTERMEDIATE parameters result in (see calculation below):

Parameter	Measure Unit	Values
$ES_{EEM\,i}(0)$	[kWh/unit x year]	12,74
$aqc_{BL\,i}(0)$	[R$/unit]	5,28
$aqc_{EE\,i}(0)$	[R$/unit]	10,21
$adc_{EEM\,i}(0)$	[R$/unit]	4,94
$adc_{\boldsymbol{p},\ \boldsymbol{endc},\ i}(0)$	[R$/unit]	0,0969

Table 8: Example for the INTERMEDIATE parameters of an appliance i (fluorescent lamps)

Energy savings per unit per year $ES_i(0)$:

⇨ These are the energy savings calculated firstly per unit and per year for an appliance i, that can be afterwards aggregated for the whole stock, resulting so in the Static Total Potential.

$$ES_{EEM\,i}(0) = EC_{BL\,i}(0) - EC_{EE\,i}(0) \quad \left[\frac{kWh}{year\ x\ unit}\right]$$

Equation 1: Energy saving per Unit for Static Total Potential

[37] This parameter is calculated using the discount rate that is typical for specific type of potential and a specific perspective (see the indexes).

[38] Remember that as example we are using kWh as unit for measuring energy!

$$ES_{EEM\,i}(0) = 114{,}66 - 101{,}92 = 12{,}74 \quad \left[\frac{kWh}{year\ x\ unit}\right]$$

Acquisition costs for both alternatives $(aqc_{BL\,i}(0)\ \ and\ \ aqc_{EE\,i}(0))$:

⇨ All acquisition costs added together consist of e.g. price of the appliance i, installation costs, other extra costs, etc.

$$aqc_{BL\,i}(0) = p_{BL\,i}(0) + ic_{BL\,i}(0) + exc_{BL\,i}(0) \quad \left[\frac{R\$}{unit}\right]$$

$$aqc_{EE\,i}(0) = p_{EE\,i}(0) + ic_{EE\,i}(0) + exc_{EE\,i}(0) \quad \left[\frac{R\$}{unit}\right]$$

Equation 2: Acquisition costs of the baseline and energy efficient technology i for Static Total Potential

$$aqc_{BL\,i}(0) = 5{,}28 + 0 + 0 = 5{,}28 \quad \left[\frac{R\$}{unit}\right]$$

$$aqc_{EE\,i}(0) = 9{,}41 + 0{,}6 + 0{,}2 = 10{,}21 \quad \left[\frac{R\$}{unit}\right]$$

Additional costs per unit due to the energy efficiency $(adc_i(0))$:

⇨ These costs result from the difference between all acquisition costs that would arise at the moment of replacement for the energy efficient technology and the acquisition costs for the baseline technology.

$$adc_i(0) = aqc_{EE\,i}(0) - aqc_{BL\,i}(0) \quad \left[\frac{R\$}{unit}\right]$$

Equation 3: Additional costs per unit for implementing the energy efficiency technology i

$$adc_i(0) = 10{,}21 - 5{,}28 = 4{,}94 \quad \left[\frac{R\$}{unit}\right]$$

Additional costs per unit of saved Energy$(adc_{\boldsymbol{p},\ endc,\ i}(0))$:

⇨ The additional costs per saved kWh are the annuity of the additional costs per unit resulting from comparing the acquisition costs of the defined baseline technology with acquisition cost of the energy efficient technology. Dividing this annuity by the energy savings per unit results in an additional cost per saved kWh (cost per saved energy).

$$adc_{p,\ endc,\ i}(0) = \frac{\dfrac{r_{p,\ endc}(0)}{\left(1 - \dfrac{1}{\left(1 + r_{p,\ endc}(0)\right)^{t_{EE}}}\right)} \cdot adc_i(0)}{ES_i(0)} \qquad \left[\frac{R\$}{kWh}\right]$$

Equation 4: Additional costs per unit for one unit energy saved due to the energy efficiency technology i

$$adc_{p,\ endc,\ i}(0) = \frac{\dfrac{0{,}12}{\left(1 - \dfrac{1}{(1+0{,}12)^6}\right)} \cdot 4{,}94}{12{,}74} = 0{,}0969 \qquad \left[\frac{R\$}{kWh}\right]$$

Calculation of OUTPUT parameters for a technology i or system j:

Finally, having the INTERMEDIATE parameters the 2 OUTPUT parameters for the CPCs can be calculated. For the Static Potential, the Energy Savings $ES_i(0)$ are aggregated for the whole stock considering the share of stock of the energy efficiency technology. For the Net Marginal Costs for Saved Energy (also called “Additional Costs per Saved Energy”) are weighted with the Long-Run avoided Costs for Energy Saved and the difference of the Operational Costs of the baseline and energy efficient technology i.

Those two parameters can be plot in a chart for the construction of CPCs (see chapter 2.3.4 Plotting CPCs for a whole sector, region, etc).

Parameter	Unit Measure	Description
$Pot_{stat,\ i}(0)$	[kWh[39]/year]	Static Total Potential for appliance i at t=0
$c_{net,\ p,\ endc,\ i}(0)$	[R$/kWh]	Net costs per unit Energy saved due introducing the energy efficiency technology for an appliance i in t=0 (private end consumer perspective)

Table 9: OUTPUT parameters for an appliance i

Example:

Using the INPUT and INTERMEDIATE parameters, the following OUTPUT parameters were calculated and plotted in the chart (see calculation below).

Parameter	Unit Measure	Values
$Pot_{stat,\ i}(0)$	[kWh/year]	2548
$c_{net,\ p,\ endc,\ i}(0)$	[R$/kWh]	-0,3150

Table 10: Example for OUTPUT parameters for an appliance i (fluorescent lamps)

[39] If the value in kWh gets to high, it can naturally be given in another decimal like TWh or MWh.

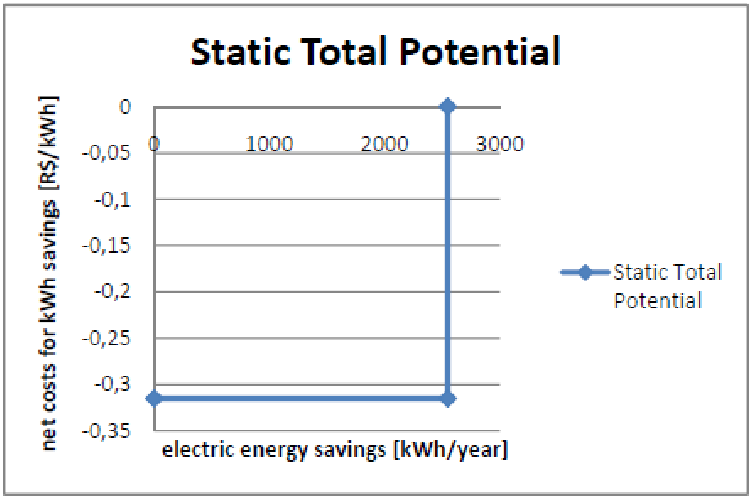


Figure 8: Example for a CPC for Total Static Potential of one appliance i (fluorescent lamps)

Remark:

- We included the chart for illustrative reasons, only to show how to plot the OUTPUT parameters on the chart. Normally it makes no sense to publish the potential for one appliance i only.

Static Total Potential ($Pot_{stat,\ i}(0)$):

⇨ Is defined as the amount of energy savings on the basis of the respective stock that would be achieved if the whole stock of an appliance i was converted to the best energy efficiency level at once.

$$Pot_{stat,\ i}(0) = \left(\text{maxpN}_{EE\,i}(0) - \text{N}_{EE\,i}(0)\right) \times \text{N}_i(0) \times ES_i(0) \quad \left[\frac{kWh}{year}\right]$$

Equation 5: Static Total Potential for an appliance i

$$Pot_{stat,\ i}(0) = (100 - 0) \times 200 \times 12{,}74 = 2548 \quad \left[\frac{kWh}{year}\right]$$

Net costs for saved energy ($c_{net,\ p,\ endc,\ i}(0)$) :

- Net costs result from adjusting the calculated additional costs per kWh by the saved costs for electricity. Additionally they can also be adjusted by existing operating costs that differ between the baseline and energy efficiency technology.

$$c_{net,\ p,\ endc,\ i}(0) = adc_{p,\ endc,\ i}(0) - c_{p,\ endc}(0) - [oc_{EE\,i}(0) - oc_{BL\,i}(0)] \left[\frac{R\$}{kWh}\right]$$

Equation 6: Net costs for a unit saved energy for an appliance i from a private end consumer perspective

$$c_{net,\ p,\ endc,\ i}(0) = 0{,}0969 - 0{,}41194 - (0 - 0) = \ -0{,}3150 \quad \left[\frac{R\$}{kWh}\right]$$

2.3.2 Difference between Static Total and Dynamic Potential

As mentioned before, the Static Total Potential is not realistic since it might not be possible to exchange all the actual stock of a specific appliance i or system j by the energy efficient one at once. However, estimating it gives an idea sufficiently meaningful for knowing how much energy efficiency could in the best case be implemented and is used as starting point for estimating the more realistic Dynamic Potential. The Total Static Potential has the advantage that data gathering is easier and is based on real facts (real statistic study).

The Dynamic Potential is based on a projection model. This model should represent the trend for the use of an energy consuming appliance i or system j for a specific time horizon. Based on statistical data gathered and some assumptions, this model must be build for each appliance i and system j in order to be able to estimate the standardized average INPUT data for the projected year t. This data is needed for estimating the OUTPUT parameters for the Dynamic Potential.

It should be clear, that the projection model should represent how the market is estimated to develop without any introduction of energy efficiency policies (this is also called BAU development). To be able to achieve a good projection, a vast quantity of statistical information from the past (for t<0), in addition to the statistical data collected for the base year, is helpful. Furthermore, every kind of already existing projected data about the market development of an appliance i or system j is also valuable.

Possible data sources for these projections could be: energy institutions, statistic institutions, suppliers of the appliance i or system j, consumers surveys, etc.

We recall at this point the 'normal' reinvestment or refurbishment assumption, that based on the age structure of currently used appliances i and system j as well as typical replacement rates, gives the percentage of the current stock in t=0 for an appliance i or system j, which realistically can be replaced by the energy efficient technology. Furthermore consumers preferences for an appliance i or system j observed until the base year t=0 could also play an important role for the projected data, based on this the trend for the consumption of energy efficient technologies could be estimated.

It is important to remark, that the better the quality of the gathered data, the better the quality of the projected data and consequently the quality of the constructed CPC! Because of the amount of data needed and the complexity of building a model, the data acquisition for the Dynamic Potential is much more sumptuous as for the Static Total Potential. Therefore, the resultant CPCs with Dynamic Potentials give a realistically idea of how much energy efficiency is possible to reach.

