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Demand-side management in liberalized electricity markets

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To my wife and sons

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Abstract

Electric utilities revenues depend, ultimately on energy sales volume. Therefore, it is apparently counter intuitive that utilities engage in energy efficiency promoting activities. Nevertheless, utility-based Demand-Side Management (DSM) programmes started after the oil crises of the 70's, under regulated environment, when utilities were mostly vertically integrated and quite a number of them publicly-owned. In the early 1990s, DSM programmes were already adopted by many utilities, integrated in resource plans where both the supply and the demand side were considered as equivalent alternatives in the planning procedure (addressed as Integrated Resource Planning - IRP). The deregulation of the electricity industry that started in the 1990s, threatened DSM. During this period utilities were more focused in the restructuring process and, due to uncertainties on the availability of funds and to the new regulatory environment, investments in DSM dropped sharply. Energy Efficiency Resource Standards (EERS) arouse as a market-oriented mechanism requiring utilities to achieve certain energy savings targets through energy efficiency programmes. In some European countries these targets are addressed to as Energy Efficiency Obligations (EEO). The savings obtained by utilities can be certified, a "white certificate" being issued accordingly. This is the case of the Flemish region of Belgium, Denmark, France, Italy, and UK, alongside with Canada and Australia. In some countries, these obligations/savings can also be traded.

Different approaches have been adopted to deal with the paradox of utilities involvement in EE fostering or to explain it: regulatory impositions, sharing of costs and benefits of DSM between utility and customers, plain utility's marketing strategy. The option for using legal/regulatory frameworks that lead utilities to foster the efficient use of energy must ensure their economic and financial balance as well as maintain, or even improve, their competitiveness. IRP and EEO are two regulatory measures that induce utilities to seek the most cost-effective demand-side alternatives. After the evaluation of the various alternatives, procedures must be in place to allow the selection of some alternatives over others. This is particularly more important when those EE measures/programmes are funded by ratepayers.

In the thesis, a characterization of the involvement of utilities in the promotion of energy efficiency measures, in several countries is presented, as well as of the conditions that determine this involvement. The regulatory procedures used for the selection of the measures to be implemented by the utilities are also addressed. It becomes quite apparent that direct and strict regulatory influence

must be exerted in order that electric utilities engage in DSM activities in a structured way, driven by societal interests and objectives.

The Portuguese energy regulator (ERSE) has developed a tender mechanism to promote energy efficiency in electricity consumption (PPEC). This tender mechanism is financed by an annual budget paid by all electricity customers. Electric utilities and other organizations can submit measures, to be implemented and partly financed by PPEC budget. The measures may target different consumer segments (industrial, agricultural, residential, commerce and services) and may imply the installation of equipment or just disclosure of information. The ranking of measures is subject to an evaluation based in a set of criteria and their weighting factors, publicly known in advance.

A methodological proposal is made to help strengthen the present tender mechanism as an evolved form of procurement. The use of public funds, as well as money from the utilities, to innovatively pursue societal objectives, calls for the definition of societal objectives as explicit drivers of both the procurement procedure and the evaluation and ranking of candidate measures. A methodology was developed, based on two simultaneous objectives: minimize the cost of saved energy and maximize saved energy. The use of this bi-objective approach is compatible with the regulator practice so far, maintaining the transparency of the tender mechanism and providing a greater flexibility and societal advantage of the portfolio of selected measures for market transformation.

Resumo

Na medida em que as receitas das empresas do setor elétrico dependem, em última análise, da quantidade de energia elétrica vendida, a promoção da eficiência energética por estas empresas aparenta ser um contrassenso. No entanto, programas de gestão da procura (Demand-side management - DSM) surgiram após a crise do petróleo dos anos 70, em ambiente regulado, onde as operadoras de eletricidade eram na sua maioria verticalmente integradas e, em muitos casos, de capitais públicos. No início de 1990, os programas de DSM eram já prática corrente de muitas operadoras, fazendo parte de planeamento integrado de recursos (Integrated Resource Planning - IRP), em que os recursos da oferta e da procura são avaliados como alternativas em pé de igualdade. A desregulamentação do setor elétrico, que começou na década de 1990, ameaçou DSM. Durante este período as operadoras estavam mais focadas no processo de reestruturação e devido às incertezas sobre a disponibilidade de recursos e ao novo ambiente regulatório, os investimentos em DSM foram reduzidos. As obrigações de eficiência energética surgiram como um mecanismo orientado para o mercado, exigindo às operadoras metas de redução de consumos de energia através de programas de eficiência energética. Nos Estados Unidos da América (EUA) estas obrigações são vulgarmente conhecidas por Energy Efficiency Resource Standards (EERS) e em alguns países europeus, por Energy Efficiency Obligations (EEO). Em alguns países as reduções de consumo obtidas pelas operadoras podem ser certificadas, através da emissão de um "certificado branco". Alguns dos países com EEO são a região flamenga da Bélgica, a Dinamarca, a França, a Itália e o Reino Unido, juntamente com o Canadá e a Austrália e alguns estados dos EUA. Em alguns países, essas poupanças podem ser transacionadas no mercado.

Diferentes abordagens têm sido adotadas para lidar com o paradoxo do envolvimento das operadoras de eletricidade na promoção de eficiência energética ou para o explicar: imposições regulamentares, partilha de custos e benefícios entre empresas e consumidores, ou simples estratégia de marketing da operadora. As disposições regulatórias deverão assegurar o equilíbrio económico e financeiro das operadoras, incluindo na promoção da eficiência energética, bem como manter, ou mesmo melhorar, a sua competitividade. IPR e EEO são duas medidas regulamentares que induzem as operadoras a melhorar a relação custo-benefício das alternativas do lado da procura. Após a avaliação das diversas alternativas, deverão existir procedimentos que permitam a seleção de umas alternativas

em detrimento de outras. Isto é particularmente mais importante quando essas medidas/programas de EE são financiados pelos clientes das operadoras.

Neste trabalho, é efetuada uma caracterização do envolvimento das operadoras de energia elétrica na promoção de medidas de eficiência energética, em vários países e das condições que viabilizavam este envolvimento. Torna-se evidente a necessidade de dispositivos regulatórios bem específicos para assegurar o envolvimento das empresas elétricas na promoção da eficiência energética nos usos finais, conduzido por interesses e objetivos societais.

A Entidade Reguladora dos Serviços Energéticos (ERSE) desenvolveu o Plano para a Promoção da Eficiência no Consumo de energia elétrica (PPEC). Este mecanismo, baseado num concurso, está sujeito a um orçamento anual pago por todos os consumidores de eletricidade. As operadoras de energia elétrica e outras organizações podem apresentar medidas candidatas a serem implementadas e co-financiadas pelo orçamento do PPEC. As medidas podem atingir diferentes segmentos de consumidores (industrial, agrícola, residencial, comércio e serviços) e podem implicar a instalação de equipamentos ou apenas a disseminação de informações. O ranking de medidas está sujeito a uma avaliação com base em um conjunto de critérios e seus pesos, conhecidos com antecedência.

Os procedimentos regulamentares utilizados para a seleção das medidas a serem implementadas pelas operadoras também são abordados. É também feita uma proposta metodológica para ajudar a fortalecer o mecanismo. Objetivos societais são claramente explicitados e usados na avaliação e ordenação das medidas candidatas. A metodologia foi desenvolvida, baseada em dois objetivos: minimizar o custo de cada kWh poupado e maximizar a energia poupada. A utilização desta abordagem bi-objetivo é compatível com a prática regulatória seguida até agora, mantendo a transparência do programa e proporcionando uma maior flexibilidade na seleção das medidas para a transformação do mercado.

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List of Abbreviations and Acronyms

A

AC – Avoided Consumption

ACC – Arizona Corporation Commission

ACEEE – American Council for an Energy-Efficient Economy

ACT – Australian Capital Territory

ADEME – French Environment and Energy Management Agency - *Agence de l'Environnement et de la Maîtrise de l'Energie* (France)

AEEP – Argentina Energy Efficiency Project

AEP – American Electric Power

AMCRE –Above Market costs in order to stimulate renewable energy sources

ANEEL – National agency of electrical energy - *Agência Nacional de Energia Elétrica* (Brazil)

APS – Arizona Public Service

ARI – Annual Revenue Impact

ARI_{RIM} – Annual Revenue Impact for the Ratepayer Impact Measure test

ARRA – American Recovery and Reinvestment Act

B

BCR – Benefit-cost ratio

BCR_{PAC} – BCR of the Program Administrator Cost test

BCR_{RIM} – BCR of the Ratepayer Impact Measure test

BCR_{TRC} – BCR of the Total Resource Cost test

BEE – Bureau of Energy Efficiency (India)

BPA – Bonneville Power Administration (US)

BPC – Botswana Power Company

BTU – British Thermal Unit

C

CCEF – Connecticut Clean Energy Fund

CDM – Clean Development Mechanism

CDM – Conservation and Demand Management (Canada)

CEA – Chugach Electric Association (US)

CEB – Ceylon Electricity Board

CEC – California Energy Commission

CEEF – Connecticut Energy Efficiency Fund

CERT – Carbon Emissions Reduction Target (UK)

CFE – Mexican national energy company

CFL – Compact Fluorescent Lamp

CHP – Combined Heat and Power

COPUC – Colorado Public Utilities Commission

CPUC – California Public Utilities Commission

CSk – Cost of each Saved kWh

CSk_{PPEC} – Costs of each Saved kWh allocated to the PPEC budget

D

DEA – Danish Energy Agency

Dena – Germany energy agency – *Deutsche Energie-Agentur*

DII – Direct Investment Index

DM – Decision Maker

DNO – Distribution Network Operator

DOER – Department of Energy Resources (Massachusetts, US)

DPU – Department of Public Utilities (Massachusetts, US)

DR – Demand Response

DSM – Demand-Side Management

E

EA – Evolutionary Algorithms

EACEM – European Association of Consumer Electronics Manufacturers

EC – European Commission

ECO – Energy Conservation and Commercialization

EDF – Electricity of France - *Electricité De France*

EDP – Electricity of Portugal – *Eletricidade de Portugal*

EE – Energy Efficiency

EEAC – Energy Efficiency Advisory Council (Massachusetts, US)

EEAP – Energy Efficiency Action Plan (EU)

EEC – Energy Efficiency Commitment (UK)

EECA – Energy Efficiency Conservation Authority (New Zealand)

EECRF – Energy Efficiency Cost Recovery Factor (Texas, US)

EEO – Energy Efficiency Obligation

EEPM – Energy Efficiency Police Manual

EEPS – Energy Efficiency Portfolio Standard

EERS – Energy Efficiency Resource Standard

EEU – Energy Efficiency Utility

EGAT – Electricity Generation Authority of Thailand

ELI – Efficient Light Initiative

ELIB – Efficient Light Initiative of Bangladesh

EM&V – Evaluation, Measurement and Verification

ENOVA - Norwegian national energy agency (Norway)

ERSE – Energy Services Regulatory Entity - *Entidade Reguladora dos Serviços Energéticos* (Portugal)

ESB – Electricity Supply Board (Ireland)

ESCO – Energy Service Company

EST – Energy Savings Trust

ETO – Energy Trust of Oregon (US)

ETS – Emission Trading Schemes

EU – European Union

EVN – Electricity of Vietnam

F

FCA – Fixed-Cost Adjustment

FERC – Federal Energy Regulatory Commission

FIDE – Trust fund for electric energy savings – *Fidelcomiso para el ahorro de energía eléctrica* (Mexico)

FOE – Focus on Energy (Wisconsin, US)

FPSC – Florida Public Service Commission

FRI – First-year Revenue Impact

G

GA – Genetic Algorithms

GCA – Green Communities Act (Massachusetts, US)

GDP – Gross Domestic Product

GEAT – Generating Electric Authority of Thailand

GEF – Global Environment Facility

GGAS – Greenhouse Gas Reduction Schemes

GHG – Greenhouse Gas

GME – Electricity Market Operator (Italy)

GW - Gigawatt

GWh – Gigawatt-hour

H

HECO – Hawaiian Electric Company

HVAC – Heating, Ventilation and Air Conditioning

I

ICE – Costa Rica Institute of Electricity – *Instituto Costariccense de Electricitad*

IDCEO – Illinois Department of Commerce and Economic Opportunity

IEA – International Energy Agency

IFC – International Finance Corporation

ILSAG – Illinois Energy Efficiency Stakeholders Advisory Group

IOU – Investor-Owned Utility

IRP – Integrated Resource Planning

K

KIUC – Kauai Island Utility Cooperative

kW – kilowatt

kWh – kilowatt-hour

L

LDC – Local Distribution Company (Ontario, Canada)

LED – Light-Emitting Diode

LM – Load Management

LRI – Lifecycle Revenue Impact

M

M&V – Measurement and Verification

MDU – Montana Dakota Utilities

MECA – Michigan Electric Cooperative Association

MEEAC – Massachusetts Energy Efficiency Advisory Council

MEPS – Minimum Energy Performance Standards

MERC – Maharashtra Electricity Regulatory Commission (India)

MINAE – Ministry of Energy and Environment (Costa Rica)

MT – Market Transformation

MW - Megawatt

MWh – Megawatt-hour

N

NEA – Nepal Electricity Authority

NEEAP – National Energy Efficiency Action Plan

NEEC – National Energy Efficiency Campaign (Botswana)

NERSA – National Energy Regulator of South Africa

NGO – Non-governmental Organization

NPV – Net Present Value

NPV_{PAC} – NPV of the Program Administrator Cost Test

NPV_{RIM} – NPV of the Ratepayer Impact Measure test

NPV_{TRC} – NPV of the Total Resource Cost test

NSGA-II – Non-dominated Sorting Genetic Algorithm II

NSW – New South Wales (Australia)

NVE – Norwegian Water Resources and Energy Administration (Norway)

NYPA – New York Public Authority (US)

NYPSC – New York Public Service Commission (US)

NYSERDA – New York State Energy Research and Development Authority (US)

O

OEB – Ontario Energy Board (Canada)

OECD – Organization for Economic Co-operation and Development

Ofgem – Office of Gas and Electricity Markets (UK)

OPA – Ontario Power Authority (Canada)

OPEC – Organization of Petroleum Exporting Countries

P

PAC - Program Administrator Cost test

PBC – Public Benefits Charge

pBCR – Proportional BCR

PBF – Public Benefit Fund

PECO – Philadelphia Electric Company (US)

PGC – Public Goods Charge

PGE – Portland General Electric (US)

PGP – Demand-side management plans – *Programas de Gestão da Procura* (Portugal)

PNAC – Climate Change national Plan

PNAEE – National Energy Efficiency Action Plan

POU – Publicly-Owned Utility

PPEC – Demand-Side Efficiency Promotion Plan – *Planos de Promoção de Eficiência no Consumo (Portugal)*

PROCEL – National Programme for Electrical Energy Conservation – *Programa Nacional de Conservação de Energia Elétrica* (Brazil)

PSC – Public Service Commission

PSCo – Public Service Company of Colorado

PSO – Public Service Obligation

PUC – Public Utilities Commission

PURPA – Public Utility Regulatory Policy Act

R

R&D – Research and Development

RAP – Regulatory Assistance Project

rBCR – Ranked BCR

REC – Regional Electricity Company (UK)

REEC – Regional Energy Efficiency Centre (Norway)

REEE – Rational Use of Electrical Energy

REEEF – Renewable Energy and Energy Efficiency Fund (Jordan)

REEEP – Renewable Energy and Energy Efficiency Partnership

REES – Residential Energy Efficiency Scheme (Australia)

REF – Rural Electrification Fund (Jordan)

REPS – Renewable and Efficiency Portfolio Standard

RES – Renewable Energy Sources

RGGI – Regional Greenhouse Gas Initiative

RIM – Ratepayer Impact Measure test

ROC – Rank-Order Centroid

ROE – Return On Equity

ROI – Return On Investment

RPS – Renewable Portfolio Standard

S

SBC – System Benefit Charge

SBX – Simulated Binary Crossover

SCE - National System for the Energy and Air Quality in the Interior of Buildings Certification - *Sistema Nacional de Certificação Energética e da Qualidade do Ar Interior nos Edifícios* (Portugal)

SETF – Sustainable Energy Trust Fund (in District of Columbia, US)

SEU – Sustainable Energy Utility

SGCIE – Management System of Intensive Energy Consumption - *Sistema de Gestão dos Consumos Intensivos de Energia* (Portugal)

SI – Sensitivity Index

SOP – Standard Offer Programme (South Africa)

SoP – Standards of Performance

SPG – Super Priority Group (UK)

SPM – Standard Practice Manual

STIMEV – Energy Efficiency Lighting Scheme (The Netherlands)

SWEPCO – Southwestern Electric Power Company

T

TEP – Tucson Electric Power (Arizona, US)

TOU – Time-of-Use

TRC – Total Resource Cost test

TVA – Tennessee Valley Authority

U

UC – Utility Cost test

UK – United Kingdom

UNDP – United Nations Development Program

US – United States

USAID – United States Agency for International Development

V

VEET – Victorian Energy Efficiency Target (Australia)

VEIC – Vermont Energy Investment Corporation

VSD – Variable Speed Drive

Chapter 1.Introduction

Energy efficiency is usually said to one of the “twin pillars” of a sustainable energy policy (Prindle et al., 2007). The other one is renewable energy. Energy efficiency (EE) is essential for slowing down the growth of energy demand as is renewable energy for diversifying energy sources reducing the demand for fossil fuel sources. This reduction intends, not only to preserve our scarce energy resources, but also to reduce the environmental impact of the use of fossil fuels. On the other hand reducing the demand for fossil fuel sources is, for many countries, associated to reducing dependence from third parties. Although finding and using more energy from non-fossil sources is important, is also important to keep in mind that no matter how “green” the energy consumed may be, a kWh consumed in excess is more than a lost kWh. Also, renewable energy sources are not yet, and probably will not be, based on currently known technologies, a true alternative to fossil fuels, under current and projected consumption levels, due to the low density of primary energy flows. Hence it is very important to encourage the efficient use of energy. The difference between the actual level of investment in energy efficiency and the level that would be cost-effective to the consumer’s perspective is referred by “efficiency gap” (Brown, 2001). Besides the European Union (EU) concerns with security of supply, dependence from third party countries, the impact of energy consumption on climate change and on the competitiveness of the EU economy, the commitment assumed by the signers of the Kyoto protocol have also contributed to policies focused on energy consumption and climate change due to energy use. Such policies include EU Emissions trading Schemes (EU ETS), white certificates, green certificates, voluntary agreements, subsidies, loans, taxes, among others (Oikonomou et a., 2010). In this matter, the EU has been developing a common policy for all member states, allowing them some flexibility on directives implementation, depending on each member states’ peculiarities.

According to Oikonomou et al. (Oikonomou et al , 2010), it is possible that different policies may interact and that some have a either positive or negative influence on the success of others. Potential benefits from energy-efficient measures may not be fully realized because of various barriers. Barriers may differ from region to region and from sector to sector. Vine et al. (2003) distinguish policy level barriers from programme level barriers. The former are barriers to the achievement of public interest goals (reflecting the societal perspective), the latter identify barriers to the implementation of certain programmes (mostly reflecting end-user perspective). Low cost of energy to end users, lack of information to end users, end users do not investing in EE because of habits, lack of experience, financial constraints, are some programme barriers to the realization of the potential benefits of EE measures.

Examples of policy barriers are short-term perspective, split incentives to energy providers, lack of awareness by policy makers, and little market transformation experience, among many others. Vine (2003) also identifies as a general barrier the almost inexistent attention from governments to energy efficiency. Weber (1997), on the other hand, refers to barriers as belonging to one or several of these types: Institutional barriers (caused by political institutions, either state government or local authorities); market barriers or market failures (obstacles conditioned by the market); organizational barriers (barriers inside the organizations); and behavioural barriers (depending on individual values and attitudes towards energy efficiency). Verbruggen (2003) divides barriers into artificial and natural barriers. According to Verbruggen, the difference between actual efficiency and market potential can be reduced by eliminating what he refers to as "artificial" barriers. These are barriers such as not transparent tariff systems and biased investment rules, among others. Barriers like high interest rates are natural barriers. Overcoming these barriers requires societal transformations. Regardless of the type of barrier, Tonn and Peretz (2007) point out that government intervention may foster the penetration of markets by EE technologies that otherwise may take a long time.

Some actions taken to boost the transformation of technological products that provide energy services, in order for that transformation to occur faster than it would happen without those stimuli, are addressed as market transformation (MT) mechanisms. Among the diversity of agents involved in MT, energy providers have been identified as one of the most suitable for this mission, although they have to deal with the reduction in sales due to the improvement in EE.

In order for the measures and support schemes to be able to overcome barriers to EE improvement, they should be designed specifically to the barriers they address, according to the consumers sector and end-uses targeted, and to the specificities of region/country where they will be implemented.

In section 1.1 a short review of barriers to EE improvements is presented. The involvement of utilities in promoting EE is briefly addressed in section 1.2. In section 1.3 a thesis overview is presented.

1.1 Barriers to energy efficiency

One of the most referred barriers to EE is lack of information (Verbruggen, 2003), (Tonn and Peretz, 2007) (CEER, 2008) (Waide, et al., 2005): consumers are not aware of the energy consumption of appliances neither are they aware of alternative technologies/process or savings they provide; consumers may find new technologies unreliable, hard to use, or of lower quality than those they are used to. This barrier can be overcome by information and communication policies, e.g. labels, informative campaigns, events, and training. Besides more efficient technologies and/or processes, the attitude of consumers towards energy is also extremely important. Even when a consumer has the information, his behaviour may not reflect it. A consumer may consider that his energy costs are not high enough to make up for the effort of adopting a more conservative behaviour or even adapting to new and different and more efficient equipment. Consumer habits may prevent obtaining the EE potential the technology can provide. Therefore, being the energy bill often a low share of the total budget, the cost may not always be an incentive to increase energy efficiency. Low energy prices, and more important, low energy bills, besides not stimulating a change of consumer habits, make alternative solutions less cost-effective. For industrial and commercial consumers, some energy prices increase the Return on Investment (ROI) period of EE measures. Besides price, tariff structures can be an obstacle to energy efficiency. In other cases, consumers may not be able to invest in more energy efficient equipment as, very often, the decision to invest is not theirs. Split incentives are often referred to as another barrier to EE. Landlords, for example, may not have the incentive to invest since they are not the ones who benefit from the change. As landlords, there are other market players that do not pay the bills but whose investment options decide the energy consumption of others (a well-known principal-agent problem). Such is the case of architects that design buildings, builders that decide upon materials and appliances to install, central departments in institutions and companies that rent or install office spaces and equipment. An additional barrier, of cultural nature, corresponds to the prejudice of associating energy savings or low energy consumption to poverty or shortness of freedom (Verbruggen, 2003).

In order to overcome some barriers is necessary to inform, to give financial aid, to impose some regulatory procedures, to involve several agents in the market. It is necessary to turn energy efficiency attractive to consumers. In general, the benefits of higher EE levels and more conservative behaviours are known to all. Usually the consumer makes an evaluation of EE alternatives under financial or economic perspectives. There are other perspectives, mainly the societal perspective. The key is to show these other perspectives to the several agents in the market, as well as to the consumer.

Energy efficiency measures are often designed to eliminate or attenuate at least one barrier. Often there is a thin line separating an EE measure and a support scheme or mechanism to increase energy efficiency. Energy efficiency measures/support schemes can be divided into four main categories: financial and fiscal measures, legal or regulatory instruments, voluntary agreements and information. Some measures may come in a package (e.g., regulation together with information campaigns and financial incentives), making it sometimes hard to classify the instrument in a specific group.

Legal or regulatory instruments and guidelines

Mainly through regulation governments can give precise indications of its energy efficiency policy. Among the instruments used are the Energy Efficiency Action Plans (EEAP). Governments can impose standards for technology, building codes and "set legal requirements on power companies, industry and households with financial penalties in case of non-compliance" (CEER, 2008). Savings obligations can be imposed to energy utilities or to other organizations.

Financial mechanisms

Subsidies and taxes are examples of financial mechanisms. Subsidies can include, for instance, grants for investments in energy efficiency, subsidized audits and loans, tax reduction for the purchase of more energy-efficient equipment. Grants are public funds given directly to those that implement energy efficient projects. Public, or soft loans, for investments in energy efficiency, are loans usually subsidised by public funding that are offered at interest rates below the market values. Innovative funds, involving banks and the private capital can be combined with these loans (CEER, 2008).

The energy use or the emissions that result from the consumption of energy can be subjected to taxes and fees. These taxes can act as an incentive to reduce wasteful energy consumption habits or processes, such as energy taxes, CO_2 taxes (energy-related), pollution levies, and public benefit charges.

Energy Service Companies (ESCOs) can help removing barriers associated to the unavailability of access to capital, as they invest or find an investor in energy efficiency projects.

Voluntary agreements

Voluntary agreements are commitments celebrated between power producers, industries, equipment manufacturers, and a public authority. Voluntary agreements can result, for instance, from agreements between policy makers and industry. Performance indicators and exchanges of good practice almost always follow voluntary agreements. Usually some incentives are necessary to stimulate the industry participation. In general such "incentives include reimbursement of certain energy and environmental taxes, promises of energy taxes stability for industries that enter the agreement and meet their targets, and subsidized energy audits" (CEER, 2008). Several countries have pursued voluntary agreements with industries in order to reduce energy consumption as well as emissions intensity.

Information and communication

Information, communication, education, and training actions are means used to raise awareness to EE issues as well as to disclose energy efficiency policies and case studies. One way to raise awareness to EE is to give information to consumers about their own consumption and their energy savings potential. This can be done through energy audits, systems and productive processes analyses. Also information on energy efficient technological alternatives and rational behaviours should be disclosed.

1.2 Electric utilities involvement in the promotion of EE

Electric utilities are oriented to meet electricity demand by investing on the supply-side, selling energy being their business. Following the 1973 rise in prices that followed the OPEC oil embargo, utilities (mainly in the US) started looking at the demand-side as a manageable resource. For the energy costs to drop, their targets were to take the most out of the existing facilities of generation and transmission, in order to postpone investments, influencing the customers consumption habits, while trying to reduce the customers energy needs. By then, the decision to invest in measures to influence customers behaviour was mostly a political one. The changes in the load diagram aimed by utilities in order to achieve the goals are illustrated in Figure 1-1.

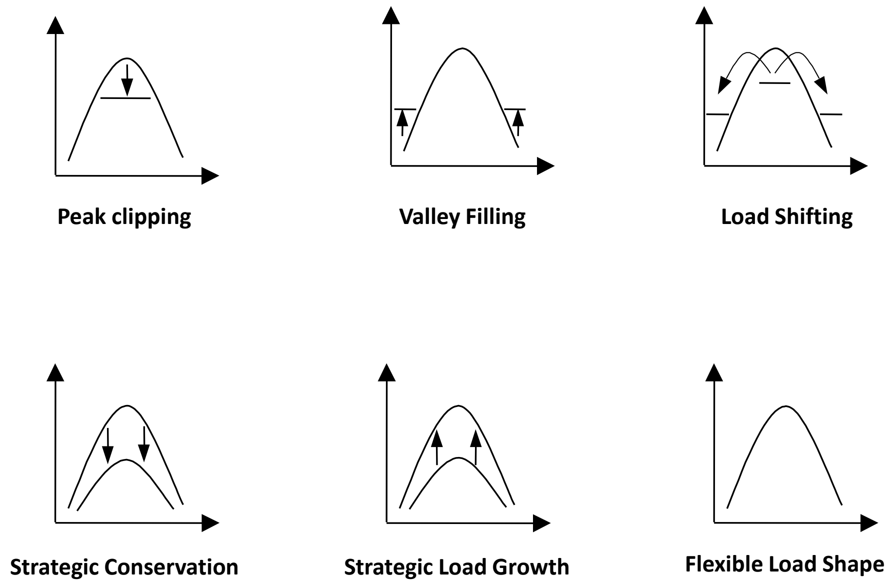


Figure 1-1 – Load shape objectives addressed by Demand-Side Management (Gellings, 1985).

Peak clipping, valley filling, and load shifting can improve the use of the existing assets, and are usually addressed as load management. Strategic conservation usually addresses measures that focus on the reduction of consumption, while strategic load growth aims at minimizing stranded costs of investments already done, by increasing energy efficient consumption. Flexible load shape allows utilities to react to sudden and sometimes unpredictable events, by influencing or controlling customers loads. It turns out that Demand-Side Management (DSM) objectives, improving the use of resources without reducing either comfort or production levels, were in the interest of the society at large.

Meanwhile, the evolution of the electricity sector towards unbundling and de-regulation caused the financial and economic interests of electric utilities (privately-owned or co-existing with publicly-owned) to become an important, almost decisive, issue in energy planning decisions. The pressure to obtain short-term profits caused situations where the utilities objectives were hardly in line with societal objectives. Increasing energy efficiency would reduce utilities revenues in the short-term, causing a strong disincentive for utilities to foster EE on the demand-side. However, as shall be seen in detail in chapter 2, there are currently many utilities in many parts of the world actively engaged in EE programmes, only less than two decades after the liberalization boom.

The choice upon who should deliver EE programmes has always to be addressed. According to (Waide and Buchner, 2008), two factors should be considered: motivation and competence. The engagement of utilities in promoting EE programmes is usually due to:

- Availability of financial and human resources;
- Access to customers (retailers case);
- Access to consumption patterns and history, allowing strategically targeting efforts;
- Competence in marketing and in engineering.

On the other hand, utilities are traditionally profit oriented. Conservation efforts may found some resistance since they have implications on profits and also because the skills to design EE programmes are different from those required to produce and sell energy.

Other organizations, as ESCOs or energy efficiency agencies, do not have to struggle against their business nature, and find the necessary competences to deliver EE programmes. On the other hand, they probably do not have easy access to customers' consumption data. In a recent study reporting the US experiences, R. Sedano (2001) concluded that the success of EE programmes is more related to the stability of policies, supported by consensus, than to the nature of the programmes administration - a utility or a third-party.

According to (Waide and Buchner, 2008), the evidence of higher levels of savings when utilities are under savings obligations schemes, suggests that EE obligations are an effective mean to deal with the motivation of utilities to promote energy savings. Under savings obligations, utilities will try to promote the measures/programmes with higher cost-effectiveness, in order to reduce their costs.

Usually stimulated by regulators, energy efficiency procurement intends to search for the most cost-effective alternatives to promote EE through screening processes for the selection of the "best" alternatives, under a set of criteria. Under another perspective, that is not the one followed in this work, efficiency procurement is used when public authorities challenge the manufacturers to produce new innovative technic/technological solutions that are above the market standard.

1.3 Thesis overview

In this thesis, the apparent paradox of EE promotion by electric utilities will be addressed, trying to shed some light on the identification of some mechanisms that are usually put in place in order to involve utilities in EE programmes. Therefore, two of the research questions dealt with in this thesis are: Is it possible that in a competitive environment, electric utilities engage in promoting energy efficiency on the demand-side? If the first question has a positive answer, what are the necessary conditions for such involvement to happen?

A case study in Portugal is specifically analysed, configuring an energy efficiency procurement activity, where the assessment of energy efficiency measures is based on an additive value function. A methodological proposal is presented, implemented and discussed, for driving the process of ex-ante selection of EE measures according to explicitly formulated societal objectives. In this context and additional research question is formulated: Is it possible to define societal objectives as explicit drivers in a process of a priori selection of EE measures based in an additive value function?

In chapter 2 an extensive characterization is made of the situation regarding the involvement of utilities around the world in the promotion of energy efficiency programmes in competing environments. The purpose of this chapter is to provide evidence on the current solutions that economies are using to deal with the apparent paradox of electric utilities involvement in activities that tend to cut on their revenues. Due to the restructuring process of the electricity industry around the world, the first step was to identify the countries/jurisdictions where competition was already a part of the electricity systems business environment. Some difficulties were found in gathering information of some countries. In chapter 3 a characterization is made of the EE procurement procedures used for the selection (also addressed as screening) of energy efficiency measures/programmes to be implemented by utilities, in some countries/jurisdictions. Chapter 4 deals with the involvement of utilities in the promotion of energy efficiency in Portugal. The evolution of the regulatory framework and some results obtained regarding utilities participation are highlighted. In chapter 5 a methodological approach is proposed for the use of societal objectives as drivers in the selection of measures candidates to the demand-side EE promotion plan (PPEC). Without modifying the use of an additive value function, used by the regulator, the proposed approach consists of using explicitly assumed societal objectives for the ranking of the measures. Tests and results of the proposed methodology are presented in chapter 6. In chapter 7 some conclusions and guidelines for future work are presented, followed by some personal opinions concerning utilities involvement in the promotion of energy efficiency on the consumer side of the meter as well as a personal point of view on the Portuguese energy efficiency procurement mechanism, which are presented in chapter 8.

Chapter 2. Dealing with the paradox of energy efficiency promotion by electric utilities

2.1 Introduction

The implementation of energy efficiency measures by utilities is, in abstract, a paradox. As a matter of fact, usually the income of a utility depends on the amount of energy sold, and so does the profit, as well as a return on the amount of capital invested in transmission lines and power plants. Therefore, it may not be an easy task to motivate utilities to engage in energy efficiency fostering strategies, mainly in a competitive environment. Nevertheless, nowadays it is very common to find energy efficiency programs implemented by utilities (Sciortino, et al., 2011).

Traditionally, the supply-side of the energy system was responsible for ensuring the provision of energy in conditions requested by the demand. Ensuring sufficiency and security of supply under the current conditions, where the economy is based on fossil fuels, is no longer viable. Non-fossil resources for energy generation have limitations. Besides the increase of several environmental and health issues/concerns on nuclear energy, uranium is also not an infinite resource. Renewable energy sources are not yet, and probably will not be, based on currently known technologies, a true alternative to fossil fuels, under current and projected consumption levels, due to the low density of primary energy flows. Also, the environmental impact of energy use, mainly from fossil sources, is not addressed by the current energy business model (Steinbergeret al., 2009). Looking at developing countries, mainly those with very low electrification rates, the need to ensure an electricity supply adequate to a reasonable quality of live is of even greater importance. The infrastructures of the electricity system of those countries are usually old, fragmented and unreliable, with high technical and commercial losses, dependent on expensive and carbon intensive fuels. Power sectors in these countries are subject to increasingly frequent power shortage events. Although these events seldom have a single and the same cause, they are usually associated to underinvestment in infrastructures, increasing demand growth, and natural causes such as drought, hot/cold weather (Heffner et al., 2010). In these cases, the electricity system does not meet its purpose of ensuring the needs of the population. This inability to deliver the amount of energy required within acceptable quality parameters may be an opportunity for utilities to engage in the promotion of end-use energy efficiency, not only as an opportunity to reduce demand, but also due to social and political pressure. For electric utilities, implementing energy efficiency programmes represents, in the short-term, incurring upfront costs and, in the long-term, losing revenues from electricity sales due to lower consumption values. Therefore, usually only through regulation it is possible to engage utilities in energy efficiency programmes. According to Alix Clark (2001), experiences in several countries show that it is no longer clear whether utilities should be the ones responsible for funding and/or implementing energy efficiency programmes. For instance, in 2002, Enova (the Norwegian national energy agency) has the responsibility of managing EE programmes, instead of the Regional Energy Efficiency Centres (REEC) that, on the other hand, were established to implement EE programmes instead of the utilities (Finamore, et al., 2003). In New Zealand, the Energy Efficiency Conservation Authority (EECA) is responsible for the promotion of energy efficiency, the preparation of regulatory acts, such as MEPS, labelling, and disclosure of information to compile statistics (IEA, 2011a). Two main reasons were appointed: utilities tend to prefer investments that are in their best interest and are not looking for the social perspective, "they are not in the best place to provide the diversified mix of resources that meet the economy needs of the electric service at the lowest possible life-cycle costs"(Clark, 2001). On the other hand, suppliers are closer to their customers. They know who they are, they know their consumptions habits, are in a position to collect and analyse data, they are a familiar brand, among others. They are, traditionally, the ones responsible for providing energy services. They also have the human, technical and financial resources and their experience gives them more ability to advise customers on energy efficiency (Clark, 2001). They have a privileged relation with customers and the opportunity to mobilise trade allies, such as municipalities and other local institutions (IEA, 2010a). Network operators, since their activity is usually regulated, their revenues are not so depending on the amount of energy sold, are in some countries the obliged party in implementing EE programmes. According to a study comparing alternative solution to the administration of ratepayer EE programmes, the worst performing model was the one that gave the administration of EE programmes to state agencies (Sedano, 2011). State agencies miss the flexibility and the independence from the government, and also the presence of the government in competitive business can be an inconvenient for the state's legislative and regulatory functions. It could not be clearly said that third-parties perform better than utilities in delivering cost-effective EE programmes. Nevertheless, some authors claim that the fundamental economic interests of a utility still tend to weaken its involvement in end-use energy efficiency programs over time. Different countries (or jurisdictions) treat the problem differently, for instance, through a blend of programme cost recovery, remuneration of sales, and sharing of benefits of energy efficiency programmes (Taylor et a., 2008). Sam Swanson (2012) identifies a set of more common regulatory mechanisms such as Energy Efficiency Obligations, Integrated Resource Planning, Stable funding, Markets' adaptation to foster energy efficiency investments, requiring disclosure of demand-side resource opportunities in system resource plans, performance incentives, tariff design, and independent energy efficiency providers.

In this chapter the involvement of electric utilities in EE activities in several countries is addressed. The countries analysed resulted mostly from gathering information on IEA/OECD countries and others whose information could be found in the Policy and Regulation Review Database of the Renewable Energy and Energy Efficiency Partnership (REEEP) website. Since the focus is on the existing paradox of private interests engaged in activities that could reduce their own income, countries where private entities are practically non-existent in the electricity sector were not addressed. On the other hand, energy suppliers are in better position to implement energy efficiency measures than energy generating companies. These are probably the reasons why in countries with private financial interests only in the production of electricity (e.g. mainly Independent Power Producers), almost no energy efficiency fostering by private utilities was found. However, some of these countries received support from international organizations to the implementation of Demand-Side Management (DSM) programmes, and are referred to in section 2.4.3. In Appendix A lists are presented of the countries, structured according to the participation of private interests in the electric sector: countries without private interest in the electric sector, countries with interests only in generation, and countries with private interest in the electric sector, besides generation. This last group contains the target of this work. However, for some of them no information was found regarding the involvement of utilities in DSM activities. Those countries are mostly developing countries that have privatized the electric sector as a way of increasing capital investment for the improvement of their electric system. Some of them also received donor funding. From the IEA/OECD countries, in some more recent reviews IEA suggests that some of the countries should foster the involvement of utilities in EE promotion. Some examples are Chile (IEA, 2009a), Czech Republic (IEA, 2011b), Luxembourg (IEA, 2009b), New Zealand (IEA, 2011a), Norway (IEA, 2011c), Poland (IEA, 2011d), and Turkey (IEA, 2009c).