Moreover, we recommend defining a time horizon no longer than 10 years, to assure realistic projections!

Example:

The following example gives an overview of all the data that might be needed to be projected with the help of an appropriate model[40] and some assumptions in order to estimate the projected standardized INPUT parameters needed to calculate the dynamic potential and the respective marginal costs for an appliance i or system j.

Projection Models for general data:

Projection of energy price

Development of the energy price:

Years	[R$/kWh]
2010	0,41194
2011	0,415552
2012	0,419164
2013	0,422776
2014	0,426388
2015	0,43

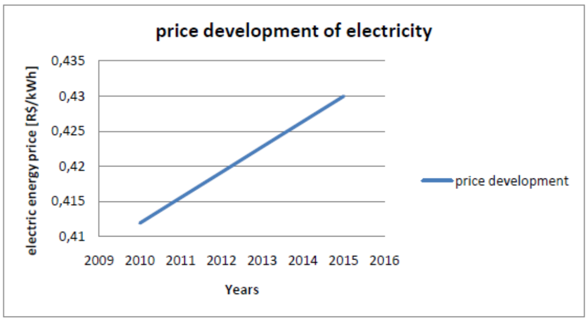


Table 11: Price development of electricity till t=T

Figure 9: Price development of electricity till t=T

A linear price increment is projected, therefore, in the projected year t=5 the price is 4,38% higher than the one in base year.

Projection Model for the market of fluorescent lamps:

As baseline technology T8 fluorescent lamps were defined and the T5 ones are the energy efficient alternative. LED tubular lamps were not considered as energy efficient technology, because of the high unit prices (Once more we remark, that they could be defined as energy efficient technology. The result would probably be a high energy saving potential and no beneficial opportunity cost). However, LED tubular lamps are considered in our model for the projection, since they could have an important role by influencing the market share and stock share in the future.

The table below gives an overview of the technologies considered in the model.

Description of the technologies analyzed:

Symbol	Description	energy status	Consumption [W]	Color [K]	light flow [lm]	useful life [h]	Average price 2010 [R$]
A	T8 Fluorescent	standard	32	4000	2500	7500	R$ 5,28
B	T5 Fluorescent	efficient	28	4000	2600	20000	R$ 10,21
C	T8 LED	more efficient (in future)	22	4000	2400	50000	R$ 261,27

Table 12: Considered technologies for the Dynamic Potential

The model starts creating some assumptions about the market share of the 3 technologies.

[40] What we show in this example is not really a model and the assumptions are not described with realistic arguments, however the example should help to show how could be the approach to estimate the projected standardized INPUT parameters to calculate the dynamic potential.

Years	Market share (supply) [%] A	[%] B	[%] C
2010	70	30	0
2011	65	32	3
2012	50	45	5
2013	40	50	10
2014	30	40	30
2015	25	40	35
2016	20	40	40

Table 13: Market share development of technologies till t=T

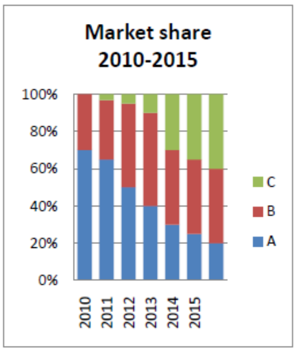


Figure 10: Market share development of technologies till t=T

The assumptions for the normal development of the tubular lamps would be as follows.

- Due to the trend for energy efficiency and good marketing strategies, the modern, energy efficient technologies are well sold on the market gaining a considerable market share.
- Old, energy inefficient technologies are in this way pushed out of the market.

The market share is accompanied by a development of the prices of the 3 technologies.

Years	Price development [R$] A	[R$] B	[R$] C	Price difference [R$] A-B	[R$] A-C
2010	5,28	10,21	261,27	4,94	256,00
2011	5,10	10,04	257	4,94	251,90
2012	4,6	9,5	250	4,90	245,40
2013	3,9	8,5	230	4,60	226,10
2014	3,3	7,9	190	4,60	186,70
2015	2,8	7,4	160	4,60	157,20
2016	2,5	7	150	4,50	147,50

Table 14: Price development of technologies till t=T

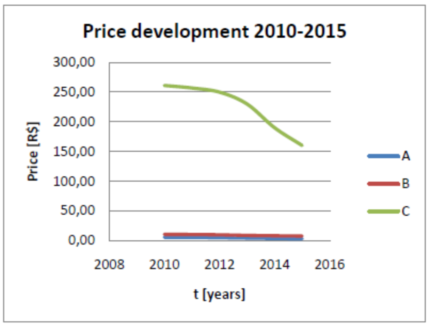


Figure 11: Price development of technologies till t=T

Explanation for price development product A:

- Demand for the product decreases due to the introduction of modern, energy efficient technologies. Prices decrease to keep the product competitive against the modern ones.

Explanation for price development of product B:

- The same as for product A

3 Phases for development of LED Prices:

- Product introduction; high production costs
- Learn curve; cost digression; penetration strategy
- Limit of product costs (long life); energy efficiency is recognized

The normal replacement of fluorescent lamps in relation to the stock age structure and the market evolvement was also modeled.

Stock age structure

Years	A [units] 0 year	1 year	Total	Share
2010	100	100	200	100%
2011	100	100	200	100%
2012	84	100	184	92%
2013	76	84	160	80%
2014	48	76	124	62%
2015	48	48	96	48%
2016	*0*	*48*	48	
2017	*0*	*0*	0	

Years	B [units] 0 year	1 year	2year	3 year	4year	5 year	Total	Share
2010							0	0%
2011							0	0%
2012	16						16	8%
2013	24	16					40	20%
2014	28	24	16				68	34%
2015	20	28	24	16			88	44%
2016	*0*	*20*	*28*	*24*	*16*		88	
2017	*0*	*0*	*20*	*28*	*24*	*16*	88	

Years	C [units] 0 year	1 year	2 year	3 year	Total	Share
2010					0	0%
2011					0	0%
2012					0	0%
2013					0	0%
2014	8				8	4%
2015	8	8			16	8%
2016	*48*	*8*	*8*		64	
2017	*48*	*48*	*8*	*8*	112	

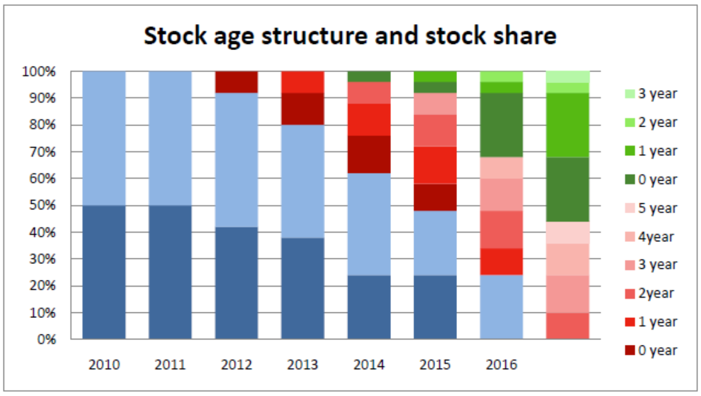
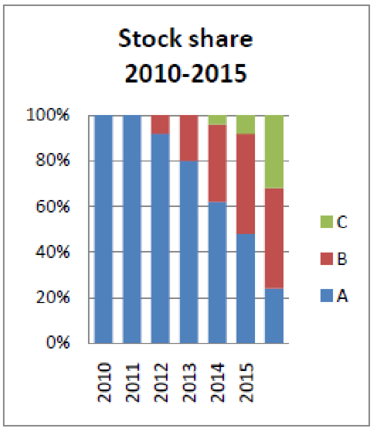


Figure 12: Age structure and share of stock of technologies till t=T

In reference to the modeled ‘normal’ replacement of fluorescent lamps, results the following evolvement for the share of stock.

Years	Stock share different technologies (# 200)		
	[units]	[units]	[units]
	A	B	C
2010	100	0	0
2011	100	0	0
2012	92	8	0
2013	80	20	0
2014	62	34	4
2015	48	44	8
2016	24	44	32

	baseline	energy efficiency
static share of stock:	100	0
Trend share of stock:	48	52



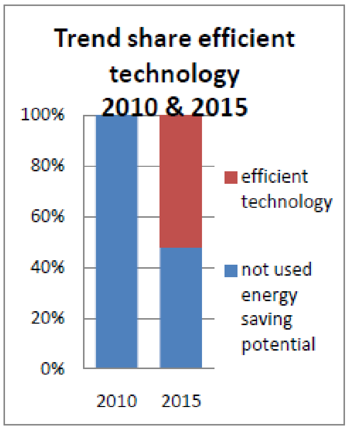


Figure 13: Estimation of the trend share of stock of the energy efficient technology

In this way it is possible to estimate a trend share of stock for the energy efficiency technology of 52%.

Considering a useful life for the baseline technology of 2 years, there is an calculated exchange rate of 50%.The preferences for the exchange of fluorescent lamps are assumed as follows:

- 2011 user is not aware of the energy efficiency of the T5 technology
- 2012 user gets aware of the T5 technology; it will be used, but not for all replaced lamps
- 2013 T5 technology is recognized as good; still some lamps are replaced by T8 (still T8 lamps on the replacement stock)
- 2014 LED tubular lamps are tested; T5 still recognized as energetic efficient; still some lamps are replaced by T8 (replacement stock)
- 2015 same as 2014
- 2016 LED are preferred due to its energy efficiency; T5 still on the replacement stock; T8 usage ceases.

2.3.3 Dynamic potential

The Dynamic Potential is the energy saving potential and its associated marginal costs (opportunity costs) for a point in time t=T years into the future, considering typical exchange rates of the baseline technologies. This is a function of the age structure of the current stock and the appliances or systems' lifetime. (Fischedick, 2010)

To calculate the Dynamic Potential, following projections are made:

- a trend is estimated for the replacement of current appliances i and systems j by the energy efficient technology that break or turn obsolete along the time horizon.
- forecasts are made for:
  - the price development of appliances i and systems j
  - the development of the energy consumptions depending on possible introduction of new energy efficient technologies (e.g. LED lamps)
  - the development of the useful life
  - the development of the discount interest rate
  - the development of energy prices
  - other specific factors characteristic for the analyzed appliances i and systems j

The time variable characterizes the projected data. Therefore, the parameters are given for a point in time t in the future.

Example:

For the fluorescent lamps example, these forecasts were simulated for 5 years in the future. It was considered that for the first time fluorescent lamps will be replaced after one year, because of the age structure being of 0 and 1 year for the actual used lamps. Due to the short useful life and high intensity of use of the lamps defined as baseline technology, in 5 years the defined baseline technology can be replaced between 1 to 3 times. It was considered, that more energy efficient technologies (e.g. LED T8 lamps) are going to be introduced and gain energy efficiency importance on the market in the next 5 years. (see for illustration the example in the previous chapter 2.3.2)

2.3.3.1 General INPUT and INTERMEDIATE data specific for a type of potential:

Based on the general INPUT and INTERMEDIATE data for the base year, with the help of projection models and in the literature found studies on that data, the projected standardized INPUT and INTERMEDIATE parameters for the projection year t=T are estimated.

The purpose of these parameters is the same as for the Static Total Potential - make the marginal costs for one unit of saved energy for each appliance i and system j comparable and characterize the type and perspective of the calculated potential - with one difference - based on projected data for year t in the future (taking the data for t=0 as starting point for the projection).

Parameter	Measure Unit	Description
$r_{p,\ endc}(t)$	[%]	Discount interest rate in t (private end consumer perspective)
$p_{kWh,\ p,\ endc}(t)$	[R$/kWh]	Energy price (in kWh) in t (private end consumer)
$c_{kWh,\ p,\ endc}(t)$	[R$/kWh]	Long-run avoided system costs for Energy (in kWh) in t(private end consumer perspective)

Table 15: Projected standardized INPUT parameters for an appliance i

Remarks:

- Usually, the discount interest rate $r_p(t)$ is kept constant, because it might not vary much for the recommended time horizon.
- An appropriate model with the respective assumptions should be built to estimate the above projected parameters. A well founded argumentation for what is considered is essential.

Example:

Using the model and assumptions made for our example in the previous chapter, the parameters result as follows:

Parameters	Measure Unit	Values	Argumentation
$r_{p,\ endc}(t)$	[%]	12	Assumed to stay constant
$p_{kWh,\ p,\ endc}(t)$	[R$/kWh]	0,43	Projected with a model under specific assumptions (see previous chapter 2.3.2)
$c_{kWh,\ p,\ endc}(t)$	[R$/kWh]	0 43	Equal to $p_{kWh,\ p,\ endc}(t)$, because end consumer perspective considered

Table 16: Example for projected standardized INPUT parameters for an appliance i

2.3.3.2 Standardized average INPUT, INTERMEDIATE, OUTPUT data needed specifically for an appliance i or system j:

Congruently to the Static Total Potential, we describe here in detail the needed projected standardized average INPUT parameters and the formulas to calculate the OUTPUT parameters for the Dynamic Potential.

The difference lies in assuming now a previously appropriate projection of the data for the appliances i and systems j for the year t in the future under meaningful assumptions!

Standardized average INPUT parameters for an appliance i or system j:

For each appliance i and system j, the projected standardized INPUT parameters refer to stock, share of stock, yearly energy consumption, different prices and costs, and useful life. Most of them are needed in each case for the baseline and energy efficient technology.

Compared to the Static Total Potential, the INPUT parameters are now representative for the year t in the future and other values are needed like the market share of an appliance i or system j[41].

Parameter	Measure Unit	Description
$\mathrm{N}_i(t)$	[units]	Stock for a specific appliance i in t (projection)
$\mathrm{N}_{EE\,i}(t)$	[%]	Trend share of stock of energy efficient technology i for t (projection)

[41] The Market share plays an important role for estimating the trend share of stock of the energy efficient technology when building the projection model for the parameter of an appliance i or system j. For the following calculations this parameter is not really used. However, estimating it as a standardized INPUT parameter might be helpful for having a better understanding of an appliance i or system j for the further steps.

$MS_{EE\,i}(0)$	[%]	Market share energy efficient technology i at t=0
$MS_{EE\,i}(t)$	[%]	Market share energy efficient technology i at t (projection)
$EC_{BL\,i}(t)$	[kWh/unit x year]	Energy consumption baseline technology i per unit per year at t (average projected values)
$EC_{EE\,i}(t)$	[kWh/unit x year]	Energy consumption energy efficient technology i per unit per year at t (average projected values)
$t_{BL\,i}$	[year]	Useful life baseline technology i
$t_{EE\,i}$	[year]	Useful life energy efficient technology i
$p_{BL\,i}(t)$	[R$/unit]	Price baseline technology i at t
$p_{EE\,i}(t)$	[R$/unit]	Price energy efficient technology i at t
$ic_{BL\,i}(t)$	[R$/unit]	Installation costs baseline technology i at t
$ic_{EE\,i}(t)$	[R$/unit]	Installation costs energy efficient technology i at t
$exc_{BL\,i}(t)$	[R$/unit]	Extra costs baseline technology i by the time of acquisition at t
$exc_{EE\,i}(t)$	[R$/unit]	Extra costs energy efficient technology i by the time of acquisition at t
$oc_{BL\,i}(t)$	[R$/unit x year]	Operating costs baseline technology i per year t (maintenance, spare parts, salaries, etc)
$oc_{EE\,i}(t)$	[R$/unit x year]	Operating costs energy efficient technology i per year t (maintenance, spare parts, salaries, etc)

Table 17: Projected standardized INPUT parameters for an appliance i

Remarks:

- The economic evaluation of the Dynamic Potential is also based on projected data, because it is assumed that the potential is always economically evaluated for the year that it exists. In this case the projected year t.

  Another interpretation for the Dynamic Potential, is that it is the remaining potential for the year t after elapsed time horizon from t=0 to t=T (for t=T as the end of the time horizon) assuming a 'normal' reinvestment or refurbishment. So, it should be evaluated with economic data for the year t=T.

- It is assumed, that along the time horizon, some replacement or new acquisitions are going to be made with the energy efficient technology i. As a consequence, there exists a trend for the energy efficient technology.

- The market share for the energy efficient technology i is needed to calculate the trend share of stock for the energy efficient technology. For the estimation of the trend share of stock, based on the market share, an appropriate modeling is needed.

- For the Dynamic Potential a variation of the standardized average energy consumption INPUT parameters is created, since for the projected time horizon the baseline and energy efficiency technologies are not expected to be necessarily the same as for the base year t=0 and would influence the energy saving potential in t=T. For the approach well founded argumentation is needed!

- For the prices and costs of technologies, a price and cost degression is expected in general. Again for the approach this should be well argued!

Example

In the previous chapter we modeled based on some assumptions the projections for the year t. The resulting projected standardized INPUT parameters are given in the table.

A time horizon of t=5 years was considered (baseline in 2010, projection for 2015)

Parameter	Measure Unit	Values	Argumentation
$N_i(t)$	[units]	200	Stock is static for the time horizon
$N_{EE\,i}(t)$	[%]	52	From model
$MS_{EE\,i}(t)$	[%]	75	"
$MS_{EE\,i}(t)$	[%]	25	"
$EC_{BL\,i}(t)$	[kWh/unit x year]	111,22 (=114,66*0,97)	Estimated the consumption of T8 tech. to be reduced by 3% (considering introduction of new technologies)
$EC_{EE\,i}(t)$	[kWh/unit x yea]	96,82 (=101,92*0,95)	Estimated the consumption of T5 tech. to be reduced by 5% (considering the introduction of LEDs)
$t_{BL\,i}$	[year]	2	
$t_{EE\,i}$	[y ar]	6	
$p_{BL\,i}(t)$	[R$/unit]	2,80	Price degression (estimated)
$p_{EE\,i}(t)$	[R$/unit]	7,40	"
$ic_{BL\,i}(t)$	[R$/unit]	-	
$ic_{EE\,i}(t)$	[R$/unit]	0,6	
$exc_{BL\,i}(t)$	[R$/unit]	-	
$exc_{EE\,i}(t)$	[R$/unit]	0,2	
$oc_{BL\,i}(t)$	[R$/unit x year]	-	
$oc_{EE\,i}(t)$	[R$/unit x year]	-	

Table 18: Example for the projected standardized INPUT parameters for an appliance i (fluorescent lamps)

Calculation of INTERMEDIATE parameters for a technology i or system j:

As for the Static Total Potential, some INTERMEDIATE parameters are also needed for the Dynamic Potential. In addition, for the Dynamic Potential also the Maximum possible share of stock should be calculated. This is needed to calculate the aggregated potential.

Parameter	Measure Unit	Description
$\mathrm{maxpN}_{EE\,i}(t)$	[%]	Maximum possible share of stock of energy efficient technology i at t (projection considering the useful life of the baseline technology i)
$ES_i(t)$	[kWh/unit x year]	Energy savings per unit per year due to the energy efficiency measure i at t

$aqc_{BL\,i}(t)$	[R$/unit]	Acquisition costs baseline technology i at t
$aqc_{EE\,i}(t)$	[R$/unit]	Acquisition costs energy efficient technology i at t
$adc_{\,i}\,(t)$	[R$/unit]	Additional costs per unit due to energy efficiency measure i in t
$adc_{p,\ endc,\ i}(t)$	[R$/unit]	Additional costs per each unit of energy saved due to energy efficiency measure i in t (private end consumer perspective)

Table 19: Projected standardized INTERMEDIATE parameters for an appliance i

Example:

Using the standardized INPUT parameters, the INTERMEDIATE parameters result to (see calculation below):

Parameter	Measure Unit	Values	Argumentation
$\mathrm{maxpN}_{EE\,i}(t)$	[%]	100	Short useful life of current lamps
$ES_i(t)$	[kWh/unit x year]	14,4	
$aqc_{BL\,i}(t)$	[R$/unit]	2,80	
$aqc_{EE\,i}(t)$	[R$/unit]	8,20	
$adc_i\,(t)$	[R$/unit]	5,40	
$adc_{p,\ endc,\ i}(t)$	[R$/unit]	0,0938	

Table 20: Example for the projected standardized INTERMEDIATE parameters for an appliance i (fluorescent lamps)

Maximum possible share of stock for the energy efficient technology $(\mathrm{maxpN}_{EE\,i}(t))$:

- ⇨ It gives the share of stock that can be maximally replaced by the energy efficient technology considering the age structure, useful life and resulting typical exchange rates of the actual used appliances along the time horizon.
- ⇨ There are 3 different ways of choosing the $maxpN_{EE\,i,t}$[42]**:**
  - Case 1:
    If $t > t_{BL\,i}$, then until t all the actual stock could possibly be replaced by the energy efficient one.

$$maxpN_{EE\,i}(t) = 100\ [\%]$$

  - Case2:
    If $t < t_{BL\,i}$, but the share of stock with an age older than $(t_{BL\,a} - t)$ isn't bigger than $\left(\frac{1}{t_B} \times t\right)$, then use the formula which considers average replacement rates $\left(\frac{1}{t_B}\right)$ typical for the appliance i or system j.

$$maxpN_{EE\,i}(t) = \frac{\left(\frac{1}{t_{BL\,i}} \times t \times N_i(0)\right) + (N_i(t) - N_i(0)\,)}{N_i(t)} \times 100 \quad [\%]$$

Equation 7: Case 2 for maximum possible share of stock for EE technology

[42] See Annex C for demonstration and illustration of this case distinction.