Looking at developing countries, where utilities are obliged to serve customers at tariffs below the supply costs (low-income or peak-period customers) EE programmes can help reduce utilities losses (World Bank Independent Evaluation Group, 2009).

This chapter starts with a reference to the role of DSM before the restructuring of the electricity sector, followed by the report of some of the impacts of the restructuring process on DSM. According to the jurisdictions on which it was possible to gather information, it was decided to present the information in two main groups regarding the funding (section 2.4) and the obligations (section 2.5). The strategies used to raise funds to be invested by utilities including donor funding from international organizations is addressed, as well as the use of revenue recovery strategies and shareholders incentives to encourage utilities participation in EE programmes. Some particular DSM experiences are also reported (section

2.6). Although the statistical significance of the collected information was not previously set as a pre-requisite, since the set of jurisdictions reported were, as a methodology option, a consequence of the availability of information, some characterization for the whole set is presented in the conclusions section. A paper on the subject was presented at the SDEWES 2013 conference (Sousa et al., 2012a).

2.2 Utilities involvement in DSM activities before the electricity sector reform

Utility-based Demand-Side Management (DSM) programmes started after the oil crises of the 70's. The unprecedented increase in oil prices showed the vulnerability of the economies of most countries. DSM programmes had their origin in policies implemented by the federal regulators and state public service commissions (PSC) in the US. Under the Public Utility Regulatory Policies Act (PURPA) of 1978, energy conservation issues were to be included in state utilities regulations. DSM programmes started as information campaigns and loan programmes. However, more aggressive programmes were needed to involve consumers. Higher financial incentives were needed to convince consumers to make more solid savings choices. Some programmes included cash rebates to stimulate consumers buying specific energy-efficient equipment. These financial incentives were a strong tool for utilities engaged in integrated resource planning (IRP). Under this planning approach, DSM alternatives are equally considered to other options based on increasing generating and network capacity. The main motivation for these schemes was the cost-efficiency of the alternatives, and not their impacts on the environment and on the security of supply (Waide and Buchner, 2008). Usually the most successful energy efficiency programmes implemented by utilities are those that are part of a resource plan. This turns it easier to assess cost-effectiveness, evaluate results, and justify the programmes. Some examples are the province of Ontario, in Canada and the State of California in the US (IEA, 2010a). With DSM as an alternative in the planning process, an increase in the allocation of resources to new programmes was reported. Even so, the participation of consumers and the amount of savings obtained were not in line with the expectations. In order to obtain more savings and more participation, a more committed involvement of utilities was necessary. This involvement was accomplished through higher financial incentives and closer proximity of the utility to customers, not only during the purchase/installation of equipment, but in the long run, helping the customers getting more benefits from their participation in the programmes. This kind of involvement, not only had higher participation costs for the utility but also was time consuming, resulting in the possibility of serving only a relatively small number of consumers. On the other hand, analysts noted that DSM measures were producing sustained changes in the market, as the changes persisted beyond the end of the programme (Birner and Martinot, 2005). This was then looked at as permanent transformation of the market. MT alternatives included demonstration and training/information projects, and financial incentives, whose purpose was that after the MT initiative, the market penetration of the most energy efficient service/equipment would be near 100%. This would mean that the market was transformed. The customer would be presented the best solutions, without the need for any additional resources. However, MT alternatives require a contribution from diverse parties and demand some considerable organizational efforts. The labelling of equipment and minimum energy performance standards have been of major importance as MT initiatives. In European countries IRP was not a common approach, but there are experiences with DSM programmes. The motivations for DSM vary from country to country, being related to environmental concerns (the Netherlands, Denmark, and Germany), capacity shortages (Ireland), transmission and distribution constraints, and customers pressures related to nuclear power plants (Austria and Italy). In France, from September 1993 to February 1994, seven regional agreements were celebrated between EDF, the local authorities, and ADEME, for the implementation of pilot DSM programmes covering CFLs, public lighting, household appliances, energy audits, and industrial motors. Unlike France, the governments of Denmark and the Netherlands maintained a sustained and proactive attitude towards energy conservation since 1973. In Denmark, with the building regulations emphasizing energy efficiency and with ambitious pollution reduction targets, including a 20% CO_2 reduction target on 1990 levels by 2005, there was a strong societal acceptance of the importance of EE. Danish utilities were actively promoting DSM activities since 1986, with the implementation of programmes for the promotion of CFLs, and free energy audits to industrial and public customers. Also in the Netherlands CFLs had been actively promoted, and the climate change and other energy related pollution concerns were the drivers of EE since 1988 (Boyle, 1996).

China started implementing DSM in the early 1990s, due to the economic growth, partly supported by electricity consumption. DSM was mostly supported by funds from the government and most of the measures targeted load management rather than energy efficiency (RAP, 2012). DSM has been in place, since its introduction, although with uneven implementation throughout the provinces, without a clear policy for its support (Yu, 2011). The recognition of the important participation of energy providers in achieving EE through activities directed to the end uses, lead to a DSM rule (Guidance on Electricity Demand-Side Management Regulations, came in effect on January 1, 2011) that placed EE obligations on the State Grid Corporation of China and China Southern Grid Corporation Company. These two companies are government-owned and operate electricity transmission, distribution, and commercialization to the majority of customers in China. Since these two companies operate in different areas, there is almost no competition. As a matter of fact, these companies resulted from the reform of 2002 when the only company that produced and delivered electricity was divided. These two companies are the general buyers and sellers, monopolizing the market (RAP, 2012; Yu, 2011).

In the 1990s, a new trend in the electric business was underway, leading to liberalization, privatization, and deregulation. Due to the dimension and diversity of functions in the electricity business, vertically integrated companies were first unbundled in different companies, according to types of activity (generation, transmission, distribution, and supply), and then sold. Generation was the first system function opened to competition. Transmission and distribution were considered natural monopolies and all energy was sold, at an initial stage, to the transmission operator – situation known as the single buyer model. The full liberalization of the market allowed each customer to buy energy from a freely chosen supplier. Since DSM was conceived to operate in a monopoly organization of the sector, some changes needed to be made to foster EE/DSM in the new organizational context.

2.3 Restructuring of electricity sectors

Before the 1990s, when the movement towards restructuring of the electricity sector began, DSM programmes included information, financial assistance and direct installation of energy-efficient equipment. After the 1990s, these programmes were already standard practice for many utilities, changing their business to include provision of energy services, besides selling energy. Although DSM was standard practice, the deregulation of the electricity industry, which was occurring at the same time, threatened DSM programmes, due to lack of funding (Haney et. al, 2010). Utilities needed to reduce costs in order to minimize the average rates to face a competitive market. The uncertainty and the risk associated to the new market structures, as well as the fear of losing regulatory support for EE programmes, led to a reduction of the funding (York et al., 2012). The competition that resulted from the restructuring of the electricity sector reduced significantly the incentive for utilities to invest in energy efficiency measures, despite the opportunities that can emerge in the new market structures (Haney et al., 2010). Although it was argued that the liberalization of the electricity sector would have a catalytic role in the creation of an energy efficiency market, the truth is that this did not happen (OCDE/IEA, 2003; Yu, 2010). Energy efficiency services were expected to be an asset to keep and gain more customers. Instead, utilities effort was put in the marketing and in the sales departments. Thus, not only the electricity sector did not become more energy efficient, nor the security of supply or the environmental impact were addressed (Waide and Buchner, 2008). The overlapping between commercial and societal interests is one of the major disadvantages of the utilities involvement in promoting energy efficiency on the demand-side. Another is the competitive disincentive to incur in the costs of the programme, increase prices or reduce sales due to programme success. However, advantages may be considered to supersede the disadvantages: ready access to capital, proximity to the customer (including billing system and access to consumption data), familiar brand name, and responsibility to anticipate and accommodate energy and peak demand growth (IEA, 2010b). Prior to system reform, electric utilities in developed countries had the means and the resources to invest in the promotion of energy efficiency measures. In developing countries, on the other hand, privatisation was a mean to deal with the lack of funds to invest in the modernization/maintenance of the electricity systems, unable to respond to demand growth. The electricity systems were characterised by relatively low electrification rates, high distribution and commercial losses, vulnerability to weather changes (mainly drought), and consequent dependence on expensive energy resources. The use of other energy options, such as diesel generators, has higher contributions for the amount of greenhouse gas emissions. In some countries, even without the minimum admissible quality of service, the electricity tariffs are even higher than in developed countries or are highly subsidized (REEEP, 2012; Eberhard and Shkaratan, 2012). This was the case of India where, for example, tariffs to agricultural consumers were subsidized to 80%-90% in some states (Balachandra et al., 2010). Also low-income consumers in Mexico have highly subsidized tariffs (Birner and Martinot, 2005). DSM could be considered as a way to reduce power shortages and mitigate weather influence in energy supply, both reducing energy needs and supply costs. Also DSM is an opportunity to reduce the energy bills of those, namely low-income customers, as well as utilities commercial losses.

Although Chile was the first country in the world to reform the electricity sector, in 1982, California is perhaps the most commonly reported, at least regarding DSM before and after the restructuring of the electricity sector. California was the first US state to restructure the electricity sector, in 1994, with the aim of providing consumers the opportunity to choose their supplier. By 2000, the electricity sector of 21 more US states and the District of Columbia were under a new regulatory environment. In this regulatory environment, electric utilities had much less funds to spend in DSM programmes (IEA, 2008a). Due to the uncertainties about newly restricted markets and the expected loss of cost recovery mechanisms, the funding for ratepayer-funded energy efficiency programmes reduced from almost $1.8 billion in 1993 to $900 million in 1998 (nominal dollars). As a matter of fact, from 1993 to 1999, the decline in utility spending in DSM was 55% (Gillingham et al., 2004). Noting that the reduction of spending in DSM was related to deregulation, some states started setting mechanisms to restrain it.

In Norway, the energy Act of 1991 included an obligation for utilities to integrate DSM in the planning process (IRP). This obligation was then replaced by the recommendation that all utilities should engage in DSM programmes, such as information, demonstrations and audits. This resulted in a minimum of DSM involvement and investment (Clark, 2001).

The UK electricity sector was privatized during 1989-90. The new structure resulted in a few generation companies and ten regional electricity companies (RECs), mainly responsible for the distribution of electricity, and that altogether own the transmission company. Initially the pricing formula did not include specific incentives for DSM (Boyle, 1996). This mechanism discouraged investments in DSM that resulted in poor investments. OFFER, the regulator, (now Ofgem – Office of Gas and Electricity Markets) partially decoupled utility sales from revenues and profits. Also the Standards of Performance (SoP) were introduced and a revenue allowance was collected and used to finance DSM activities of the utilities. The SoPs were set by OFFER and impose a level of energy savings to the RECs. Much of those funds were not invested in DSM by the RECs. As a matter of fact, only cost recovery was possible to utilities. Unlike in the US, in the UK utilities were not allowed to profit from DSM. This resulted that US utilities were more willing to implement DSM programmes than UK utilities (Clark, 2001).

Public benefit funds (PBF) were then established by the regulators to fund DSM programmes, more precisely to fund energy efficiency programmes, renewable energy, low-income assistance and other public-interest energy R&D. These PBF were funded by a “wires charge”, also addressed as Public Benefits Charge (PBC), Public Goods Charge (PGC), or even Systems Benefit Charges (SBC). This way all ratepayers contribute to activities that are considered of public interest (Eto et al., 1998), releasing utilities from part of the cost of the EE programmes.

2.4 Funding energy efficiency utility programmes

Systems benefits charges (SBC) are added to all electricity bills. SBC can be collected as a percentage of gross annual utilities revenues, fixed values per kWh or fixed amounts. The reasons underlying the programmes financed by these charges were not related to provide electricity system resources (that was a “market” responsibility) but to support the benefits of energy efficiency to the society (Nowak et al., 2011). The energy efficiency programmes financed by these charges are usually managed by utilities and include financial incentives such as loans, grants, and rebates. When utilities have to fund EE programmes, some of the costs may be recovered through the electricity bills or tariffs. Other sources of funding are governmental budgets, grants from other agencies, earmarked energy or environmental taxes, stimuli funds, licencing and permitting fees, carbon finance, and donor funding (such as United States Agency for International Development - USAID, World Bank, Global Environment Facility - GEF, and United Nations Development Programme - UNDP) (IEA, 2010b).

The availability of funds to energy efficiency programmes managed by utilities is a key factor to involve utilities in developing EE programmes. Altogether, the risks of not recovering the programme costs, the losing of revenues or failing profits may be discouraging. Several approaches are used to address the loss of revenues or failing profits that utilities may experience due to successful EE programmes. The most commonly found are decoupling sales from profits and utilities/shareholder incentives. Decoupling is a process used to compensate utilities for the reduction of sales due to energy efficiency programmes. The rates are periodically adjusted to reflect the difference between actual energy sales and the sales forecast used in the rate setting process. Also, and as a stimulus for the companies to keep working for more savings, some countries/states created "shareholder incentives that reward utilities for the successful implementation of energy efficiency programmes" (Nowak et al., 2011).

Once the investment in EE becomes a business requirement, the costs associated with EE promoting should be considered a cost of business and should be included in the rates. According to Sedano (2011), surcharges have usually a negative impact on customers and there is some vulnerability in these funds (for example, the governments of the US states of Maine, New Jersey, and Wisconsin, have taken possession of the EE funds).

In Figure 2-1 it is possible to see the reduction of the investments in the US during the period of restructuring the electricity sector and the recovery due to stimuli that were introduced in the market to foster utilities participation. By 2000, the utilities spending on DSM was increasing due to state encouragement of PBF. After the decrease occurred between 1993 and 1998/99, the total budget spent in electric energy efficiency programmes rose and was around $4.5 billion by 2010 (IEA, 2008b).

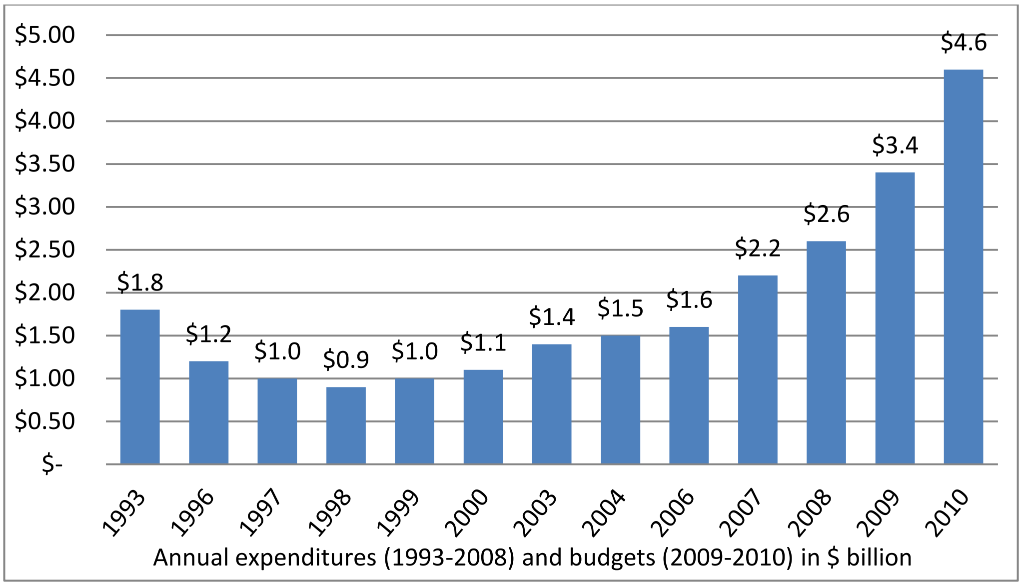


Figure 2-1 – Total US state-level energy efficiency programme spending or budgets by year (in (York et al., 2012))

In the next sections extensive references are presented to the cases of countries/jurisdictions of which there was data available in the literature, which aim at identifying the context, motivation, stimuli and constraints that help to understand how it is possible, namely under liberalised market conditions, for electric utilities to promote EE on the demand-side. The US were the cradle of DSM and of energy efficiency fostering by the electricity industry itself. Therefore, extensive experience is accumulated in the US on this field, covering a high diversity of situations. This determined the option of organising the present section in such a way that the US experience is presented in a separate subsection from the rest of the studied countries.

2.4.1 US experiences in funding energy efficiency

The California state is a national leader in the implementation of utility-sector energy efficiency programmes which started in the 1970s. The California Public Utilities Commission (CPUC) sets policies, programme goals, approves the spending levels, and oversees the energy efficiency programmes administered by investor-owned utilities (IOUs). The programmes are implemented by IOU and other third-party contractors. The IOUs are required to fulfil their unmet resources needs firstly through energy efficiency and demand reduction resources that can be obtained in a cost-effective, reliable and feasible way. On the other hand, Publicly-Owned Utilities (POUs) provide programmes on a voluntary basis. The CPUC does not have regulatory authority over the POUs. In California, the customers started paying a Public Goods Charge (PGC), in 1996, for a four-year period. The period was then extended to 2012.The funds for the energy efficiency programmes come from resource procurement budgets and from the PGC on the energy bill. The PGC on electricity consumption is around US$ 0.48 cents/kWh and is used in energy efficiency, renewable energy, and R&D. About US$ 0.3 cent of those go to support energy efficiency programmes (Nowak et al., 2011).

The state of California has decoupling implemented since 1982 for the three investor-owned utilities (IOU). Due to the restructuring of the electricity sector, the decoupling mechanism was suspended by CPUC in 1996, and then resumed in 2004 for Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric companies. Currently, the decoupling mechanism is applied to all IOU. It is considered an important policy for energy efficiency. The revenue decoupling programme is complemented with performance incentives for meeting and exceeding the energy efficiency targets. In 2007, minimum performance standards were set by CPUC, under the Risk/Reward Mechanism for IOU. Utilities receive 9% of net benefits if they achieve between 85 and 99% of the savings targets, and 12% if they met or exceed the savings targets, not exceeding the earning caps for each utility. Both public and IOU have been achieving savings of around 1% annually and should maintain these amounts of savings until 2020 (RAP, 2011a; Nowak et al., 2011; Sciortino et al., 2011).

In Colorado, as in other states, the amount of spending in DSM programmes reduced due to the deregulation and restructuring of the electricity sector. During the period 2000-2005, the Public Service Company of Colorado (PSCo) restarting providing energy efficiency programmes as a counter part for the approval of the construction of a coal-fired plant. The energy efficiency programmes of PSCo and other IOU are funded by a DSM cost adjustment rate rider. PSCo is authorized to recover the costs of its energy efficiency and demand programmes. Before the adoption of EERS (addressed in section 2.5), in 2007, there was no alternative business model for the utilities in Colorado. No revenue decoupling or shareholder incentives for IOU were allowed. The energy efficiency programmes were mostly funded by the utilities themselves. With the establishment of savings obligation for utilities, they were provided with incentives to implement cost-effective EE programmes. Colorado has not adopted any decoupling mechanism to electric utilities. The PUC has allowed PSCo to earn a return between 0.2% and 12% of the net benefits of DSM programmes costs, as long as PSCo achieves 80% of the savings annual target. However, the incentive is capped at 20% of the total cost of the DSM programmes (Nowak et al., 2011).

In the state of Connecticut, utilities have been providing energy efficiency programmes since the 1980's. The electricity distribution companies and municipal electricity companies provide portfolios of energy efficiency programmes to their customers (RAP, 2011b; Nowak et al., 2011). With the use of portfolios, EE programmes can evolve in a framework ensuring that all customers have equal access to cost-effective programmes (IEA, 2010b). In Connecticut, the energy efficiency programmes are administered by the utilities and implemented by them and by the contractors they hire. The Connecticut Energy Efficiency Fund (CEEF), funded by a charge in customer's energy bill, was created in 1999 as a response to the increase of energy demand and costs. The municipal electric utilities are also required to establish a fund and a SBC for EE and renewable energy. The surcharge was set at US$2.5 mills/kWh since 2011. Since 2007, the electric utilities from the state of Connecticut have the revenues decoupled from the sales. Three strategies are suggested to electricity distributors to decouple distribution revenues from energy sold: a mechanism that adjusts actual distribution revenues to allowed revenues; increase the amount of revenue recovered through fixed distribution charges; and/or a clause for sales adjustment. Performance incentives are also in practice in Connecticut. If a utility fulfils 70% of its obligations it will receive an incentive of 1% of the programme costs before taxes. This incentive rises to 5% for a 100% of the obligations. At a 130% of goals, the incentive would be 8%. On the other hand, if an obliged utility does not fulfil its savings obligation, it may purchase savings (section 2.5) from others or pay a penalty for each kWh not saved. These penalties feed the Connecticut Clean Energy Fund (CCEF), for the development of renewables sources (RAP, 2011b; Nowak et al., 2011).

In 2008, the District of Columbia (DC) established the Sustainable Energy Trust Fund (SETF) to replace the Reliable Energy Trust Fund. The SETF is administered by the Sustainable Energy Utility (SEU). SEU is funded by a rider on natural gas and electricity rates, by the Regional Greenhouse Gas Initiative (RGGI), or any successor programme. The rider on electricity rates amounted to US$0.0011 in 2009, US$0.0013 in 2010 and US$0.0015 in 2011. SEU is responsible for the administration of EE programmes.

Financial incentives will be provide if SEU surpasses the performance benchmark accorded with the DC Energy Office, and penalties being applied if SEU fails to meet the required target (RAP, 2011c; ACEEE, 2012). The RGGI is a market-based regulatory programme that invests the money obtained by selling emissions allowances, through auctions, in energy efficiency, renewable energy and other clean energy technologies. RGGI is a cooperative of the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont (RGGI, 2012).

In Florida, utilities are required to implement cost-effective EE programmes since 1980. In 2008, the savings through EE programmes were 0.16% of total retail sales. In 2009 the Public Service Commission (PSC) defined EE targets based on a study that reported a technical savings potential of 34%. Utilities may recover conservation programme costs through surcharges in customer bills. The PSC sets the energy conservation cost recovery factor to be applied in the upcoming year, estimated on the conservation costs for each utility. In Florida there is no decoupling mechanism, but the PSC stated that utilities may increase rates to maintain a reasonable Return On Equity (ROE) when energy efficiency programmes reduce the revenues. In 2008, the legislation authorized PSC to provide financial rewards and penalties for EE performance. Utilities were allowed to earn additional ROE for exceeding goals (RAP, 2011d; ACEEE, 2012).

In the state of Georgia, the utilities EE and DSM programmes are funded by a tariff rider that is applied to households and commercial customers. Disincentives to foster EE are addressed by an additional sum above the EE programme cost that may be awarded by the Commission, in a case-by-case basis. These “additional sum” has the purpose to compensate utilities for lost revenues and increased risks that may result from the implementation of demand-side measures and renewable energy technologies. A State Energy Policy Strategy recommends that PSC should consider alternative utility regulation, identify disincentives to invest in EE, and ensure that utilities are allowed to earn a return on the investments in EE they make. For the load control programme from Georgia Power, the only regulated utility, the utility earns an additional 15% of the NPV of the net benefits resulting from the programme, if the programme achieves at least 50% of the projected participation levels (RAP, 2011d; ACEEE, 2012).

The major IOU Hawaiian Electric Company (HECO) collects a PBC from its customers. The HECO has a third party administrator, Hawaii Energy, of its EE programmes and has a decoupling mechanism. Hawaii Energy is compensated for its performance. The Kauai Island Utility Cooperative (KIUC) administers its own programmes and recovers its costs through a DSM and IRP surcharge. In Hawaii the throughput incentive and the disincentives to EE fostering have been addressed on a case-by-case basis. (RAP, 2011a; ACEEE, 2012).

In Idaho, Montana, Oregon, and Washington, a four-state region served by Bonneville Power Administration (BPA) and part of the Northwest Power and Conservation Council, conservation resources are equally considered as generation resources, and utilities have to procure all cost-effective resources.

Northwest Power Act (of 1980) gives EE a 10% cost advantage over other resources, considering an EE programme as being cost-effective even if it is up to 10% more expensive than the next more expensive resource. The Sixth Northwest Power Plan (from 2010) recommended that EE should meet 85% of the new demand for electricity during the next 20 years. In Idaho, utilities EE programmes are not imposed by law. However, IOUs administer and implement EE programmes and file IRP. The programmes are funded by utilities that recover the costs through energy efficiency tariff riders and adjusting their rates. In 2009 Idaho electric utilities saved 0.82% of the sales. Idaho's energy efficiency programs are supported and supplemented by regional organizations, including the BPA, the Northwest Energy Efficiency Alliance and the Northwest Power and Conservation Council. In Idaho, the decoupling mechanism is called a Fixed-Cost Adjustment (FCA). From the FCA results a surcharge or a credit, when the fixed costs per customer varies above or below a base previously established by the Commission. There was a pilot test of a performance incentive, but was discontinued. However, Idaho Power is studying a new incentive mechanism (ACEEE, 2012). In Montana, the Universal System Benefits Program requires all electric utilities to contribute annually to the programme with 2.4% of their 1995 revenues. This programme supports cost-effective energy conservation measures, weatherization, renewable projects, R&D related to EE and renewables, market transformation, and low income energy assistance. The funds may be spent by the utilities in their own programmes or in programmes contracted externally. The funds can also be turned to Montana Department of Environmental Quality to administer. Utilities may recover the costs associated to planning and portfolio development of DSM alternatives, if the Commission finds them to be reasonable. Some DSM costs are recovered through rates. In Montana, the NorthWestern Energy is authorized to use a four-pilot decoupling mechanism. Regarding performance incentives, 2% can be added to the authorized rate of return for DSM investments. However, it has not yet been approved for any utility (RAP, 2011a; ACEEE, 2012). In Oregon, since 1989 utilities were required to include DSM in their resources plan. In 1999 was established a SBC (addressed as public purpose charge) equal to 3% of the total revenue collected by utilities, leading to approximately US$60 million for electric energy programmes. Also in 1999 was established the Energy Trust of Oregon (ETO), a non-profit organization that delivers EE programs to Pacific Power and Portland General Electric (PGE) customers (which together had 68% of statewide MWh sales and served 73% of Oregon customers in 2010). These utilities have SBC as a base funding and a rider for incremental funding. The Idaho Power, that serves a small portion of Oregon, administers its own efficiency programs, funded by a rider. Consumer-owned electric utilities (which together had 29% of statewide MWh sales and served 26% of customers in 2010) are not subject to regulatory jurisdiction of the PUC. These utilities purchase power from BPA, which undertakes its own EE programs. The Commission approved tariffs for additional EE funding for both Pacific Power and PGE in 2008. In Oregon, Idaho Power administers its own EE programs, and has been granted lost revenue recovery. Portland General Electric in

2009 was granted decoupling for residential and small non-residential customers, and lost revenue recovery for large non-residential customers with loads less than 1 MW, in average; both mechanisms were set initially for two years. Currently there are no performance incentives in place (RAP, 2011a; ACEEE, 2012). Washington utilities, both publicly- and privately-owned, have a long history of offering energy efficiency programmes to their customers. The DSM programmes offered by IOU are under regulatory oversight of the Utilities and Transportation Commission. There is no public benefits fund in Washington. IOUs recover the costs of EE programmes through tariff riders. Electric utilities serving more than 25,000 customers are required to acquire all cost-effective EE alternatives. The Commission has to approve tariffs to recover electric utility EE expenses, and utilities are permitted to recover all prudently incurred costs associated with EE activities. Avista and Puget Sound Energy recover costs through tariff riders. Pacific Power uses a surcharge, called a system benefits charge, but this mechanism is equivalent to a rider. Avista Utilities has a lost revenue recovery mechanism. Although no incentive is in place, utilities can be penalized if they are unable to meet their savings goals (RAP, 2011a; ACEEE, 2012).

The Pennsylvania state is, perhaps the state with the fastest expansion regarding energy efficiency programmes. Until recently there were virtual no energy efficiency plan and nowadays it has a major, multi-sector portfolio, according to Nowak et al. (2011). The West Penn Power Sustainable Energy Fund collects funds from transmission and distribution rates (around 0.001/kWh). Electric distribution companies have a cost-recovery tariff mechanism to fund EE programmes and to ensure recovery of reasonably costs. Also there is the possibility of recovering costs through a reconcilable adjustment mechanism. An annual spending cap of 2% of the total annual revenues of the electricity distribution companies for energy efficiency and conservation programmes is also allowed. Cost recovery is also allowed to programmes designed to low-income customers in the residential rate class, via a SBC. Pennsylvania has no decoupling mechanism nor shareholder incentives (Nowak et al., 2011; RAP, 2011e). Also Illinois had a rapid development in promoting EE by electric utilities. Prior to 2007 there was little involvement of utilities in Illinois with energy efficiency. After 2007 there were impressive budget amounts that allowed the development of a comprehensive portfolio of energy efficiency measures. Utilities are allowed to recover costs for providing energy efficiency programmes and should implement cost-recovery tariffs. Utilities are required to administer 75% of the funds and the Illinois Department of Commerce and Economic Opportunity (IDCEO) the remaining 25%. Electric utilities reported savings in 2009 and 2010 of 0.4% (550 GWh) and 0.5% (670 GWh) of rate sales, respectively. The state of Illinois, as well as the state of Pennsylvania, has no decoupling mechanism nor shareholder incentives (RAP, 2011e; ACEEE, 2012).

In Indiana, utilities were asked, by the Commission, to establish a set of statewide programmes (Core programmes), since the beginning of 2012. Utilities must contract with a single independent third party administrator to jointly administer and implement the Core programmes. The EE programmes are funded by a surcharge (ACEEE, 2012). Also in New Hampshire electric utilities altogether, run statewide Core EE programmes. Each utility can also run its own programmes. The Core programmes are funded by a SBC of US$1.8 mills/kWh. Also there is a separate surcharge for low-income energy programmes and renewable programmes, of US$1.5 mills/kWh. In New Hampshire, the throughput incentive will be addressed on a case-by-case basis, under utilities proposition. Three options are considered: performance incentives, rate design, and reconciling rate adjustment mechanisms. Shareholder incentives for Core programmes can vary between 8% and 12% (cap value) of the programme budget. In Indiana, lost recovery mechanisms proposed by the utilities were approved. Performance incentives may also be approved, under utilities proposal (RAP, 2011e; ACEEE, 2012).

In Iowa electric utilities are required to submit an EE plan for approval to the Iowa Utilities Board. These EE plans are developed in five-year cycles and should contain electricity consumption estimates for 20 years ahead, with future supply options and costs. The utilities may recover the cost through rates. Starting in 2012, electricity and gas utilities are not required to be rate regulated but must report, every two years, the progress in meeting EE goals and amendments to their EE plans. In Iowa utilities may apply for automatic adjustment mechanisms or other rate design changes in a case-by case basis. Until the mid-1990s incentives were provided, when DSM cost-recovery was done once every several years. In 1996, the incentive was removed since true-up became annual (RAP, 2011e; ACEEE, 2012). True-up is a price adjustment mechanism used when the collected revenues differ from the allowed revenues.

In Kentucky the implementation of EE programmes by the regulated utilities is overseen by the PSC. Since 2010, the PSC can require the implementation of DSM programmes by the investor- or publicly-owned utilities. Utilities prepare annually IRP to file to the PSC. Utilities recover their costs due to EE programmes through surcharges. The utilities in Kentucky are allowed lost revenue recovery for electric DSM programmes. The recovery mechanism is decided in a case-by-case basis. Also the incentive mechanism is approved by the Commission in a case-by-case basis. Financial rewards are given to utilities to encourage the implementation of cost-effective DSM programmes (ACEEE, 2012; RAP, 2011c).

In Maryland, most of the EE programmes that ran during the 1980s and early 1990s were discontinued due to the regulations removal as a consequence of the restructuring of the sector in the late 1990s. In 2008, statewide energy efficiency reduction goals were set. The 2009 savings, reported by the electric utilities due to EE programmes was equivalent to 0.44% of the retail sales. A per kWh surcharge is used to recover the costs of the EE programmes implemented by the utilities. The PSC of Maryland approved revenue-per-customer decoupling for three IOU. Two of them file bill stabilization adjustments monthly. By the law, rate-making policies may provide financial incentives for electric and gas companies to implement EE programmes. In Maryland there is no resource planning obligation (RAP, 2011c; ACEEE, 2012).

The state of Massachusetts is one of the leaders in the implementation of energy efficiency programmes, for more than 30 years, across all consumption sectors. By 1993 the electric utilities had saved a cumulative amount of electricity around 1,619 GWh. Before and during the restructuring of the electricity sector, that took place around 1997, the state provided utility energy efficiency programmes to their customers. In the state of Massachusetts the electricity industry has competition in the generation and retail markets. The distribution companies remain regulated and are responsible for the management and implementation of energy efficiency programmes for a few years. The funds for the energy efficiency plans in Massachusetts come from the SBC, from revenues of the ISO New England Forward Capacity Market, from the RGGI, and from an adjusting distribution charge approved by the Department of Public Utilities (DPU), to the extent necessary to be able to procure all cost-effective energy efficiency and demand resources (RAP, 2011b; Nowak et al., 2011; ACEEE, 2012). Actually, in 2008, the Green Communities Act (GCA) required that gas and electric utilities pursue all cost-effective energy efficiency. A cap of US$ 0.25/kW on the SBC was removed in order to fund scaled-up programmes. The EE programmes are proposed by utilities and reviewed by the Energy Efficiency Advisory Council (EEAC) before approval by the regulator. Utilities prepare three-year plans in accordance with portfolio guidelines, ensuring that EE measures are available for each customer segment. Energy providers formed working groups in order to identify the best practice programme design. They also agree that the core EE programmes by customer segment should be uniform, even when run by different providers. Evaluation approaches were harmonised to allow cost-savings through state-wide evaluation for each EE programme. Also gas and electric efficiency programmes were combined and those that encouraged uneconomical fuel switching were eliminated (IEA, 2010a). In Massachusetts, utilities submit rate plans in order to separate the revenue collected from the sales they need to cover their operating costs plus profit; this means that the revenue is “decoupled” from sales. This will protect utilities from revenue erosion. Also, performance-based incentives for energy provider shareholders are in place. According to the IEA, the “Massachusetts model includes most of the governance elements considered important for energy provider-implemented EE programmes: sufficient EE funding to reach the overall target; institutional arrangements to remove the risk of lower sales, programme cost non-recovery and adverse regulatory treatment through automatic mechanisms; appropriate incentives to motivate utilities to deliver EE through a performance-based shareholder scheme; harmonisation and standardisation to align with other government-sponsored programmes, and to eliminate multiple programme offerings; a statutory stakeholder engagement process that provides a forum for consensus building on future EE programmes; Ex ante cost-effectiveness evaluation mechanism that ensures programmes are economical, as well as post ante evaluations that are co-ordinated to reduce the drain of evaluation on programme budgets; Effective programme design that can deliver real resource value, which in turn is linked to specific resource targets" (IEA, 2010a). By 2011, the state of Massachusetts was implementing a decoupling strategy for all the utilities. An incentive for meeting the programme goals can reach up to 5.5% of the programme costs, for the IOU that administers the efficiency programme. The incentive is based on energy savings, net benefits, and market transformation results (Nowak et al., 2011).

The state of Michigan initiated utility energy conservation programmes in the late 1970's due to the natural gas crises. By the mid-1990s electric utilities reported a cumulative annual savings of 770 GWh. By that time, and with the restructuring of the electric sector, DSM and IRP were discontinued and so they remained until 2008. In Michigan there are limits to how much a utility can collect and invest on energy efficiency programmes. In 2009 the savings due to EE programmes amounted to 0.4% of retail sales. In 2011 the spending cap was 1.5% of the total retail sales revenue of 2009, as from 2012 the cap is 2.0% regarding the retail sales from two years before. Each utility plan has to be approved. The approval is based on its cost-effectiveness, if it is reasonable and prudent. In Michigan decoupling mechanisms are allowed. Regarding shareholders incentive, there are two ways in which a utility may receive economic compensation for investing in energy efficiency. The utilities may request that the costs on energy efficiency programmes be capitalized and receive a normal rate of return. The utilities may also request a performance incentive if they exceed the savings target. The incentive cannot exceed 15% of the total cost of the programmes, or 25% of the net cost reduction experienced by the customers as a result of the programme (RAP, 2011e; Nowak et al., 2011; ACEEE, 2012).

The state of Minnesota has also a long history of implementing energy efficiency programmes, even before the restructuring of the sector. Before 2010, electric utilities were obliged to invest 1.5% of their gross operating revenue, 2% if they had nuclear power, on energy efficiency programmes. Regulated utilities had to include energy efficiency and conservation savings in their plans to meet consumer's energy and demand in the years to come. IOU had obtained energy savings of 1% and 0.5%, electric and natural gas respectively, for the 2007-2008 retail sales, and spent $230 million. The funding is obtained "via tracker accounting, allowing utilities to recover their cost, which are trued-up annually or in the course of a rate case proceeding". In Minnesota, the PUC has authorized one or more rate-regulated utilities proposals for rate decoupling. Utilities may also receive performance incentives for energy savings. For savings above 1.5% of the retail sales, electric utilities will earn an incentive of $0.09 per kWh saved. The percentage of the net benefits that each utility will receive due to energy savings is set at the beginning of each year (RAP, 2011e; Nowak et al., 2011).

In Missouri, since the early 1990s rules have been in place for IRP and DSM, without significant results, until recently. In 2009, IOUs were required to capture all cost-effective energy efficiency opportunities. However, some difficulties have been faced, mainly due to the conviction that, in accordance with the rules, utilities may not recover the programme costs or loss revenues quickly enough. Currently costs are recovered over a 6 or 10 years period. Others say that IOUs are simply not interested in fostering EE on the demand-side. EE programmes have been promoted by rate-regulated utilities. The recovery of the costs is not yet in place. In Missouri, the PSC has authorized utilities to file for recovery of lost revenues. Utilities may propose performance incentives based on net shared benefits their programmes can generate (RAP, 2011e; ACEEE, 2012).