- Case3:
  If $t < t_{BL\,i}$ and the stock of share with an age older than $(t_{BL\,a} - t)$ is bigger than $\left(\frac{1}{t_B} \times t\right)$, then use the stock of share with an age older than $(t_{BL\,a} - t)$ instead of $\left(\frac{1}{t_B} \times t\right)$ in the formula which considers average replacement rates typical for the appliance i or system j.
  That share of the current stock $\mathrm{N}_a(0)$ might be possibly exchanged along the time horizon and would not be considered if common formula is used considering only an average replacement rate.

$$maxpN_{EE\,i}(t) = \frac{(\text{"}share\ of\ stock\text{"} \times N_i(0)) + (N_i(t) - N_i(0))}{N_i(t)}\ x100 \quad [\%]$$

Equation 8: Case 3 for maximum possible share of stock for EE technology

Example:

For the fluorescent lamps example, the first case is applied. The analyzed time frame is t=5 and the useful life of the baseline technology is $t_{STD,i} = 2$, as a consequence is $t > t_{STD,i}$. Because of this, the whole stock will be replaced at least once in 5 years.
The resulting Maximum possible share of stock for the energy efficient technology is then:

$$maxpN_{EE,i,t} = 100\ [\%]$$

Energy savings per unit per year $(ES_i(t))$:

⇨ Those are the energy savings calculated first per unit and per year, that can be afterwards aggregated for the whole stock, resulting so in the Dynamic Potential.

$$ES_i(t) = EC_{BL\,i}(t) - EC_{EE\,i}(t) \quad \left[\frac{kWh}{year\ x\ unit}\right]$$

Equation 9: Energy savings per unit per year Dynamic Potential

$$ES_i(t) = 111{,}22 - 96{,}82 = 14{,}4 \quad \left[\frac{kWh}{year\ x\ unit}\right]$$

Acquisition costs for both alternatives $(aqc_{BL\,i}(t)\ and\ aqc_{EE\,i}(t))$:

⇨ All acquisition costs added together consisting of e.g. price of the appliances, installation costs, other extra costs, etc.

$$aqc_{BL\,i}(t) = p_{BL}(t) + ic_{BL\,i}(t) + exc_{BL\,i}(t) \quad \left[\frac{R\$}{unit}\right]$$

$$aqc_{EE\,i}(t) = p_{EE\,i}(t) + ic_{EE\,i}(t) + exc_{EE\,i}(t) \quad \left[\frac{R\$}{unit}\right]$$

Equation 10: Acquisition costs for both alternative (BL and EE) Dynamic Potential

$$aqc_{BL\,i}(t) = 2{,}80 + 0 + 0 = 2{,}80 \quad \left[\frac{R\$}{unit}\right]$$

$$aqc_{EE\,i}(t) = 7{,}40 + 0{,}60 + 0{,}20 = 8{,}20 \quad \left[\frac{R\$}{unit}\right]$$

Additional costs due to energy efficiency per unit $(adc_{\,i}(t))$:

⇨ These costs result from building the difference between all acquisition costs that would arise at the moment of replacement for the energy efficient technology as well as for the baseline technology.

$$adc_{\,i}(t) = aqc_{EE\,i}(t) - aqc_{BL\,i}(t) \quad \left[\frac{R\$}{unit}\right]$$

Equation 11: Additional costs due to energy efficiency per unit for Dynamic Potential

$$adc_{EE\,i}(t) = 8{,}20 - 2{,}80 = 5{,}40 \quad \left[\frac{R\$}{unit}\right]$$

Additional costs per saved kWh $(adc_{p,\ endc,\ i}(t))$:

⇨ The additional costs per saved kWh are the annuity of the additional costs per unit resulting from comparing the acquisition costs of the defined baseline and the energy efficiency measure. Dividing this annuity by the energy savings per unit results in an additional cost per kWh.

$$adc_{p,\ endc,\ i}(t) = \frac{\dfrac{r_{p,\ endc}(t)}{\left(1 - \dfrac{1}{\left(1 + r_{p,\ endc}(t)\right)^{t_{EE}}}\right)} \cdot adc_i(t)}{ES_i\,(t)} \quad \left[\frac{R\$}{kWh}\right]$$

Equation 12: Additional costs per saved kWh for Dynamic Potential

$$adc_{p,\ endc,\ i}(t) = \frac{\dfrac{0{,}12}{\left(1 - \dfrac{1}{(1 + 0{,}12)^{6}}\right)} \cdot 5{,}40}{14{,}4} = 0{,}0938 \quad \left[\frac{R\$}{kWh}\right]$$

Calculation of OUTPUT parameters for an appliance i or system j:

Finally, having the standardized INTERMEDIATE parameters, the 2 OUTPUT parameters for the CPCs can be calculated. For the Dynamic Potential, the Energy Savings $Es_i(t)$ are aggregated for the whole stock considering the share of stock of the energy efficiency technology. For the Net Marginal Costs for Saved Energy, Additional Costs per Unit of Energy

Saved are weighted with the Long-Run avoided Costs for Energy Saved and the difference of the Operational Costs.

Those two parameters are plotted in a chart to construct CPCs.

Parameter	Measure Unit	Description
$Pot_{dyn,\ i}(t)$	[TWh/year]	Dynamic Potential for appliance i at t
$c_{net,\ p,\ endc,\ i}(t)$	[R$/kWh]	Net costs per unit energy saved due to the energy efficiency measure i at t (private end consumer perspective)

Table 21: Projected standardized OUTPUT parameters for an appliance i

Example:

Using the standardized INPUT and INTERMEDIATE parameters, the following OUTPUT parameters were calculated and plotted in the chart (see calculation below).

Parameter	Measure Unit	Values
$Pot_{dyn,\ i}(t)$	[kWh/year]	1382,4
$c_{net,\ p,\ endc,\ i}(t)$	[R$/kWh]	-0,3362

Table 22: Example for the projected standardized OUTPUT parameters for an appliance i (fluorescent lamps)

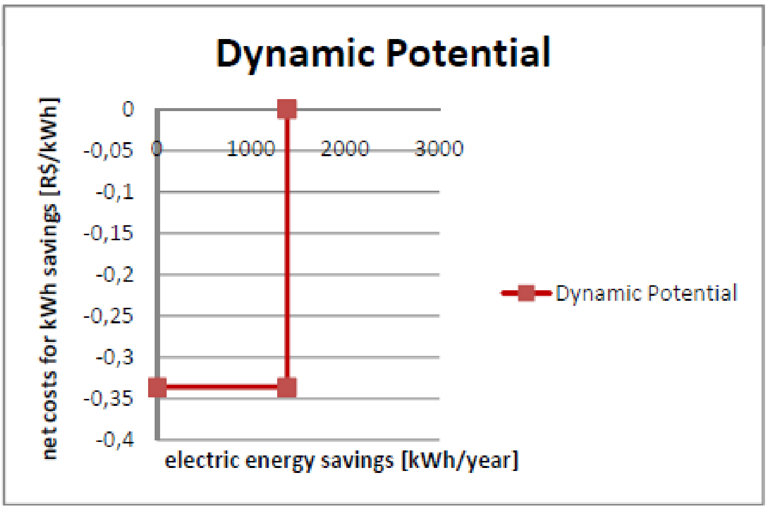


Figure 14: Example of CPC for Dynamic Potential of one appliance i (fluorescent lamps)

Here we give the chart comparing the Static Total and the Dynamic Potential to show that there is a difference between them in both, the Energy saving Potential and the Net Marginal costs:

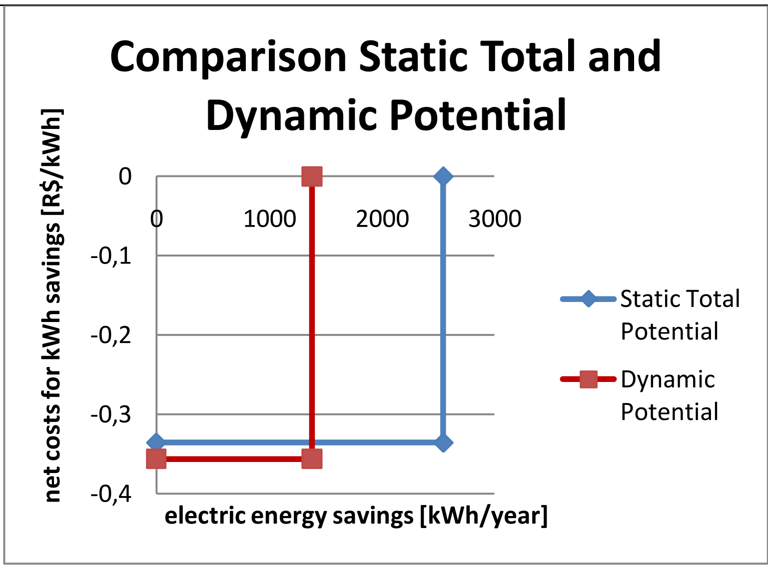


Figure 15: Comparison of CPCs for Static Total and Dynamic potential of one appliance i (fluorescent lamp)

Remark:

- We added the chart only to show how to plot the OUTPUT parameters on the graphic. Normally it makes no sense to publish the potential for one appliance i only.
- It is not common to plot the Static Total and Dynamic Potential in the same graphic. For illustration reasons we did it so, to show that the both have different results and that normally the Dynamic Potential uses to be smaller (because of the trend for the energy efficient technology and because it is not always possible to replace the whole stock in the selected time horizon) and that the Marginal Net Costs for one Unit of Energy saved tends to be smaller (with the time the energy efficient technology will be more economically attractive).

Dynamic Potential $(Pot_{dyn,\ i}(t))$:

⇨ Is defined as the amount of savings that would be achieved if all the stock of a technology possible to replace were converted to the defined energy efficiency level considering typical exchange rates within a specific time period.

$$Pot_{dyn,\ i}(t) = \left(\mathrm{maxpN}_{EE\,i}(t) - \mathrm{N}_{EE\,i}(t)\right) \times \mathrm{N}_i(t) \times ES_i(t) \quad \left[\frac{TWh}{year}\right]$$

Equation 13: Dynamic Potential

$$Pot_{dyn,\ i}(t) = (1 - 0{,}52) \times 200 \times 14{,}4 = 1382{,}4 \quad \left[\frac{kWh}{year}\right]$$

Net costs for saved energy $(c_{net,\ p,\ endc,\ i}\ (t))$:

- Net costs result from adjusting the calculated additional costs per kWh by the saved costs for electricity. Additionally they can also be adjusted by existing operating costs that differ between the baseline and energy efficiency measure.

$$c_{net,\ p,\ endc,\ i}(t) = adc_{p,\ endc,\ i}(t) - c_{kWh,\ p,\ endc}(t) - (oc_{EE\ i}(t) - oc_{BL\ i}(t)) \quad \left[\frac{R\$}{kWh}\right]$$

Equation 14: Net costs for saved energy for Dynamic Potential

$$c_{net,\ p,\ endc,\ i}(t) = 0{,}0938 - 0{,}43 - (0 - 0) = -0{,}3362 \quad \left[\frac{R\$}{kWh}\right]$$

2.3.4 Plotting CPCs for a whole sector, region, etc

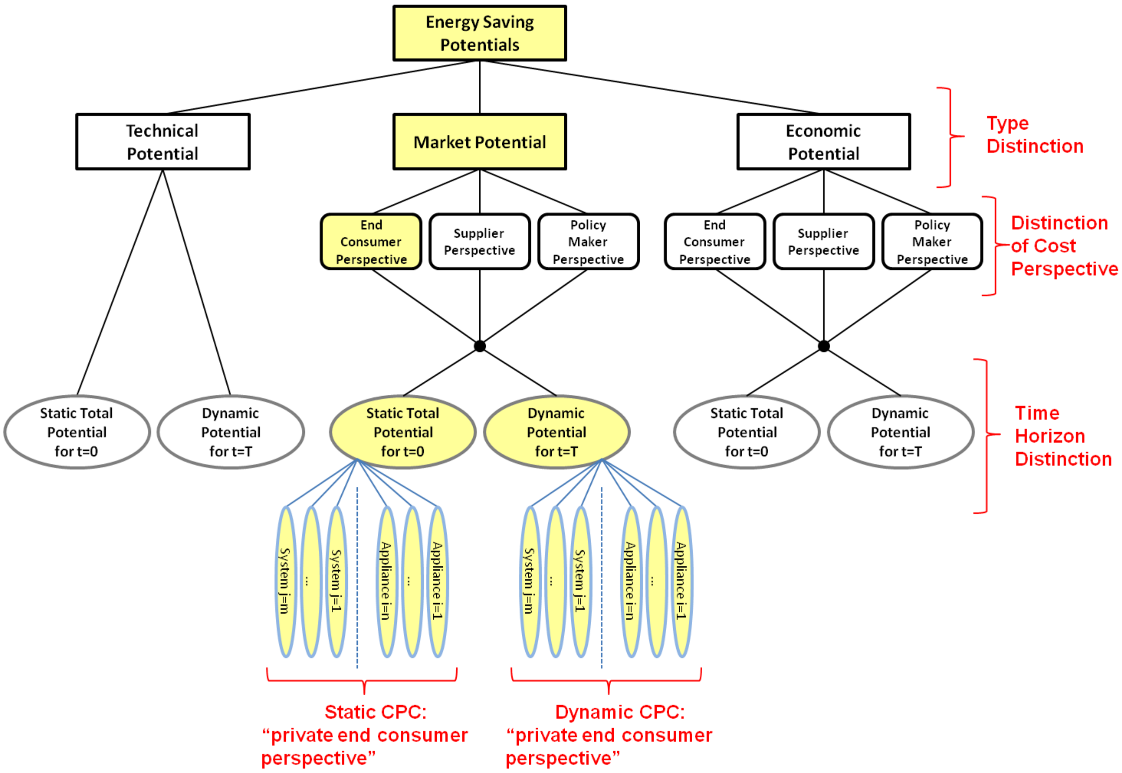


Figure 16: CPCs for a specific type, from a specific perspective, combining all appliances i and systems j for the segmentation done

For a specific sector, region, or further differentiation and for the specific kind of potential that has been calculated, all the analyzed appliances i or systems j should be plotted together in a chart, either for the Static Total or Dynamic Potential to result finally in a CPC.

The appliances i and systems j are ordered by their Net Marginal Cost OUPUT parameters. Starting with the lowest net marginal cost, the value for the net marginal cost is placed on the upper right of the y-axis and then a line is drawn along the x-axis for the right size of the potential. For plotting the next appliance i or systems j with the next lowest net marginal cost, a line is then drawn along the y-axis until the right height for the value of the net marginal cost and from there a line is drawn again along the x-axis for the right size of the potential. The process is continued until all appliances i and systems j have been plotted. The result is a curve with the shape of stairs.

On the x-axis at the end of the chart the cumulative energy saving potential for all appliances i and systems j can be found. And for each, the net marginal costs per unit energy saved can be found on the y-axis.

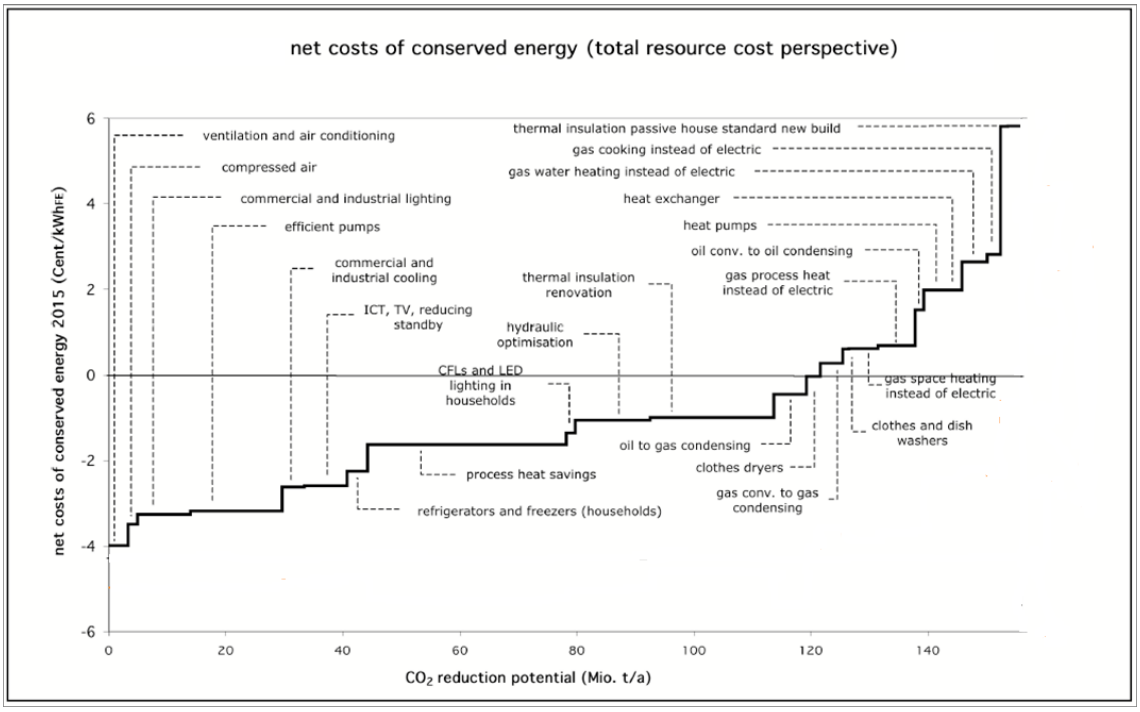


Figure 17: Example of CPC for one sector (dynamic potential with basis year 2005) (Fischedick, 2010)

2.3.5 Interpreting the CPCs and making a plausibility check

The resulting CPC has the shape of stairs showing with the length of each step the potential for the whole stock of an appliance i of system j. The high of the step at the y-axis gives its respective net marginal cost for each unit of energy saved if the energy efficiency measure would be implemented. The length of the step (the potential) multiplied by the net marginal cost, results in the total cost for implementing the energy saving potential for the whole stock of a specific appliance i or system j.

Confusing can be observing that some appliances i or systems j with a net marginal cost smaller and others higher than 0. The ones with a net marginal cost smaller than 0, result in benefits along the useful life of the appliances i or system j if the proposed energy measure would be implemented (see definition of the net marginal cost). That means, with an appropriate financial plan which considers affording the high initial investment cost, the energy efficiency measure will bring an economic benefit in the long run (in addition to the positive aspect of saving energy!).

The appliances i and systems j with a net marginal cost higher than 0, require a financial incentive for the energy efficiency measure being implemented. In the long run, the high acquisition costs for the energy efficiency measure cannot be gained back through the energy saving costs along the useful life of the appliance i or system j.

As a conclusion it can be interpreted that possible energy efficiency policies should consider implementing first energy efficiency measures for the appliances i or systems j appearing at the beginning of the curve (close to the y-axis). The convincing argument for doing so is the economic benefit that they could bring in the long run!

A plausibility check has the goal to evaluate if the constructed CPC is significant enough to make energy efficiency policies decisions based on them, or at all, if there are significant enough to be published.

For the plausibility check it is important to review if the CPC calculated for the selected sector, region, or whichever segmentation, is at all meaningful. Therefore should be checked, for which energy unit the energy efficiency measures were defined and if it makes sense. It is important to review the correctness of the potentials and net cost values, as well as to check how meaningful it is to consider energy efficiency for the chosen appliances i and systems j.

2.3.6 Parameters distinction between CPCs definitions

At the beginning of this document in chapter 2.1.4 there was presented a general distinction between potentials regarding the type, the cost perspective and the time horizon. In that chapter Figure 2 was shown and general explanation was made.