Nevada returned to a traditional regulated utility structure after it restructured its industry in the 1990s. The IOUs are now again vertically integrated companies. The IOUs are obliged to perform IRP and offer EE programmes that are funded by a SBC on customer bills. Every two years, utilities file rate cases and request full recovery of the programmes costs. The EE programmes have to be approved by the PUC before its implementation, usually done by contractors hired by the utilities. Utilities saved through EE programmes 1.3% of 2009 retail sales. In Nevada utilities may recover the costs and receive adjustments for lost revenues annually. If utilities meet their EE targets, they may receive performance incentives, on a programme-by-programme basis (RAP, 2011a; ACEEE, 2012).

In New Mexico, since 2005, utilities are required to implement cost-effective DSM programmes, establish a cost recover mechanism, and the Commission is required to remove financial disincentives for the promotion of EE programmes by the utilities. In 2008, utilities were required to acquire all EE resources that were cost-effective and achievable. EE programmes costs may be recovered through a tariff rider or in base rates, or by a combination of both. The rider may not exceed US$75,000 on the annual customer's bill, without customer's consent. In New Mexico, electric utilities may propose rate design and ratemaking methods to remove disincentives to EE savings. In order to address the performance incentives, a tariff rider or base rates will be based on energy savings achieved by each utility (RAP, 2011a; ACEEE, 2012).

In North Carolina, the Commission, upon petition of an electric utility, may approve an annual rider to the electricity rates for the utility to recover the costs due to the implementation of DSM and EE programmes. The recovery of lost revenues due to EE programmes is addressed through lost revenues adjustment (for Duke Energy Carolinas and Progress Energy Carolinas utilities). The Commission had also approved incentives for the implementation of EE measures. The Duke Energy is allowed to earn a percentage of avoided costs, capped between 5-15% of actual programme costs. Progress Energy Carolinas may earn between 8-13% of NPV of savings provided by its EE measures (RAP, 2011d; ACEEE, 2012).

The restructuring of the electric markets in Ohio started in 1999. During the 1990s, Ohio electric utilities provided energy efficiency programmes to their customers. A cumulative annual savings value of 1,198 GWh by 1996 is reported. In 1999 a ratepayer fund was established, the Advanced Energy Fund. Part of this fund, the Energy Efficiency Revolving Loan Fund is dedicated to energy efficiency initiatives. Another fund, the Ohio Energy Loan Fund is also supported by a service rider, a type of surcharge, of about $0.0001758 per kWh (approximately $15 million per year), and intends to provide low income bill assistance and energy efficiency initiatives. The IOUs are obliged to implement plans for energy efficiency improvements. In Ohio, all electric utilities may recover the costs of the programmes. Each electric distribution utility may submit an application for approval of a revenue recovery mechanism. Lost revenue recovery mechanism is determined for each individual case. Financial incentives for the utilities for their achievements may be approved in a case-by-case basis. For instance, the Duke Energy received incentives for the Save-a-watt programme, in 2008. If Duke achieves 101% or more of the target, it receives a return on the investment on programme cost between 6% and 15% (RAP, 2011e; Nowak et al., 2011).

In Oklahoma, one of the main two IOU, the Oklahoma Gas and Electric (OGE), intends to avoid the construction of new power plants before 2020. OGE offers a limited set of programmes, investing more in demand response programmes. This made it one of the leaders, if not the national leader, in smart grids technology. The Commission sets the utilities cost recovery in rates or riders on a case-by-case basis. They may also receive an incentive for implementing successful programmes. In 2010 the savings obtained were about 0.23% of the sales. The Commission has approved shared benefit incentive plans that are paid in addition to 100% programme cost recovery and lost revenue recovery mechanisms, for both Public Service Oklahoma and Oklahoma Gas and Electric Company. For example, the Oklahoma Gas & Electric was authorized to implement a 2-part incentive for its DSM programmes: for programmes with Total Resource Cost (TRC – see Annex A) above one, the company would be rewarded with 25% of the savings value; for the programmes with TRC below one, the company would recover 15% of the savings value. The same model was adopted for other utilities (RAP, 2011e; ACEEE, 2012).

In Rhode Island, a single IOU, Narragansett Electric (a National Grid Company) accounts for 99% of the statewide electricity sales and administers a portfolio of EE programmes for its customers. A SBC of US$3.2mills/kWh (in 2009) was set to fund DSM programmes from the National Grid. The National Grid proposed a decoupling mechanism, for 2011. The shareholders incentive is based on the performance of the National grid in achieving the target (RAP, 2011b; ACEEE, 2012).

In South Carolina, all three IOU have been implementing EE programmes. The savings amounted to 46 GWh in 2009. The Commission allows cost-recovery, a return on investment at least as high as supply-side measures, and ensures that utility net income is at least as high as it would have been without DSM measures. The cost-recovery is made on a case-by case basis. Although not are required by law IOU, are submitting IRP, with the incorporation of DSM and EE programmes (RAP, 2011d; ACEEE, 2012).

In Texas electricity transmission and distribution utilities are obliged to accomplish energy efficiency targets (EERS – section 2.5), since 1999. These utilities administer the EE programmes implemented by retailers or energy efficiency service providers. Programmes are mostly funded by ratepayers (RAP, 2011a). Decoupling is not allowed, but IOU may share benefits. When the utility exceeds the reduction target, without surpassing the established cost limits, is rewarded with a performance bonus. The bonus entitles the utility to receive a share of the net benefits; a utility that exceeds 100% of its demand reduction goal, will receive 1% of the net benefits for every 2% that the demand reduction goal has been exceeded, with a maximum of 20% of the utility's programme costs (RAP, 2011a; ACEEE, 2012).

In Utah, utilities run their own EE programmes as required by the PUC, and they are part of IRP since 1992. The funding for EE programs is provided by a 3% tariff rider on customer bills. Rocky Mountain Power (RMP), an IOU, serves 80% of the population and administers a comprehensive set of EE programmes. There is no decoupling mechanism nor incentives are in place for electric utilities, despite a Joint Resolution by the Utah Legislature supporting both decoupling and incentives for utility EE fostering (RAP, 2011a; ACEEE, 2012).

In Virginia several attempts to introduce EE goals and resource standards have not been successful. Some programmes to residential and commercial customers are offered by Dominion Power. The investment in EE programmes by electric utilities in 2007 and 2008 has been minimal. In 2008, regulations required IRP that utilities begun filing in 2009. IOUs are allowed to recover the costs of EE programmes through rate adjustments. Electric utilities are not authorized to decouple their profit from their sales. The recovery of revenue is limited and subject to industrial standard M&V procedures. There seems to be no incentives to promote EE on the demand-side of the electricity sector (RAP, 2011c; ACEEE, 2012).

Due to impressive prices increase in West Virginia, utilities are beginning to implement EE programmes as a way to lower customers' energy bills. Under a 2010 rule, utilities are required to implement approved EE programmes, such as: low-income weatherization, residential audits, residential lighting, and commercial/industrial prescriptive incentives. There is no funding for EE programmes implementation. Some expenses associated to conservation programmes may be recovered in rates, although very little activities were implemented by the utilities. There is no incentive for the implementation of successful EE programmes, or any loss revenue recovery mechanism, in place (RAP, 2011c; ACEEE, 2012).

In some states, EE programmes are not administered by utilities. The funds are channelled from the utilities to third-party organizations that are responsible for the administration of EE programmes. In 1999, when restructuring of the energy sector, a SBC for all IOUs was established, to fund EE programmes in New

Jersey. Since 2003, the New Jersey Clean Energy Program is responsible for offering statewide EE programmes. In 2010, electric utilities reported that the savings obtained were equivalent to 0.44% of the sales. In New Jersey decoupling is authorized for both electric and gas utilities (RAP, 2011c; ACEEE, 2012). The state of New York has one of the most extensive and complex energy efficiency infrastructures. New York was also one of the first states to establish a SBC. The utilities in New York were not responsible for the implementation of EE programmes. They collect the SBC and revenues that feed an account managed by a statutory authority. The New York State Energy Research and Development Authority (NYSERDA) has been the major administrator of EE programmes, collectively known as New York Energy $mart™, since 1990s. NYSERDA offers EE programmes to commercial and industrial customers, depending on the amount of SBC collected from them. From 2006-2008, ratepayer funding through the SBC was in the range of US$220 million and US$240 million per year. The utilities involvement in EE programmes changed after the establishment of the Energy Efficiency Portfolio Standards (EEPS - addressed in section 2.5) in 2008 and the annual funding has increased to US$334 million (IEA, 2010a; RAP, 2011c; Nowak et al., 2011). The EmPower New York℠, part of the New York Energy $mart™, is a DSM utility responsible for programmes to lower low-income customers energy bill. The utility is funded by a SBC paid by electric distribution customers (United Nations Economic Commission for Europe, 2010). Besides the programmes authorized by the Commission, two more public power authorities offer SBC-funded energy efficiency programmes to their customers, the New York Power Authority and the Long Island Power Authority. In New York, electric and gas utilities must submit proposals for trued up based decoupling mechanisms. Both Consolidated Edison and Orange & Rockland electric utilities have a revenue-per-class decoupling mechanism, with annual true-ups. Utility may receive incentives for their involvement in energy efficiency promotion. The utilities that achieve more than 80% of their targets receive incentives, being rewarded with the maximum incentive if the target is achieved (ACEEE, 2012; RAP, 2011c; Nowak et al., 2011). Vermont has an Energy Efficiency Utility (EEU), the Efficiency Vermont that is responsible for the implementation of EE programmes. These programmes are financed by a SBC paid by all electricity and gas consumers on a per kWh or per therm basis. The Vermont Energy Investment Corporation (VEIC), a non-profit organization, is the EEU contractor. The VEIC has no conflict in fostering energy efficiency. The VEIC is not an investor-owned utility, looking for profit through sales increase. The incentive to promote energy efficiency is very strong. The Efficiency Vermont has more staff for each dollar in the budget than any other efficiency organization in the US. This has allowed them to create a closer and personal relation with the customers. They have Efficient Vermont Account Managers that are called at the beginning of a plant or facility intervention, helping their customers to obtain more energy savings from theirs project. The customers can access money, advice, technical assistance, for building a more energy efficient project. Lighting has been the most frequent end use category in EE programmes, mainly through the replacement of incandescent bulbs by CFL. Reaching what could be the saturation of CFL, new programmes are focusing dimmable, 3-way lamps, specialty CFL, and LEDs. In Efficiency Vermont the Efficiency Products Program made up a quarter of the total energy savings in their portfolio through lighting products. From 2009 to 2010 there was a shift from 10 to 20% of the budget to increase specialty bulbs. Efficiency Vermont has collaboration with lighting designers that help commercial customers save energy and money. The savings achieved helps paying for the lighting design audit. The cost-effectiveness of the programmes is measured through the Societal Test (see Annex A), and VEIC imposes a minimum of 1.2:1 factor of gross electric benefits. The Efficiency Vermont does not offer a portfolio of energy efficiency measures but operates under a performance contract model. They have flexibility to change the programmes in order to achieve their goals. This flexibility allows them to invest in measures where they can maximize long-term savings for each dollar invested. In 2007 they saved 103 GWh at a cost of 2.7 cents per kWh (over the lifetime of the measures) and in 2008 they accomplished 150 GWh of savings at a cost of 2.9 cents per kWh. VEIC can receive performance incentives for accomplishing or exceeding the saving targets (ACEEE, 2012; Nowak et al., 2011).

As well as Vermont other US states have EEU, such as Delaware, Maine, and Oregon (IEA, 2010a). In the last years Delaware has made important efforts is strengthening its EE programmes. The Delaware Sustainable Energy Utility (SEU), a non-profit organization that runs EE and renewable energy (RE) programmes. The SEU is mostly funded by the state of Delaware. In parallel with the SEU initiatives, utilities are implementing DSM programmes that are not reported, since EE programmes are managed by SEU. Since 2006 utilities are under the obligation of performing IRP, being required to first consider demand programmes and DSM programmes as strategies to first meet the base load and the load growth. In Delaware decoupling is evaluated in a case-by-case basis. No performance incentives to implement EE programmes are in place (ACEEE, 2012). In 2009 the Efficiency Maine Trust was established as the administrator of the Efficiency Maine, that is responsible for the implementation of EE programmes. The Trust is required to submit triennial plans, with long-term targets, including achieving electricity and gas savings of 30% by 2020. The Commission is required to assess each transmission and distribution utility for EE programmes according to a set of criteria. In Maine decoupling and incentives are authorized but not currently used. EE programmes are implemented by Efficiency Maine and not by the utilities (RAP, 2011b; ACEEE, 2012).

In Wisconsin, there has been no restructuring of the electric sector, and vertically integrated, IOU are still regulated providers. Prior to 2000, programme administration was done by the utilities. Between 2000 and 2007, statewide programmes had a third-party administration, they were funded separately by utilities and overseen by the Department of Administration. Since 2007, IOUs are required to collectively fund a third-party efficiency administrator. The Focus on Energy (FOE) gathers initiatives regarding EE, renewable energy, and R&D. Through FOE, residential customers, business, and public institutions can access to information, financial and technical assistance, and other services. IOUs are required to invest 1.2% of their annual gross operating revenues in EE and renewable resources, through the FOE initiative. Utilities may also develop and implement voluntary EE programmes, with additional funding, approved by the Commission. Also Municipal utilities and energy cooperatives may be a part of FOE or administer their own programmes. The PSC guarantees that IOUs recover from the ratepayers the amounts spent on mandatory programmes. The cost recovery of the programmes implemented voluntarily by the utilities may be done through rates. In Wisconsin, decoupling was approved for the Wisconsin Public Service, in 2008, called Revenue Stabilization Mechanism, which allows the utility to implement a four-year pilot programme. Utilities may propose incentives as part of their rate cases. The Wisconsin Power & Light (Alliant Energy) was allowed to earn the same rate-of-return on some investments in EE as it earns on other capital investments (RAP, 2011e; ACEEE, 2012).

Electric and gas utilities in Arizona must provide energy conservation plans. These plans must, at least, include consumer education and assistance programmes, in order to help consumers reduce energy consumption and increase the participation in energy conservation programmes. The funding for the DSM and energy efficiency programmes offered by IOU, depends on the utility, and may come from a SBC (collected on electricity bills), or from an adjustment mechanism. The cost recovery is allowed and depends on the utility to choose the method. The Tucson Electric Power chose to recover its costs through a surcharge rider. In Arizona none of the electric utilities have revenue decoupling. However, the two major IOU have shareholder incentives in place. The incentives are set at 10% of the DSM programme net economic benefits, and are capped at 10% of total DSM expenditures (RAP, 2011a; Nowak et al., 2011).

In Arkansas, utilities are required to implement DSM programmes, and IRP was recently established. The cost-recovery mechanisms are mainly obtained through a rate rider. In Arkansas, revenue recovery mechanism is allowed to all utilities. In 2010 the Commission approved incentives to reward IOUs by their achievements in delivering EE services (RAP, 2011d; ACEEE, 2012).

In some states utilities are not obliged to implement EE programmes, as in the cases of Alabama, Louisiana, Kansas, Mississippi, Wyoming, and South Dakota. In Alabama, the savings obtained in 2009 due to EE programmes promoted by electric utilities amounted to approximately 0.08% of the sales, which is the result of the inexistent effort by the Alabama's regulator to push the sole IOU (Alabama Power) to pursue EE on the demand-side. Utilities can recover lost revenues from EE programmes, annually through a rate rider, although very little EE activities can be found (RAP, 2011d; ACEEE, 2012). In Louisiana, the Entergy New Orleans is the only utility in Louisiana to offer a portfolio of EE programs to its customers, and there is a tariff rider that depends upon the savings accomplished. No IOU reported any spending in EE programmes in 2008. In order to recover the programme costs, as well as for net lost revenues and a shared savings incentive, Southwestern Electric Power Company (SWEPCO) and Entergy have proposed an annual tariff rider. Both utilities prefer a lost revenue adjustment over decoupling. No EE programmes promoted by SWEPCO in Louisina were reported. Actually there is a rate rider, for Entergy, that provides recovery of lost contribution to fixed costs. This rate rider can also provide performance incentives, being the utility obliged to achieve the minimum of 75% of the target. 125% of the annual projected savings goal in the incentive cap (RAP, 2011d; ACEEE, 2012). In Kansas, although EE programmes implemented by utilities are not required by law, both IOU and POU have been offering them. In 2010 the IOU budget for EE programmes was $5.4 million, funded by customer rates. The Commission was considering the decoupling proposals on a case-by-case basis. Some incentives may be allowed but only for some particular programmes, such as: programmes for low and fixed income customers and renters; proposals that demonstrate the potential for long-term savings using a whole house concept. Shared savings performance incentives can also be evaluated in a case-by-case basis (RAP, 2011e; ACEEE, 2012). In Mississippi, utilities have no obligation to deliver EE programmes. They may voluntarily offer their own but there are only a small number of programmes, with savings accounting only to 0.07% of the sales, in 2009. There is no cost recovery for the EE programmes. However, the subject is under consideration (RAP, 2011d; ACEEE, 2012). In Wyoming utilities offer EE programmes, even not being obliged to. In order for the Commission to approve a DSM programme, utilities must provide evidence and justification for the expected benefits. No statewide study on the cost-effective EE potential has been done. In 2007 the Rocky Mountain Power completed a DSM potential study and contracted an update to it in 2010. Cost recovery is done on a case-by-case basis (RAP, 2011a). Wyoming has approved a tracking adjustment mechanism that includes recovery of lost revenue for a small service territory covered by Montana-Dakota Utilities (MDU). The adjustment applies to all MDU customers to recover costs and lost revenues for load management programs only. Rocky Mountain Power has no such adjustment. Performance incentives are not in place in Wyoming (RAP, 2011a; ACEEE, 2012). In South Dakota, utilities have been implementing EE programmes for the last 6 years. Both a cost recovery surcharge, to pay for DSM programs, and a performance incentive were approved. Lost revenue recovery mechanisms are also allowed (RAP, 2011e; ACEEE, 2012).

In Alaska, there is no mandatory IRP, although some utilities have completed theirs. Such is the case of the Chugach Electric Association (CEA), in 2004. In 2010 the Commission have recommended to find other ways to promote DSM besides IRP. EE programmes are voluntary. The Commission has also recommended to implement a SBC to support EE programmes (RAP, 2011a; ACEEE, 2012).

In the state of Nebraska all 162 electric utilities are publicly-owned. The most of the energy efficiency promotion is made by four utilities, although there are other 84 that have some EE programmes (ACEEE, 2012).

2.4.2 Other countries experiences with funding energy efficiency

In Canada, in the provinces of Ontario, British Columbia and Quebec, large EE programmes have been operated by energy utilities. These programmes are ratepayer-funded programmes that in 2009 accounted for almost US$750 million. In Ontario, the implementation of energy efficiency programmes is the part of the provincial power development plan, setting the target of 6,300 MW of cost-effective EE programmes, for a 20 years period. In 2009 US$250 million were spent on EE, through rates. Under the Green Energy Act, the responsibility for the implementation of EE programmes has been given to Local Distribution Companies (LDC) that are obliged to meet EE targets. The Ontario Power Authority (OPA, an independent and non-profit corporation) is developing a set of programmes that will be available to all customers, but branded by each LDC. LDCs also have flexibility to develop their own programmes (IEA, 2010b). In British Columbia the electricity EE savings target is set to meet 50% of BC Hydro's incremental resource needs in 2020. In order to meet this goal 10,000 GWh had to be met through demand reduction measures, including EE, conservation, load displacement and fuel switching. Utilities are also engaged in increasing awareness, through information and education on EE technologies and conservation actions. Utilities are creating partnerships with communities and municipal leaders in order for them to include EE in their plans, and promoting innovative technologies to reduce electricity consumption. According to the IEA, the Canadian approach to utility DSM illustrates the value of including EE programmes in long-term resource planning. The base of the success is the intervention and close collaboration between the regulator, the government, and the energy provider. Both OPA and BC Hydro DSM programmes have specific time-bound targets allocated to customer segments, and are based on estimated market potential. The Canadian experience also shows, that with a constant regulatory and public support, the funding of EE through rates can be as effective as a SBC (IEA, 2010a). For the 2005-2010 period, distributors delivered the Conservation and Demand Management (CDM) programmes, equivalent to DSM programmes, either through approved distribution rate funding or through contracts with the OPA. To promote the participation of distributors in delivering CDM programmes, the Ontario Energy Board (OEB) made available mechanisms for recovery of lost revenues, for all programmes. For the period 2011-2014, the OEB authorized the establishment of a small variant of the lost revenues recovery mechanism, to capture the difference between the verified impacts of distributors CDM authorized activities and any other activities being undertaken by the distributor or any other third party, and the level of CDM programme included in the load forecast by the distributor (included in the rates) (OEB, 2012).

In Belgium, the EE programmes are financed by a levy of approximately 0.00025c€/kWh, paid by all electricity customers. Between 1996 and 2001, the total budget was €64.6 million, of which €53.3 million were used in informative campaigns and training, energy audits, and rebates. The remainder was allocated to the administration of the programmes (IEA, 2005). In the Flemish region of Belgium the cost recovery of the investments in EE programmes was done through tariffs based on the approved action plans. No performance incentives are available (RAP, 2012).

In the UK, the Carbon Emissions Reduction Target (CERT), started in 2008, imposes a three-years obligation to obtain carbon savings on competitive retail energy suppliers. The suppliers meet their targets financing a variety of EE measures to their residential customers. Using the billing and the metering processes, utilities are able to inform their customers about energy-savings opportunities and may offer a menu of EE goods and services. The risks of EE investments can be mitigated by the utility through information and their own commercial credibility. By November of 2010, 86% of the CERT target was achieved. Due to the results the programme was extended to the end of 2012. New sub-programmes were included such as an Insulation Obligation and a Super Priority Group (SPG) Obligation designed to provide additional EE measures to low-income and vulnerable groups. In the first two years of the CERT, over 230 million CFLs were distributed, mostly by mail, corresponding to about nine CFLs for each household, what was considered excessive, since the number of light fittings in each house are estimated between eight and ten. As a consequence, the estimated carbon savings may not be achieved. According to IEA, the UK experience with CERT illustrates the challenge of achieving a balanced portfolio of EE measures through implementers subject to competitive business pressures. With specification of portfolio standards imposed by supplier, and increased evaluation protocols, by the regulator, it is possible to avoid that energy suppliers deliver the specified carbon alleged savings for a specific target group, when the unit cost is higher. This would create an incentive for the supplier to develop lower-cost EE measures to other groups, to avoid passing on the programme costs to customers (IEA, 2010a).

In Denmark, since 2006, the grid electric utilities (as well as natural gas and district heating) are obliged to promote energy efficiency, although electric utilities have been working actively in energy efficiency fostering since 1990. The funds to invest in energy efficiency come from a SBC (Togeby, 2009). Simultaneously, distribution companies also had to provide, free of charge, information on energy savings, individual energy advice to households, energy advice to companies, institutions, and public services, and research and development of new technologies. Among energy efficiency activities conducted by grid companies are the access they provide to energy meters, for example, for individual appliances in order for the customer to be informed of the amount of energy those appliances consume. They also give the consumer access to demonstration facilities where he can experience new and more efficient technologies. Competitions to find the most energy-efficient company or municipality are also organized by distribution companies as a strategy to improve energy efficiency. Every three years, distribution companies have to plan activities according to the guidelines issued by the Danish Energy Agency (DEA), and every year report the success of their measures. Unlike before, nowadays, the money collected in each consumer group does not have to be invested in measures in that same consumer group, nor within the company franchise area (IEA, 2006a). The utilities are highly involved with other stakeholders, allowing them to give and receive more information regarding EE and the programmes, and improve their image.

In Norway the investments in energy efficiency are funded by a DSM distribution charge. Regional Energy Efficiency Centres (REEC) were established to implement energy efficiency programmes on behalf of the utilities. According to the Norwegian Water Resources and Energy Administration (NVE) opinion, these REEC were in better conditions than utilities to advise customers (Clark, 2001). In 1997 REECs carried out a simple audit to households, free of charge, with the purpose of estimating the energy consumption (ISIS, 2005). As referenced before, they were then replaced in their function, by ENOVA.

A SBC was suggested to overcome the financial “bottleneck” that China is experiencing (Yu, 2010). Since the 1990s China has been implementing DSM programmes, mainly load management, in order to reduce the peak load and improve load factors. Some of the alternatives are the promotion of energy storage, time-of-use tariffs, and interruptible tariffs, among others. There is almost no experience with utilities involvement in EE programmes, besides load management. Before the 2000s the funds to DSM came from power supply discount charges and fees over power capacity expansion, and from fines for excessive use of power. Those sources of funding terminated in 2002 (Hu et al., 2005). According to Yu (2010) a SBC will not only provide stable and sufficient funding for DSM programmes, but will also involve all society in participating in energy efficiency improvements. It is expected that SBC will help to overcome the difficulties experienced and can help bridge the gap between the pilot studies that have been implemented since the early 1990s and the full adoption of a DSM framework (Finamore et al., 2010). A problem with committed involvement of utilities with DSM is due to the lack of regular, sufficient, and long-term resources. Besides some provinces, such as Hebei, Tianjin, Jiangxi, Shanxi, Jiangsu, Fujian, and Shanghai, whose funds are hardly enough, other regions have not established special DSM funds. Nevertheless those funds come from a surcharge per kWh that is very small, and not expected to last (Yu, 2011). China is developing Efficiency Power Plants (EPP) in five provinces. EPP must implement programmes to achieve a certain amount of savings previously set. EPPs are expected to contribute to the 20% energy efficiency target (ICER, 2010).

In Brazil, the regulatory agency, ANEEL, set a 1% of annual net revenues of private utilities that should be invested in energy efficiency and R&D projects. Most of the investment was then made in the supply-side, reducing technical and commercial losses of the utilities. Since 2000, the measures had to focus on end-use energy efficiency, and the 1% of annual revenues obligation was extended to transmission and generation companies, both private and state-owned, although those contributions were not for energy efficiency (Taylor et al., 2008). Part of those amounts was to be invested by utilities and another part was collected by a PBF, the CTEnerg. The CTEnerg was also in charge of funding energy efficiency programmes.

Over time, the ANEEL has been imposing some restrictions to the money spent. For instance, the establishment of a maximum for the cost-benefit ratio of 0.8 for most projects and 1.0 for public lighting; the use in marketing measures was forbidden; minimum allocation for different consumer segments was imposed; and projects could be extended for more than one year. Utilities were allowed to recover 50% of their expenditures in energy efficiency, through performance base contracts with most of the beneficiaries (excluding contracts with educational, municipal and residential sectors). The recovered funds should be applied in additional EE measures and to reduce electricity rates. Due to low tariffs to public lighting and the fact that municipalities often don't pay, public lighting received a big share of utilities investment in EE. For the utilities, this was a way of compensating the lack of payments by the municipalities (Taylor et al., 2008). Some of the utilities used the wire-charges to contract services from ESCOs and other engineering firms. Utilities decide the type of energy efficiency project they are interested in and the ESCOs design and implement them. These contracts are not performance based contracts but conventional services contracts with "remuneration on a cost-plus basis". After 2003 the obligation rose to 1.1% (Jannuzzi, 2005). On the other hand, government-owned utilities execute and co-finance the PROCEL, a national programme for electricity conservation, in operation since 1985. PROCEL received funds from the Global Reversion Fund (a federal fund that receives resources from concessionary companies), and from international entities, such as the GEF (ended in 2006) (Boshell et al., 2008). Some problems arise from the Brazilian option to foster EE by utilities. Among them are: "It is implemented by utilities that have little interest in reducing demand through energy savings, since under existing rates they are likely to lose revenue in most segments; rigid criteria are used to determine expenditure shares in economic sectors, independent of the size of the utility or the characteristics of the market in its franchise area; little if any (independent) *ex post* evaluation of costs and benefits of implemented projects has taken place, while there is excessive bureaucracy in the *ex ante* process; the programme is highly fragmented with many small and short-term projects; participation of customers or market forces in the programme design and the implementation has been very limited; it is not backed by public energy efficiency policies providing strategic guidance on how to maximize social benefits; it has not resulted in leveraging of resources or involved commercial financing; and it has been an important source of revenue and projects for ESCOs, but has done little to prepare them for a more sustainable future based on commercial financing" (Taylor et al., 2008). According to Zannuzzi (2005), in Brazil, some utilities have used energy efficiency programmes as a strategy to retain non-franchise customers, manily large consumers.

Besides the SBC, the funds for DSM programmes can come from revenues from differentiated electricity prices, and other government budget allocations. Also some expenses may be incorporated into power supply cost (Finamore et al., 2010). In the Indian states of Delhi and Maharashtra, electricity regulators have allocated electricity sector revenues for pilot DSM programmes. The Regulatory Multi-State

DSM Programme was established with the purpose of creating a common platform for utilities interested in initiating EE programmes, regardless the state they belong to. Consumer tariffs usually increase when energy efficiency programmes are financed using utilities revenues, leading to a probable reduction of sales. On the other hand, with the reduction in demand, some investments may be unnecessary, affecting the long-run returns of the utility. Actually, no large-scale energy efficiency programmes have been implemented in India using resources from utilities. The challenge in India could be the development of rates that address the disincentives to utilities funding large EE programmes. As a matter of fact, policymakers and regulators intend to maximize the cost-effectiveness of EE savings, while obtaining an equitable share of costs, benefits, and risks among all stakeholders (Abhyankar and Phadke, 2012). In 2010, the Maharashtra Electricity Regulatory Commission (MERC), issued the regulatory framework for DSM implementation (MERC, 2010). The funds for DSM activities must be provided by tariffs, where by all costs must be recovered. The distributors must add to the Annual Revenue Requirements all the costs in order for DSM programmes to be cost-effective for both customers and distributors; to protect customers' interests and be implemented in an equitable manner; and to result in overall tariff reduction for all customers. However, the regulations allow the possibility of establishing a SBC, if considered beneficial. The programmes developed by the distributors must complement the ones promoted by the Bureau of Energy Efficiency (BEE), in particular. The BEE is responsible for the implementation of EE programmes. Among their activities are the management of EE policies and programmes. The standards developed by BEE foster EE in industry, commerce, standards and labeling, DSM, training of energy managers and auditors, among others (Balachandra et al., 2010).

In 2004, the promotion of EE and DSM were licensing requirements for electricity distributors to operate in South Africa. The same regulatory act issued by the National Electricity Regulator of South Africa (NERSA) also established the EE/DSM fund, to be administered by Eskom, a parastatal utility company. This EE/DSM fund was the main source of resources to government-supported energy efficiency initiatives between 2004 and 2008. The administration of the EE/DSM fund was considered overly bureaucratic, and with long approval periods, among other criticism. These difficulties in the administration of the Fund resulted in the loss of stakeholders support for utility to manage EE in South Africa. In 2010 the Standard Offer Programme (SOP) was established as a new model to use the EE/DSM incentives. The Eskom reduced its role, mostly to a collector of the ratepayer funds (IEA, 2010a).

In Jordan, the SBC is used to generate US$42 million in annual funding for both the Jordan Renewable Energy and Energy Efficiency Fund (REEEF) and the Rural Electrification Fund (REF) (IEA, 2010a).

Until 2001, before the restructuring of the electric sector of Korea, the budget for DSM projects was provided by the Korea Electric Power Corporation. Since 2002, the Electricity Industry Fund receives money collected by a surcharge on all electricity customers. Several programmes were implemented by electric utilities, mostly related with load management objectives. More recent programmes address energy efficiency improvements and strategic reduction of GHG emissions, targeting lighting, appliances, and motors (IEA, 2005).

Some other countries receive the support of international organizations to implement pilot DSM programmes that may be important to establish DSM programmes as a regular practice in those countries.

2.4.3 International cooperation in DSM activities

Several international organizations, such as the World Bank, the International Finance Corporation (IFC, is a unit of the World Bank), the United Nations Development Program (UNDP), the United States Agency for International Development (USAID), the Asian Development Bank, among others, have been financing DSM activities, through loans, some of them with grants from the Global Environment Facility (GEF). This kind of collaboration for the development of DSM projects helps building local expertise, helps the development of more permanent support mechanisms, and facilitates stakeholder involvement. Projects in this context arise mostly as strategies to mitigate the number and frequency of load supply interruptions, due to poor electricity services, high commercial and technical losses, growing demand rates, high costs of supply, and/or low prices to customers. In some countries, according to the Asian Development Bank and the World Bank, projects of DSM using CFLs can be between 60 to 90% cheaper than building new power plants (Boyle, 1996). With this support utilities can find an incentive to implement DSM programmes by influencing customers to reduce demand. Although most of the utilities involved in these programmes are publicly-owned, these donor funding projects provide a good example of the benefits of DSM in developing countries, although some of them were unable to make DSM become a part of the country's strategy.

In Mexico, the high efficiency lighting pilot programme intended to sell CFL at lower prices to residential consumers. The main target was low-income consumers since they have heavily subsidized tariffs, paid by the utility. The economic return for the utility was larger for CFL installed in those costumers' households than in other customer. The CFL were sold by the Mexican national electric company (CFE). Since the CFL were purchased by CFE in bulk, significant discounts over retail price were obtained. The customers could pay for the CFLs in full or in every electricity bill for a period of up to two years. Between 1995 and 1997, the CFE sold 2.5 million CFLs, high above the target of 1.7 million. After the end of the project, the price of CFL had fallen 30%, and the distributors and retailers of CFL saw their sales increase. Although this project was not designed to target a market transformation, the results indicate that there was a transformation of the market. A public/private non-profit organization, FIDE, together with the GEF continued this project. This programme was also replicated to building insulation and air conditioning

(Birner and Martinot, 2005). A mass distribution of CFL in Argentina, under the Argentina Energy Efficiency Project (AEEP) that received a 15M€ GEF grant, was interesting to utilities involved in the programme, that were obliged to sell electricity below the cost price. The participation of the GEF corresponded to 10% of the project costs, being the remaining financed by the Government of Argentina (46%) and the utilities (44%) (GEF, 2008). Besides utilities participation, this AEEP project had also the objective of the development of the Argentina Energy Efficiency Fund. The Independent Evaluation Group of the World Bank believes that the results would have been much better if the CFL distribution was used to help increasing the tariffs (World Bank Independent Evaluation Group, 2009). The IFC/GEF Argentina Efficiency Street lighting Programme, between 1999 and 2001, targeted introduction of energy efficient SL technology in public lighting. The project was considered a success in expanding the technology in Argentina, and in creating legislative, technical, and financial conditions to the dissemination of the technology (Ashar and Knight, 2002).

In 2004 a World Bank project regarding the power sector development in Burkina Faso gave support to utility DSM education and investments in public administration buildings. This started with pilot cases in the public administration before expanding to other sectors (World Bank Independent Evaluation Group, 2009; Singh et al., 2010).

The Efficient Light Initiative (ELI) programme (1997-2009), financed by the GEF was implemented in two tranches. Tranche I included Argentina, Peru, and South Africa, and tranche II included the Czech Republic, Hungary, Latvia, the Philippines. Electric utilities implemented some of ELI activities, such as selling and financing energy efficiency lamps to their customers, in Argentina, Peru, the Philippines, and South Africa (Birner and Martinot, 2005; World Bank Environment Department - Climate Change Team, 2004). Although there have been many other outcomes of this project, here will be highlighted only the ones directly involving utilities. In Argentina, a pilot project implemented in low-income households, lead to a 20% bill reduction due to CFL-generated savings, and to a reduction of 35% in non-paid bills. Due to these results, utilities had extended these offerings to 60% of residential consumers. Actually, by reducing electricity costs, ELI was considered a success and used as a reference by allowing more electricity services to the communities, mainly those struggling with fewer resources. Another positive effect of ELI was the increase in the load factor of the Peruvian electrical demand, since 1999, from 0.7 to values between 0.8 and 0.82 (GEF, 2009). South Africa was also suffering from power shortages for more than a decade, but emerged as a national crisis in 2008. DSM alternatives are one of the measures that Eskom was using to face the crisis and reduce consumption while building more capacity. Some of the major DSM measures are CFL replacement programme, and installing smart meters that allow the demand control (Heffner et al., 2010).

In 2009, The World Bank financed the Efficient Lighting Initiative of Bangladesh (ELIB). This project consisted of a large-scale replacement of incandescent bulbs by CFL in order to reduce the impact of peak load deficits and poor level of electricity service. Through the substitution of 10 million lamps to residential customers the project will contribute to the reduction in peak power demand and load shedding (Sarkar and Singh, 2010). The world bank approved a project in Central African Republic, where a 100 thousand CFL bulbs were distributed as a strategy to avoid more expensive power generation and fight against poverty (Heffner et al., 2010).

In 1998, the USAID provided technical assistance to the Costa Rica Institute of Electricity (*Instituto Costariccense de Electricidad* – ICE) in the development of a load management project, aimed at reducing the peak loads, targeting intensive industrial and commercial electricity consumers. This project emerged from the need to deal with increasing demand associated with difficulties in making new investments. In accordance with the Rational Energy Use law, the Law 7447 of 1994, electricity utilities and the Ministry of Energy and Environment (MINAE) have to implement energy efficiency programmes targeting intensive electricity consumers (Morey, 2006). In 2008 the Efficient Lighting Programmes: "Three-for-two Promotion for Compact Fluorescent Lightbulbs" targeted residential consumers that were offered to buy three CFLs by the price of two. The goal of this project was to save 30MW and an investment of US$ 30million in fuel during the CFL lifetime (United Nations Economic Commission for Europe, 2010).

The support given to the Botswana by the World Bank resulted from the rapid electricity growth, expansion of the mining sector, and a lagging investment in generation and transmission. The Botswana Power Company (BPC), a vertically publicly owned utility, implemented the National Energy Efficiency Campaign (NEEC). This campaign included bulk procurement and distribution of CFLs, load control of electric water heaters, awareness and promotional campaigns, and large customers conservation programme (including demand management and cogeneration retrofits) (Heffner et al., 2010).

In Uganda the power shortage began in 2004 due to a severe drought, reducing the hydropower generation capacity. With the intervention of the World Bank, DSM measures, including loss reduction and bulk replacement of CFLs were implemented. The CFL programme started with a survey that demonstrated that only 1/3 of the households were using efficient lighting solutions. This survey was followed by an awareness campaign and 800,000 CFL were produced and distributed. For each household, three CFLs were given, by the state utility, in return for three incandescent bulbs. From the evaluation resulted that the cost of the CFL programme is 1/10th of the cost of electricity from diesel-fired generation (Heffner et al., 2010).

In Croatia, the GEF supported an Energy Efficiency Project that started in 2003 (World Bank Independent Evaluation Group, 2009). This project aimed at the development of an ESCO as a subsidiary of the electric utility, HEP (Singh et al., 2010).