Now, after showing the methodology for the calculation of the OUTPUT parameters for the Static Total and Dynamic potential and knowing the INPUT parameters that are needed, we will discuss which parameters make the distinction between the different kinds of potentials. We remind the reader that on our methodological description the distinction is given with the indexes of the parameters. For better illustration we give once more another version of the known Figure 2:

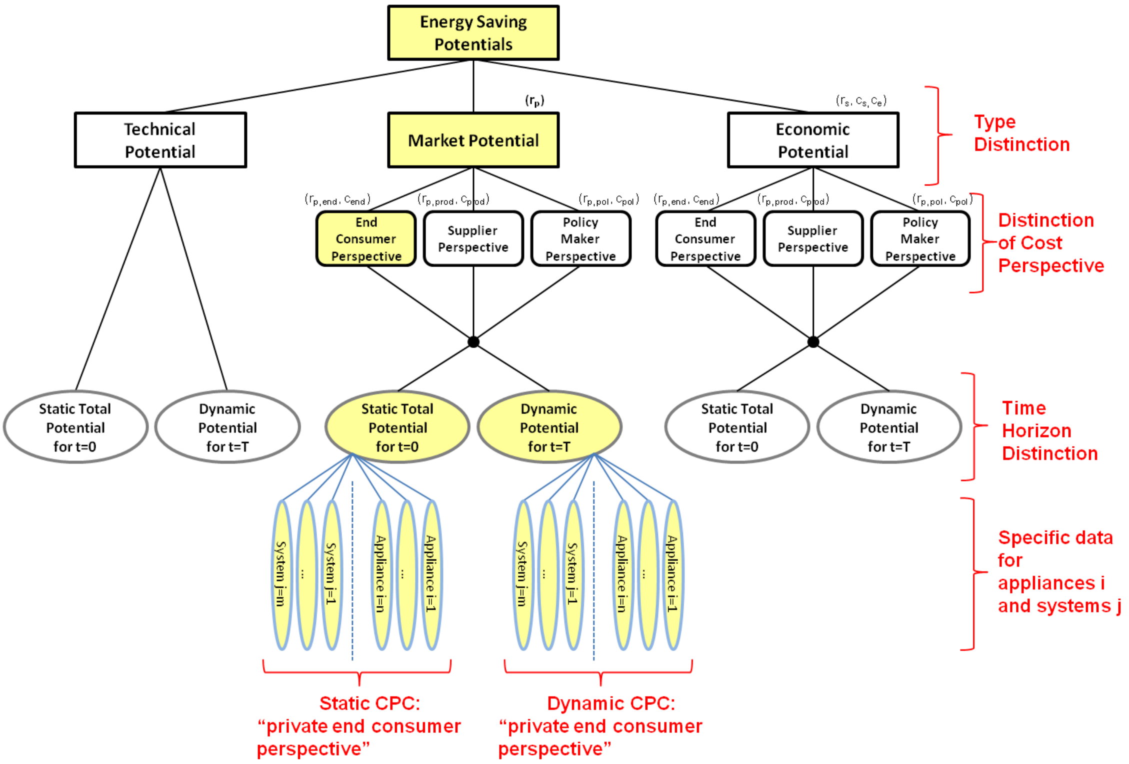


Figure 18: Illustration of the energy saving potentials distinction with the help of the INPUT parameters

The INPUT parameters were separated in 2 groups, general INPUT parameters and INPUT parameters specific for the appliances i and systems j. Only the general INPUT parameters are going to describe the type and the cost perspective of the CPCs and those refer specially to economic values. This is well illustrated on Figure 18.

Regarding the type of the perspective, it will be differentiated between a private and social discount rate (r_p, r_s) to characterize the Market and Economic Potential. In addition, social and environmental costs (C_s, C_e) are characteristic and should be considered for the Economic Potential. Those are needed for the calculation of the Net Marginal Cost per unit Energy saved, which are added or subtracted depending if they are really costs or benefits.

$$c_{net,\ p,\ endc,\ i}(t) = adc_{p,\ endc,\ i}(t) - dc_{kWh\ ,\ p,\ endc}(t) - \left(oc_{EE\ i}(t) - oc_{BL\ i}(t)\right) \pm C_s \pm C_e \quad \left[\frac{R\$}{kWh}\right]$$

Equation 15: Net costs for saved energy considering social and environmental costs for the Economic Potential

Regarding the cost perspective, the discount rate characteristic for the type might have different values depending from which perspective it is considered. It is going to be characterized as shown in the table and it should be carefully estimated for each case.

Perspective	Parameters
end consumer	$r_{p,\ endc}(t)$,
Supplier	$r_{p,\ sup}(t)$
policy maker	$r_{p,\ pol}(t)$

To characterize the cost perspective, the appropriate cost for energy or long-run system costs are needed. They are characterized as shown on the table and they should carefully be estimated.

Perspective	Parameters
end consumer	$c_{endc}(t)$,
supplier	$c_{sup}(t)$
policy maker	$c_{pol}(t)$

Regarding the time horizon, all parameters (general and specific) are typical for a specific point in time. This is characterized by the time variable t, being t=0 characteristic for the Static Total Potential and other t for the Dynamic Potential.

3 Outlook: CPCs for Brazil

3.1 Proposal for implementing CPCs as instrument of energy efficiency of current use

Figure 19 shows a strategy to implement CPCs as an instrument for current use of energy efficiency in Brazil. The main focus of the strategy is implementing a well structured data base for the calculation of CPCs. The data base should contain all relevant information needed for the CPCs purpose, but primarily standardized data (representative data for the analyzed appliances i and systems j) that eventually is used to calculate CPCs based on the CPCs methodology as described in this document.

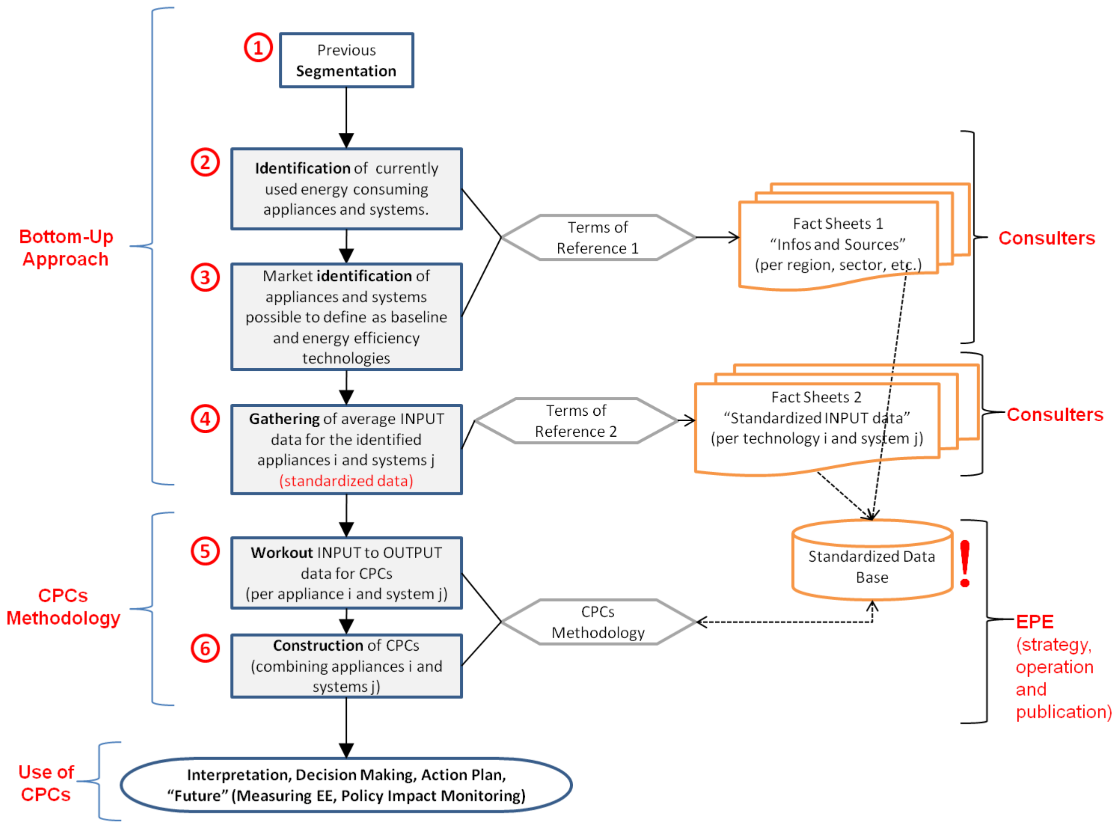


Figure 19: Mind Map for the strategy to implement CPCs as an instrument of current use

3.2 Who could be in charge of which step?

In chapter 2.2 steps for the implementation of CPCs were described. It is not expected one institution, nor one person to be in charge of doing such a widespread work. Furthermore, only some entities have the decisive power to be in charge of some steps, e.g. implementing energy politics based on results shown in CPCs. Therefore, we publish a table with possible appropriate entities to be in charge of the several steps.

Step 1	EPE, Consulters				
Step 2[43]	Consultant 1	Consultant 2	Consultant 3	…	…
Step 3	Consultant 1	Consultant 2	Consultant 4	…	…
Step 4	Consultant a	Consultant b	Consultant c	…	…
Step 5	EPE				
Step 6	EPE				
Step 7	MME, EPE, ONS, ANEEL, …				
Step 8	MME, MCT, MMA, …				
Step 9	MME, …				

Table 23: Appropriate entities to carry out the steps

3.3 Remarks and Recommendations

Along the document remarks and recommendations have already been done. In this chapter we repeat some of them which we believe there are important to consider for implementing CPCs in Brazil. We are going to work them out following the order of the steps showed in Figure 4, the steps to follow for the data gathering and calculation of CPCs.

The main goal of calculating CPCs is to indentify realistically energy efficiency potentials and their cost-effectiveness if possible for the whole country Brazil. As can be noticed from the methodology for calculating the OUPUT parameters for CPCs, the INPUT parameters needed are "simple" representative average values for a whole stock of appliances i or systems j. To let these average values be really representative the stock should be as homogeneous as possible. Therefore, an exhaustive previous segmentation to look for homogeneous stocks is very important for the end result of the CPCs. Especially for an heterogeneous country as Brazil this first segmentation before gathering the needed data for the calculation of CPCs should be carried out in detail.

The explanation could sound some kind of general that is why we try to describe it now with an example for the household sector. We refer here to the theses of (Grözinger, 2010) in which the author analyzed the end use energy consumption of the residential sector of Brazil to make it energy efficient. To achieve its purpose, the author made first of all a classification of the residential building in Brazil. Afterwards, he estimated the energy consumption per building type and defined reference buildings for each type. Finally he described the BAU scenario and the energy efficient one. Being the regions, states and cities in Brazil so heterogeneous, to complement the work of (Grözinger, 2010) and make it more precise, the same study with the same methodology can be made for each region, state, city or maybe more segmented, for each urban and rural area of a state. A similar approach could also be used for other sectors. Maybe, similar research studies as (Grözinger, 2010) for other sectors already exist and can help as reference for doing the previous segmentation needed for the mission of calculating CPCs.

The previous segmentation is a generic and intuitive one, based on experience or found research works. That is why, on the second step of starting to look for energy consuming

[43] The different columns refer to the segmentation done in step 1.

appliances i and systems j is important to confirm, that the segmentation done in step 1 is useful. With the help of the Fact Sheets 1 on annex A this should be possible.