In India, in 2001, the USAID assisted the government in the Energy Conservation and Commercialization (ECO) that intended to promote energy efficiency technologies and services, by the Indian utilities. Also the World Bank supported the DSM programmes as part of the reform strategy in states like Orissa, Haryana, Rajasthan, and Andhra Pradesh, although the implementation was very slow due to administrative and institutional barriers (Vashishtha and Ramachandran, 2006).

Although most of those projects were successful, the lack of political engagement did not allow the experience to work as a starting point to the sustainability and durability of DSM programmes. The Thai project was considered quite successful as a market transformation one. During the project period, the government allowed a tariff charge to finance the project. After that, the Electricity Generating Authority of Thailand (EGAT) started funding DSM initiatives through their regular tariff revenue, since they found DSM programmes to be worthwhile in their ability to improve EGATs public image. A DSM office was created within the utility. But the funds eventually decreased for the most part. Then, DSM was encouraged by the government but not required by regulations, neither were funds attributed to DSM programmes. A similar situation could be found in Vietnam. In accordance with Vietnamese regulations, the government has to consider DSM but there seems to be no imposition for the utilities to invest in DSM (Heffner et al., 2010; IEG-World Bank, 2009; Singh, 2004). Some studies were conducted in Oman that concluded that despite the high potential for DSM and energy conservation measures there has been no corresponding effort from the government to promote them (Al-Badi et al., 2011).

A large number of DSM programmes is based in bulk procurement and distribution of CFLs. These programmes based on the replacement of incandescent bulbs by CFLs can be quickly implemented, and have immediate results to fill capacity and energy gaps. An additional benefit, particularly important for the low-income consumers, is the reduction of the electricity bills. The cost of using CFL can be 1/20th of the cost of adding emergency diesel generators, thus being much less expensive than the alternative. Another advantage of the replacement of incandescent bulbs for CFLs is the reduction in greenhouse gas emissions, meaning that these programmes are suitable for carbon financing, through the Clean Development Mechanism. Also, in many developing countries the use of lighting is usually associated with electric systems peaks, which corresponds to another advantage of the use of CFL and a reason for the popularity of these programmes (Heffner et al., 2010). The Clean Development Mechanism is a mechanism, created under the Kyoto protocol, that allow projects that contribute to the reduction of emissions, to earn credits on emission reductions that can be sold to the industrialized countries (UNFCCC, not dated) .

A government clear message is needed in order to involve private actors in effective DSM programmes. Hence, political will is fundamental to reduce uncertainty, clearing the government line of action (World Bank Independent Evaluation Group, 2009; Haney et al., 2010). Government decisions can benefit from stakeholder engagement in the energy efficiency policy. The involvement of governments, private companies, inter-governmental organizations, and NGOs, among others, can help building a political consensus and ensures better conditions for the implementation and success of the programmes, apart from that it can lead to a better policy design. In some cases these co-operation is mandatory (IEA, 2010b). Nevertheless, even with private interests, utilities can be an interested party of DSM and market transformation projects (Birner and Martinot, 2005).

2.5 Energy Efficiency Obligations

Imposing the investment of certain amounts on energy efficiency measures is no guarantee of investment in the most suitable options, regarding the societal objectives allegedly pursued. Some countries impose, by regulation, energy reduction targets to guarantee utilities involvement in energy efficiency activities, thereby contributing to the reduction of energy resources depletion and environmental impact of energy use with the best performing measures.

In the present section, detailed reference is made to those cases where some kind of energy efficiency obligations are documented. Although it is possible to establish an analogy of the situation around the world, as regards to obligations, to the general case of regulatory environments presented in the previous section, the total amount of information on this particular instrument does not justify structuring the present section in sub-sections.*

After a growing number of system reliability problems that culminated with the California energy crises in the winter of 2000-2001, utilities attention was more directed to programmes with short-term results, although continuing stimulating customer purchases of energy efficient equipment, mainly under MT programmes. The focus of energy efficiency programmes was again set on their ability to be considered as a system resource. There even are studies suggesting that there is a large untapped potential for energy savings, the amounts obtained by utility programmes remaining rather small – fractions of a per cent of annual sales. As reported by Nowak in 2011, achieving annual savings of about 1% of annual sales was a rare achievement. Typically, long experienced programmes may have achieved 0.5% to 0.7% of annual sales (Nowak et al., 2011).

Some causes for the increase in the interest of utilities in energy efficiency programmes were (1) the increase and the volatility of fuel prices; (2) large costs associated to construction of new power plants; (3) the shrinking of the reserve margin leading to concerns about the reliability of the system in many regions; (4) growing concerns about the ability to finance and secure cost-recovery for large generation

* Therefore, the case of the US will be followed by the cases of other countries, without any explicit break.

construction projects; (5) more stringent environmental regulations affecting fossil fuel generation plants; (6) growing concerns about global warming (York et al., 2012).

Energy Efficiency Resource Standards (EERS) arise in this context as a market-oriented mechanism that requires utilities to achieve certain targets of energy savings through energy efficiency activities. The expression Energy Efficiency Portfolio Standard (EEPS) is also used for this same mechanism. In European countries EERS are commonly addressed as Energy Efficiency Obligations (EEO), and this will be adopted in this text, except when addressing a particular jurisdiction. These EEO schemes are very similar to the Renewable Portfolio Standards (RPS) policy that requires minimum amounts of energy to be obtained by renewable sources. The energy savings targets of the EEO could be set as a minimum amount or a percentage of the total system supply (Nowak et al., 2011). Energy efficiency targets can provide a concrete basis for organizing the programmes, justify funding, and obtaining resources. They can also be used to access the policy and conduct any adjustments. Some caution must be taken in order for the targets to be credible and achievable. Also, the time frame should be appropriate for the target. If targets are set too high to be accomplished in a short period of time, they will be unachievable and no serious attempt will be done to meet them. On the other hand if the targets are set too far in the future, there is a "risk of creating complacency instead of urgency" (IEA, 2010b). Another important guideline is to avoid the existence of several targets. This can lead to a dispersal of efforts and supports (IEA, 2010b). In Table 2-1 some types of energy efficiency targets are presented.

Table 2-1 – Type of energy efficiency targets (IEA, 2010b).

Type of target	*Description*
Defined improvement	Energy consumption or emissions (GWh, $MtCO_2$)
Intensity	Energy consumption or emissions per unit of economic activity
Elasticity	Ratio of growth in energy consumption or emissions to growth in GDP or output
Benchmark	Energy consumption or emissions relative to others
Transactional	Number of actions/equipment implemented/installed

Some jurisdictions put the obligation on suppliers (retail companies) and others on distribution companies (grid owners). Both options have pros and cons. Suppliers have a strong relation with final customers and may have motivation for market value-added services; although they have a strong incentive to sell more kWh, the obligations may push them to move their business from pure commodity sale towards energy service sales. On the other hand, distributors are usually more state regulated, which means that, with proper tariff regulation, they do not feel the urge to sell more kWh (Bertoldi, et al., 2010).

The US state of Texas was the first to establish EERS, in 1999, for electric utilities. The Texas electric utilities were required, by the electricity restructuring law, to obtain a 10% offset of their demand growth by end-use energy efficiency activities. This target was easily achieved and even exceeded. The 2010 EERS update set the EE goals in 20% of the utilities annual growth in demand for 2011, 25% for 2012 and 30% for 2013 (RAP, 2011a; ACEEE, 2012).

By 2011 there were more 25 US states with EERS for electricity. The savings obligations can be set on an annual basis or a cumulative amount for the whole period of the mechanism duration. Some other states have annual savings target with a cumulative objective.

In some states utilities are obliged to pursue all cost-effective DSM alternatives before implementing supply-side resources. In California a set of programmes, that are part of an energy efficiency portfolio, are implemented consistently with the purpose of simplifying the programme participation, reduce the customer confusion, and reduce administration and supervision costs. In order for the IOUs to obtain the largest amount of savings possible, they learn as much as possible about each consumer segment and rely on other market agents to help them. These agents can be retailers, contractors, and manufacturers to promote energy efficient products and the utility programs to residential and small business customers. For large customers, utilities ally with account representatives who work with energy service companies, etc., to inform customers about the programmes best suited for them. Regarding the 2006-2008 programme cycle, the net savings were very close to the goals. The shortfalls should be compensated in the 2009-2012 programme cycle. Programmes that include extensive customer education and staff training are a key factor for long-term savings. A good evaluation procedure is also central to provide the necessary feedback on how to improve each programme. Nowadays it is more difficult for the utilities to meet their savings targets, with more stringent energy codes and standards. As a consequence, the benefit-cost ratio of the current portfolios is around 1.1 and 1.2. Funding emerging technologies, tracking the implementation of audit recommendations over time, and increasing focus on behavioural changes are examples of utilities efforts to increase energy savings. The state of California is particularly interesting due to scope, scale and duration of the achievements in energy efficiency. By 2007 the Californian electricity utilities savings amount was above 21,000 GWh, corresponding to more than 30% of the total for the 50 states. Two specific policies may have helped these successes: first, all cost-effective energy efficiency measures should be implemented before making new commitments to supply-side alternative (renewable or not); and only if the EE programmes reach at least 85% of the savings goals set by CPUC, incentives will be given to the utility. Since 2007, the electric utilities in the state of Connecticut have energy efficiency requirements, and the revenues are decoupled from the sales, in order for these targets to be achieved. By the same legislation (the Electricity and Energy Efficiency Act), the electric distribution companies are required to procure all cost-effective energy efficiency alternatives as their first-priority resource. Every two years, distribution companies have to submit assessments for energy and capacity requirements in three, five, and ten years plans, as well as plans to eliminate energy demand growth, and other demand-side and environmental objectives. If an obliged utility does not fulfil their savings obligation, they can purchase savings certificates from others or pay a penalty for each kWh not saved. These penalties go to the Connecticut Clean Energy Fund (CCEF), to the development of renewables sources. If a utility fulfils 70% of its obligations it will receive an incentive of 1% of the programme costs before taxes. This management fee rises to 5% for a 100% of the obligations. At a 130% of goals, the incentive will be 8%. Together with the Electricity and Energy Efficiency Act, decoupling strategies, and the incentives mechanism, the increase in spending in EE has been an important issue in achieving higher energy savings. Other strategies that have been used and resulted in the increase of energy savings are: many contractors work for multiple utilities allowing the reduction of the overhead costs and take advantage of shared promotions; a lot of the programmes are directed to both electricity and natural gas; and the integration with other programmes. The end-use that also has accomplished more savings continues to be lighting. The IOUs have used several lighting technologies and are combining lighting with HVAC and other uses. In order to get deeper savings per project, utilities are implementing programmes that address the whole house, regardless of the fuel, with both electricity and gas utilities collaborating under the Home Energy Solutions brand. As an example, a utility (CL&P) pays up to 40% of the business customer cost of implementing some measures, and will pay up to 50% of the cost of the entire project, as a way of stimulating the implementation of more measures. A reduction of budgets from US$104 million to US$73 million in 2009, was followed by a reduction of savings from 354 GWh to 237 GWh. The lack, or uncertainty on availability of funds, may be a big challenge for the utilities investment in energy efficiency (RAP, 2011b; Nowak et al., 2011). EERS were created to the Delaware state in 2009, setting goals of 15% reduction in electricity consumption by 2015. Until the proper regulation is issued the EERS targets remain voluntary. The Sustainable Energy Utility (SEU), an energy efficiency utility, is responsible for determining the measures and the criteria to select the measures and the programmes. SEU has a 30% reduction target in annual energy consumption for participants (targeted to be 33% of Delawareans, by 2015). If SEU achieves less than 80% of programmes targets, a penalty should be issued. On the other hand, if 120% of the targets are obtained, SEU receives a bonus. SEU should implement demand response programmes, DSM and other EE activities. Since SEU does not use ratepayer funds, it is not obliged to use traditional utility cost-effectiveness process. It is funded by tax-exempt bonds and leases, regional greenhouse gas initiative, federal stimulus funding, and fees and interest on financing (Energize Delaware). It uses direct rebates and makes sure of the availability of programmes to all market segments (RAP, 2011c; ACEEE, 2012). In 2008 the Massachusetts Energy Efficiency Advisory Council (MEEAC) was created to collaborate with utilities to develop a three-year cycles plan to foster energy efficiency. The first of these plans aims the achievement of 2.4% of electricity savings in 2012. The distribution companies administer their own energy efficiency programmes with the collaboration and the supervision of the Department of Energy Resources (DOER) and the Department of Public Utilities (DPU). More precisely, the MEEAC, a stakeholder board headed by the DOER, works with utilities to develop coordinated energy efficiency three-year plans. These plans are submitted to the DPU for approval. The plans are evaluated in accordance with their cost-effectiveness and with the extent to which competitive procurement for EE is used. This procurement for cost-effective EE programmes that are less expensive than supply resources is an investment obligation for distribution companies that started with the Green Communities Act of 2008. Then, utilities have to, jointly, present a comprehensive and fully funded state-wide energy efficiency plan. The savings for each year of the first plan, regarding the retail electricity sales, were set at 1% for 2009, 1.4% for 2010, 2% for 2011 and 2.4% for 2012 and hereafter. The cumulative annual impact in 2012 should be 2,625 GWh. The rate of increase, level, and duration of annual savings puts Massachusetts EERS as one of the most ambitious. Annual savings of 2.4% after 2012, would represent a cumulative energy savings equivalent to 30% of the retail electricity sales in 2020. Customers will consume 23.4% less electricity in 2020 than the expected. The state recognizes the necessity of designing new programmes, services, and delivering mechanisms in order to achieve the state energy savings goals. Also they are following the approach “go deeper, then broader” (Nowak et al., 2011) as a way of maximizing the savings in each customer/sector and programme, before expanding the participation. For example, more savings can be obtained with increased budgets for rebates and other financial incentives combined with contact to each customer. For instance, residential customers have meetings on how to obtain more benefits from the programme, and business have dedicated account executives. There is a set of cost-effective measures for all sectors. CFLs are discounted at the wholesale level. This way the customers do not need a coupon nor get a discount when purchasing CFL.

In Arizona, an EERS requires distribution companies to achieve, through EE programmes, a cumulative target of 22% of annual energy savings, by 2020. EE programmes are administered by IOUs, but the funding and spending are approved by the Arizona Corporation Commission (ACC). Tucson Electric Power (TEP) company, a major IOU, work with its stakeholders, getting information about the implementation of the energy efficiency plan, as a strategy to increase energy savings. Also a close relation with a measurement and evaluation group helps TEP gather information on the interest to the community of programmes being proposed. TEP also works with trade allies to get as much information as possible on the ways to improve its programmes. Although most of the TEP portfolio includes lighting, they are looking for alternatives to increase savings, working together with other gas and electric utilities, including Arizona Public Service (APS) utility. The APS utility has created partnerships with local bank for the financing, at reduced interest rates, of the implementation of energy efficiency measures (RAP, 2011a; Nowak et al., 2011).

In Arkansas EERS were approved in 2010. The targets are moderate, rising from a reduction of 0.25% of annual sales to 0.75% between 2011 and 2013 (ACEEE, 2012).

The Colorado Public Utilities Commission is required to set energy saving goals for the utilities. The Xcel Energy's operating subsidiary Public Service Company of Colorado (PSCo) planned an aggressive savings programme for the commercial and industrial sector, expanding CFL and commercial lighting. Xcel Energy combined less cost-effective energy efficiency measures with other whose cost-effectiveness is above the threshold. This way large projects with large energy savings are implemented, that otherwise would not. This strategy is used to both commercial and industrial consumers, and is also in place in Minnesota. The savings have increased 50% for a small group of consumers. Part of the success seems to be due to the fact that energy efficiency measures and projects are looked at holistically over several years, facilities, and processes. PSCo has been running air conditioning pilot programmes in the residential sector, including retrofits of central air conditioning systems, a regular maintenance programme, and high performance installation. Some more services have been offered, such as process efficiency services and small business lighting, where a lighting auditor is hired by the PSCo to the business owner. In order to increase savings in the next years, PSCo also has increased rebates from 20-25% of consumers incremental cost to 40%, and offers rebates for more products (Nowak et al., 2011).

In Hawaii, a 2009 legislation established an EERS of 4300 GWh reduction in electricity consumption by 2030 (RAP, 2011a).

In Illinois, the contribution of utilities for the EERS goals is 75%. The remaining 25% should be achieved by the Department of Commerce and Economic Opportunity (IDCEO), which is responsible for programmes for the government and low-income customers. Due to only recent experience with energy efficiency programmes, the Illinois Energy Efficiency Stakeholder Advisory Group (ILSAG) was established in part to strengthen the large utilities energy efficiency programmes portfolios and the IDCEO's portfolios. Also there were meetings between major environmental and consumer groups with utilities and state representatives. The largest electric utility, ComEd, puts a strong emphasis in lighting programmes, including the service sector, such as warehouses and light manufacturing. As well as ComEd, also Ameren Illinois, has lighting and CFLs as the core of their programmes. Both justified the option as being risk-averse. The risk-aversion results from regulatory and policy constraints, such as net-to-gross attribution of savings and measure-level cost-effectiveness tests. In order to diversify and compensate from the reduction of savings from lighting measures, ComEd is investing in non-lighting energy efficiency programmes for commercial and industrial consumers, with measures such as the improvement of the efficiency of industrial processes, installation of variable speed drives (VSD) and HVAC systems. In Illinois the high demand for EE programmes lead ComEd to reduce rebates in order to conserve the funds. Ameren Illinois has been able to meet its savings goals, due to a combination of the economic rebound, incentives paid to the community of energy efficiency contractors, and to the increase in the number of certified EE contractors. ComEd also increased bonuses to contractors and the advertising of its programmes to contractors (Nowak et al., 2011).

In Indiana, a 2% of annual energy savings goal, to be achieved by utilities, was set, in 2009, for a ten years period (RAP, 2011e).

In Kentucky, by 2011, an energy plan calls for Renewable and Efficiency Portfolio Standard (REPS), whereby 25% of the energy needs in 2025 should be met through EE, conservation, and renewable energy. As part of the REPS, an EERS is called for to achieve the target of reducing the energy consumption by 16% below the projected consumption for 2025 (RAP, 2011c).

In Maryland, utilities are responsible for implementing EE programmes in order to achieve electricity savings of 5% per capita, by the end of 2011, and 10% by the end of 2015. Regarding peak demand, utilities are responsible to reduce peak demand by 5% by 2011, 10% by 2013, and 15% by 2015, compared to 2007 levels (RAP, 2011c).

In Michigan, the regulated IOU (88.9%), including municipal utilities (7.8%) and cooperative operators (3.3%), are the only ones responsible for meeting the savings targets. In Michigan, and in order to maximize the effectiveness of the energy efficiency programmes, the Michigan Electric Cooperative Association "Energy Optimization Collaborative" (MECA) gathers together energy providers, whose participation is mandatory, with other stakeholders, including energy efficiency experts and equipment installers. In 2009 and 2010, the main programmes were addressed to lighting. Such as utilities in Arizona and Ohio, in Michigan utilities are also running behavioural pilot programmes in the residential sector. Also the utilities have reported high participation and the funds for commercial programmes run out in June 2010. Such as in Illinois, some of the utilities had to reduce their rebates due to their popularity. Consumers Energy utility has been employing staff with experience in energy efficiency programmes from the period before the sector restructuring. The Consumers Energy strategy for its portfolio is taking the best characteristics of programmes that had been proven, working with contractors to help in the development of the programmes, choosing these contractors by their experience in these programmes. Most of the savings from the utility DTE Energy were related to ENERGY STAR products programmes. DTE Energy in cooperation with OPower (a service company that help customers increase savings) is sending information to residential customers comparing their energy consumption with the ones of their neighbours (Nowak et al., 2011).

In Minnesota, since 2010, utilities have to save 1.5% of their retail sales. The first 1% has to be obtained directly from energy efficiency or conservation programmes. Up to 0.5% may be obtained through improvements in the utility's infrastructure (generation, transmission and distribution). The Societal Cost Test (Annex A) is the one predominantly used to measure the cost-effectiveness of the programmes. Some strategies have been implemented to maintain and increase energy savings, such as, (a) increase rebates and enhance financial incentives to boost participation; (b) a visit to residential consumers helps increase participation and the volume of energy savings; (c) under the Trillion BTU programme, the businesses are audited (paid by Xcel), the engineering studies are performed on at the firms' facilities (25% paid by the businesses and 75% by Xcel and the improvements are covered by a Port Authority Loan and Xcel Rebate); (d) energy reports about the consumer are send together with comparisons with the consumption of neighbours and some suggestions to improve energy efficiency are made. On the other hand, the impact of higher appliance standards and building codes on utility savings has to be addressed, since it will probably reduce the savings due to utility programmes. A closer involvement with the customer seems to be an important component of the utilities strategy (Nowak et al., 2011).

Nevada has a Renewable Portfolio Standard (RPS) for electricity providers. EE must fulfil up to 20% of the standard in 2015 and 25% in 2025. If the utility decides to use EE to comply with the standard, then at least 50% of the savings must be obtained in the residential sector. Also, the EE measures must be implemented at the retail customer's location; must be partially or full subsidized by the electric utility; and must contribute to reduce the energy demand (RAP, 2011a; ACEEE, 2012).

The New Jersey Board of Public Utilities has been authorized to adopt electric and gas EERS with saving targets of 20%, by 2020, relative to the estimated consumption in 2020. However there is no consequence if the targets are not met (RAP, 2011c; ACEEE, 2012).

New Mexico requires that all electric and gas IOUs should acquire all cost-effective and achievable EE and LM. Regarding electric utilities, this requirement should not be less, by 2014, than 5% of the total retail kWh sales in 2005, and 10% of the total retail kWh sales of 2005, by 2020. These savings amount should be the result of the programmes implemented after 2006 (RAP, 2011a; ACEEE, 2012).

The New York Energy Efficiency Portfolio Standards (EEPS) were created in 2008 by the New York Public Service Commission (NYPSC). Those EEPS where part of a state-wide programme to reduce by 15% the forecast levels of electricity consumption, by 2015 (known as the '15 by 15' goal). This target can be met using not only utility EE programmes, but also accounting savings from state agencies, codes and standards, and improvements in transmission and distribution systems. In order to achieve these goals, there was also an increase in funding, from SBC and other sources. More programmes were approved. State utilities were mandated to present EE programmes and NYSERDA was also invited to submit EE programmes proposals. The marketing and informative campaigns are more directed to the target. Such as California, New York invested in education and training, in order to obtain as much savings as possible. The New York Public

Authority (NYPA) lends money to energy savings programmes at lower rates (RAP, 2011c; Nowak et al., 2011).

In North Carolina, the REPS are different from publicly- to Investor-owned utilities. IOUs are required to obtain up to 25% of retail sales through EE, by 2020, and 40% from 2021 on. The REPS also impose, to each electricity provider, the implementation of DSM and EE programmes to establish the least cost mix, together with the supply-side options, to meet the needs of their customers (RAP, 2011d; ACEEE, 2012).

EEPS were established in 2008, in Ohio. Electric distribution utilities must achieve an amount proportional to theirs share of retail sales. These values ramp up from 0.3% in 2009 to 2% in 2019 and thereafter until 2025. In case on noncompliance with the targets, the utilities have to pay a penalty that is credited in the Advanced Energy Fund. Each large utility has its own active stakeholder collaborative, with the mission of maximizing the energy effectiveness of the programmes. The CFLs based programmes are very common, since they allow obtaining significant savings almost immediately. The LED lighting is not cost-effective under Ohio's cost-effectiveness tests. This will make Duke Energy Ohio utility invest in persuading residential consumers to install already bought bulbs, from previous programmes. Also the Dayton Power and Light utility (DP&L) will focus on lighting. In its initial plan (2008-2015), 75% of residential savings came from CFLs. The residential programmes also include appliances rebates, rebates and maintenance programmes for furnaces, low income programmes, among others. However, the majority of the savings projected by DP&L are supported by rebates for more than one hundred measures to commercial and industrial sectors. Utilities in Ohio are also running behavioural pilot programmes in the residential sector, such as residential feedback systems. American Electric Power (AEP) utility, although with great success with lighting programmes, is more engaged in market segmentation, adding programmes to specific consumer targets, such as to agricultural customers and restaurants (RAP, 2011e; Nowak et al., 2011).

The utilities in Oklahoma are obliged to meet specific saving goals set by the Commission. The savings may target to reduce the rate of growth of peak demand, energy usage, and capacity additions, and may be expressed in kW, kWh, percentage of reduction or limitation, years that anticipated construction of utility plant is delayed, and/or other quantifiable measurement approved by the Commission. The target of 15% of all capacity for electricity generation in the state must be of renewable sources. Within this target, no more than 25% can be met by conservation and DSM programmes (RAP, 2011e).

Pennsylvania electric distribution companies were required to achieve, through EE measures, savings of 1% by 31st of May of 2011, compared to the company's load forecast by the PUC for the 1st of June of 2009 to the 31st of May of 2010, and 3% by the 31st of May of 2013. Also, a 4.5% reduction in peak load by the 31st of May of 2013 is demanded. Electric distribution companies that serve more than 100,000 customers are required to implement EE and conservation plans. These plans are subject to approval by the PUC. They can be rejected or modified by the PUC. The Pennsylvania utilities may experience some penalties that can go from $1 million to $20 million if they do not meet their targets in specific dates. Like in other states, the Philadelphia Electric Company (PECO) had to reduce the rebates levels on some appliances due to the massive adhesion to the programme (RAP, 2011c; Nowak et al., 2011).

Utah adopted a RPS in 2008 to meet 20% by 2025. Energy savings from EE measures can contribute to the standard, but, unlike others states, Utah does not impose a cap on energy savings to contribute to the RPS (ACEEE, 2012).

In Washington, EERS were approved in 2006. The targets for each utility are updated every two years. Whenever a utility was unable to meet its target, it has to pay a penalty for each MWh of shortfall (ACEEE, 2012).

West Virginia approved, in 2009, an Alternative and Renewable Energy Portfolio Standard that allows EE and DSM initiatives. However, very little initiatives have been taken by utilities (RAP, 2011c).

In Wisconsin, in 2010 were set annual targets for reduction of electricity and natural gas, in a four-years period. Regarding electricity, a percentage of peak load and electric sales of 0.75% was set to 2011 ramping up to 1.5% in 2014. The amount of investments required was estimated in 2.5% of the utilities revenues. Due to the 1.2% investment cap the targets were seriously compromised (RAP, 2011e; ACEEE, 2012).

In some states, the EE targets are voluntary. In June 2010 was set a goal to reduce the per capita electricity consumption in the state of Alaska by 15% in 2020, that should be part of utilities requirements under EERS. EE programmes are voluntary and result from initiatives of utilities. There are few programmes available for electricity customers. The Golden Valley Electric Association has been implementing EE programmes since 1992 (RAP, 2011a) (ACEEE, 2012). In Kansas, in 2007 producers were asked to reduce consumption in 5% by 2010 and in 10% by 2020, without any EERS (RAP, 2011e). Missouri has voluntary EERS. Electric utilities should achieve cumulative savings of 9.9% in 2020 (ACEEE, 2012). In North Dakota, there are no obligations to the implementation of EE programmes, although some utilities implement them voluntarily (RAP, 2011e). In South Carolina there are no EERS (ACEEE, 2012). In South Dakota, a voluntary objective was set in 2008 of achieving 10% of retail electricity sales from renewable and recycled energy sources by 2015. In 2009, the law permitted that “conserved energy” could help meeting this objective. As a matter of fact, the spending in EE in South Dakota is minimal, only due to some voluntary programmes implemented by utilities (RAP, 2011e). In Tennessee, TVA has set internal goals, namely to reduce the load growth by 1,400 MW by the end of 2012, and lowering electricity capacity requirements by approximately 4% by 2012. In 2010, TVA set a new goal to achieve 3.5% of sales in energy efficiency savings by 2015. TVA established partnerships with local municipal and cooperative utility distributors to deliver EE programmes (RAP, 2011d).

Some utility programmes may foster the implementation and adhesion to other non-utility programmes, such as buildings codes and MEPS.

Together with the obligation, the majority of the states allow utilities to receive a percentage of the net benefits and/or of the programme costs, when they achieve near 100% of the savings goal and an even higher percentage if they exceed the targets (Nowak et al., 2011).

The EERS/EEO can provide some flexibility for the targets to be achieved through market-oriented mechanisms, such as energy efficiency trading schemes: those utilities that save more than their target can trade with others that did not fulfil their obligations. This is the case of Denmark, France, Italy, and UK, alongside with Canada and New South Wales, in Australia. In some countries the savings obtained by utilities can be certified, and a “white certificate” is issued.

The 2005 Action Plan for Renewed Energy Conservative Efforts, of Denmark, calls for energy savings through building codes and enforcement, in the public sector, and through distribution companies. In this plan, the distribution companies have seen their obligation to save energy increased. The savings annual target was 1.7%. The Action Plan imposed that the energy efficiency measures that the distribution companies had to implement in order to increase energy savings should be done without any tariff adjustment to cover additional costs. The companies have to be more cost-effective in achieving savings otherwise they will lose money. The companies are free to choose the methods, and the consumer targets, and are also able to trade obligations. Under this new plan distribution companies do not need Danish Energy Authority (DEA) approval of the actions they intend to implement. The companies are no longer restricted to their jurisdiction area, for the implementation of energy efficiency measures, nor are they limited to invest the amounts received from one group of consumers in that same group. When a company implements measures to customers of another company jurisdiction, the savings accounts to this latter company but a payment is due to the company that implemented the measures. This allows the specialization of companies in measures for certain groups of consumers, such as residential, industrial, etc. The trading of obligations allows those companies that could save above their obligations to sell to those that did not reach theirs (IEA, 2006a). The targets are expressed in final energy and result from an agreement between several public entities. Targets are also set on the basis of the average market share of the electricity distribution of the previous three years. The cost recovery scheme in Denmark is a levy of 0.06eurocent/kWh, on average, paid by all customers. There are no certificates in Denmark (Bertoldi, et al., 2010). The Danish utility companies have been working actively in DSM activities since 1990. In 2005 the utility companies (electricity, natural gas, district heating, and oil) had an obligation to save 2.95PJ/year. By 2008 the obligation on utilities was 5.4 PJ/year. The activities performed by the utilities cover mostly energy audits, information, subsides, or a combination of these. However, due to the better relation programme costs *vs* energy savings obtained, utilities have been focusing in programmes to industrial consumers (Togeby et al., 2012). Obliged parties must implement measures through a third-party. The performance incentives are based on the lifetime of the measures, giving preference to longer lifetimes (RAP, 2012).

Energy efficiency certificates (white certificates) were introduced in New South Wales (NSW), Australia, in 2003, as part of the Greenhouse Gas Reduction Scheme (GGAS). GGAS was intended to reduce greenhouse gas emissions related to production and use of electricity and to promote activities that should offset emissions production. In 2005 the GGAS was extended to the Australian Capital Territory (ACT). Under the GGAS, certain obliged parties (addressed as benchmark participants) have individual benchmark targets for GHG emissions. These benchmark participants are all electricity retailers that supply customers in NSW and ACT, generators that supply electricity directly to end-use customers in NSW and ACT, and all NSW and ACT customers that buy electricity directly from the wholesale National Electricity Market. The Benchmark targets are set per capita, regarding the population of NSW and ACT (Crossley, 2008). The costs associated with the implementation of EE measures are assumed to be costs of being in business, therefore, they are paid by the consumers. There are no performance incentives for the utilities (RAP, 2012).

In Australia there are three different EEO schemes. The South Australia Residential Energy Efficiency Scheme (REES) was implemented in three-years phases. The first phase started in 2009 and REES should run until 2014. This scheme does not allow trading. However obliged parties, suppliers that serve 5,000 or more customers, will accumulate credits. It is possible to transfer some credits to other obliged suppliers. This policy has three main objectives: increase EE in households, reduce energy costs in households, and help households prepare themselves for increases in energy prices, mainly low-income households. The suppliers must implement measures that they choose from a list of measures approved by the Ministry. There is no performance incentive and the costs of the programmes are paid by the customer (RAP, 2012).

In the Australian State of Victoria, the Victorian Energy Efficiency Target (VEET) came into place in 2009 and is supposed to run until 2029. From 2012, the scheme that targeted only households was extended to commercial and other non-residential installations. The obliged parties are energy suppliers with 5,000 or more customers, whose individual savings target is set in accordance with the number of customers. The suppliers must choose to install equipment from a list of pre-approved products – addressed as "prescribed activities". It is possible to request the approval of products in a case-by-case basis. The funding of this scheme comes from the customer. No incentives are allowed (RAP, 2012).

In Italy, the utilities involvement in energy efficiency initiatives is mostly done through the Energy Efficiency Certificates scheme. This scheme started in 2001, imposed on distribution companies with more than 100,000 customers, and intends to certify primary energy savings achieved through measures directed to energy consumers. Since 2008, electricity or gas distributors serving more than 50,000 customers are obliged to improve energy efficiency under this scheme. The certificates are valid for 5 years and are issued by the electricity market operator (GME) to utilities and Energy Service Companies (ESCOs). The individual savings targets are set annually, for each distributor, and based upon the ratio between the amount of energy distributed to their customers and the total amount of energy distributed in the country (Bertoldi, et al., 2010). The energy efficiency targets in final uses must be accomplished through interventions that, without reducing service quality standards, decrease the consumption of primary energy (IEA, 2003a). The certificates can be traded through bilateral contracts or in the market. Since 2009 cost recovery is no longer fixed but depends on the energy sales price variation (Bertoldi, et al., 2010). The regulatory authority has a list of pre-approved measures for the obliged parties to choose from. However, other measures can be evaluated in a case-by-case basis. There is a performance incentive but its removal from 2013 was proposed. The funds come from a “unitary tariff contribution” that is established annually. The idea underlying this limitation is to foster obliged parties to look for highly cost-effective measures (RAP, 2012).

In Ontario, Canada, the EEO scheme results from an evolution of obligations that were set upon the distributors by the authority. The distributors must have their EE plan approved. Since 2010 the savings target has two components, in MW and in GWh, addressed as CDM target. For each utility these targets depend on the distributors’ share of peak demand and annual energy consumption. The programmes are paid by the customer and there is a performance incentive scheme that rewards the distributors based on a percentage of the target (RAP, 2012).

EE programmes in the UK are usually regulatory measures, either as white certificates or as energy savings obligations set by the government (IEA, 2008b). Under the Energy Efficiency Commitment (EEC), since 2002, electricity and gas utilities are required to achieve EE targets in the households sector. The targets for each supplier are set by the regulator, Ofgem. The utilities are free to choose the means to fulfil their obligations. They can, for instance, promote high-efficient lamps, boilers, and appliances, and install insulation. However, at least half of their savings obligations have to be obtained in the “priority sector” (households that receive income-related benefits and/or tax credits), and the savings obligations can be traded among suppliers. Utilities usually provide grants to assist consumers in reducing their energy bill. There is no explicit cost recovery mechanism. It was considered that since utilities are in a competitive environment, they are competing for their market share, and can pass through the costs of these measures as much as possible. So far there were three phases of EEC. The first phase (EEC1) ran from 2002 to 2005, the second phase (EEC2) between 2005 and 2008, and the third (EEC3) ran from 2008-2011. The savings amounts above the obligation target could be carried over to the next period. In case of non-compliance, obliged suppliers suffer a penalty equal to 10% of their revenue (IEA, 2007a). IEA (2007a) considers that the success of the EEC programme is due to four main factors. Firstly, since obligations are put on a limited number of energy suppliers, the programme management is relatively simple. Secondly, the savings are simple to calculate. A list of measures that the suppliers can implement with the savings they can lead to, are published by Ofgem. This procedure relieves the amount of work involved. Thirdly, there have been a lot of “easy to get” savings. Fourthly, some synergies with the Energy Savings Trust (EST) have been exploited. The EST is an independent body whose purpose is to promote energy efficiency and emissions reduction in households. Its main activities are enhancing awareness, and providing advice and technical support to energy efficiency alternatives. The support to the development of new and more energy efficient services and appliances is also accomplished by stimulating partnerships, innovation, providing training, and accreditation. The EST budget exceeds GBP 100 million funded by utilities obligations and other sources. The EEC3 was re-named Carbon Emission Reduction Target (CERT). The share of savings that had to be obtained in the priority sector reduced from 50% to 40%. In the UK the obliged parties have to present their energy savings plans to the regulatory authority for pre-approval. The obliged utilities are those with more than 50,000 residential customers (IEA, 2007a; Clarke et al., 2008 ; Bertoldi, et al., 2010; IEA, 2010a).

In France, since 2006, energy suppliers are obliged to achieve energy savings targets for a time period. They will receive a “white certificate” for the energy savings they manage to obtain. An energy supplier that, by the end of the period, was not able to fulfil its obligations, can buy certificates from other utilities that outperformed, otherwise it has to pay a penalty for each kWh not saved. At the beginning, energy efficiency measures proposed by utilities under this scheme targeted the residential sector, now all sectors are allowed, except for the ETS. Other companies besides energy suppliers were able to participate in this scheme (IEA, 2010c). Actually, any economic agent that obtains savings above 1GWh, over the lifetime of the project, can get its savings certified (Bertoldi, et al., 2010). The results obtained for the first phase, 2006-2009, surpassed the target. A reformulation of this scheme is under way regarding the entry of new market players and the need to ensure that the savings are obtained in a cost-effective way (IEA, 2010c). In France there is no specific cost recovery mechanism for the white certificates. Since most of the tariffs are regulated, the regulator should take into account, in the tariffs update, the cost of complying with the obligation by the obliged party. As a matter of fact, the tariffs evolution takes into account the inflation rate, social and renewable energy feed-in-tariffs, evolution of transmission and distributions costs (Bertoldi, et al., 2010). The obliged party must choose upon a set of pre-approved standard measures, non-standard measures, and measures targeting fuel poverty, information and training, and innovative measures. There is no incentive mechanism and the cost recovery through tariffs has to be approved (RAP, 2012).