In step 2 and 3, the first approach to identify end use energy consumption is done. As a consequence, in those steps should be also been looked for homogeneous stocks and, of course, also representative stocks for identified energy consuming appliances i and systems j. Detailed methodologies to achieve the homogeneous stocks should be developed (as for e.g. in (Grözinger, 2010))

Once a well done segmentation has been achieved and, as far as possible, homogeneous stocks has been indentified, the next challenging work is finding representative average values for all INPUT parameters of energy consumptions and prices or costs. Here again a detailed and vast research has to be done to achieve high quality CPCs. We recall at this stage the importance of the `heroic' assumption to be carried out with success (chapter 2.1.3 and (Meier, 1982)).

Regarding the different types, perspectives and time horizons of potentials that can be calculated, we recommend due to the complexity of the INPUT data needed to initially calculate the Market Potential from end consumer perspective in the two time forms, Total Static and Dynamic.

Why the Market potential? As we mentioned before, because the data gathering for it lies on the market and the data gathered can be realistic. The Technical Potential has the disadvantage of not having reference to costs and the Economic Potential needs as INPUT parameters also externalities that are difficult to estimate and are sometimes too subjective. A study that tried to calculate the three Potentials can be found in (Schaeffer, Cohen, J. de Agiar, & V.R. Faria, 2009).

Why to choose an end consumer perspective? The goal after having identified realistic energy efficient potentials is to develop an action plans to implement the energy efficiency potentials. Since mainly the end consumers are the ones who are going to implement the energy efficient technologies the reference to cost should be specific for them. If we imagine the policy makers introducing a policy for energy efficiency giving economical incentives, the cost are going to be the ones from end consumer perspective.

And, why calculate both, the Total Static and Dynamic Potentials? The Dynamic Potentials is clear, because it represents realistically the BAU scenario for a specific time horizon t=0 to t=T. The Total Static Potential, although it cannot be realistic, can be interesting to know for example how much energy efficiency can be maximal achieved. Who knows, maybe there is a financial possibility to implement the Total Static Potential, at least for one kind appliance i or system j!

Here again some remarks and recommendations to calculate realistic Dynamic Potentials. Due to the amount of information that has to be projected, we recommend a maximum time horizon form 10 year (also supported by the Wuppertal Institute). Possible could be a five years time horizon for feedback purposes (measuring and policy monitoring after 5 years) and 10 years horizon for CPCs to be published in the PDE.

On the other hand, to short time horizons are also not recommended, because the useful life of appliances i and systems j have the tendency to be at least 3 years (e.g. fluorescent lamps by high intensity use) and since the Dynamic Potential considers a `normal' refurbishment or reinvestment, few items of a stock would be replaced in a short time horizon resulting a low Dynamic Potential that is not significant.

An idea that needs to be work out after CPCs based on Bottom-Up studies have been implemented, is using the energy planning tool also for measuring energy efficiency and policy impact monitoring. Using the CPCs and Bottom-Up data for that purpose in combination with Top-Down data can also be helpful.

CPCs are sensitive to the global parameters like are the discount rate and energy costs. We remember to be careful to assign the significant values to those parameters and recommend reading (Wuppertal-Institute, 2010) chapter “Strength and Weaknesses of CPCs” for a detailed explanations of the sensitivity of CPCs to those parameters.

List of Abbreviations

AP	Action Plan
EE	Energy Efficiency
SoA	State of the Art
BAU	Business-as-Usual
GHG	Green House Gases
CPC	Cost Potential Curve
PDE	“Plano Decenal de Energia”
PNE	“Plano Nacional de Energia”
MME	“Ministerio de Minas e Energia”
MMA	“Ministerio de Medio Ambiente”
ONS	“Operador Nacional do Sistema Elétrico”
ANEEL	“Agencia Nacional de Energia Elétrica”
MCT	“Ministério de Ciência e Tecnologia”

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Annex A:

"Fact Sheets 1: Initial segmentation and identification of energy consuming appliances and systems for the segmentation done"

Fact Sheets 1 – Identification of energy consuming appliances and systems for a relevant segmentation of the energy consumption in the country

These Fact Sheets should help as a guide to make a first identification of energy consuming appliances and systems for a selected segmentation of energy consumption in a country made in order to estimate energy efficiency potentials.

They contain some questions that should be answered in detail to achieve significant information to be able to define energy efficiency measures and further on, to estimate energy efficiency potentials with the CPCs methodology based on a bottom-up study.

The overall purpose of these Fact Sheets is to get a well **structured mind map** of **energy consuming appliances and systems** for the **selected segmentation** of energy consumption in a country based on a bottom-up approach, as well as a first approach to defining possible energy efficiency measures.

Another important issue for these Fact Sheets is the fact that studies that estimate energy efficiency potentials to be found in the literature for Brazil up to the present have the following approach:

What data has already been gathered that could be used to estimate energy efficiency potentials applying a specific methodology? With existing data, studies were done.

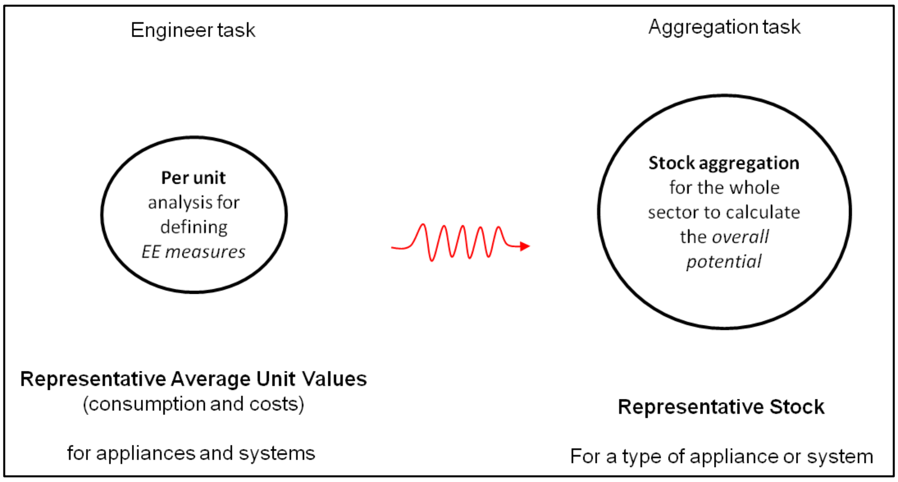
With these Fact Sheets it should be possible to achieve the following approach:

What are all possible energy efficiency potentials that can be estimate and how and where do we get the needed information to calculate them? (Methodological approach for gathering data and calculating energy efficiency potentials plotting them as CPCs)

To illustrate the aim of these Fact Sheets in a better way, we give at first a short remark to the Bottom-Up approach needed for the identification of energy efficiency potentials.

Short Remark to the Bottom-Up approach:

The graphic shows two different tasks that should be accomplish to achieve a significant estimation of energy efficiency potentials based on a Bottom-Up study.



The Engineer task accomplishes for a specific type of energy consuming appliance or system a detailed study for defining at unit level a baseline and an energy efficiency technology. For this task a methodology should be developed for defining significant average unit values that would be representative for a whole stock (see Fact Sheets 2). This is called in the literature the 'heroic assumption', since it should be very sumptuous to estimate those average values.

The aggregation task requests a proper segmentation which makes it possible to estimate a representative stock for a specific type of appliance or system with the help of statistical studies.

By means of these Fact Sheets it should be first generically found out which is a proper segmentation of energy consumption in a country in order to identify energy efficiency potentials, which are energy consuming appliances and systems that should be analyzed for the selected segmentation, as well as first approaches for defining energy efficiency measures for those and finally, collect information sources that could be helpful for mission of identifying energy efficiency potentials.

General analysis:

Which energy unit should be made energy efficient?

- [kWh/year], [tep/year], [J/year], etc.
- Starting from an energy efficiency approach, it is always possible with an appropriate methodology found in the literature to convert energy efficiency into reduction of e.g. GHG. However, defining from the beginning of the study, that a reduction of GHG is the main interest, would help to search for energy efficient measures that directly reduce the GHG emissions.

What segmentation of energy consumption in a country is going to be used, in order to look for energy efficiency measures?

- It is recommended to do the segmentation in sectors and further segmentations for analyzing the sector:
  - Residential sector, industrial sector, public sector, commercial sector, transport sector, transformation (Energy) sector, agricultural sector
  - Further segmentation in regions, areas in a region – urban and rural areas, cities, etc.
- Every other kind of segmentation is possible. One should be selected that allows afterwards a methodological gathering of information for the country and contributes to indentifying energy efficiency for the selected energy measure!

What could be an initial list of energy consuming appliances or systems for the selected segmentation?

Item: appliance or system	Service offered
e.g. for residential sector: clothes dryer	Dry clothes
….	…

Analysis for the identified energy consuming items (this should be done for each item of the list):

Regarding the Engineer Task

What is the function of the item? How can be it described?

What is the service offered by the item? How can it be described?

Is it possible to offer the same service using another energy source? Description! (Technologies found in the country, in foreign countries)

What different brands and models of the item are on the market? Give a list describing the energy potentials and costs!

Brands	Models	Energy potential	Costs
e.g.: Prime	WD1403 RD	Xxx [W]	x [R$](Price), y [R$/year] (operation costs)
…			

How could the item be defined, as homogeneous or heterogeneous type[44]?

- Regarding energy potential demanded, use intensity, prices, intensity of development of modern technologies, etc.

Which are useful information sources for the item?

- Institutions (statistical, energy, …)
- Scientific research (papers, …)
- Others

Which could be a possible energy efficiency measures for the item? Give some examples for defining a baseline and energy efficiency technology!

Baseline technology	Energy Efficiency technology
e.g.: high energy consumption and bad drying efficiency of clothes dryer (should be described more in detail)	e.g.: clothes dryer with the best energy efficiency and good drying efficiency
…	

Regarding the Aggregation Task

For estimating the stock, is the segmentation done sufficient or would it be better to carry out another detailed segmentation to find a representative stock for the item?

- E.g. residential sector: segmentation regarding rent, habitants per residence, other characteristics to define a reference residence, etc.

Which institutions working on statistical studies could have information for stock or should be the one carrying out statistical studies on finding out the number of stock?

[44] This classification may be important for the estimation of standardized average INPUT parameters that is later on going to be accomplished with Fact Sheets 2. Estimation standardized average INPUT parameters for a homogeneous type of item might be easier than for a heterogeneous type.

Final Remark:

- For the segmentations proposed, giving mind maps is very helpful!
- For the identified items in the list, an exhaustive analysis per item is needed. Give enough relevant information!
- Use the questions and tables given in this proposed Fact Sheet 1 as reference. Furthermore, adding any further information that would help to realize the mission of identifying energy efficiency potentials more accurate is useful!