In Belgium, the Flemish energy savings obligations were established in 2003. By then, 16 distributors were covered. The savings, in any fuel, should be obtained through measures directed to residential, commercial, and non-energy-intensive industrial consumers. For the period 2003-2008, the savings target for low-voltage consumers was 10.5%. For high-voltage customers and for the same time period, the savings target was 1% annually. If the targets were not reached, fines could be imposed to the distributor. The penalty imposed by the Flemish regulator was 10 Euro cents for each unachieved kWh. The programme costs are incorporated in the electricity tariffs, but the fines are not. In 2003, the savings (763 GWh) more than doubled the target (381 GWh), spending less than the allocated budget. The programme costs per kWh saved were 3.7 euro cents for residential consumers and 1.02 euro cents for commercial and industrial (Nadel, 2006). From 2008, the Flemish DNO have a target of 2% reduction of the annual primary energy, for residential customers, and 1.5% for the other ones (IEA, 2010d). In Flanders region, grid operators must provide energy advice, information and historical electricity consumption data to customers. The cost recovery mechanism is based on the budget for energy-savings obligation compliance that network operators have to submit every year, and that has to be approved by the federal regulator in charge of the tariffs (Bertoldi, et al., 2010). As of 2012, the targets were removed and replaced by specific "actions obligations". The action obligations are set by the Flemish government. Some of the actions obligations that were introduced since the beginning of the EEO scheme were: each DNO had to send to households in their distribution area a coupon that could be exchanged for a CFL, energy-saving shower, or energy meter (in 2004-2005); DNOs, were required to send a voucher for a free energy-saving lamp to every other member of the household (in 2006-2007); DNO were required to carry out a defined number of energy scans for every 100 household connections, and some interventions should be done when advisable (such as energy saving light bulbs, water-economy showerheads, pipe insulation and radiator foil); DNO should disseminate information material and give personalized energy-savings tips to households; DNO, between 2006 and 2011, were required to help in the development of energy accounting schemes for schools and health care facilities, whose costs were shared between the buildings and the DNO; and DNO are required to help municipalities in planning and implementation of the local energy policies. The funds come from tariffs and there is no incentive for obliged parties (RAP, 2012). Brussels-Capital, without any quantified obligations, requires that electricity operators promote energy efficiency to their final customers. On the other hand, Wallonia promotes energy efficiency by giving premiums to energy suppliers for the implementation of energy saving measures (IEA, 2010d). Since 2001 the Solar heaters programme involve energy suppliers and local authorities in the promotion of solar boilers, in the three regions. In Flanders and Brussels regions, the electricity distributors co-financed the installation of solar heaters under their public mission to promote the rational use of energy (ISIS, 2006).

In Norway, Enova has the mission to promote energy savings, renewable energy sources, and environmentally sound measures. Enova projects are funded by the Energy Fund, that receives funds from a grid levy (around € 0.001/kWh), a distribution tariff, and from the state budget. The total budget accounted for € 207 million in 2010. The projects are selected through a tender mechanism. Enova also provides information and advice, and consultancy services to business and household consumers. Due to the lack of

EE programmes promoted by energy utilities in Norway, the IEA suggests that the involvement of utilities in EE promotion should be stimulated (IEA, 2011c).

Korea intends to foster the investment in DSM activities by putting an obligation on the Korea Electric Power Corporation, the Korea Gas Corporation and the Korea District Heating Corporation. There is no mandatory savings target, but the budgetary amount invested in DSM must exceed the amount invested in the previous year. This obligation will eventually be extended to private utilities (RAP, 2012).

In China, in January 2011, a DSM regulatory framework came into force where the government-owned power grid companies are obliged to obtain energy savings that amount, at least, to 0.3% of sales volume, and to 0.3% of maximum load, compared with their previous year (Finamore et al., 2010; RAP, 2012).

In 2004, a scheme to save energy was implemented in Argentina, targeting a 5% reduction (compared to the same period of the previous year) in electricity consumption for all commercial and industrial customers with energy consumption above 600 kWh on a bimonthly basis. Those unable to reach their savings target had to pay a penalty for each additional kWh consumed. On the other hand, a credit is issued for those customers that outperform. For the residential customers there is no penalty, if they consume more than the year before, as long as they consume less than 600 kWh over two months. If they lower their consumption, they will receive a credit on their bill equal to the cost of the amount of electricity they save in relation to the same period in 2003 (Hu et al., 2005)

EEO is a regulatory strategy to involve utilities in energy efficiency fostering activities. Setting EE targets, more than just imposing amounts of money to be invested in EE measures, should lead to the choice of the most cost-effective measures. When no loss compensation mechanism exists, these strategies may foster utilities efforts.

Other experiences that were found and considered interesting are presented in the next section.

2.6 Other experiences

Before the liberalization of the electricity sector, in Austria, as well as in Australia, Belgium, Denmark, France, Germany, Italy and Spain, utilities were involved in DSM and IRP activities. The major programmes aimed at increasing consumer awareness of rational use of energy, through informative campaigns and advice, and improving the utilization of the production capacity providing TOU and interruptible tariffs and load management services. These activities could be carried out in co-operation with regional or with municipal utilities. The investments in these programmes were highly reduced after the liberalization of the electricity sector, due to the pressure of the competitive environment. The environmental concerns were the reason to keep investing in DSM. The rising of the energy prices and transmission constraints increased the interest in DSM and energy efficiency (IEA, 2003b). This raise in interest is from the government and not from the industry (IEADSM, 2005). Municipalities and public authorities have taken the responsibility of increasing awareness. There are strong incentives to invest in renewable energy, but the same does not happen to investments in energy efficiency, regardless the energy efficiency potential. For instance, since the Electricity Act in 2000, distribution system operators are obliged to buy a percentage of electricity generated by renewables, under regulated prices. These costs are charged to the customers as a surcharge on the network tariff (EUSUSTEL, 2006). In a competitive environment, the investments in energy efficiency and awareness rising are becoming tools to retain customers. The branding has become an important issue (IEADSM, 2003). Some regional electric utilities subsidise the purchase of energy efficient equipment for the residential customers, enterprises or public institutions. Some utilities subsidise the installation of gas fired condensing boilers (AEA, 2009). Utilities also run informative campaigns to encourage more energy efficient behaviours. Although utilities get themselves involved in energy efficiency programmes, in many of these cases they are not compelling by law. There are no mandatory targets for the contribution of utilities to the reduction of consumption (IEA, 2008c).

In Cyprus, the government promotes and subsidized CFL in the households sector. For each household, five lamps are distributed free of charge, by the utility company (Ademe, 2011).

Under the 2007 National Energy Efficiency Action Plan (NEEAP) utilities are required to offer information as energy services to end-users, in the Czech Republic (IEA, 2009d).

In Ireland, Powersave is a voluntary scheme offered by electricity suppliers to their customers. Consumers will receive financial incentives if they reduce electricity demand on request. The purpose is to use this scheme in generation shortfall, avoiding the load shedding of customers. Also two other schemes are in place to influence customers to change their consumption pattern. The Winter Peak Demand Reduction Scheme provides financial incentives to business consumers that reduce their electric energy consumption during peak hours in winter months (November-February). The Winter Demand Reduction Incentives provides incentives for customers to displace their consumption to off-peak hours (IEA, 2007b; CEER, 2008; ISIS, 2012a). The Ireland's Electricity Supply Board (ESB) produced a brochure "Power Savings for Industry" aiming to help industrial customers, consultants, plant designers, and purchasers of equipment, to reduce energy costs by adopting cost-effective energy efficient technologies and operating practices. This measure was in place between 1990 and 1995 (ISIS, 2008).

In Germany, major industries and utilities agreed to reduce CO_2 emissions intensity by 20% between 1990 and 2005. In return, the German government offered low-interest loans for investments in energy efficiency improvements (Geller et al., 2006). Since 2002 supply energy companies, in collaboration with the Germany energy agency (Dena), and supported by the Federal Ministry of Economics and Technology (BMWi), are conducting a nationwide energy efficiency campaign ("Initiative EnergieEffizienz") that targeted the households sector, the services and industry (since 2005). The focus of the campaign is to inform customers about EE opportunities in each sector (ISIS, 2011). There is no obligation for utilities to offer EE programmes, even though municipally-owned utilities have been offering EE programmes, under a voluntary framework (Wasserman and Neme, 2012).

In the Netherlands, the distribution companies of gas, electricity, and district heating, established the Environmental Action Plan, in 1991, with the purpose of encouraging energy customers to save energy. Several measures were developed, such as, promotion of energy savings in space heating and lighting for non-residential buildings, housekeeping techniques for industry (information, advisory, and financial services), among others (ISIS, 2007). Part of the Environmental Action Plan, the Energy Efficiency Lighting Scheme (STIMEV) was a subsidy scheme open to non-residential buildings that paid a levy for m^3 of gas and kWh of electricity. The STIMEV promoted HF ballasts, mirror-optical armatures, PL armatures, lighting control systems, power reduction on existing installations. After 1992 the scheme was offered by distribution companies to their customers. Between 1991 and 1994 the STIMEV contributed to a reduction of 100,000 MWh. The scheme lasted until 2000 (ISIS, 2012b). Since 2008, the associations for energy companies, the construction sector and the installation sector, and the Energy transition platform for the built environment, signed a covenant "More with Less" that aimed at saving energy in the construction sector. There is a comprehensive set of measures to allow considerable savings (IEA, 2009e).

In Slovenia, the measure *Financial incentives for efficient electricity consumption in the public sector* has the aim of increasing efficiency in the use of electricity in public lighting, public utility services and other electricity uses in the public sector. Energy suppliers provide financial support for EE measures in lighting and other end uses. The measures stated in 2008 and shall last until 2016 (ISIS, 2012c).

In Switzerland, electricity suppliers offer advice and consulting to their customers, having developed special EE instruments and products (IEA, 2012).

In Brazil, during the 2001 power shortage, the Electropaulo, a local utility from São Paulo, 4 million CFL were given to low-income customers as a measure to obtain instant effect on the load curve. The Electropaulo intentions were neither long-term market transformation nor cost reductions through efficiency (Hu et al., 2005).

Since 1996, even without any legal mandate, the Generating Electric Authority of Thailand (GEAT), the national electric utility, has been running a voluntary energy labeling covering several end-use equipment (Waide and Buchner, 2008).

In Vietnam, the national utility, Electricity of Vietnam (EVN) carried out, since 2001, programs to promote the use of energy-saving lighting equipment, such as CFLs and thin-tube, "T8" fluorescent lamps. Under the 2006-2010 Energy Savings Program, 40 million incandescent lamps should be replaced by CFLs, FTLs, and T5 lamps, been EVN a part of this project (Waide and Buchner, 2008).

In Sri Lanka, a privately-owned distribution company, the Lanka Electricity Company, was partner with the Ceylon Electricity Board (CEB), the vertically integrated public utility, in a DSM programme to deal with power crisis of the 1990s. The Energy Conservation Fund also collaborated with the implementation of this programme in the public sector. This programme aimed to reduce the peak load and the energy demand, through the sale of CFL to utility customers. CFL were then paid during a 12 month period, through an item in the electricity bill. The number of lamps sold to participants was 261,000 and the number of CFLs purchased by non-participants was almost five times higher (1,235,000). This programme was in place between 1994 and 2001 (Taylor et al., 2008).

2.7 Conclusions

In the following analysis of the occurrences of some regulatory mechanisms, within the set of jurisdictions reported, the sets of information for each jurisdictions are not equally complete for all cases, since the data on some variables lack here or there. As a consequence, for each mechanism there is a subset specific for that mechanism.

Different approaches have been adopted to overcome the paradox of utilities involvement in energy efficiency fostering: regulatory impositions, system benefits charges or other designed to promote EE, allowing utilities to recover the programme costs and to compensate from lost revenues, rewarding utilities with performance-based incentives. The approaches adopted by different jurisdictions may include all of them or just a combination. The involvement of utilities in the promotion of EE measures, on the other hand, is mostly done by economic or financial interest (mainly in developing countries), regulatory impositions, and as a marketing strategy.

With the restructuring of the electricity sector and with the scarcity of funds, DSM alternatives, that once were regular practice, started being put aside. Through regulation, funds are channelled to DSM activities mainly through a SBC. Besides the funds to invest in EE programmes, some countries/jurisdictions found it important to compensate utilities for the loss in sales due to successful programmes and allow them to recover revenues. Loss revenues compensation mechanisms and shareholder incentives are two very common strategies to compensate utilities for loss revenues and to stimulate them to invest in programmes that allow more savings. Of all 50 jurisdictions of which there is no doubt the existence or absence of any revenues compensation mechanism, 78% have implemented some mechanism to compensate utilities of lost revenues. There are examples where even without compensation mechanisms, utilities get involved in EE activities, such as Austria, Alaska (US), Louisiana (US), among others. For instance there are 23 out of 94 jurisdictions, corresponding to 24% of the analysed cases, where utilities adopted the implementation of EE programmes without any obligation. In several US states, energy efficiency has been seen as a resource, and EE programmes were evaluated side-by-side with supply side resources, in an IRP framework. It should be stressed that this particular method was used in a differently regulated context, prior to the sector restructuring, with vertically integrated companies and keeps being used in the new reality of the electric systems. As a matter of fact, for the jurisdictions where it was possible to assess the existence of IRP, around 69% adopted IRP, all in the North America.

Imposing the investment in EE programmes of certain amounts of money, such as in Korea and in Minnesota (US), is no guarantee that the "best" options, regarding energy savings, will be chosen. Therefore most jurisdictions impose savings targets, or impose the implementation of EE promotion measures. When imposing EE promotion by the utilities, then the costs of implementing the programmes may be considered as part of the business and, accordingly in some jurisdictions, they are included in rates, instead of being a surcharge. For the reported jurisdictions, 61% impose obligations to deliver EE programmes upon utilities, and 49% impose savings obligations. Even regarding different sets of jurisdictions, the relative number of jurisdictions that allow performance incentives to increase utilities motivation is 63%. Some jurisdictions that impose EEO do not allow performance incentives, such as Australia (all three regions studied), France, Belgium (Flanders), Poland, among others.

In some jurisdictions, EE programmes are part of portfolios, and evaluated all together. Portfolios are justified as allowing the implementation of innovative EE programmes. Innovation is usually associated to low cost-effectiveness. Being the cost-effectiveness evaluation done for the entirely portfolio, measures with higher cost-effectiveness performance can compensate for the others. However, this procedure removes some flexibility in changing the programmes to achieve the goals (case of Vermont). Also if cautions are not taken to balance the portfolio of measures, utilities may give preference to measures that allow them to obtain the obliged targets with measures in a unique sector, even with higher unit costs, and deliver to the other sectors lower cost measures.

If the parties under an obligation are not able to accomplish their target, a penalty can then be issued, or, in some countries the savings may be traded among parties. Utilities that outperform can sell energy savings to those that wouldn´t be able to reach their targets.

In Table 2-2 a summary of the main characteristics of the involvement of utilities in EE programmes, in some countries, is presented. The characterization of the US is presented in Table 2-3. In jurisdictions with IRP was considered that an ex ante evaluation was mandatory.

Table 2-2 – Main characteristics of utilities involvement in energy efficiency programmes.

Country (Region)	Mandatory involvement	Mandatory targets	Voluntary involvement	Performance incentives	Ex ante evaluation by authorities	Ex post evaluation
Argentina	No	No	-	-	-	-
Australia (ACT)	Yes	Yes	n/a	No	-	-
Australia (NSW)	Yes	Yes	n/a	No	No	Yes
Australia (South Australia)	Yes	Yes	n/a	No	No	Yes
Australia (Victoria)	Yes	Yes	n/a	No	No	Yes
Austria	No	No	Yes	-	-	-
Bangladesh	No	No	-	-	-	-
Belgium (Flanders)	Yes	Yes	n/a	No	No	Yes
Belgium (Brussels-Capital)	Yes	No	n/a	-	-	-
Belgium (Wallonia)	No	No	Yes	Yes	-	-
Botswana	No	No	-	-	-	-
Brazil	Yes	Yes	n/a	-	Yes	No
Burkina Faso	No	No	-	-	-	-
Canada (Ontario)	Yes	Yes	n/a	Yes	Yes	Yes
Canada (British Columbia)	Yes	Yes	-	-	-	-
Central African Republic	No	No	-	-	-	-
China	Yes	Yes	n/a	Yes	-	Yes
Costa Rica	Yes	No	Yes	-	-	-
Croatia	No	No	-	-	-	-
Cyprus	No	No	-	-	-	-
Czech Republic	Yes	No	-	-	-	-
Denmark	Yes	Yes	n/a	Yes	No	Yes
France	Yes	Yes	n/a	No	Yes	Yes
Germany	No	No	Yes	-	-	-
India	No	No	-	-	-	-
Ireland	Yes	No	n/a	-	-	-
Italy	Yes	Yes	n/a	Yes	No	Yes
Korea	Yes	Yes	n/a	No	-	Yes
Mexico	No	No	Yes	-	-	-
The Netherlands	No	No	Yes	-	-	-
Norway	No	No	No	-	-	-
Oman	No	No	-	-	-	-
Peru	No	No	-	-	-	-
The Philippines	No	No	-	-	-	-
Poland	Yes	Yes	n/a	No	-	Yes
Slovenia	No	No	Yes	-	-	-
South Africa	No	No	-	-	-	-
Sri Lanka	No	No	-	-	-	-
Switzerland	No	No	Yes	-	-	-

Country (Region)	Mandatory involvement	Mandatory targets	Voluntary involvement	Performance incentives	Ex ante evaluation by authorities	Ex post evaluation
Thailand	No	No	Yes	-	-	-
Uganda	No	No				
UK	Yes	Yes	n/a	Yes	Yes	Yes
Vietnam	No	No	Yes	-	-	-

n/a – not applicable; "-" – no information was gathered

Table 2-3 - Main characteristics of utilities involvement in energy efficiency programmes, in the US.

State	IRP	Mandatory involvement	Mandatory targets	Voluntary involvement	Performance incentive	Ex ante	Ex post	Lost revenue recovery
Alabama	No	No	No	Yes	No	No	No	Yes
Alaska	Yes	No	No	Yes	No	No	No	No
Arizona	Yes	Yes	Yes	n/a	Yes	Yes	Yes	No
Arkansas	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
California	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-
Colorado	Yes	Yes	Yes	n/a	Yes	Yes	Yes	No
Connecticut	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
Delaware	Yes	Yes	No	Yes	Yes	No	No	Yes
District of Columbia	No	No	No	n/a	Yes	Yes	No	-
Florida	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
Georgia	Yes	Yes	No	n/a	Yes	Yes	Yes	Yes
Hawaii	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
Idaho	Yes	No	No	Yes	Yes (pending)	Yes	Yes	Yes
Illinois	No	Yes	Yes	n/a	No	Yes	Yes	No
Indiana	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
Iowa	Yes	Yes	Yes	n/a	No	Yes	Yes	Yes
Kansas	No	No	No	Yes	Yes	Yes	Yes	Yes
Kentucky	Yes	Yes	Yes	n/a	Yes	Yes	No	Yes
Louisiana	No	No	No	Yes	Yes	No	No	Yes
Maine	No	Yes	Yes	n/a	Yes	Yes	Yes	Yes
Maryland	No	Yes	Yes	n/a	Yes	Yes	Yes	Yes
Massachusetts	No	Yes	Yes	n/a	Yes	Yes	Yes	Yes
Michigan	Yes	Yes	Yes	n/a	Yes	Yes	No	Yes
Minnesota	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
Mississippi	No	No	No	Yes	No	No	No	No
Missouri	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Montana	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
Nebraska	Yes	Yes	No	n/a	No	Yes	No	No
Nevada	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
New Hampshire	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
New Jersey	Yes	Yes	No	n/a	-	Yes	Yes	Yes
New Mexico	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
New York	No	Yes	Yes	n/a	Yes	Yes	Yes	Yes

State	IRP	Mandatory involvement	Mandatory targets	Voluntary involvement	Performance incentive	Ex ante	Ex post	Lost revenue recovery
North Carolina	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
North Dakota	No	No	No	Yes	No	Yes	No	No
Ohio	Yes	Yes	Yes	n/a	Yes	Yes	No	Yes
Oklahoma	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
Oregon	Yes	Yes	Yes	n/a	No	Yes	Yes	Yes
Pennsylvania	No	Yes	Yes	n/a	No	Yes	Yes	No
Rhode Island	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
South Carolina	Yes	No	No	Yes	Yes	No	Yes	Yes
South Dakota	No	No	No	Yes	Yes	Yes	Yes	Yes
Tennessee	Yes	No	No	Yes	No	Yes	No	No
Texas	No	Yes	Yes	n/a	Yes	Yes	Yes	Yes
Utah	Yes	Yes	No	n/a	No	Yes	Yes	No
Vermont	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
Virginia	Yes	Yes	No	n/a	No	Yes	Yes	Yes
Washington	Yes	Yes	Yes	n/a	No	Yes	Yes	Yes
West Virginia	No	Yes	No	n/a	No	No	No	No
Wisconsin	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wyoming	No	No	No	Yes	No	Yes	Yes	Yes

n/a – not applicable; "-" – No information gathered.

Sources: (ACEEE, 2012; RAP, 2011a, 2011b, 2011c, 2011d, 2011e)

It turns out, from practical experience around the world that energy efficiency fostering, driven by societal concerns does not happen spontaneously, some regulatory stimuli being necessary. The graph in Figure 2-1 is an illustration of the implicit general recognition of this conclusion, given the evidence of the decrease in DSM expenditures in the US due to the restructuring process.

The utilities promotion of EE on the demand-side is mostly done by regulatory impositions. Some flexibility could be found regarding the way utilities choose to increase the benefits of the EE programmes they run. Utilities with long experience in implementing EE programmes are investing in gathering consumer information, as much as possible, in order to be able to design the appropriate programmes. These usually require the combination of different end uses, such as lighting (several technologies), HVAC, insulation, among others, independent on the fuel, and even in cooperation between electricity and gas utilities. These approaches usually required collaborative efforts with other entities. Utilities are improving the relation utility-customer. A better relation will make easy the participation in programmes, in the E&V procedures, and as a customer retention strategy. With a good relation with customers is easier to gather information about the customer that will allow the design of new programmes intended to maximize the savings of each customer.

However, it should not be neglected that investing in energy efficiency measures, even without recovering the costs, is nowadays a practice adopted by some utilities in competitive environments, assuming a potential reduction in sales as a cost of customers' retention. The image of a utility that promotes energy efficiency, seems to be also valued as an intangible asset, once it is associated to societal objectives, valued by the public opinion. Labels such as "friend of the environment" or "organization concerned with climate change" seem to be considered as a potentially distinctive mark, a way of market positioning against competitors.

As a final remark, the importance should be stressed of a legal/regulatory framework that specifically creates the appropriate condition for utilities to foster the efficient use of energy, driven by societal objectives, ensuring their economic and financial balance as well as maintaining, or even improving, their competitiveness.

Chapter 3. Energy efficiency procurement

3.1 Introduction

As part of the regulatory practice, EE measures are subject to evaluation. This evaluation can be performed before, *ex ante*, and/or after, *ex post*, the implementation of the measures. As part of an *ex ante* evaluation, also addressed as screening, of energy efficiency measures, the most common approaches are based on additive value functions and on the California Standard Practice Manual (SPM) (CPUC and CEC, 2001).

The screening of energy efficiency measures is a procedure that allows choosing the "best" alternatives, in an *ex ante* evaluation. This is particularly important when those measures are applying for public funds, or funds paid by all energy customers. The previously called "best" options are obviously dependent on the objectives that drive the choice and the criteria behind the selection. IRP and EEO are two important "mechanisms" that lead utilities and other responsible parties in the search for the "best" alternatives.

The "best" DSM alternatives are only called so if they detach themselves from others, attending a set of criteria. Some of the screening criteria may include (IEA/DSM, 1996): "option fit with core competency and role of organization, lead time before profitability, opening of new markets, pollution reduction, broaden product/service mix, transferability to other customers, compliance with regulations and standards, positive long-term development, impact on product quality, competition-customer retention/attraction, competitive advantage, capital requirements, payback, product/market positioning, synergies with other options, risk reduction, security/reliability of service, expected market size/share, compatibility with strategic corporate goals, improvement of company image, customer satisfaction, and resource needs".

In an additive value function, an intuitive assessment method, of widespread use, after the selection of the screening criteria, a weighted factor is assigned to each criterion, which reflects its relative importance for the utility and/or government objectives. A typical classification interval is 1-10, or 1-100, with the highest scores applied to the criteria that closer reflect the pursued objectives. The result of the multiplication of the criteria weights by the performance value assigned to each alternative are added resulting in the overall performance of the alternative. Alternatives are then ranked from the highest to the lowest in accordance with the overall performance values.

When screening among a large number of alternatives, detailed procedures as the one described may be useful for the selection of the measures. The additive value function approach usually provides transparency to the priorities and to the results.

The other most common approach to screen EE measures is based on the SPM tests. According to the SPM, the cost-effectiveness of each EE measure should be evaluated on four/five different perspectives (see Annex A). The perspectives suggested by the SPM are reflected in four/five different tests: the Participant test, the Ratepayer Impact Measure test, the Total Resource Cost test (that has a variant called the Societal test), and the Program Administrator test (formerly designated Utility Cost test). Although the SPM recommends the use of all perspectives in order to evaluate the cost-effectiveness of an EE alternative, it is common to see some authorities basing their decision in only some of the perspectives, or even in only one perspective.

The regulatory practice does not seem to have adopted yet structured approaches such as the ones in (Neves et al., 2009), or in (Vashishtha and Ramachandran, 2006).

Under EEO and IPR utilities are required to procure all cost-effective efficiency resources ("an efficient procurement requirement" (Sciortino et al., 2011)) to be able to meet their energy efficiency targets. When comparing demand-side to the supply-side options, analysing the cost-effectiveness of the programmes is of particular importance, both for comparing and for ranking the options. Usually the most successful energy efficiency programmes implemented by utilities are those that are part of a resource plan. Several US states are obliged to procure all cost-effective demand-side resources before choosing any supply-side alternatives. This turns it easier to compute cost-effectiveness, evaluate results, and justify the programmes (IEA, 2010a).

The focus of this chapter is on the procedures adopted for screening or selecting measures/programmes, mainly in the criteria and weights, if used. In section 3.2 a brief description of the procedures for the selection of measures adopted in the US are presented. Procedures adopted by some countries under the EEO are presented in section3.3. Other examples found in the literature are presented in section 3.4.

3.2 Procurement strategies of US states

3.2.1 California procurement strategy

Energy efficiency programmes to be fund by SBC are subject to a set of rules, initially in the document approved by the Commission, "Adopted Policy Rules for Energy Efficiency Activities". These rules were then replaced by the "Energy Efficiency Policy Manual" (EEPM) that counts four versions. According to versions 1, from 2001 (CPUC, 2001), and version 2, from 2003 (CPUC, 2003), the EE programme proposals are ranked in accordance with their performance following a set of criteria, each of them having a maximum possible score. The maximum possible scores sum up to 100 points. In both versions of the EEPM, each programme is evaluated individually and then by portfolio. More recently, following versions 3 (CPUC, 2005) and 4 (CPUC, 2008), each program administrator must present a portfolio of programmes that will meet or even exceed the savings goals set by the Commission. Instead of evaluating each programme individually, in these two versions, the cost-effectiveness is evaluated for the entire portfolio. The portfolio evaluation enables innovation and some risk-taking in pilot programmes in the portfolio, allowing the existence of programmes that, if evaluated individually, would be rejected. Versions 2 and 4 will are briefly presented in Annex B and C, respectively. The version 2, although not presently in place, is presented due to some similarity in with the Portuguese PPEC programme, in the use of an additive value function to evaluate the measures, and also to present a significant change in the screening procedures that was made from this to the version 4 of the EEPM.

In version 2, the programmes could be divided in (1) PGC “hardware” and Incentives Programs and (2) Information-only and Statewise marketing Outreach Programs. The programmes are evaluated in accordance with two sets of criteria: the Primary criteria and the Secondary criteria.

The Primary set of criteria for the first type of programmes in presented in Table 3-1, and for the second type of programmes in Table 3-2, with the weights assigned to each criterion.

Table 3-1 - The Primary criteria for the first group of programmes and their weights.

Criterion	Weight
Cost-effectiveness	30 points to the programme net benefits, and 10 points for the BCR
Long-term annual energy savings	15 points
Electric peak demand savings	15 points
Equity	10 points
Ability to overcome market barriers	5 points
Innovation	5 points
Coordination with programs run by other entities	5 points

To evaluate the cost-effectiveness of the programme, the Societal version of the TRC test and the Participant test were performed.

Table 3-2 - The Primary criteria for the second group of programmes, and their weights

Criterion	Weight
Ability to overcome market barriers	25 points
Equity	25 points
Innovation	25 points
Coordination with other program implementers	25 points

The Secondary set of criteria (Table 3-3) has not the purpose of selection the measures, but intends to ensure that the contractor, who will implement the measure, has the necessary conditions to do it.

Table 3-3 - The Secondary criteria used for both kinds of programmes.

Criterion	Weight
Quality and viability	30 points
Distribution and reasonableness of budgets	20 points
Programme objectives and tasks clearly identified	20 points
Experience with successful delivery of similar programmes	20 points
Alleviates transmission constraints in an area identified by the California Independent System Operator	10 points

The steps of the screening process that will evaluate each programme and suggest the design of the portfolio are:

- Apply the primary and secondary sets of criteria to each proposed programme;
- The programmes will be ranked in accordance with their scores on the primary set of criteria; as a result, a shorter list with the proposals with the highest scores is created;
- The programmes in the second list will then be ranked in accordance with the resulted score from the combination of the primary and secondary scores;
- The portfolio results from the combination of those programmes, from top to bottom, respecting the available budget.

In version 4 of the EEPM, the CPUC returned to the use of the SPM tests, since the Commission no longer considers a set of criteria, as before with the additive value function approach, and started using the TRC and PAC tests, a procedure which is designated "Dual-test". Any proposal that passes both tests allegedly proves that no more money is spent with incentives and rebates than the necessary. The TRC test is the primary test.

3.2.2 Other US states

Besides the California, whose EE screening procedure was detailed in the previous sections, other states have implemented procedures to select EE measures/programmes to be funded by a SBC. Most of them also use the tests from the SPM to assess the cost-effectiveness of the proposed programmes. Some states use the tests with some modifications. A brief description for other US states is presented in Annex D.

In this section a summary table with the cost-effectiveness tests used can be found. The information regarding modifications in some of the tests is not reflected in Table 3-4.

Table 3-4 – Summary table with cost-effectiveness tests used by several US states.

State	Participant test	RIM test	TRC test	Societal test	PAC test	Other
Arizona				Y		
Arkansas	Y	Y	Y		Y	
Colorado			Y			
Connecticut			Y		Y	
District of Columbia				Y		
Florida	Y	Y	Y			
Georgia		YY	Y	Y		
Hawaii	Y	Y	YY	Y	Y	
Idaho	Y		YY		Y	
Illinois			Y			Y
Indiana(1)	Y	Y	Y		Y	
Iowa	Y	Y		Y	Y	
Kansas	Y	YY	YY	Y	Y	
Kentucky	-	-	-	-	-	-
Louisiana (2)			Y			
Maine				Y		
Maryland	Y	Y		Y	Y	
Massachusetts			Y			
Michigan					Y	
Minnesota				Y		
Mississippi	-	-	-	-	-	-
Missouri			Y			
Montana				Y		
Nebraska	Y	Y	YY		Y	
Nevada			Y			
New Hampshire			Y			
New Jersey(3)			Y	Y		
New Mexico			Y			
New York			Y			
North Carolina	Y	Y	Y		Y	
North Dakota	(Y)	(YY)	(Y)	(Y)	(Y)	
Ohio			Y			
Oklahoma	(Y)	(Y)	(Y)	(Y)	(Y)	
Oregon				Y		Y
Pennsylvania			Y			
Rhode Island			Y			
South Carolina	-	-	-	-	-	-
South Dakota		Y	YY			
Tennessee		Y	Y		Y	
Texas					Y	
Utah	Y	Y	Y		Y	
Vermont				Y		
Virginia	Y	YYY	YY		Y	
Washington			Y			
Wisconsin			Y			
Wyoming			Y			

- "Y": the test is required. The number of "Y" in each cell denotes the degree of importance given to the test; "()": there is no preference on the tests to perform; "-": no particular tests are required.
- (1) Source: 170 IAC 4-7-7 (IAC, Not dated); (2) No regulation establishes the tests to use, but the City of New Orleans considers the TRC test; (3) According to RAP (RAP, 2011c), they were unable to confirm this information.
- Sources: (RAP, 2011a; 2011b; 2011c; 2011d; 2011e; ACEEE, 2012).

There seems to be a preference for the TRC test, possibly due to the potential of applicability to conservation, load management and fuel substitution programmes. On the other hand, this test to combine the costs and benefits of both the Participant and the RIM test. While the information in Table 3-4 reflects the main characteristic of the test performed in each state, each test does not necessarily follow exactly the test as defined by the CPUC and the California Energy Commission (CEC).

In some states, weights are used to differentiate the importance that the Commissions assign to each test.

3.3 Procurement strategies of some countries under EEO

Under EEO schemes the procedures for the selection of EE measures vary from country to country. There are countries, such as UK and Australia (South Australia state), that offer a list of preapproved EE measures, each of them with assigned deemed energy savings values. These deemed values are usually assigned to simple EE measures and result from estimates of the savings typically achieved by the measure. These deemed values contribute to the reduction of the transaction costs of implementing EE measures. Other countries, such as Belgium (Flanders region), and Australia (New South Wales state), accept any EE measure and use procedures to compute the energy savings in a case-by-case basis. Countries like, Italy, France, Denmark, and Australia (Victoria state) have a list of EE measures, but also accept other measures (RAP, 2012).

3.3.1 Belgium

As of 2012, in Flanders, Belgium, the DNO are no longer under the obligation of meeting savings targets, but have to implement “action obligations” set by the Flemish government. Some of the measures that were implemented since the beginning of the EEO obligations were referred to in chapter 2, section 2.6 (RAP, 2012).

3.3.2 Canada

In Ontario, Canada, the distributors’ strategies for meeting their targets are subjected to approval. The “Ontario Power Authority Cost-effectiveness Tests” define the tests that the distributors are required to use for portfolio evaluation: the TRC and the PAC. For both, the results must be expressed as a BCR (OEB, 2012).

3.3.3 Denmark

In Denmark, distributors are obliged to reach energy efficiency targets. A catalogue of more than two hundred EE measures with deemed savings values is available for the distributors. The deemed saving values are the result of estimates of the savings based in the experience from previous implementations and/or in engineering calculations. The selection of the programmes to be implemented is made by the utilities, without any need for approval. All measures implemented are then reported by the utility, with the savings obtained, based on the deemed values available (RAP, 2012).

3.3.4 France

In France the savings obligations on retail companies have at their disposal a set of standard measures (proximately 180 (Bertoldi et al., 2010)). As was reported in 2009, the utilities preferences were to only a few of them: individual efficient boilers, collective efficient boiler, heat pumps, thermal insulation, and windows. The reason could be the eligibility of the measure for the tax credit for household energy efficiency. This highlights that suppliers directed their programmes to take advantage of other existing support scheme (Eyre et al., 2009; Bertoldi et al., 2010).

3.4 Procurement strategies in other countries

3.4.1 Brazil

ANEEL has imposed of maximum values for the cost-benefit ratio of the measures: 0.8 for most projects and 1.0 for public lighting (Taylor et al., 2008). Some proposals require a detailed initial evaluation, such as pilot-projects, supply-side projects (such as peak clipping, load shifting, and new tariff structures that stimulate consumer change of behaviours) educational projects, energy management projects, including municipal energy management. Projects with a cost-benefit ratio above 0.8 and considered highly relevant will be submitted to a simplified initial evaluation. Highly relevant projects, under ANEEL criteria, are projects with societal and environmental relevant impact, or that present important contributions for MT, encouraging the development and use of new technologies and the adoption of more energy efficient consumer behaviours. Some other projects do not need any initial evaluation. Some examples are projects for which the utilities have already a long experience, and those whose main actions are related with the replacement of light bulbs, refrigerators, electrical showers, air-conditioning split, chillers, and motor drive systems (ANEEL, 2008).

3.4.2 Nepal

In Nepal, in a study to identify the most cost-effective technologies/areas for DSM, several experts were consulted in a procedure used as a screening methodology to select DSM programmes. The consultation was informed with the results of gathering and analysing several documentation and opinions from stakeholders. Only after this consultation process a cost-benefit analysis was made (Yang, 2006).

The screening criteria and weights for those criteria were established during rounds of discussion with the Nepal Electricity Authority (NEA) staff members. Fifteen questionnaires were then distributed to 15 experts. With the results of the questionnaires it was possible to compute the average scores for each criterion in order to rank the set of DSM alternatives. The three more promising and suitable ones were then subject to a cost-benefit analysis and to an assessment of implementation impact (according to a few established scenarios) (Yang, 2006).

3.4.3 Latvia

In Dzene et al. (2011) a screening procedure is described to select measures to contribute to the reduction of the environmental negative externalities of a regional energy system. In a step-by-step approach, the steps of the procedure are:

- List the possible options of improvements in different parts of the regional energy system;
- Select and list the assessment criteria;
- Set the weights and the scoring system;
- Compute the total scores, and
- Rank the options in accordance with their performance.

The screening criteria and their weights were set as the result of a consultation with experts, with a procedure similar to the one described for Nepal (section3.4.2). The scores to be assigned to each alternative, for each criterion, were integer numbers between -2 and +2, where the -2 is the worst negative impact among the alternatives and +2 the highest positive impact of the alternative, regarding the criterion. To compute the total scores of each measure, an additive value function was used.

3.4.4 India

The Maharashtra Electricity Regulation Commission uses as cost-effectiveness criteria to assess DSM programmes the TRC test, the RIM test and the Life-cycle revenue impact (LRI_{RIM}). Under this LRI_{RIM} test, the tariff increase should not be higher than Rs. 0.01/kWh or above 0.1% of the existing tariff.

The screening procedure is accomplished in accordance with the following steps:

- All DSM programmes whose NPV of the TRC is above one, are evaluated with the RIM tests. The others are excluded;
- All programmes that have a positive value for the NPV of the RIM should be implemented;
- The programmes that do not have a positive result under the RIM test, but whose tariff impact is lower than the highest value between Rs. 0.01/kWh and 0.1% of the existing tariff, should be implemented.

3.5 Conclusions

In this chapter several procedures adopted by some countries to procure EE measures were briefly presented. In North America the procedures are mainly supported on the cost-effectiveness tests developed by the CPUC. In some states only a single test is used, in others all of them. Some states impose no distinction on the results of the different tests, regarding the cost-effectiveness of a programme, while others weight some tests more than others. In general, the TRC test is the one most frequently found as the preferred cost-effectiveness test. In all this cases, the states Commissions or other authorities have to approve the measures/programmes or portfolios of programmes. In California the use of an additive value function was abandoned after some years to return to the exclusive use of the SPM tests, although in a short-form version. In fact instead of using all five tests, CPUC just relies on two, arguing that these (TRC and PAC) are enough to ensure that no more than the necessary money is spent in EE promotion campaigns. In the Maharashtra region of India, for example, the TRC and the RIM tests are used, being the TRC the primary test.