Annex B:

"Fact Sheets 2: Estimation of standardized average INPUT parameters for the appliances and systems identified with Fact Sheets 1"

Fact Sheets 2 – Estimating standardized average unit parameters for appliances and systems

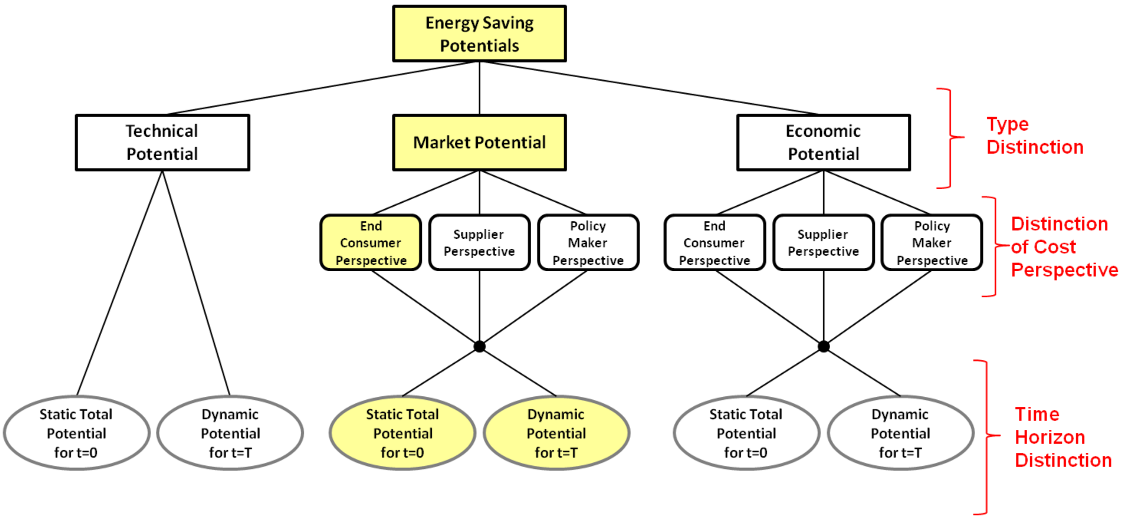
These Fact Sheets should help as a **methodological approach** for estimating the needed **standardized average INPUT parameters** needed for the **calculation of CPCs**.

They are based on the knowledge gained with the help of the Fact Sheets 1, which accomplish a general segmentation and identification task.

The task with this fact sheets is to collect statistically real data and describe the used approach to estimate the required standardized average INPUT parameters (see the 'heroic assumption' (Meier, 1982)). The methodology for calculating CPCs distinguishes between general INPUT parameters and specific INPUT parameters for each appliance i and system j. These Fact sheets should describe with well-founded arguments how all these INPUT parameters were estimated. The task should be realized for each appliance i or system j considered.

For a detailed description of purpose of the INPUT data needed we refer to the methodology for calculating CPCs.

Description of the type and perspective of the energy efficiency potential to be calculated:



	Description	Index
Type of Potential:		tech / p / s
Cost Perspective:		endc / sup / pol
Energy efficiency measure:		kWh / toe / BTU

➔ Normally both the Static Total and Dynamic Potential need to calculated!

Data sheets with appliances i and systems j need to be analyzed:

- Basis on the Fact Sheets 1

Appliances	Running index	Short description
	a	
	b	
	…	
	n	

Systems	Running index	Short description
	A	
	B	
	…	
	M	

Static Total Potential:

Estimating general INPUT parameters:

Clear and brief:

- Adjust indexes

Parameter	Measure Unit	Values	Short Argumentation
$r_{p,\ endc}(0)$	[%]		
$p_{kWh,\ p,\ endc}(0)$	[R$/kWh]		
$c_{kWh,\ p,\ endc}(0)$	[R$/kWh]		

Description and Argumentation:

- Describe the parameters selection approach
- Sources, assumptions, arguments, etc.

Estimating specific INPUT parameters for an appliance i or system j:

- This must be accomplished for every item given in the data sheets above!

Clear and brief:

- Adjust index for the item as described on the data sheet (i.e. replace “i”).

Parameter	Unit	Values	Short Argumentation
$N_i(0)$	[units]		
$\mathrm{maxpN}_{EE\,i}(0)$	[%]		
$N_{EE\,i}(0)$	[%]		
$EC_{BL\,i}(0)$	[kWh/unit x year]		
$EC_{EE\,i}(0)$	[kWh/unit x year]		
$t_{EE\,i}$	[years]		
$p_{BL\,i}(0)$	[R$/unit]		
$p_{EE\,i}(0)$	[R$/unit]		
$ic_{BL\,i}(0)$	[R$/unit]		
$ic_{EE\,i}(0)$	[R$/unit]		
$exc_{BL\,i}(0)$	[R$/unit]		
$exc_{EE\,i}(0)$	[R$/unit]		
$oc_{BL\,i}(0)$	[R$/unit x year]		
$oc_{EE\,i}(0)$	[R$/unit x year]		

Description and Argumentation:

- Describe the ‘heroic assumption’: describe the approach for defining the average values
    - Give brands, models, sources, etc.

Dynamic Potential:

Estimating general INPUT parameters:

Clear and brief:

- Give the time horizon (recommended maximum 10 years)

Variable	Unit	Value	Short Argumentation
t	[years]		

- Adjust indexes

Parameter	Unit	Values	Short Argumentation
$r_{p,\ endc}(t)$	[%]		
$p_{kWh,\ p,\ endc}(t)$	[R$/kWh]		
$c_{kWh,\ p,\ endc}(t)$	[R$/kWh]		

Description and Argumentation:

- Describe the parameters selection approach
- Sources, assumptions, arguments, etc.
- Projection model

Estimating specific INPUT parameters for an appliance i or system j:

- This must be accomplished for every item given in the data sheets above!

Clear and brief:

- Adjust index for the item as described on the data sheets.

Parameter	Unit	Values	Short Argumentation
$N_i(t)$	[units]		
$N_{EE\ i}(t)$	[%]		
$MS_{EE\ i}(t)$	[%]		
$MS_{EE\ i}(t)$	[%]		
$EC_{BL\ i}(t)$	[kWh/unit x year]		
$EC_{EE\ i}(t)$	[kWh/unit x year]		
$t_{BL\ i}$	[year]		
$t_{EE\ i}$	[years]		
$p_{BL\ i}(t)$	[R$/unit]		
$p_{EE\ i}(t)$	[R$/unit]		
$ic_{BL\ i}(t)$	[R$/unit]		
$ic_{EE\ i}(t)$	[R$/unit]		
$exc_{BL\ i}(t)$	[R$/unit]		
$exc_{EE\ i}(t)$	[R$/unit]		
$oc_{BL\ i}(t)$	[R$/unit x year]		
$oc_{EE\ i}(t)$	[R$/unit x year]		

Description and Argumentation:

- Describe the projection model and assumptions.

Annex C:

"Validation of the case distinction for estimating the Maximum Share of Stock maxp$N_{EE,\,i}$ (t) for replacing appliances or systems of a stock along the time horizon"

Some parameters for building an example for demonstration:

Parameter	Unit	Values	Argumentation
$N_a(0)$	[units]	500	For a:= e.g. computers
$t_{BL\,a}$	[years]	6	Useful life for the baseline technology a
t	[years]	4	Time horizon
$N_a(t)$	[units]	600	There is an increment in stock of 20% until the year t=4

Case 1: Is $t > t_{BL\,i}$? (this case is trivial and has not to be demonstrated)

$$t = 4 \; < \; t_{BL\,i} = 6 \qquad Answer: \; no!$$

➔ If the answer is yes, than it is obvious that the whole current stock might be replaced along the time horizon t.

Case2: Is $t < t_{BL\,i}$ but the stock of share with an age older than $(t_{BL\,a} - t)$ not higher than $\left(\frac{1}{t_B} \times t\right)$?

Example for which case 2 applies!

➔ Is $t < t_{BL\,i}$?

$$t = 4 \; < \; t_{BL\,i} = 6$$

Answer: yes!

➔ Is the stock of share with an age older than $(t_{BL\,a} - t)$ higher than $\left(\frac{1}{t_B} \times t\right)$?

- Analyze the age structure for the share of stock for which the age is higher than $t_{BL\,i} - t$ (from current stock $N_a(0)$):

Share of stock		Age	Share of stock with age higher than $t_{BL\,i} - t = 6 - 4 = 2$
[units]		[years]	[%]
100	->	1	20
100		2	20
100		3	$60 \; > \; \frac{1}{t_B} \times t \; = \; \frac{1}{6} \times 4 \; = \; 66{,}66$
100		4	
100		5	

Answer: No!

➔ Then use the formula which considers average replacement rates typical for the appliance i or system j.
The result is:

$$maxpN_{EE\,a}(t) = \frac{\left(\frac{1}{t_B} \times t \times N_i(0)\right) + \left(N_i(t) - N_i(0)\right)}{N_i(t)} \times 100 \quad [\%]$$

$$= \frac{\left(\frac{1}{4} \times 6 \times 500\right) + (600 - 500)}{600} \times 100 \quad [\%]$$

$$= 72{,}22\ [\%]$$

Case3: Is $t < t_{BL\,i}$ and the stock of share with an age older than $(t_{BL\,a} - t)$ bigger higher than $\left(\frac{1}{t_B} \times t\right)$?

Example for which case 3 applies!

➔ Is $t < t_{BL\,i}$?

$$t = 4 < t_{BL\,i} = 6$$

Answer: yes!

➔ Is the stock of share with an age older than $(t_{BL\,a} - t)$ higher than $\left(\frac{1}{t_B} \times t\right)$?

- Analyze the age structure for the share of stock for which the age is higher than $t_{BL\,i} - t$ (from current stock $\mathrm{N}_a(0)$):

Share of stock		Age	Share of stock with Age higher than $t_{BL\,i} - t = 6 - 4 = 2$
[units]		[years]	[%]
50	->	1	20
50		2	20
150		3	
150		4	80 > $\frac{1}{t_B} \times t = \frac{1}{6} \times 4 = 66{,}66$
100		5	

Answer: yes!

➔ Then use the stock of share with an age older than $(t_{BL\,a} - t)$ instead of $\left(\frac{1}{t_B} \times t\right)$ in the formula which considers average replacement rates typical for the appliance i or system j !
That share of the current stock $\mathrm{N}_a(0)$ might be possible to exchange along the time horizon and would not be considered by the formula considering only average replacement rates.

The formula and result is as follows (with a “share of stock” = 0.8):

$$maxpN_{EE\,a}(t) = \frac{\left(0{,}8 \times N_i(0)\right) + \left(N_i(t) - N_i(0)\right)}{N_i(t)} \times 100 \quad [\%]$$

$$= \frac{(0{,}8 \times 500) + (600 - 500)}{600} \times 100$$

$$= 83{,}33 \;\; [\%]$$