In some other countries with EE obligations, there is no selection of EE measures by the authorities. The obliged parties usually choose the EE measures from a catalogue of previously approved measures and implement them, ensuring that they meet their target. In some countries, the portfolios of each company can be implemented without any need of approval, while in others the approval is mandatory. The results are then reported and can be confirmed by the authorities.

In Brazil the cost-benefit ratio is the main criteria and a threshold for acceptance of the programme was set. For very common projects, that respect the cost-benefit ratio threshold, no evaluation is necessary, while other projects, that are considered highly relevant, need a detailed evaluation.

Both in Latvia and in Nepal, the selection is subject to a set of criteria that results from consultation with experts.

The process of assigning preferences seems to be the result of subjective reasoning, usually supported by the experience of experts that reflects the result of the interests and convictions in a moment, usually before the measures/programmes are known.

Nevertheless, most of the countries/jurisdictions, studied, are relieving the selection process, through the suggestion of a set of pre-approved measures or through the use of fewer criteria to evaluate the EE alternatives. That will certainly require extra care if societal interests are to be safeguarded.

Chapter 4. Portuguese utilities involvement in the promotion of EE

4.1 Introduction

In 1998 the first regulatory framework that fosters the involvement of electric utilities in the promotion of EE on the demand-side was approved.

An ordinance from 2002 states that the Energy Services Regulatory Entity (ERSE) should, among other things, contribute to the improvement of the technical economical, and environmental conditions, stimulating the adoption of behaviours that contributes to a more efficient use of energy with environmental concerns. The restructuring of the electricity market, together with regulatory evolution, has fostered the improvement of the supply-side efficiency. However, there are barriers that hampers the increase of the efficiency in the demand-side, namely the promotion of EE on the demand-side by electric utilities (DR, 2008).

Under the Kyoto Protocol, Portugal assumed the commitment to limit the increase of GHG emissions in 27% of the 1990 amount for the 2008-2012. The Portuguese Climate Change National Plan (PNAC) quantifies the national effort in the context of diverse policies and measures over all activity sectors. The PNAC assigned to the ERSE, the development of mechanisms for the promotion of energy efficiency in the demand-side, with the main goal of the reduction of electricity consumption by 2010 (ERSE, 2010).

A national strategy for energy, promotes, among others, energy efficiency in both the supply- and demand-side. Among several strategies, the fourth guideline - *Energy Efficiency Promotion* – that establishes several measures to be adopted, such as the *Promotion of energy efficiency policies by electricity suppliers* and *Fund energy efficiency promotion actions*. In this framework was approved the National Energy Efficiency Action Plan (PNAEE): Energy Efficiency 2015. The PNAEE sets a 2015 target to achieve through energy efficiency measures an improvement of 10% in energy final consumption.

In 2009, the European Directive n.º 2006/32/EC on energy end-use efficiency and energy services turned into national law. Under this law a 9% target of energy savings until 2016, is set to be achieved through the implementation of an action plan for energy efficiency improvement. These savings target will receive the contribution of the PPEC.

In 2010 the National Strategy for Energy 2020 (ENE 2020) was established. This strategy sets the savings target of 20% in energy final consumption by 2020, highlighting the contribution of behavioural and tax measures, innovative projects, mainly electric vehicles and smart girds, distributed generation based on renewable sources and the optimization of public lighting models and of energy management in public buildings, households and services.

The regulatory frameworks for the involvement of electric utilities in the promotion of EE measures under the Demand-Side Management Plans framework (section 4.2) and under the Demand-Side Efficiency Plans (section 4.3) are presented. Section 4.2 and 4.3 provide information of the regulatory framework, and its evolution, concerning the promotion of energy efficiency promoted by utilities. The characterization of the involvement of electric utilities in the promotion of EE in Portugal under both programmes is addressed in section 4.4.

4.2 Demand-Side Management Plans

The tariff regulation code approved in 1998 *(Despacho n.º 16 288-A798,* 15th of September) established that the costs associated to demand-side projects, are to be included in the revenues from the tariffs applied to electricity consumption. This methodology was first applied in the first regulatory period, between 1999 and 2001. The Tariff regulation of 2001 (DR, 2001), imposed that supply tariffs of the public electricity system provided revenues that should include reimbursement of the costs associated to demand-side programmes, as well as 50% of the associated benefits. The public electricity distributors were required to present Demand-side Management Plans (PGP - *Planos de Gestão da Procura*) for each year of the regulatory period. These PGP contained a set of measures to promote EE in consumption that should be implemented in each year of the regulatory period. These rules were applied in 2002-2004 and 2005. Due to uncertainties regarding the regulatory evolution following the reform of the electricity sector, the PGP was maintained only during 2005, as a transitory period. The measures could target residential consumers, services sector, industrial consumers, or public lighting. For the selection of the measures for the residential and services sector, the potential for consumption reduction and the improvement of the load diagram, were the criteria used. For the residential sector measures that promoted the use of more energy efficient freezers and refrigerators, CFLs, and heat accumulators were allowed. For the services sector, measures such as electronic ballasts and efficient lamps, power factor correction, and heat pumps were the ones accepted. In public lighting, measures to change lamps and lamp fixtures were suggested. For industrial consumers measures were privileged that regarded EE improvement in motors, since 75% of electricity consumption is estimated to be due to electrical motors and drives. The allowed measures involved high efficiency motors, variable speed drives, and power factor correction. Besides these tangible measures, intangible measures were also allowed, that did not address any particular equipment, but were more global, addressing the way energy is consumed, such as information campaigns, training, and characterization studies (ERSE, 2009a) (ERSE, Not dated).

4.3 Demand-Side Efficiency Promotion Plan (PPEC)

Several circumstances such as the existence of barriers to the acquisition of efficient equipment and to more energy efficient habits by consumers, as well as environmental externalities not reflected in the energy prices, hamper the improvement of energy efficiency. These circumstances justify the implementation of measures that promote efficiency in energy consumption as well as stimulate energy efficient products and services. Among the market barriers to the implementation of energy efficiency, highlighted in the regulatory framework from 2008 (hereafter 2008 Rules) are: long return on investments periods, the difference between the supply prices, or the applicable tariffs, and the short-term marginal costs, externalities, lack of information and high associated transaction costs, misaligned interests between actors, and financial restrictions of customers (DR, 2008) .

Under the regulator statutes (*Decreto-lei n.º 97/2002, de 12 de Abril*) there is the obligation to improve the environmental performance of companies in the energy sector and to contribute to a more efficient use of resources, which led ERSE to launch the Demand-Side Efficiency Plan (PPEC). PPEC rules were published in 2006 (*Despacho n.º 16 122-A/2006, de 3 de agosto*) and improved two years later, in 2008 (*Despacho n.º 15 546/2008, de 4 de junho*). Some improvements were made in 2010, under the same regulatory framework.

Restricted to electricity, PPEC has the objective of promoting measures intended to improve efficiency in electric energy consumption, through actions taken by electricity suppliers, distribution and transport network operators, consumer organizations, business associations, energy agencies, higher education institutions, and R&D institutions. These actions target energy customers from different sectors, and are subjected to a selection procedure, whose criteria and corresponding weights are defined in PPEC rules. The plan is implemented through a tender mechanism that allows the selection of the “best” EE measures to be implemented by their promoters, and partially funded by PPEC’s budget.

The measures proposed to this mechanism should promote the reduction in electricity consumption or load management (LM) actions, on a permanent and accountable basis. The energy consumption reduction effect of the measures must not have been accounted for in any other specific measures. Information disclosure measures may qualify, even not having accounted for impacts, they may promote more rational behaviours and awareness and allow more informed decisions regarding the adoption of more energy efficient solutions. It is expected that the benefits of these actions remain long after the measure itself, therefore it is important to reach as many customers as possible in order to increase the spill over effect of the incentives.

Since PPEC budgets are limited, the approved measures should be those that probably would not be implemented without the incentive given by PPEC, contributing to eliminate a market barrier.

Regarding the type of promoters, there are two different tendering. One of them allows measures proposed by all types of promoters, and the other only allows promoters that are not electric utilities. This distinction allows other actors to enter the tender, not included in the electricity sector, increasing the number of winning proponents. On the other hand, many of the proponents are regional institutions, with greater proximity to customers and to a different target audience that can be reached with companies that act at a national level. Each non-utility promoter must choose between the two tenders. In order to allow a larger number of actors involved, two restrictions were imposed: the maximum amount allowed to each candidate measure is one sixth of the total budget in that tender, and each promoter can only have two winning measures. Tenders for entities that are not electricity sector agents were created by the 2008 rules. Other restriction was also created by the same regulatory framework, but regarding the tender for all promoters, setting the maximum amount to finance a measure to one third of the budget of the respective tender. Before, there was no limitation.

In the tender for all promoters, the main goal is to maximize the economic benefits. In the tender for non-utilities some restrictions are imposed in order to value more the spill over effect and the share of the benefits, reducing the value of the economic benefit and the possible hoarding of the available funds.

There are two types of measures: Tangible or “hard” and Intangible or “soft” measures. The tangible measures are the ones that are related to the installation of equipment with energy efficiency levels above the market standard. Intangible measures are those related to the disclosure of information regarding an efficient use of electricity aiming at more energy efficient consumer behaviours. Some examples of intangible measures are training courses, information disclosure campaigns, and energy audits.

Tangible measures are classified by consumer segment. The financial incentive is divided among segments, ensuring that all consumer segments can receive incentives from PPEC. On the other hand, since the financial incentives of PPEC come from a SBC paid by all electric energy customers, is important to ensure that all customers may benefit from the measures funded by PPEC. The consumer segments are Industry and agriculture, Commerce and services, and Residential. Tangible measures in the tender for all promoters are ranked within the consumer segment they are addressed to. The result will then be three ranked lists of measures, one for each consumer segment. In the tender for non-utilities, the measures are not separated by consumer segment. The result will be a single list with the measures addressed to the consumer segments. Intangible measures are ranked in each tender, resulting in two more lists of measures. In all lists measures are ranked in decreasing order of merit. The total costs of intangible measures can be financed by PPEC. The 2008 rules imposed a limitation for tangible measures, where only eighty per cent of the total cost of the measure can be paid by PPEC.

The two tenders are presented in Figure 4-1, with the type of measure in each tender and the consumer segment for each type of measure, resulting in six different tenders.

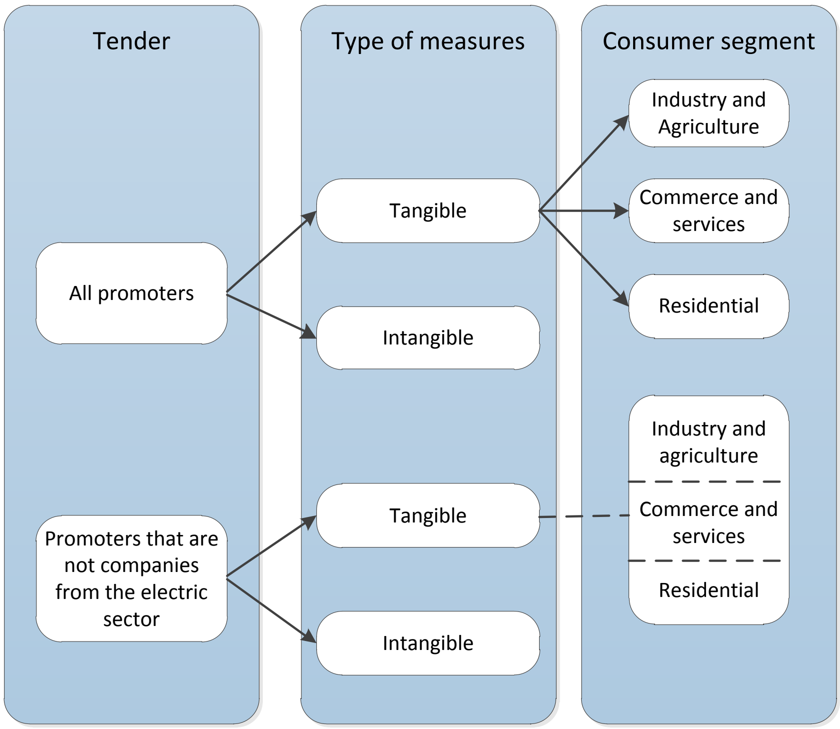


Figure 4-1 – Tenders, type of measures, and consumer segments in PPEC (adapted from (ERSE, 2010)).

The PPEC calls for proposals are a biennial event, where intangible measures can have an implementation period of one or two years and the tangible ones must be implemented in two years. This was a change introduced by the 2008 rules. Previously, the measures could be implemented for a period of up to three years. Once the calls were annual, this was inconvenient because measures from three different PPEC editions could coexist in the same year.

4.3.1 Ranking measures methodology

The methodology adopted by the regulator for ranking the measures intends to select those measures that, among other characteristics, present higher economic profitability, are accessible to a large diversity of consumers and have innovative characteristics. Thus, a set of criteria were selected to reflect those objectives. Tangible and intangible measures are subject to different sets of criteria.

4.3.1.1 Tangible measures

The ranking of tangible measures is done within each consumer segment. Each consumer segment has its own budget, limiting the sum of the cost of the selected measures.

Only tangible measures with a positive NPV, from a societal perspective, will be accepted in the tender. In other words, only measures that pass the societal test are eligible.

The performance of the measures approved in the societal test will then be computed with an additive aggregation model with a set of criteria valued differently. In Table 4-1 the criteria and their weights for all four calls for proposals are presented.

Table 4-1 – Ranking criteria for tangible measures for all four PPEC calls.

	Weights	
Criteria	**2007 and 2008**	**2009-2010 and 2011-2012**
Benefit-Cost Analysis	50 points	60 points
1. Proportional benefit-cost ratio	(25 points)	(40 points)
2. Ranked benefit-cost ratio	(25 points)	(20 points)
Scale risk	10 points	10 points
Weight of the investment in equipment in the total cost of the measure	10 points	10 points
Quality of presentation	5 points	7 points
Ability to overcome market barriers and spill over effect	5 points	5 points
Equity	5 points	4 points
Innovation	5 points	2 points
Promoter experience in similar programs	-	2 points
Energy savings sustainability	10 points	-

Sources: (ERSE, 2007a, 2007b, 2009b, 2010)

The higher Benefit-Cost Ratio (BCR) will be used if two or more measures get the same overall performance value. The measure with the higher BCR will be better placed in the ranking list.

Societal test

The NPV from the societal perspective is an indicator of the societal value of the measure. A NPV above 0 is a screening criterion for a measure to be eligible to the tender. The NPV is computed according with the following expression:

$$NPV = \sum_{t=0}^{n} \frac{B_{S_t} - C_{S_t}}{(1+i)^t} \quad (4.1)$$

Where:

B_{S_t} – Total benefits from the societal perspective associated to the EE measure in year *t*;

C_{S_t} – Total costs from the societal perspective associated to the EE measure in year *t*;

i – Discount rate;

n – Lifetime, in years.

The benefits, from the societal perspective, are the sum of the environmental benefits with the avoided supply costs. The societal costs include the financial costs incurred by the participant customers, by all electric energy customers (financed through PPEC), by the promoters or any other entities.

Criteria

The set of criteria to evaluate tangible measures comprises two different types of criteria, addressed as metric and non-metric criteria. The non-metric criteria are related to characteristics of the measures that are not directly quantifiable, and the metric criteria, on the other hand, are associated to quantifiable characteristics of the measures. The metric criteria are the *benefit-cost analysis*, the *scale risk* and the *weight of the investment in equipment in the total cost of the measure*. On the first two calls, in 2007 and 2008, the *energy savings sustainability* was also a metric criterion. The remaining are non-metric criteria: *quality of presentation*, *ability to overcome market barriers and spill over effect*, *equity*, *innovation*, and *promoter experience in similar programs*.

Benefit-cost analysis

The *Benefit-cost ratio* (BCR) is used to evaluate measures with different investments amounts and lifetimes. The BCR is calculated using the following equation (ERSE, 2010):

$$BCR = \frac{\sum_{t=0}^{n} \frac{B_{S_t}}{(1+i)^t}}{\sum_{t=0}^{1} C_{PPEC_t}} \tag{4.2}$$

where

B_{S_t}- Total benefits, from a societal perspective, regarding the EE measure, in year *t*;

C_{PPEC_t}- Total costs, from the programme point of view, regarding the EE measure, in year *t*;

i – Discount rate;

n – Equipment lifetime.

This allows distinguishing measures according to their economic benefit by unit of investment from PPEC. The BCR relates the current value of the benefits with the current value of the investment and exploration costs.

The costs must be computed under the PPEC perspective: costs incurred by the participants, by the promoters or any other entity are not considered. Only the costs financed by PPEC and initially incurred by the promoter are eligible.

This criterion has two components: the proportional BCR (pBCR) and the ranked BCR (rBCR). For the proportional BCR the score results of the relative importance of each measure's BCR to the maximum BCR value multiplied by the weight of the criterion (40 points for the last two calls), according to the following expression:

$$pBCR_m = 40 \times \frac{BCR_m}{BCR_{max}} \tag{4.3}$$

Where:

$pBCR_m$ – Proportional BCR of measure *m*;

BCR_m – BCR of measure *m*;

BCR_{max} – Maximum BCR value in the list of measures.

The rBCR intends to capture only the rank order of each measure in a BCR based ranking list. The total weight of this criterion (20 points in the last two calls) will be equally divided in as many scores as the number of eligible measures. The score of measure *m* is computed using the following expression:

$$rBCR_m = 20 \times \left[1 - (k-1)\frac{1}{n}\right] \tag{4.4}$$

Where:

$rBCR_m$ – Ranked BCR of measure *m*;

k – Ranking position of measure *m*;

n – Number of measures.

Depending on the number of measures in each consumer segment the impact of the rBCR will be different. The impact will be higher for a small number of measures in the consumer segment. On the other hand, if the number of measures is very high this index will have a very small contribution to distinguish the different measures.

Scale risk

The S*cale risk* criterion is used to evaluate the change in unit costs of each measure regarding its implementation success, giving priority to measures that present lower fixed costs. This criterion is measured by a Sensitivity Index (SI) to the variation of costs with the number of interventions considered in the measure:

$$SI = \left(\frac{FC + \sum_{i=1}^{m} VC_i}{FC + \sum_{i=1}^{n} VC_i}\right) - 1 \tag{4.5}$$

Where:

FC – Fixed costs, financed by the programme;

VC_i – Variable unit costs of intervention *i*, financed by the programme;

m – Number of interventions given in the application;

n – Half the number of interventions given in the application.

The Scale risk performance of measure *m* (SR_m) is computed using the following expression, considering that the weight of this criterion is 10 points:

$$SR_m = 10 \times \frac{SI_m}{SI_{max}} \tag{4.6}$$

Where:

SI_m – Sensitivity index of measure *m*;

SI_{max} – Maximum value for the sensitivity index within the set of eligible measures in the consumer segment.

Weight of investment in equipment in the total cost of the measure

The criterion *Weight of investment in equipment in the total cost of the measure* intends to reward those measures that favour the investment in more efficient equipment over indirect and administrative costs. This criterion is measured by the Direct Investment Index (DII) according to the following:

$$DII = \frac{K}{C} \tag{4.7}$$

Where:

K – Amount for the purchase of equipment, financed by the programme;

C – Total cost of the measure, financed by the programme.

The performance of measure m in the *Weight of investment in equipment in the total cost of the measure* criterion (WIE_m), worth 10 points, is obtained by the relative importance of the direct investment index of measure m (DII_m) in relation to the maximum values among the list of eligible measures:

$$WIE_m = 10 \times \frac{DII_m}{DII_{max}} \tag{4.8}$$

where

DII_m – Direct investment index value for measure m;

DII_{max} – Maximum DII values of the eligible measures in the consumer segment.

The appreciation of the non-metric criteria is a qualitative one that results from the analysis of the applicant measures regarding a set of established expected characteristics. In order to increase the transparency in the classification process and to better reflect the objectives behind the criteria in each appreciation, the regulator defined a classification pattern for each criterion with two scoring approaches. In some cases application of the criterion is a simple compliance verification: the score is either the maximum or zero. In other cases there are more than two alternatives. If there are three alternatives, then the score may either be the maximum value, half the maximum, or zero.

From the first PPEC call for proposals to the last, an effort has been made to make this procedure more transparent, reducing the subjectivity in the appreciation process.

In the following, the objectives behind each criterion will be presented briefly, without details regarding the appreciation process.

Quality of presentation

Under this criterion appreciation is made of the clarity, the objectivity in the description, the justification for the proposal, and the informative part of the applicant proposal.

Ability to overcome market barriers and spill over effect

This criterion intends to value those measures that contribute to eliminate some of the market barriers, to spill over its effects, and to change consumers' behaviours regarding electric energy use. It also values measures that address market segments with larger market failures, such as info-exclusion, and low income customers.

Equity

Since PPEC funds are raised from all electric energy ratepayers, applicant measures should be as much comprehensive as possible and should not discriminate between consumers, namely regarding geographic location. Other equity assurance criteria such as information disclosure procedures, non-discrimination of brands or suppliers, will also be considered in the appreciation under this criterion.

Innovation

The appreciation under this criterion is made by comparison with those EE measures that are more usually implemented. Additionally, this criterion intends to compensate innovative measures of the usually higher costs associate to innovative aspects, due to a probably non-existent market and to more expensive procedures of design, monitoring, and verification.

Promoter experience in similar programs

The success of the promoters and their partners in similar programmes is valued, since these previous experiences carry the expectation of success for the applicant proposal.

4.3.1.2 Intangible measures

As for the tangible measures, intangible ones are ranked according to a set of criteria and their weights, with the overall performance value obtained through an additive aggregation model. The criteria used to evaluate intangible measures are the same non-metric criteria used to assess tangible measures, addressed in the previous section, although some differences in the allocation of score may exist.

Table 4-2 presents the criteria and the weights used in the PPEC editions so far.

Table 4-2 - Ranking criteria for intangible measures for all four PPEC calls.

	Weights	
Criteria	**2007 and 2008**	**2009-2010 and 2011-2012**
Quality of presentation	20 points	25 points
Ability to overcome market barriers and spill over effect	20 points	31 points
Equity	20 points	20 points
Innovation	20 points	12 points
Promoter experience in similar programs	20 points	12 points

Sources: (ERSE, 2007a, 2007b, 2009b, 2010)

The lower PPEC cost of the measures will be used if two or more measures have the same overall performance values.

4.3.1.3 Overall performance value

The overall performance value (OP) is calculated through an additive aggregation model. In other words, the OP value of each measure corresponds to the sum of the performances of each measure under each criterion, multiplied by the weight of that same criterion, resulting in a list of measures ranked by decreasing order of the OP.

The selected measures will be those, starting from the top of the ranking list until the last one within the budget provision. The last measure may have to be resized to comply with the available budget.

4.4 Utilities participation in the PGP and PPEC editions

4.4.1 Demand-side management Plans (PGP)

The PGP was applied to the only electricity supplier. Although tangible measures were allowed, only intangible ones were implemented (Table 4-3).

Table 4-3 – Number of promoters, number and costs of the measures implemented in the PGP of 2002-2004 and 2005.

	2002-2004	2005
Number of promoters	1	1
Number of measures (Intangible)	12	11
Total cost of the measures (millions of euros)	1.1	2.4

Source: (ERSE, 2007b)

The type and the costs of the PGP implemented measures are presented in Table 4-4. The EE studies implemented were mostly characterization of consumers and networks, and ownership and utilization of electric equipment in the service sector.

Table 4-4 – Type and costs of PGP implemented between 2002 and 2005 (costs in thousands of euros).

Measures	2002	2003	2004	2005
EE studies	205	325	164	449
Promotion of EE equipment	41	36	130	120
Disclosure of information on Rational Use of Electric Energy	34	83	0	1812
Others	24	0	0	0
Total	**334**	**443**	**295**	**2381**

Source: (ERSE, Not dated)

Some of the measures implemented between 2002 and 2005 were:

- EDP awards – an incentive to the adoption of measures and processes that minimize energy costs in industry and services. These awards were implemented before, since 1989, with positive results, by EDP Distribuição.
- Characterization of consumers and networks – this measure aims the update of the typical consumption profiles of diverse low voltage consumer classes. These profiles are then used to define timely profiles for the energy to be acquired by retailers.
- The determination of adjustment factors for losses – this study aimed the establishment of adjustment factors for losses by voltage level and time of use period in transport and distribution networks.
- Ecocasa – this measure consisted in the presentation and disclosure of a virtual model that aims the promotion of energy efficiency in the household sector, focusing in lighting air-conditioning and appliances. The measure also intends to promote building solutions that reduce the electricity consumption needs.
- Promotion on energy efficient equipment – this measure intends to disclose and promote ceramic heat storage, together with time of use tariff. With this measure it was expected to reduce consumers' energy bills, and to reduce peak power demand.
- Usage habits of electrical equipment in the services sector – A study from EDP distribuição with the aim of characterizing service customers regarding their economic activity and equipment ownership.
- Disclosure of information on rational use of electrical energy (RUEE) – a set of measures that aim at raising awareness, of EDP Distribuição customers about the benefits of RUEE. The measures included were: website on energy efficiency, energy efficiency guide, Road-Show through schools, distribution of a leaflet together with the electricity bill, and an awareness campaign on energy efficiency.

The participation in the PGP seems to have been short of expectations, regarding the participation of the utility in promoting DSM programmes.

4.4.2 Demand-Side Efficiency Promotion Plans (PPEC)

As previously stated, the PPEC editions of 2007 and 2008 were annual and the following started to be every two years (2009-2010 and 2011-2012 editions). The expected budgetary amounts available for each PPEC edition are presented in Table 4-5.

Table 4-5 – Expected budget amounts for each PPEC edition (millions of euros).

	2007	2008	2009-2010	2011-2012
Intangible measures (All promoters)	2.0	2.0	3.5	3.5
Tangible measures (All promoters)				
- Industry and agriculture	3.0	3.0	5.8	5.8
- Commerce and services	2.5	2.5	4.9	4.9
- Residential	2.5	2.5	5.3	5.3
Intangible measures (Non-electricity sector companies)	-	-	1.5	1.5
Tangible measures (Non-electricity sector companies)	-	-	2.0	2.0
Total	**10.0**	**10.0**	**23.0**	**23.0**

Sources: (ERSE, 2007a, 2007b, 2009b, 2010)

Comparing the expected budget amounts for each PPEC edition (Table 4-5) with the cost of proposed measures (Table 4-6), it is possible to see the high level of participation, a clear sign of the success of the PPEC mechanism.

Table 4-6 – Costs of the measures candidates to each PPEC edition (in millions of euros).

	2007	2008	2009-2010	2011-2012
Eligible proposed measures	27.0	56.0	58.1	57.1
Intangible measures	7.3	8.7	18.2	18.3
Tangible measures				
- Industry and agriculture	4.2	7.3	10.5	7.5
- Commerce and services	8.3	17.2	16.5	19.7
- Residential	6.8	13.0	12.8	11.6

Source: (ERSE, 2007a, 2007b, 2009b, 2010)

The promoters, utilities and non-utilities, participation in PPEC editions has been changing. Although the participation in relative terms has been decreasing (Table 4-7), the number of utilities that participated in the last PPEC edition is above half the number of suppliers and distributors operating in Portugal, that presently is twenty two* (ERSE, 2012). Both the increasing number of participating utilities and non-utility type of entities is an indicator of the importance and success that this mechanism has accomplished.

* EDP Comercial - Comercialização de Energia, SA; EGL Energía Iberia S.L.; Endesa – Endesa Energia Sucursal Portugal; Galp Power S.A.; Iberdrola Generación – Energia e Serviços Portugal, Unipessoal, Lda.; Union Fenosa Comercial, S.L. – Suc. em Portugal; Nexus Energía, S.A.; Cooperativa Eléctrica de Vale D'Este; Cooperativa Eléctrica de Vilarinho, C.R.L.; Cooperativa Eléctrica de Loureiro, C.R.L.; Cooproriz - Cooperativa de Abastecimento de Energia Eléctrica, CRL.; A Eléctrica Moreira de Cónegos, CRL; A CELER - Cooperativa de Electrificação de Rebordosa, CRL; Casa do Povo de Valongo do Vouga; Junta de Freguesia de Cortes do Meio; Cooperativa Electrificação A Lord, CRL; Cooperativa Eléctrica S. Simão de Novais; EDP Serviço Universal; Electricidade dos Açores; Empresa de Electricidade da Madeira; EDP Distribuição; and Rede Eléctrica Nacional.

Table 4-7 – Electric utilities participation in each PPEC edition.

PPEC Edition	Number of utilities/number of promoters	Number of utilities (%)
2007	6/8	75
2008	10/21	48
2009-2010	11/29	38
2011-2012	12/48	25

Besides the number of participating agents the number of measures proposed has been increasing and is also an indicator of the importance that the promoters assign to this mechanism. Since some of the proposed measures were not eligible due to the violation of one or more of PPEC rules, some analysis has been done with the eligible and the approved measures. The number of eligible measures proposed by utilities raised until 2009-2010, and decreased in the last PPEC edition. On the other hand, the number of eligible measures by non-utilities more than doubled from the 2009-2010 to the 2011-2012 edition (Table 4-8).

Table 4-8 – Number of eligible measures by utility and non-utility promoters.

	2007	2008	2009-2010	2011-2012
Utilities	58	81	85	72
Non-utilities	4	32	36	74
	62	**113**	**121**	**146**

The reduction of measures from utilities is mostly due to a decrease in the number of intangible measures (Figure 4-2). The number of tangible measures considered eligible has been increasing, and so does the number of approved measures. In last PPEC edition, more than half the number of eligible tangible measures were approved. Although the number of eligible intangible measures has decreased, the total number of approved measure increased.

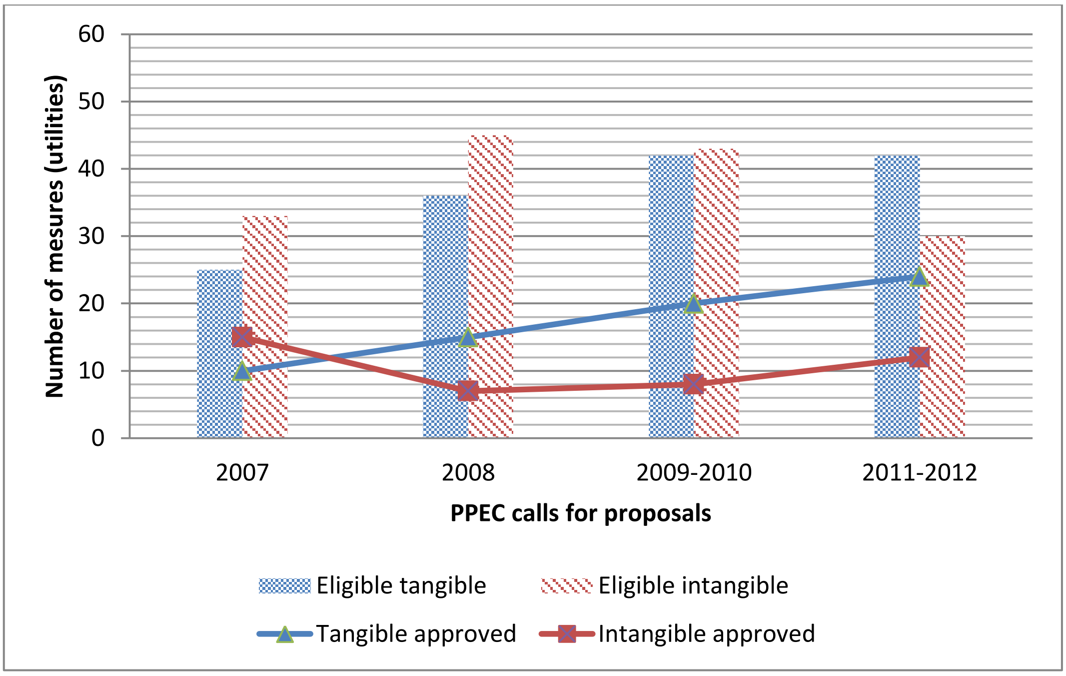


Figure 4-2 – Number of eligible and approved measures proposed by utilities for each PPEC calls for proposals.

Regarding the measures proposed by non-utilities, there seems to be a preference for intangible measures (Figure 4-3), mainly in the last PPEC edition, where the number of eligible measures more than doubled, comparing to the number of measures from the previous edition. The existence of a tender for agents that are not utilities, since the 2009-2010 edition, have been allowing to non-utilities entities the approval of a relatively important number of measures. Eight out of eleven tangible measures approved in 2009-2010, were candidates to the tender for non-utilities agents. In the 2011-2012 edition, from the twelve tangible measures approved, six of them were from that same tender. On the other hand, in the last PPEC edition, eight out of the nine intangible measures approved were candidates to the non-utilities tender. A similar situation had happened in the previous PPEC edition, where only one of the approved measures was candidate to the all proponents' tender.

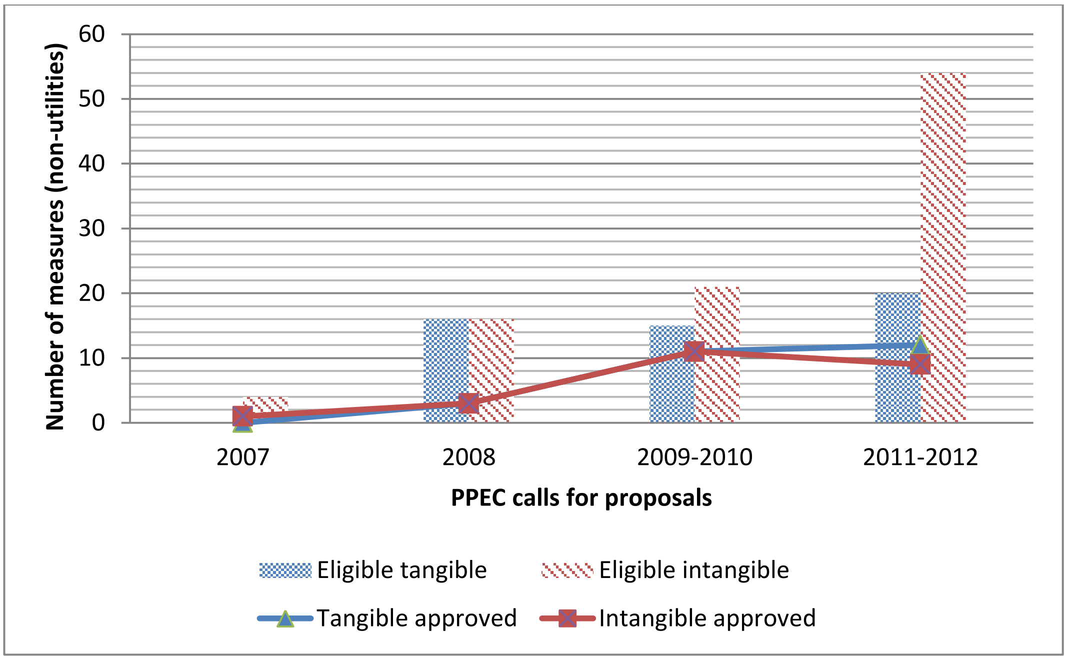


Figure 4-3 – Number of eligible and approved measures proposed by non-utilities entities, for each PPEC edition.

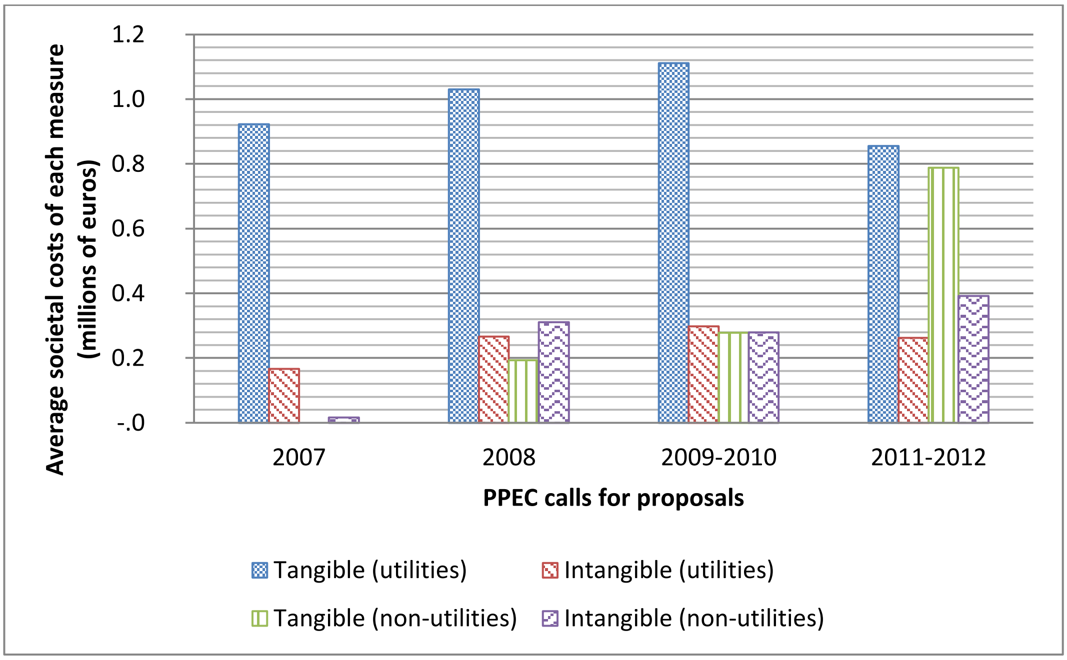


Figure 4-4 – Average societal costs of the measures approved in each PPEC edition.

Although the number of tangible measures proposed by non-utilities has slightly increased in last PPEC call (Figure 4-3), the average societal cost of each measure approved is almost three times higher in the last than in the previous one (Figure 4-4). Regarding the utilities participation, the average societal cost of the approved measures decreased in last PPEC, against the increasing tendency saw in the previous calls. As for the intangible measures, the average costs are, as expected, lower when compared with tangible measures average costs.

For the last two PPEC editions, the PPEC share in the costs of tangible measures is capped at 80% of the total costs. This resulted in an increase in promoters' share in the costs that can be seen in Figure 4-5. On the other hand, PPEC may finance all intangible measures cost supported by the promoters.

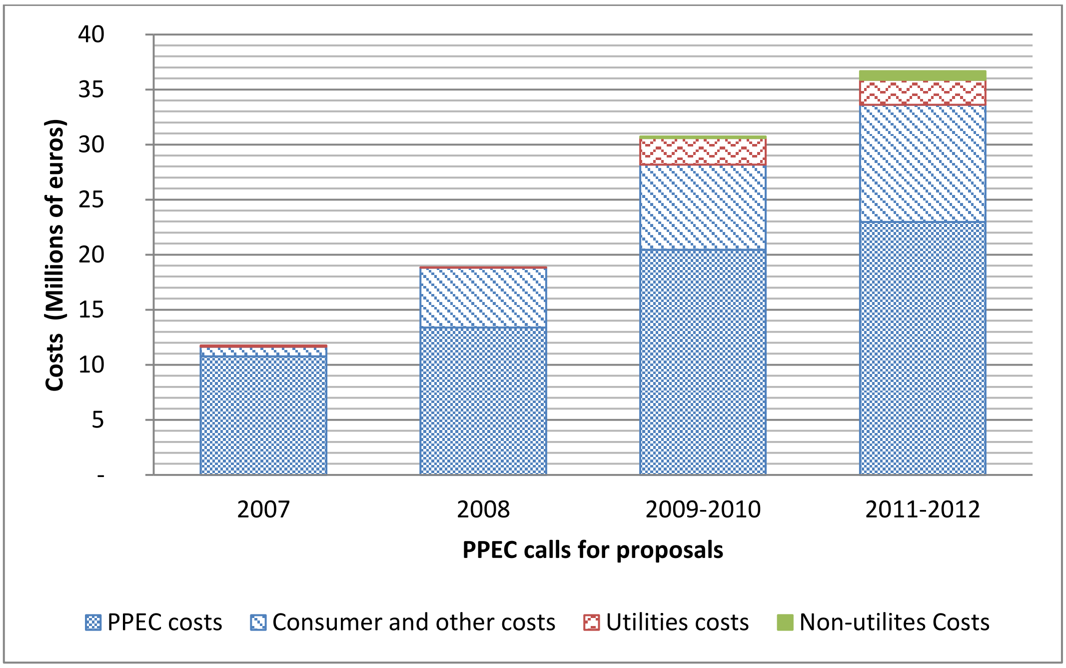


Figure 4-5 – Costs of the several PPEC editions distributed by PPEC, Consumers and other costs, and proponents (utilities and non-utilities).

The more frequent types of measures proposed by utilities are related to efficient lighting (Table 4-9). The improvement of energy efficiency in motors and drives has also received some attention from the utilities, mainly in the last PPEC call.

Table 4-9 – Number of approved measures promoted by utilities, by the more frequent type of end-use, in each PPEC edition.

End-use	2007	2008	2009-2010	2011-2012
Lighting	6	6	13	13
Drives and motors	1	3	2	7
Refrigeration	1	1	4	-
Power factor correction	2	3	-	1

Regarding non-utility proponents, measures targeting lighting and the motors and drives are among the most selected ones (Table 4-10).

Table 4-10 – Number of approved measures promoted by non-utilities, by the more frequent type of end-use, in each PPEC edition.

End-use	2007	2008	2009-2010	2011-2012
Lighting	-	-	9	6
Drives and motors	-	2	2	2
Refrigeration	-	-	-	1
Power factor correction	-	-	-	-

A preference for efficient lighting measures that has happened in Portugal, through the PPEC, has happened in other countries, due to the high cost-effectiveness associated with these measures.

4.5 Conclusions

Although the involvement of utilities in the promotion of DSM has been regulated for fifteen years, a stronger commitment in Portugal has only been seen in the last five or six years. Nevertheless, the regulator has developed a structured approach to adapt the regulatory framework, using the previous experience and the information gathered through public consultation to other entities interested in this subject.

The approach selected by the Portuguese energy regulator is based on the transparency of the procedures and results, and on concerns about equity among all customers, who are the ones contributing to the implementation of the programme, and about the cost-effectiveness of the financed measures. These concerns have influence on the selected criteria and on the weights assigned by the regulator to each criterion. The use of an additive aggregation model, as well as the setting of the criteria and their weights before each call for proposals, have precisely the advantage of contributing to a transparent process.

However, fixed weights, resulted from a static preference structure, offer no assurance that they will contribute, in the best way possible, to accomplish societal objectives that should concern the regulator, when he decides the measures to support.

The promotion of EE at the consumer side has been mostly boosted by the Portuguese regulator, firstly with the PGP and then by the PPEC mechanism. In the PGP although the costs of the measures were recovered by the promoters and the benefits where equally shared between the promoter and the consumers, only intangible measures were implemented.

EE fostering by utilities was then redeemed in 2007, with voluntary participation by utilities, under the PPEC mechanism. Only the recovery of the costs was allowed, for the 2007 and 2008 PPEC editions. After that, only 80% of the costs can be recovered for the tangible measures. Even knowing that the EE programmes would contribute to a reduction in revenues, the participation of utilities has increased. Nowadays, not only lost revenues are not addressed as the total cost of the measures is not fully paid by PPEC funds. Utilities are investing in programmes that reduce their revenues. In a competitive environment this is an apparent paradox. Nevertheless, they keep participating in the programme, probably driven by the improvement in their public image (Apolinário, et al., 2012).

Comparing the part of the costs of each saved kWh allocated to the PPEC budget (CSk_{PPEC}), both those that resulted of the first PPEC edition (2007) and the ones that are expected of the last three PPEC editions, to the additional costs incurred in paying renewable kWh above market costs in order to stimulate RES (AMCRE), stands out that saving energy is much less expensive (Table 4-11). The values paid for each saved kWh of renewable source was between 2.3 and 6.25 times more expensive than investing in saving it.

Table 4-11 – Avoided consumption values, avoided emissions, CSk_{PPEC}, and AMCRE, reported by ERSE.

PPEC editions	*Avoided Consumption (GWh)*	*Avoided Emissions (thousand ton CO_2)*	*CSk_{PPEC} (€/kWh)*	*AMCRE (€/kWh)*
2007	390	144	0.0127	0.0294
2008	878	325	0.0092	0.0416
2009-2010	3 004	1 111	0.0054	0.0281
2011-2012	2 244	830	0.0080	0.0500

Source: in (Sousa et al., 2012b)

Through the weights of the criteria, the regulator sends signals to the promoters about the most valued characteristics however they are detached from the measures in the tender. This is undoubtedly a warranty of transparency of the ranking and selection procedure, but they may not allow the selection of the measures that best fit the objectives allegedly pursued by the regulator.

Another characteristic of the PPEC ranking approach is that the performance of the measures in each criterion is done relatively to the ones with best and worst performance within the tender they are addressing. In other words, for each measure there is an indicator of their performance in each criterion in relation to the others in the tender, but there is no external reference of how good or bad each measure is. The use of external references can help setting levels of performance for the measures that should be regularly updated. Besides the benefits for the regulator to set standards of performance, the promoters are *a priori* informed of what is considered a good performance in each criterion and can design their measures based upon this information.

In the methodology proposed in this work and presented in the next chapter, the above two limitations are addressed. Actually the use of external performance levels is suggested. This will not only help to overcome the above mentioned limitations as will help avoiding the use of two different components for the BCR. The use of external performance levels prevents the effect of measures with uncommonly higher BCR, potentially reducing the number of criteria to rank tangible measures. Also the suggested approach is based on explicitly assumed objectives that will help find the most suitable sets of weights for each criterion. Instead of the weight of each criterion, the regulator sets minimum and maximum values for this weight. The use of a genetic algorithm will be used to find sets of weights that, taking into account the candidate measures, will be the most suitable regarding the assumed objectives. Without sacrificing the essential transparency, of the ranking process, the use of external performance levels is beneficial to both the PPEC and the promoters, as well as the explicitly assumed objectives correspond to additional information that the promoters can use to influence their design of the measures.

Chapter 5. Societal objectives as drivers for the selection of EE measures

5.1 Introduction

In a ranking problem every alternative is evaluated according to a set of criteria, where each criterion represents a fundamental point of view and should be valued against the attractiveness it represents to the decision maker (DM). Behind the definition of criteria, as well as of their weights, are DM preferences and objectives. Consider the case when criteria and their weights should be set before the alternatives are known. Even when weights reflect DM preferences, in the presence of the alternatives to which they will be applied, a new set of weights could result in a more interesting outcome to the DM, even maintaining his preferences.

The Portuguese energy regulator (ERSE) has developed a tender mechanism to promote energy efficiency in electricity consumption – PPEC –, with already four calls for proposals. This tender mechanism, an actual market transformation instrument, is subject to an annual budget (funds come from electricity tariffs paid by all electricity consumers). Selected measures, to be implemented by their promoters, are partly financed by this budget and must contribute to increase energy efficiency in electricity end-use. Among promoters are electricity suppliers, network operators, and consumer organizations, targeting different consumer segments (industrial, agricultural, residential, commerce and services). For the sake of transparency in the ranking and selection of measures, the regulator ensures that rules, criteria and their weights are known in advance. The regulator uses an additive aggregation model to compute the overall performance values of each measure. In the next section a brief reference to additive aggregation models is presented. Section 5.3 presents some references to the use of genetic algorithms (GA) in the search for sets of non-dominated solutions, since the proposal is based on GA to search for the best performing sets of weights in face of the candidate measures. These two sections are included only to give support to some concepts that are used in the proposed methodology. The reader can find more details in the (Deb, 2001; Deb et al., 2002;Tang et al., 2008).

In section 5.4 we make a description of the case study, highlighting the main differences between the approach followed by the regulator and our proposal. In section 5.5 is presented the proposed methodological approach, where two societal objectives were chosen to support the determination of weights for the selecting criteria. The application of the methodology and its results are presented in the chapter 6. This proposal was present with a poster in the IEPEC 2012 conference (Sousa et al., 2012c).

5.2 Additive aggregation model

Consider a set of *m* alternatives *A* = {a_1, a_2, …, a_m}, and a set of *n* criteria, {g_1, g_2, …, g_n}. Consider that

- $g_i(a_j)$: the performance of alternative a_j on the i^{th} criterion,
- $\underline{g}(a_j)$: the vector of performances of alternative a_j on the *n* criteria.

For each alternative a_j, the criteria aggregation model is an additive value function such as (Kenny & Raiffa, 1976):

$$u_j\left(\underline{g}\right) = \sum_{i=1}^{n} p_i u_{ji}(g_i) \tag{5.1}$$

where $u_j\left(\underline{g}\right)$ is the overall performance value of alternative a_j, p_i is the weight of criterion g_i, $u_{ji}(g_i)$ is the normalized value of alternative a_j on criterion g_i. In order to simplify, $u_{ji}(g_i)$ was used instead of $u_{ji}\left[g_i(a_j)\right]$.

Performance normalization follows,

$$u_i(g_{i*}) = 0, u_i(g_i^*) = 1 \;\forall i = 1, 2, \dots, n \tag{5.2}$$

$$\sum_{i=1}^{n} p_i = 100 \tag{5.3}$$

where

g_i^* - is the higher value of g_i, of alternatives on the i^{th} criterion;

g_{i*} - is the smaller value of g_i, of alternatives on the i^{th} criterion.

Weights, p_i, must be positive and between 0 and 100. Setting minimum and maximum admissible values to criteria weights allows the DM to express his preferences. Let these values be:

$$p_i^- \leq p_i \leq p_i^+, i = 1, \dots, n \tag{5.4}$$

This can be used whenever it is considered important to value criteria differently.

The normalized value of $g_i(a_j)$, the performance of alternative a_j on criterion g_i, is obtained through (5.5).

$$u_{ji}(g_i) = \frac{g_i(a_j) - g_{i*}}{g_i^* - g_{i*}} \tag{5.5}$$

An ordered list of the overall performance values for every alternative in set *A* will correspond to the ranking order of measures, according to that particular set of criteria weights. These cardinal scores provide the ordinal information of the ranking position of each alternative. Besides performance of alternatives on each criterion, weights of criteria will determine overall performance values of each alternative. Therefore, criteria weights will, and should, reflect the relative importance of each criterion. Consider, for illustrative purposes, the DM wants that alternatives with better performance on any two or more objectives should occupy the top positions of the rank. However, alternatives with better performance in one of the objectives may not have also a good performance on any other. This would certainly lead us to compromise solutions. Besides, we can pose several questions: are those criteria the only ones that matter? How should criteria be valued? How should each of the criteria be valued in order to obtain alternatives ranked in a way that satisfies DM objectives?

We propose GA to search for sets of criteria weights that will lead to good results in face of the candidate measures and the objectives of the DM.

5.3 An EA-based approach based on NSGA-II algorithm

In recent decades, GA have been widely used as tools of demand and optimization in various fields of application, such as science, commerce and engineering (Deb, 2001). GA follows principles of genetics and natural selection. First we identify the problem, objective function(s), as well as restrictions, if any. The structure of solutions, called chromosome, is a representation of decision variables, as well as of any other information considered important. Before the use of genetic operators, each solution is evaluated in terms of its results to each objective function. Unlike traditional methods of search and optimization, GA's start the search with a set of solutions generated randomly, instead of just one solution. The set of solutions, the population, is modified by all or some of the three major operators and a new population is created. The three genetic operators mentioned are reproduction or selection, crossover and mutation. After creating a new set of solutions by the genetic operators it is necessary to evaluate each one under the terms of the objective functions and restrictions. After assessment, the stop condition is tested. If the condition is not satisfied, a new generation starts.

5.3.1 Reproduction / selection

The main purpose of the reproduction operator is to perform the selection of the best solutions and eliminate the worst ones. One of the methods used for this operator is selection by tournament, which is used in this work. With this method, two solutions are chosen randomly and their performance is compared. The performance is tested in terms of dominance and crowding distances, explained in sections 5.3.5 and 5.3.6. The solution with the best performance is chosen and the other is rejected. This procedure is performed twice in order to choose two solutions. These two solutions, parents, will be used to generate two new solutions for the next generation, offspring. In fact, the operator reproduction does not generate new solutions. It only makes the selection of the parents. By this fact, in this work we will refer to this operator as selection. Different solutions are generated by two other operators, crossover and mutation.

5.3.2 Crossover

This operator is applied after parent selection. Such as for the selection operator, there are also different methods to implement it. However, general model is based on preserving genetic information from two parents selected to generate new solutions. To each pair of parents one crossover point is generated (or more than one). This is a point between two genes identifying the location at which genetic information is exchanged. The first part of chromosomes, from the first gene to the gene before the crossover point, is exchanged between the two solutions, generating two new solutions with a portion from one parent and the remaining from the other. This kind of crossover is used when genes are binary-coded. In this case, since genes are not binary-coded, but real-coded, the SBX – Simulated Binary Crossover (Deb, 2001) is used. Consider x_i the *i^th^* gene in a chromosome, $x_i^{(1,t)}$ the *i^th^* gene of the first parent in generation *t*, and $x_i^{(2,t)}$ the *i^th^* gene of second parent in generation *t*. The corresponding genes of two offspring solutions, of generation *t+1*, $x_i^{(1,t+1)}$ and $x_i^{(2,t+1)}$ are computed, from the parent solutions $x_i^{(1,t)}$ and $x_i^{(2,t)}$, of generation *t*, as follows:

$$x_i^{(1,t+1)} = 0{,}5\left[(1+\beta_{qi})x_i^{(1,t)} + (1-\beta_{qi})x_i^{(2,t)}\right] \quad (5.6)$$

$$x_i^{(2,t+1)} = 0{,}5\left[(1-\beta_{qi})x_i^{(1,t)} + (1+\beta_{qi})x_i^{(2,t)}\right] \quad (5.7)$$

where β_{qi} is obtained from the probability distribution:

$$\beta_{qi} = \begin{cases} (2v_i)^{\frac{1}{\eta_c+1}}, if\ v_i \leq 0{,}5 \\ \left(\frac{1}{2(1-v_i)}\right)^{\frac{1}{\eta_c+1}}, if\ v_i > 0{,}5 \end{cases} \quad (5.8)$$

Here v_i is a randomly generated number between 0 and 1, and η_c is a distribution index, any non-negative real number. η_c is a parameter that should be adjusted for each problem. A large value of η_c gives a higher probability of creating 'near-parent' solutions and a small one allows distant solutions to be generated as offspring.

The step-by-step procedure to create the offspring solutions is the one described:

Step 1: Choose a random number v_i

Step 2: Calculate β_{qi} using equation (5.8)

Step 3: Compute a pair of offspring solutions using equations (5.6) and (5.7).

5.3.3 Mutation

The crossover operator is mainly responsible for the search aspect of GA's, despite the mutation operator also being used for this purpose. Mutation is necessary to maintain diversity in a population. This operator will introduce an exchange in a gene with a certain, usually small, probability. When genes are binary, mutation will change '0' to '1' and '1' to '0'. Since we are not dealing with binary-coded genes, but real-coded ones, the mutation process used is based in Polynomial Crossover (Deb, 2001). Like in SBX operator, the mutation scheme uses a polynomial function:

$$y_i^{(1,t+1)} = x_i^{(1,t+1)} + (x_i^{(U)} - x_i^{(L)})\bar{\delta}_i \quad (5.9)$$

where the parameter $y_i^{(1,t+1)}$ is the offspring $x_i^{(1,t+1)}$ after the mutation procedure, $x_i^{(U)}$ and $x_i^{(L)}$ are the upper and lower limits of the interval of admissible values to x_i, and $\bar{\delta}_i$ is calculated from the polynomial probability distribution:

$$\bar{\delta}_i = \begin{cases} (2r_i)^{\frac{1}{(\eta_m+1)}} - 1, if\ r_i < 0{,}5 \\ 1 - [2(1-r_i)]^{\frac{1}{(\eta_m+1)}}, if\ r_i \geq 0{,}5 \end{cases} \quad (5.10)$$

Here r_i is a randomly generated number between 0 and 1, and η_m is a distribution index. As for η_c, a large value of η_m gives a higher probability of creating a solution near the original and a small one allows distant solutions to be generated.

The step-by-step procedure to create a mutant solution is the one described:

Step 1: Choose a random number r_i;

Step 2: Calculate $\bar{\delta_i}$ using equation (5.10);

Step 3: Compute a new solution using equation (5.9).

5.3.4 Adaptive p_c and p_m

Crossover and mutation may not be applied systematically, but according to a probability. New generation individuals (solutions) may result of crossover or can be randomly generated. This last procedure is used to introduce new genetic information in the population. All these individuals can be mutated. The mutation is necessary to maintain diversity in a population, avoiding premature convergence. Usually there should be a higher probability of crossover occurrence, in order to maintain genetic heritage, and a smaller for the introduction of new individuals in the population. These new solutions can be introduced in the population with or without going through the process of mutation. Probabilities of crossover (p_c), and mutation (p_m) can remain the same throughout the simulation or can change according to the population characteristics.

The use of adaptive p_c and p_m allows increasing diversity in the population or prevent random search. By analyzing similarity between solutions, actions can be taken in order to change p_c and/or p_m. Increasing p_c leads to rich information exchange between parents and offspring solutions, while decreasing p_m avoids random search (Tang, 2008). If solutions are very similar it is important to reduce p_c and increase p_m. On the other hand, in order to avoid premature convergence p_c must be reduced and p_m increased, allowing the introduction of new genetic information.

A solution can be seen as an N-dimensional vector and we can use the vector distance as a way of measuring the similarity between solutions. Being $Sol_i = [g_i(1), \ldots, g_i(N)]$ and $Sol_j = [g_j(1), \ldots, g_j(N)]$, two different solutions, the distance between them can be calculated by

$$d(i,j) = \sqrt{\left(g_i(1) - g_j(1)\right)^2 + \ldots + \left(g_i(N) - g_j(N)\right)^2} \tag{5.11}$$

If the distance is below a predefined threshold *D*, solutions are considered similar, and assigned a "0". On the other hand if the distance is larger than *D*, solutions are considered dissimilar, assigned a "1". The diversity of the population with N_{ind} individuals is estimated using the following equation:

$$div = \frac{\sum_{i=1}^{N_{ind}} \sum_{j=i+1}^{N_{ind}} 1_{\{d(i,j)>D\}}}{N_{ind}^2} \tag{5.12}$$

If all solutions in the population are similar, *div = 0*. If all solutions are dissimilar, *div = 1*. This means *div* is a variable in the range [0, 1]. Then, p_c and p_m must be adjusted according to the following:

$$p_c = p_c^0 + div.(1 - p_c^0) \tag{5.13}$$

$$p_m = p_m^0 - div.p_m^0 \tag{5.14}$$

where p_c^0 is the initial crossover probability and p_m^0 is the initial mutation probability. Being p_c^0 and p_m^0 chosen in [0, 1], then p_c and p_m will be in [0, 1].

5.3.5 Non-dominated sorting approach

Non-domination sorting approach is a procedure of sorting the population into different non-domination levels (Deb, 2002). The procedure used in this work was denominated as Fast Non-domination Sorting Approach (NSGA-II). The procedure starts with the calculation of 1) a domination count n_p, the number of solutions that dominate the solution *p*; and 2) S_p a set of solutions that the solution *p* dominates. All solutions in the first non-dominated front will have $n_p = 0$. For each solution *p* in the first front, every solution q in S_p, will see its domination count reduced by one. Therefore, any member of S_p with a domination count of "0" will be in the second non-domination front. The above procedure will continue until all fronts have been identified.

5.3.6 Diversity preservation and Crowded-comparison operator

NSGA-II uses a crowded-comparison approach in order to maintain some diversity among population members (Deb, 2002). The use of the crowded-comparison operator requires a density-estimation metric. To get an estimate of the density of solutions surrounding a particular solution, we calculate the average distance between two solutions on either side of this solution along each of the objectives. This distance serves as an estimate of the perimeter of the cuboid formed by using the nearest neighbors as vertices. This is called the crowding distance (Figure 5-1).

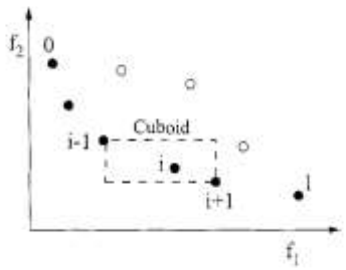


Figure 5-1 - Crowding-distance calculation. Points marked with filled circles are solutions of the same non-dominated front. (Deb, 2001).

The crowding-distance computation requires sorting the population according to each objective function in ascending order. For each objective function, the boundary solutions are assigned an infinite distance value. The boundary solutions correspond to the ones with the smallest and the largest function values. All other solutions are assigned a distance value equal to the absolute normalized difference in the function values of two adjacent solutions. This procedure is also performed with the other objective functions. The overall crowding-distance value is calculated as the sum of individual distance values corresponding to each objective. Each objective function is normalized before calculating the crowding distance.

5.4 Main differences between PPEC´s approach and our own

The aim of this work is to help setting criteria weights that are used to value alternatives, using an additive value function. The case study used in this work is a tender managed by the Portuguese energy regulator to promote the implementation of energy efficiency measures in the consumption side of the electricity sector. The selected measures are the best performing, according to a set of criteria with previously fixed weights, set by the regulator.

The rank score is obtained according to the following 8 criteria (in brackets is the weight given to each criterion by the regulator in the most recent calls for proposals): A - benefit-cost analysis (60 points), B - scale risk (10 points), C - weight of the investment in equipment in the total cost of the measure (10 points), D - quality of presentation (7 points), E - ability to overcome market barriers and spill over effect (5 points), F - equity (4 points), G - innovation (2 points), and H - promoter experience in similar programs (2 points). Benefit-cost analysis is also divided in two different sub-criteria: a proportional one (40 points), which takes into account the value of the benefit-cost ratio (BCR), and a ranking one (20 points), which only takes into account the relative position of the BCR value of each measure in the context of all measures proposed in the same consumer segment. The sum of the weights totalizes 100 points (Apolinário, et al., 2009).

Some of the criteria are related to characteristics of measures which are note directly quantifiable (addressed as non-metric criteria), such as quality of presentation (D), ability to overcome market barriers and spill over effect (E), equity of measures (F), innovation (G), and promoters experience in similar programs (H). Values of each one of these criteria result from the identification of a set of characteristics present in each measure, resulting in 3 or 4 alternative values. These non-metric criteria are related to characteristics that the regulator values and considers that should not be overlooked. The other 3 criteria are cost benefit analysis, scale risk, and weight of the investment in equipment in the total cost of the measure. An explanation of the criteria was made in section 4.3.1 of chapter 4.

The criteria aggregation model used by the regulator is an additive value function. The rank order of the alternatives results from the overall performance value (OP_j) of each measure *j* (5.15). The uppercase letter is used to identify a criterion and the correspondent lowercase letter is used for the weight of that criterion.

$$OP_j = aA_j + bB_j + cC_j + dD_j + eE_j + fF_j + gG_j + hH_j \qquad (5.15)$$

Where:

OP_j – Overall performance value of measure *j*;

A_j – Normalized value of BCR of measure *j*;

B_j – Normalized value of Scale risk of the measure *j*;

C_j – Normalized value of Weight of the investment in the total cost of measure *j*;

D_j – Normalized value of Quality of presentation of measure *j*;

E_j – Normalized value of Ability to overcome market barriers and spill over effect of measure *j*;

F_j - Normalized value of Equity of measure *j*;

G_j - Normalized value of Innovation of the measure *j*;

H_j – Normalized value of Experience in similar programs of measure *j*.

5.4.1 First difference: Number of criteria

In the proposed approach the same criteria used by PPEC is considered, exception made for the benefit-cost analysis: a single criterion regarding benefit-cost analysis, the BCR, is used. The use of the criterion regarding the rank of BCR is justified by the regulator as a strategy to prevent the effect in the rank of the measures of an uncommonly large value of BCR, since the BCR of all measures is normalized according to the extreme values found in the set of all measures in the same consumer segment (Apolinário, et al., 2007). The use of two independent external performance levels (section 5.4.3), replacing minimum and maximum values used by the regulator, prevents the abovementioned effect (Bana e Costa, 1996).

Some lack of diversity was found for the performance of the measures in the last two calls of PPEC, regarding SI and DII criteria (Table A-3 and Table A-4, in Appendix B). In Table 5-1 the corresponding values for all three sets of measures are presented.

Table 5-1 – Values characterizing SI and DII values for the three sets of data.

	SI values equal to 1	*DII values equal to 1*	*Correlation between SI and DII*
1st data set	5%	3%	0.39
2nd data set	55%	20%	0.59
3rd data set	66%	64%	0.94

The high number of measures having the highest performance values in a criterion can be considered as an indicator of the success of the mechanism as a regulatory instrument. However, one such criterion becomes less effective for evaluating, becoming essentially a screening instrument. The results obtained with the application of the methodology with SI and DII as two independent criteria, and the strong correlation between them, led us to associate them into a single criterion. The performance value of this single criterion, SI+DII, is obtained by the average value of the performances of SI and DII. We applied the methodology to approaches with 8 criteria (SI and DII as two different criteria – Chapter 6, Section 6.2.1) and with 7 criteria (SI and DII in a single criteria – Chapter 6, Section 6.2.2).

5.4.2 Second difference: Extreme values for the criteria weights

Instead of a single set of weights for the criteria, we use an evolutionary algorithm to look for the most suitable sets of weights in the pursuit of the chosen societal objectives. Setting minimum and maximum values for the weights of the criteria is a way of expressing DM preferences. In Table 5-2 we can find the extreme admissible values for the weight of each criterion.

Table 5-2 – DM preferences for the extreme values of criteria weights.

Criterion weight	***a***	***b***	***c***	***d***	***e***	***f***	***g***	***h***
Minimum value	45	5	5	6	4	3	1	1
Maximum value	75	15	15	8	6	5	3	3

The extreme values for the weights of the non-metric criteria are one point above and below the value set by the regulator. By doing so we admit some flexibility when searching for solutions, without allowing non-metric criteria to be overvalued, while keeping weights close to the ones allegedly expressing the regulator (DM) preferences. We set the extreme values for the weights of SI and DII to be 5 points above and below the value set by the regulator (10 points). The maximum (and minimum) value of the BCR weight was set to 75 (45) resulting from the difference between 100 and the sum of the minimum (maximum) weights of all other criteria.

5.4.3 Third difference: References for the performance values

According to the regulator's approach, the performance values of each measure under each criterion are normalized with reference to the maximum and minimum values found among the candidate measures in each consumer segment. The performance of each measure is compared with the performance of the others in the tender. Using this procedure, and for each criterion, we can say that a particular measure is better than the others but we cannot answer the question "Is this a good measure?". In our approach we considered, for each criterion, two impact level values – a Good and a Neutral, replacing internal references by external ones. When performance value has a "Neutral" impact level, the corresponding measure is considered neither good nor bad, whereas a measure with a performance above or equal to the value "Good" is considered a good one (Bana e Costa et al., 2002). Besides the above mentioned effect that an uncommonly large performance value of a measure has in the relative performance values of the others, rank reversal is prevented with this procedure. Rank reversal happens when measures with better performance are removed from or introduced in the initial set, leading to a different rank of the initial measures. The use of independent performance levels also gives external references that allow comparing alternatives performance beyond those that are candidates to the call and sends signals to promoters about the regulators preferences. Additionally, they can be updated from one edition of the call for proposals to the next, increasing the standards of performance of measures. Also, regular updates give flexibility to the mechanism while keeping it effective. With the use of "Good" and "Neutral" values (Table 5-3), the ranking order is not dependent neither on maximum nor on minimum performance values of the measures. Normalized values can, then, be higher than one (when the performance value is higher than the Good level) or negative (when the performance value is lower than the Neutral value). These impact values remain the same for all consumer segments.

Table 5-3 – Good and neutral impact levels set for the performance of each criterion.

Impact level	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
Good value	10	1	1	0.75	0.75	0.75	0.75	0.75
Neutral value	5	0.6	0.6	0.5	0.5	0.5	0.5	0.5

5.4.4 Fourth difference: Explicitly assumed objectives

Our approach is based on two societal objectives implicit to the regulator’s mission that will be used in the search for the weights of the criteria: maximize avoided consumption (AC) and minimize cost of each saved kWh (CSk). Since PPEC mechanism is financed with money paid by all electric energy consumers it is important and fair that all should benefit from it. Although measures from all consumer segments can compete for funding, not all consumers will directly benefit. On the other hand, the societal responsibilities of the regulator may benefit of a more objective link between explicitly assumed societal objectives for energy efficiency and the ranking of the candidate measures. In the end, we want to find the appropriate set (or sets) of criteria weights so that the resulting ranking order of the measures should be a compromise solution between total AC and the CSk.

5.5 Methodological approach

5.5.1 Objective functions

Since the purpose is to find a set (or sets) of criteria weights that would rank energy efficiency measures according to their AC and CSk values, we are in the presence of a bi-objective problem. Regarding the AC objective, our purpose is to obtain measures ranked by decreasing order of their AC value. On the other hand, for the CSk objective measures should be ranked by increasing order of their CSk value. Since, in this problem, we want to rank alternatives, we need to distinguish one rank position from the other. Therefore, rank positions are used as weights in a weighted sum, where the performance values of the alternatives are related to the objectives pursued. The result of the weighted sum will be higher for ranking solutions that place alternatives with higher performance values in rank positions where the weight is higher. This way, if we want measures with higher performance values in top ranking positions, than these positions should have higher weights. On the other hand, if we want measures with higher performance values in lower rank positions, those positions should have higher weights. In either case, the maximization of the weighted sums would result in placing best performance measures in positions that have higher weights. The rank-order centroid (ROC) method (Barron & Barret, 1996) is used in order to translate the rank positions to weights. In order for the measures with higher AC values to come in the top ranking positions, we set higher weights to the top positions. In the case of the CSk objective, we had to give higher weights to the lower ranking positions in order to place measures with higher CSk values there, the measures with lower CSk being favourites. Then we place ROC values by reverse in the case of the CSk objective. We have to include in our objective functions the fact that measures are addressed to one of three different consumer segments, and ranked in their segment. The objective functions are:

$$Maximize\ f_1{}' = \sum_{k=1}^{3}\sum_{j=1}^{m} AC_{kj} * r_{kj} \tag{5.16}$$

$$Maximize\ f_2{}' = \sum_{k=1}^{3}\sum_{j=1}^{m} CSk_{kj} * r'_{kj} \tag{5.17}$$

Where:

k – consumer segments;

m - number of measures;

AC_{kj} – AC value of measure *j* in segment *k*, in GWh;

r_{kj} – ROC weight of measure *j* in segment *k*;

CSk_{kj} – CSk value of measure *j* in segment *k*, in €/kWh;

r'_{kj} – ROC weight of measure *j* in segment *k* (values taken in reverse order).

For the implementation of the methodology we used Matlab (R2011a), and both equations, (5.16) and (5.17), are replaced by its symmetric, turning maximization functions in to the corresponding minimization (eq. (5.18) and eq. (5.19)).

$$Minimize\ f_1 = -\sum_{k=1}^{3}\sum_{j=1}^{m} AC_{kj} * r_{kj} \tag{5.18}$$

$$Minimize\ f_2 = -\sum_{k=1}^{3}\sum_{j=1}^{m} CSk_{kj} * r'_{kj} \tag{5.19}$$

We can then look at the proposed methodology as a two phase procedure. Consider that we have different sets of criteria weights whose results we want to compare. In the first phase, and for each set of criteria weights, the overall performance (OP) value of each measure is computed (5.15). For each set of criteria weights, measures are ranked by decreasing order of OP values. This procedure is followed for all the sets of criteria weights, resulting in one rank order of measures for each set of criteria weights. In the second phase, both objective functions (eq. (5.18) and eq. (5.19)) are evaluated, for each set of criteria weights. The best performing sets of criteria weights will be used in a genetic algorithm to generate new sets. At the end of the evolutionary process, the DM is presented with sets of criteria weights that better satisfy the pursued objectives. In the next section this procedure is explained in more detail.

5.5.2 Determination of criteria weights

The evolutionary process for the search of the best performing sets of criteria weights starts with a randomly generated initial population of *N* solutions (sets of criteria weights). Each solution (a chromosome) has a gene for each criterion weight. Each gene is a randomly generated number set for each weight between extreme values (Table 5-2). After all genes have been generated, their values are normalized so that their sum equals 100. Any solution that does not respect minimum and maximum limits assigned is eliminated. After the initial population has been generated, the OP value for each set of weights and each measure is calculated. The normalized performance values of each criterion are calculated using "Good" and "Neutral" reference values previously set (Table 5-3). Then, an array with the ranking order of the measures, for each solution, is built and the value of each objective function calculated. The value of each objective function is then attached to the criteria weights in each chromosome. At this point, each chromosome has one gene for each criterion, and one for the result of each objective function.

In an evolutionary approach, a set of individuals will be selected to pass on their heritage to the next generation. We used NSGA-II, Fast Non-domination Sorting Approach, proposed by Deb *et al.* (2002). In NSGA-II, in each generation, the population of size *N*, is added to its offspring, building a population of size *2N*. All individuals are sorted in non-domination levels (fronts). The population of the next generation will be formed by all individuals of the non-domination front with lower order until a population of size N is reached. If it is necessary to choose between individuals in the same front, the ones in the least crowded regions are the ones to be selected. The information regarding non-dominated fronts and crowding distances are also added to the criteria weights and objective functions values in each chromosome.

Offspring is obtained applying genetic operators: selection, crossover, and mutation. Crossover is made between two solutions selected by tournament. The crossover is the most common procedure. If crossover does not occur, than a new solution is randomly generated. Every solution can be subject to change before being introduced into the population. This change is performed by the mutation operator. Since each individual is a set of criteria weights, crossover and mutation strategies must comply with real-coded procedures (Deb, 2001).

Before entering the population, the genes in each new solution will be normalized so that their sum will be 100. With this process the criteria weights will be changed, but not their relative importance.

Before starting a new generation, the similarity of the solutions in the population is checked (comparing distance between solutions to a distance threshold value) in order to see whether crossover and mutation probabilities should change. The lack of diversity in a population may be a reason to change (decrease) crossover probability (p_c). Decreasing p_c will allow the introduction of new solutions in the population. Also, increasing mutation probability (p_m), will augment differences between offspring and their parents. On the other hand, increasing p_c leads to rich information exchange between parents and offspring solutions, while decreasing p_m avoids random search. By analysing similarity between solutions, actions can be taken in order to change p_c and/or p_m (Tang et al., 2008).

The overall process is briefly outlined in Figure 5-2.

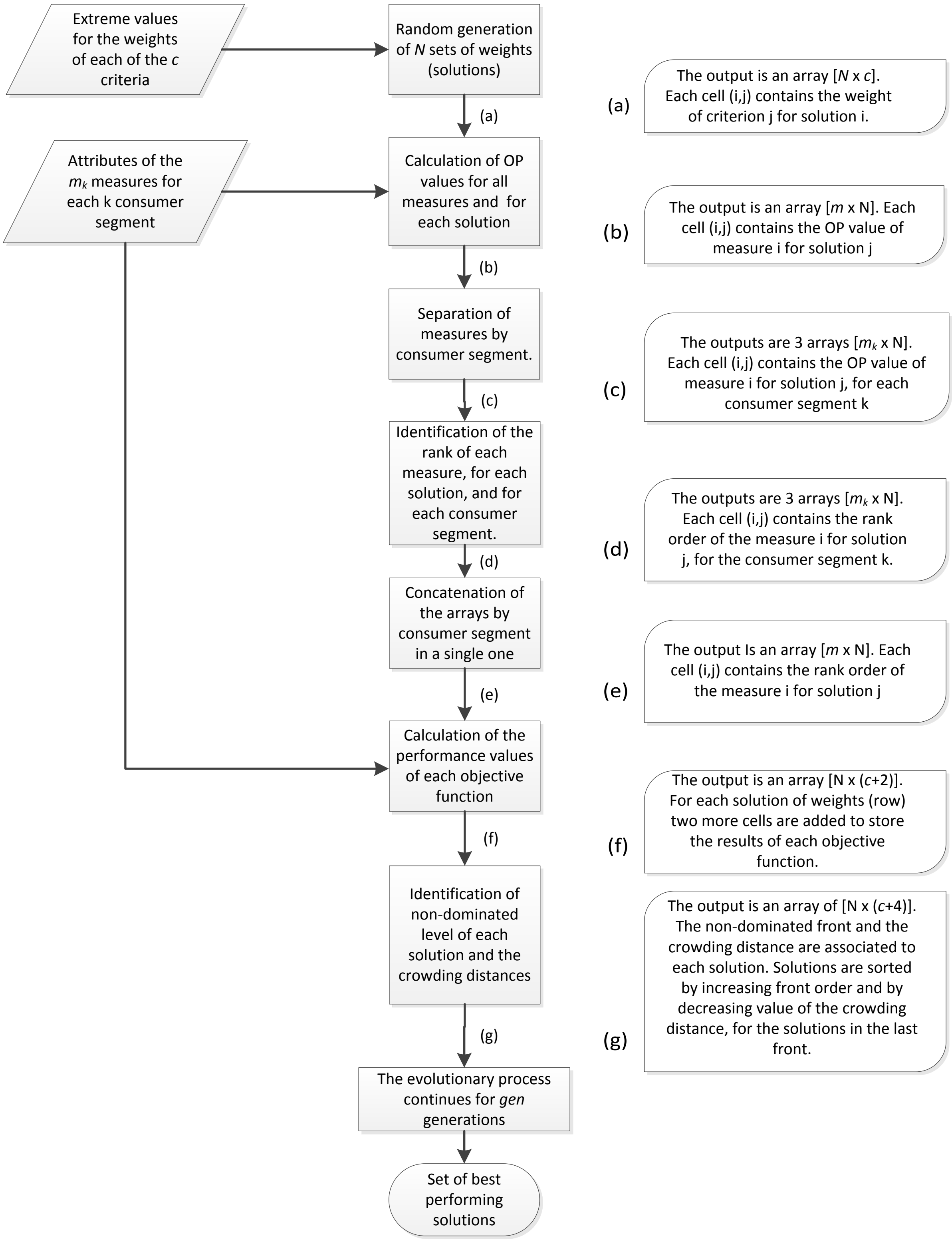


Figure 5-2 – Flowchart of the overall process.

5.6 Conclusions

The purpose of the proposed methodology is to avoid the static selection of weights, allowing that explicitly assumed societal objectives act as drivers for the selection of the weights. It is expected that, in face of different sets of measures, the same weights would lead to different results, regarding societal objectives. If some variations in the weights were allowed, it could be found the most suitable set (or sets) of weights for the pursued societal objectives.

Besides explicitly assuming the societal objectives, which are to maximize avoided energy consumption and to minimize the cost of each saved kWh, the DM imposes its preferences by setting bounds to the maximum and minimum values for each criterion. Additionally extreme performance values are set for each criterion that are used as external references for evaluating the performance of each measure under each criterion, are set. These external references avoid that only a relative assessment of the performance of the measures is done, relying only on comparing the measures in the same tender set, without being able to perform an absolute merit assessment. The regulator can also use theses external references to set standards of performance to the measures.

Chapter 6. The proposed methodology: tests and results

6.1 Introduction

An alternative approach to the ranking of the measures, as described in chapter 5, based on the definition of societal objectives that are an interesting part of the regulator's mission. This alternative preserves simultaneously the essential method of assessing and ranking energy efficiency measures presented by the applicant promoters. Although maintaining the weighted sum of values assigned to each measure according to the regulator's criteria, the proposed methodology aims at improving the capability of the DM to express his preferences and obtain a ranking of measures that better suits societal objectives of energy efficiency fostering. This is accomplished by an improved definition of the weights in the weighted sum, based on the accumulated experience of previous PPEC editions, whose results are publicly available. Since PPEC funds derive from electricity tariffs paid by all electric energy consumers, it is important to assure that all of them have the opportunity to benefit from the measures. Avoided consumption and cost of each saved kWh were the selected variables for defining the societal objectives. Reducing consumption has the well-known impact of reducing GHG emissions, attenuating the depletion of resources, reducing the supply dependence from third party countries, as well as avoiding some more expensive energy production options. Reducing the cost of each saved kWh has an important impact on the economy. Besides, reducing the cost of each saved kWh highlights the advantages of using energy efficiency as an important policy instrument, besides investing in more generation of electricity. The present application of the methodology was published in (Sousa et al., 2012b).

The application of the methodology that was presented in the last chapter and the obtained results are presented in section 6.2. In section 6.3, some considerations regarding the results obtained are presented followed by a post-processing analysis of the results regarding the selection of measures (section 6.4). The chapter ends with some conclusions where some advantages of the proposed methodology are highlighted.

6.2 Main results

We recall that the first objective (eq.(5.18), section 5.5.1) pursued corresponds to place the measures with higher avoided consumption values (objective function f_1) in top ranking positions and the second objective (eq. (5.19), section 5.5.1) corresponds to place the measures with lower cost of each saved kWh (objective function f_2) in top positions.

In this work we used measures that competed in the last three, PPEC calls, of a total of four. The measures from the 2008, 2009, and 2011 editions, are identified in this paper as measures from the 1st data set (Table A - 2), the 2nd data set (Table A - 3), and the 3rd data set (Table A - 4), in appendix B. The measures from the 1st call (2007) were not used because the rules had then some differences when compared to the last three. In this work, the energy efficiency measures are identified by an alphanumeric code where the letter stands for the consumer segment they are addressed to (*R* for residential, *S* for service and commerce, and *I* for industry and agriculture), and the number is a way of enumerating the measures in each segment.

Due to the results obtained when the methodology was applied to the problem with eight criteria (section 6.2.1) to evaluate each measure (eq. (5.15), we decided to join two of the criteria in a single one, turning the problem in to a seven criteria one (section 6.2.2). The results for both approaches are presented.

6.2.1 The eight criteria approach

The initial parameters of the genetic algorithm used for each data set are presented in Table 6-1. The population size for the 2nd and 3rd data sets are larger than for the 1st one because the number of non-dominated solutions found, in most of the 15 runs of the GA, was larger.

Table 6-1– GA's initial parameters set for the problem with 8 criteria.

Parameter	*Value*
Population size	1st data set: 100 2nd data set: 150 3rd data set: 150
Generations	75
Mutation probability	1/8 (inverse of the number of criteria)
Crossover probability	0.9
Crossover distribution index (η_c)	1
Mutation distribution index (η_m)	0.01
Distance threshold (D)	25
Number of runs of the GA	15

In Figure 6-1 we can see all 139 different solutions (sets of criteria weights) found in all 15 runs. 27 of them are non-dominated solutions. In the graphic the X-axis corresponds to the values obtained for the objective function f_1, and the Y-axis for the objective function f_2. Since we are minimizing both functions, the region of the dominated solutions is on the right-upper side of the graphic. Of these 27 non-dominated sets of criteria weights, 21 lead to different values of the objective functions. This happens because small changes in some criteria weights can have no effect in the OP values of the measures.

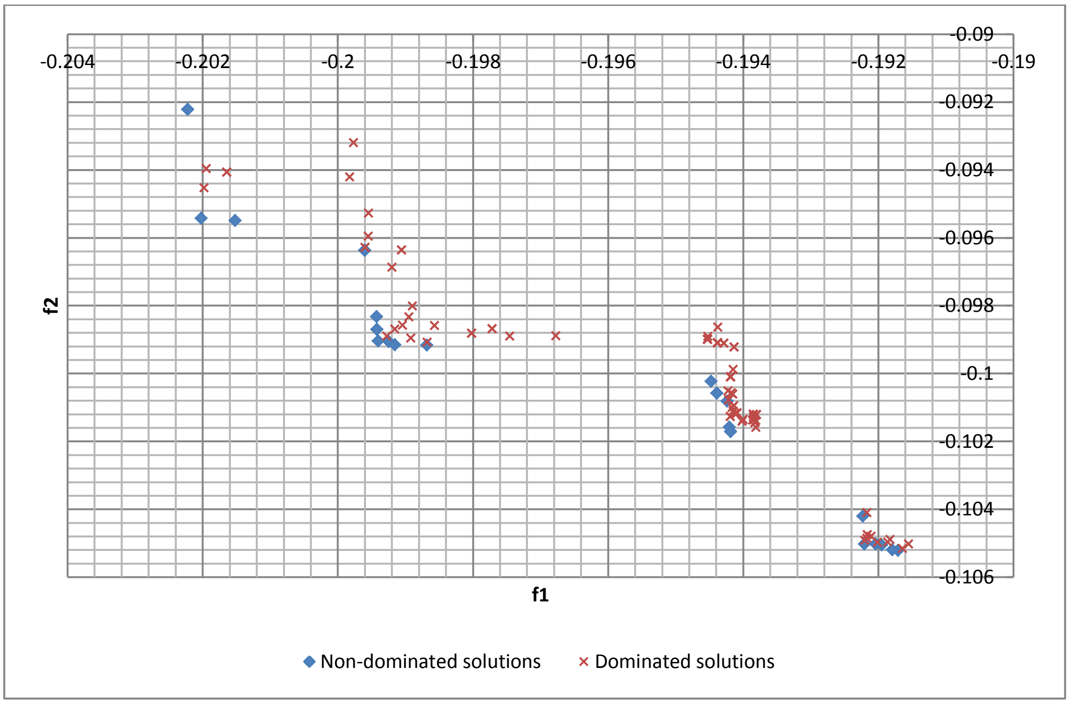


Figure 6-1 – Solutions found for the 1st data set.

In Figure 6-2 the criteria weights for all non-dominated solutions are presented. Solutions closer to the Y-axis are the ones that better comply with the AC objective (f_1). On the other hand, solutions further away from the Y-axis, are those that give better results regarding the CSk objective (f_2). The different solutions that lead to the same values of the objective functions are highlighted by a column with a pattern. Each column filled with a pattern cover the solutions with sets of criteria weights that lead to the same result regarding both objective functions. The same value for both objective functions corresponds to the same rank of measures. For instance, measures will be equally ranked when using solutions 1 or 2. Those areas in the picture with no pattern correspond to solutions that lead to different results for the objective functions, such as solutions 3, 4, 8, or 11 to 15.

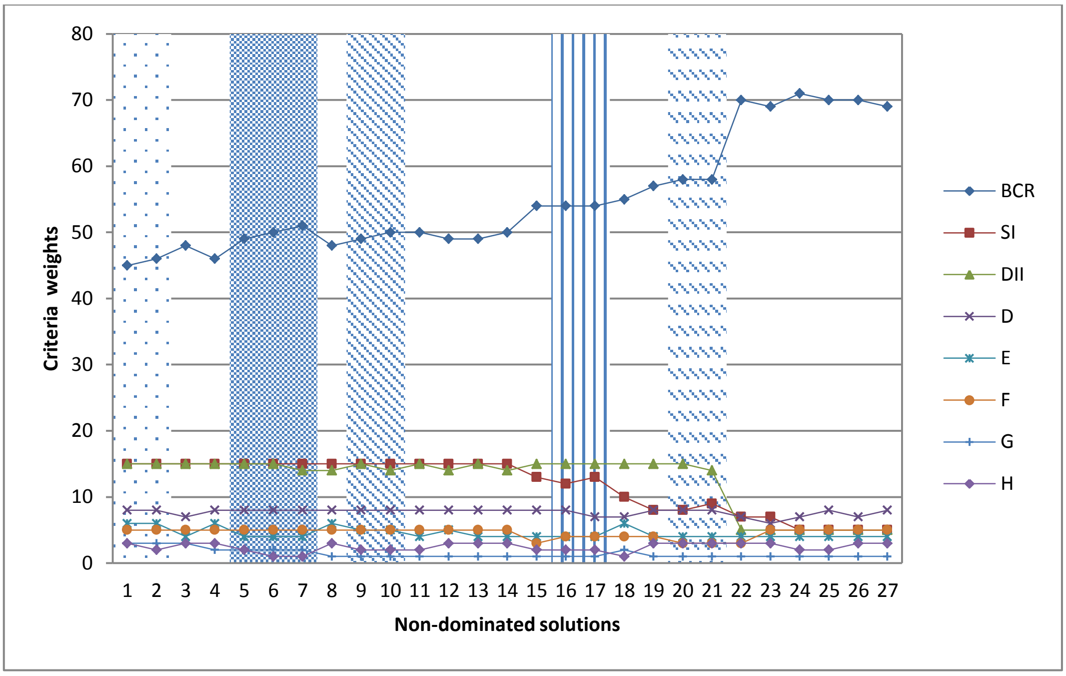


Figure 6-2 – Criteria weights of the non-dominated solutions found for the 1st data set, with 8 criteria.

In Table 6-2 the extreme values for the weight of each criterion, for all non-dominated solutions, are presented.

Table 6-2 – Minimum and maximum values of the criteria weights found for the 1st data set.

	a	*b*	*c*	*d*	*e*	*f*	*g*	*H*
Minimum value	45	5	5	6	4	3	1	1
Maximum value	71	15	15	8	6	5	3	3

In Figure 6-3, solutions for the 2nd data set are presented. 267 different sets of criteria weights were found. Of all 156 dominated solutions only 21 correspond to different results to both objective functions. Regarding the 111 non-dominated solutions, only 14 of them lead to different ranks of measures.

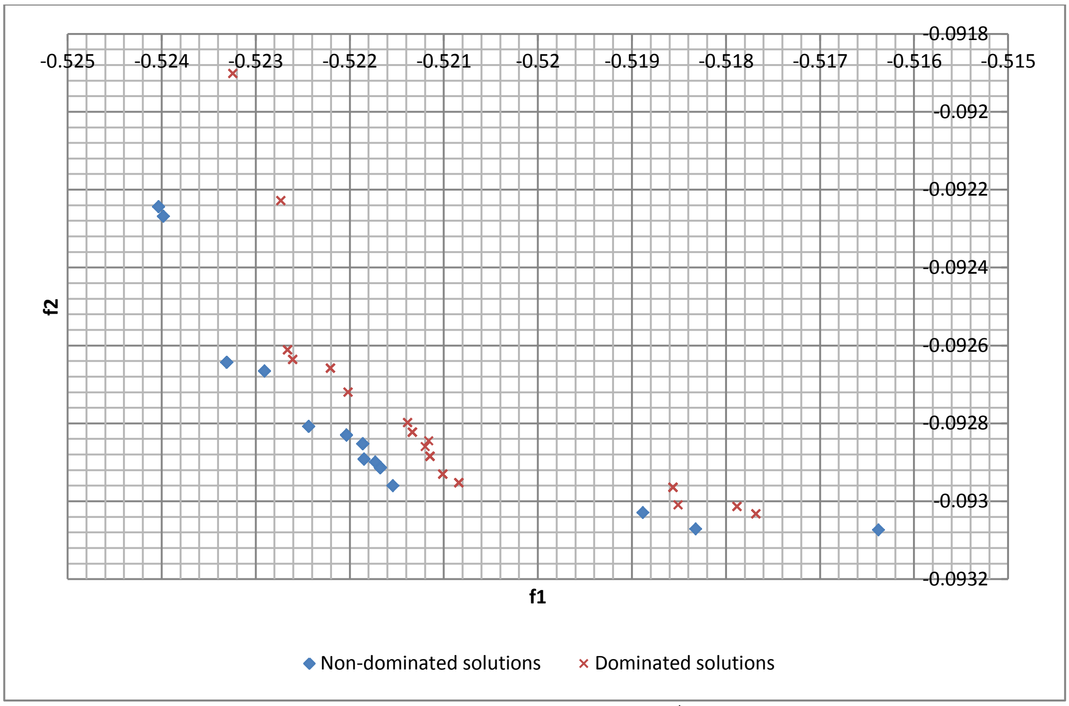


Figure 6-3 – Solutions found for the 2nd data set.

In Figure 6-4 the sets of criteria weights of each non-dominated solutions are presented. The values of the weights of the SI and the DII criteria fluctuate greatly. We can see that, even for the same result regarding the objective functions, there is some fluctuation in the weights of these two criteria. This kind of behaviour does not comply with a good evaluation criterion.

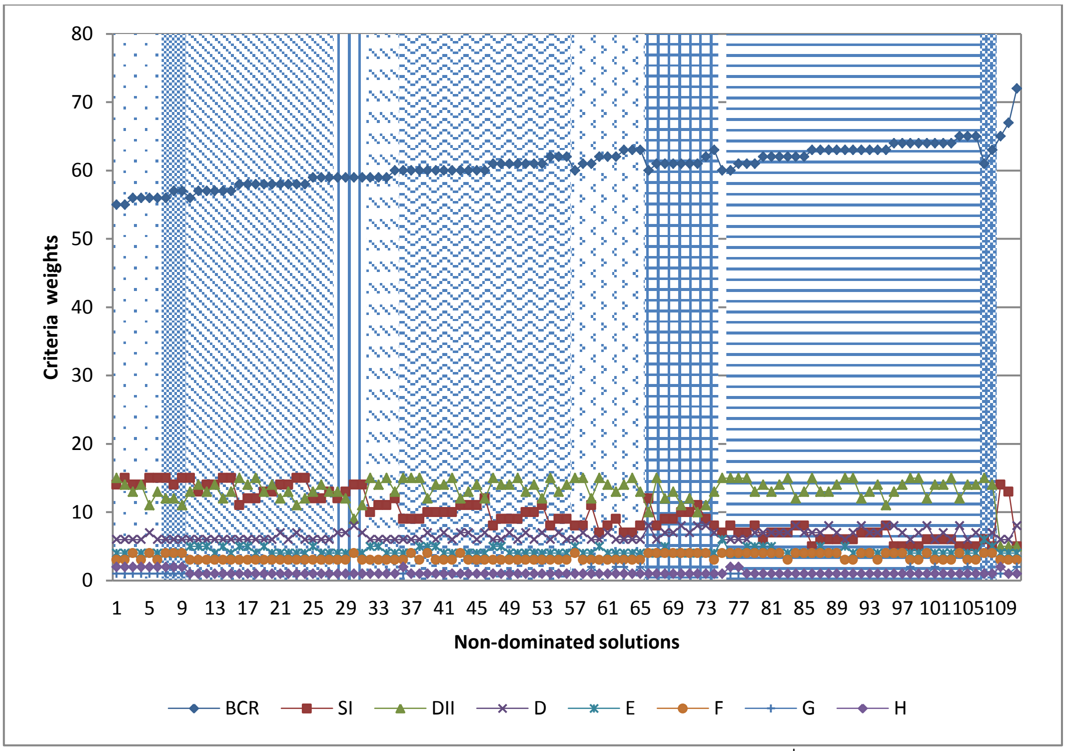


Figure 6-4 – Criteria weights of the non-dominated solutions found for the 2nd data set, with 8 criteria.

The minimum and maximum values found for each criteria weight of the non-dominated solutions are presented in Table 6-3.

Table 6-3 – Minimum and maximum values of the criteria weights found for the 2nd year.

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*
Minimum value	55	5	5	6	4	3	1	1
Maximum value	72	15	15	8	6	4	2	2

In Figure 6-5 the dominated and non-dominated different solutions for the 3rd data set, are presented. From all 203 solutions, 39 are non-dominated. Among these, only 8 correspond to different ranks of measures.

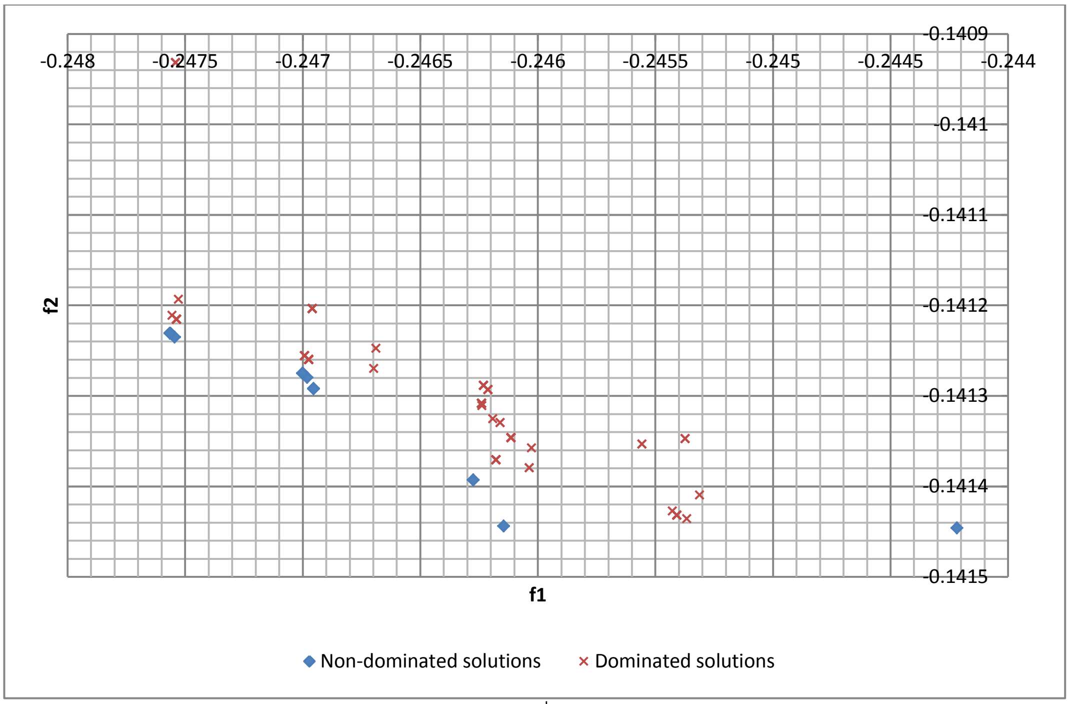


Figure 6-5 - Solutions found for the 3rd data set, for the 8 criteria problem.

The sets of criteria weights that correspond to non-dominated solutions are presented in Figure 6-6. As for the 2nd data set, some fluctuation of the values of the weights of the SI and DII criteria is observed. In order to better analyse the behaviour of the SI and DII criteria, Figure 6-6 is reproduced in Figure 6-7, regarding the values for the metric criteria only.

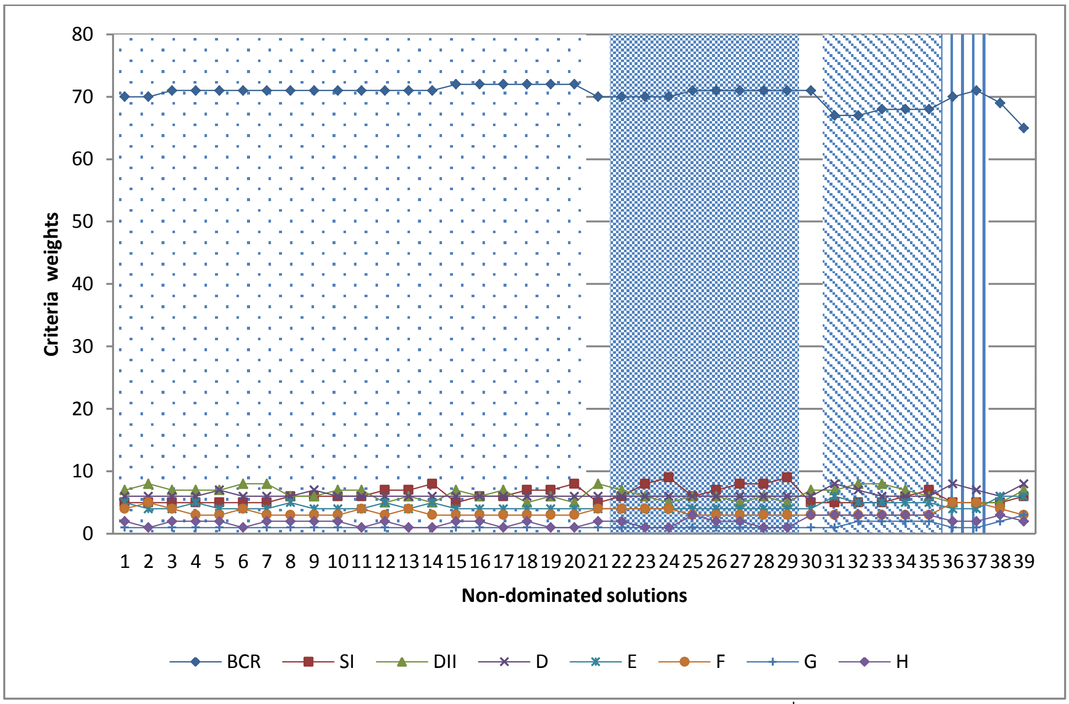


Figure 6-6 – Criteria weights of the non-dominated solutions found for the 3rd data set, with 8 criteria.

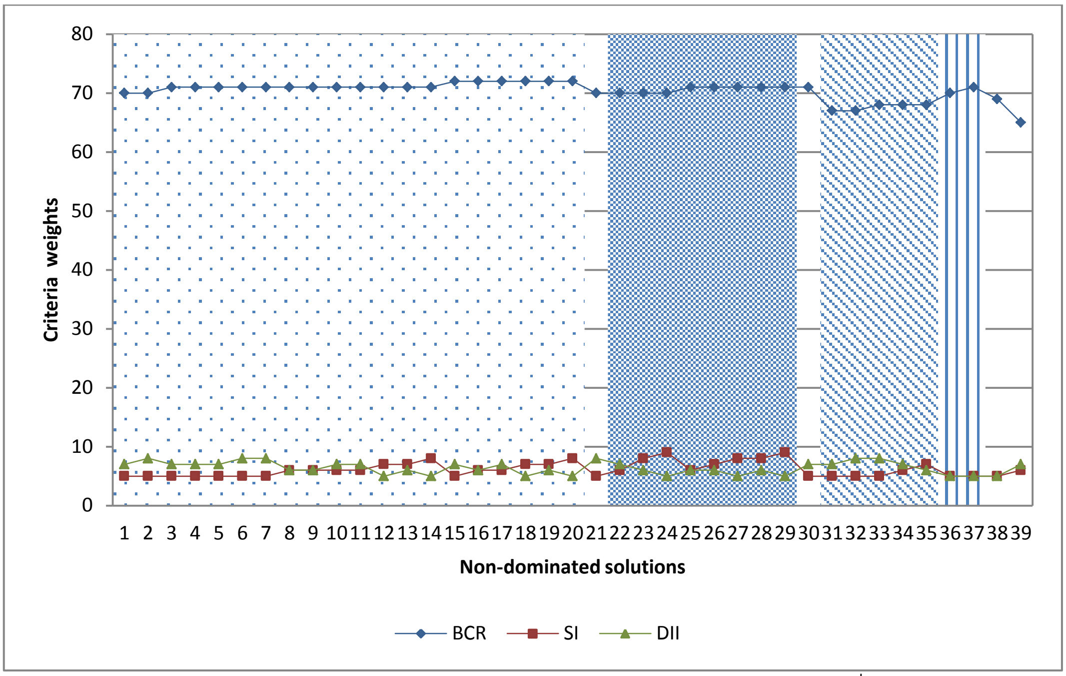


Figure 6-7 - Weights for the metric criteria of the non-dominated solutions found for the 3rd data set, with 8 criteria.

Looking at the values of SI and DII, for the three sets of data (Table A-2, Table A-3, Table A-4, and Table 5-1), we can see that the similarity between these two criteria increases from the 1st to the 3rd data set. This similarity, due to the inexistence of a distinctive feature, is probably the cause for the fluctuation of their weights. In section 6.3 this issue will be address.

In Table 6-4 the maximum and minimum values for the weights of the criteria for the non-dominated solutions are presented.

Table 6-4 – Minimum and maximum values of the criteria weights found for the 3rd data set.

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*
Minimum value	65	5	5	6	4	3	1	1
Maximum value	72	9	8	8	6	5	3	3

Due to the behaviour of the weights of the SI and DII criteria, and since these two criteria are both related to the relative importance of the investments costs in the total costs of measures, it was decided to join them together in a single criterion, SI+DII. The values of SI+DII criterion result from the average of the values of SI and DII. The average value corresponds to valuing equally both criteria, what is in line with the regulator preferences. With this procedure, we turned a problem with eight criteria into a problem with seven criteria.

6.2.2 The seven criteria approach

In this section the results obtained using seven criteria are presented. Since the number of non-dominated solutions found, for the 1st and 3rd sets of data, is lower than the ones found in the eight criteria approach, we reduced the number of individuals in the populations (Table 6-5).

Table 6-5 – GA's parameters set for the problem with 7 criteria.

Parameter	*Value*
Population size	1st data set: 50 2nd data set: 150 3rd data set: 50
Generations	75
Mutation probability	1/7 (inverse of the number of criteria)
Crossover probability	0.9
Crossover distribution index (η_c)	1
Mutation distribution index (η_m)	0.01
Distance threshold (D)	25
Number of runs of the GA	15

The minimum and maximum admissible values for the weights of the SI+DII criterion were set to 10 and 30 points, keeping the relative range of weights of these two criteria similar to the ones used in the previous applications of the methodology.

6.2.2.1 Results of the 1st data set

Of all 68 different solutions that resulted from all 15 runs of the GA, only 21 are non-dominated (Figure 6-8). Of these 21 non-dominated solutions, only 19 result in different rank orders of the measures.

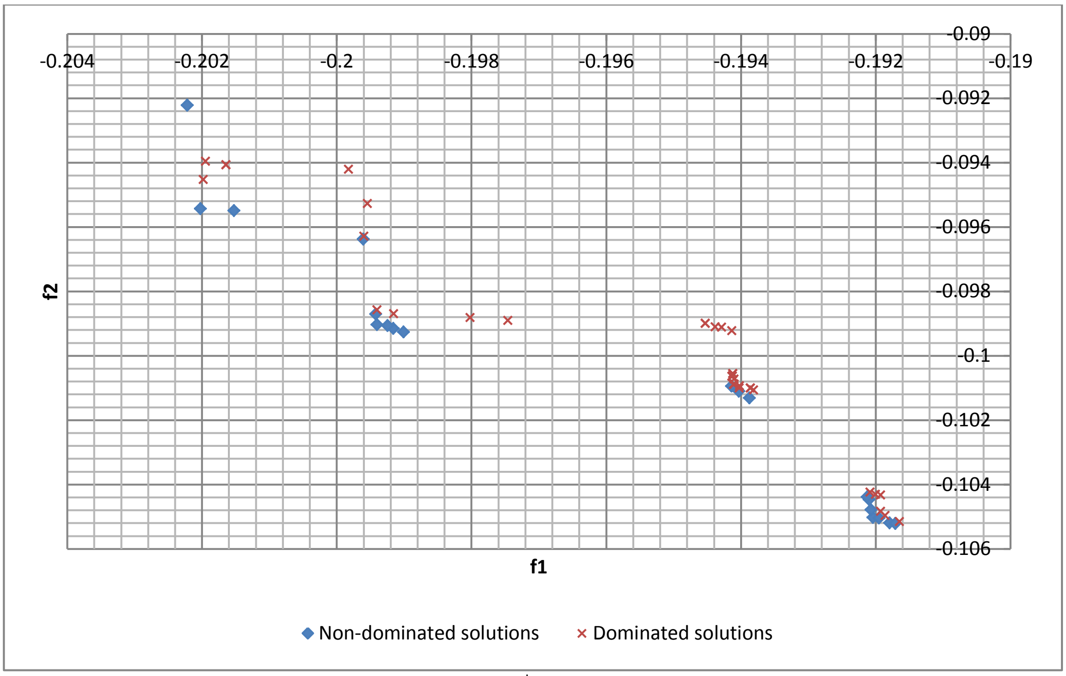


Figure 6-8 - Solutions found for the 1st data set in the problem with 7 criteria.

In Figure 6-9 the weights of the criteria for the non-dominated solutions are presented. Comparing these results with the results obtained for the tests with SI and DII as two separate criteria (Figure 6-2), we can see that the behaviour of the values of the criteria weights, as we go from the 1st solution (closer to the Y-axis) to the last solution, is very similar.

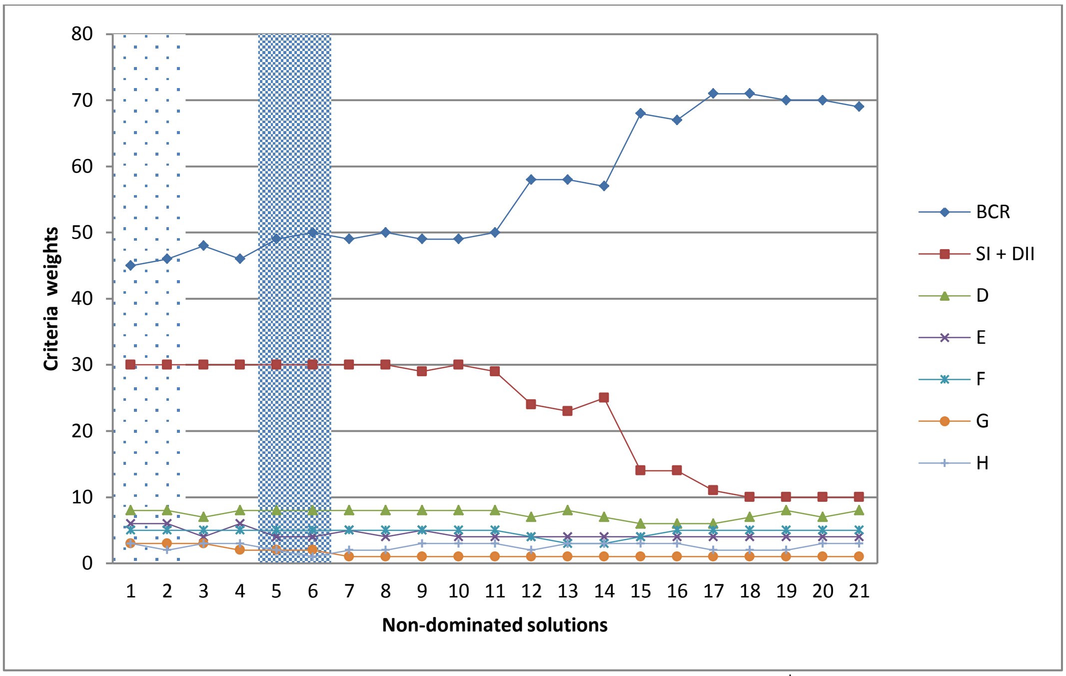


Figure 6-9 – Criteria weights of the non-dominated solutions found for the 1st data set, with 7 criteria.

Also the extreme values found for each criterion weight in the approach with seven criteria (Table 6-6) are very similar to the ones found for the problem with eight criteria, for the same set of data (Table 6-2).

Table 6-6 – Minimum and maximum values of the criteria weights found for the 1st data set.

	a	*b+c*	*d*	*e*	*f*	*g*	*H*
Minimum value	45	10	6	4	3	1	1
Maximum value	71	30	8	6	5	3	3

Each solution in Figure 6-9 leads to a rank order of measures presented in Table A – 5 where the measures are separated by consumer segment and placed according to their rank position (first column), for each non-dominated solution (first row). The table should be read from the 1st solution to the 21st. For every solution, a change in the rank position of a measure is flagged with its code highlighted. As an example, in the column of solution 2, there are no codes highlighted, meaning that the rank order of the measures is the same as was for solution 1. Remember that solutions 1 and 2 are similar regarding both objective functions (Figure 6-9). The same happens to solutions 5 and 6. Looking at solution 3, and for the residential segment, we can see that the codes of measures R8 and R10 are highlighted, meaning that for the solution 2 these two measures occupied different positions in the rank. The same analysis can be performed for every solution.

In the next figures (Figure 6-10, Figure 6-11, and Figure 6-12) the AC values of the measures are presented according to their rank position, for the extreme solutions of the Pareto front (solutions 1 and 21). Solution 1 shows better results regarding the AC objective, whereas solution 21, as will be shown next, shows better results for the CSk objective. The trend lines that can be found in the figures are used as a way of comparing the trend of the AC values of the different measures according to their rank position, for both solutions. A more negative slope of the trend line means that measures with higher AC values are closer to the Y-axis. For the residential (Figure 6-10) and the industrial (Figure 6-12) consumer segments, the slopes of the AC values for the rank of measures obtained with solution 1 is more negative than the ones obtained for solution 21. The same does not happen for the service segment (Figure 6-11). The measures placed in the first places of ranking are measures with high values of BCR, and small values of AC, mainly for the residential and services sector (measures R1, S1 and I1, cf. Table A - 5 and Table A - 2). Since the highest weights are given to this criterion, these measures are placed in top positions, leading to their small values of AC in the top positions. Generally, and for this particular rank position, we can say that the AC objective is deprecated in face of the CSk.

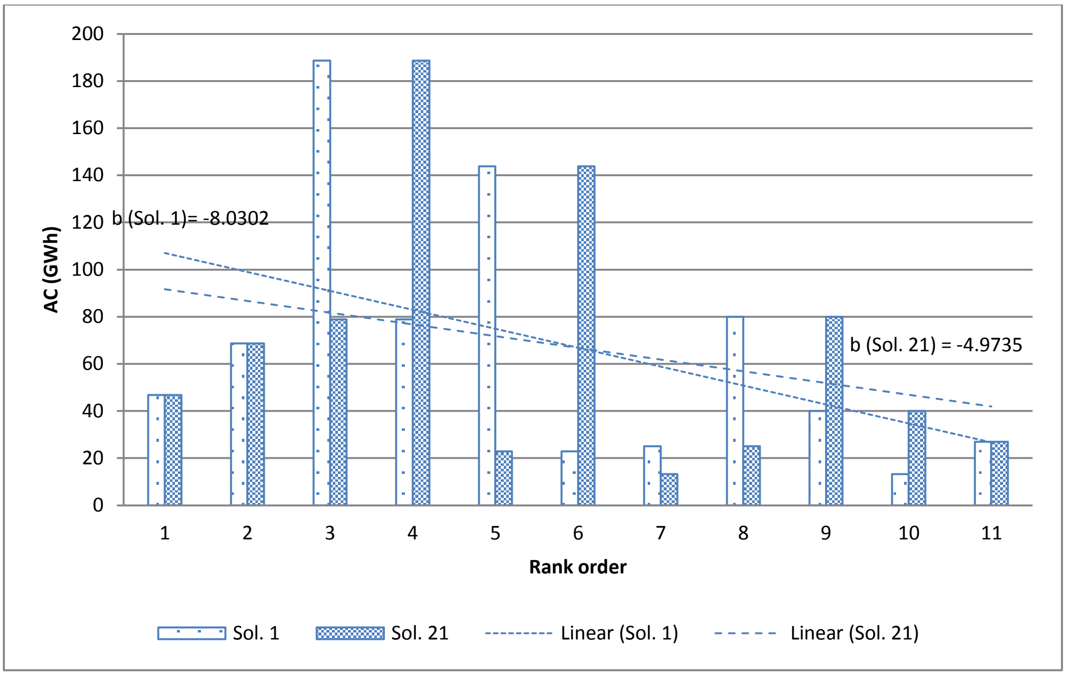


Figure 6-10 – AC values of each measure, for residential consumers, according to their rank order, for solutions 1 and 21, for the 1st data set.

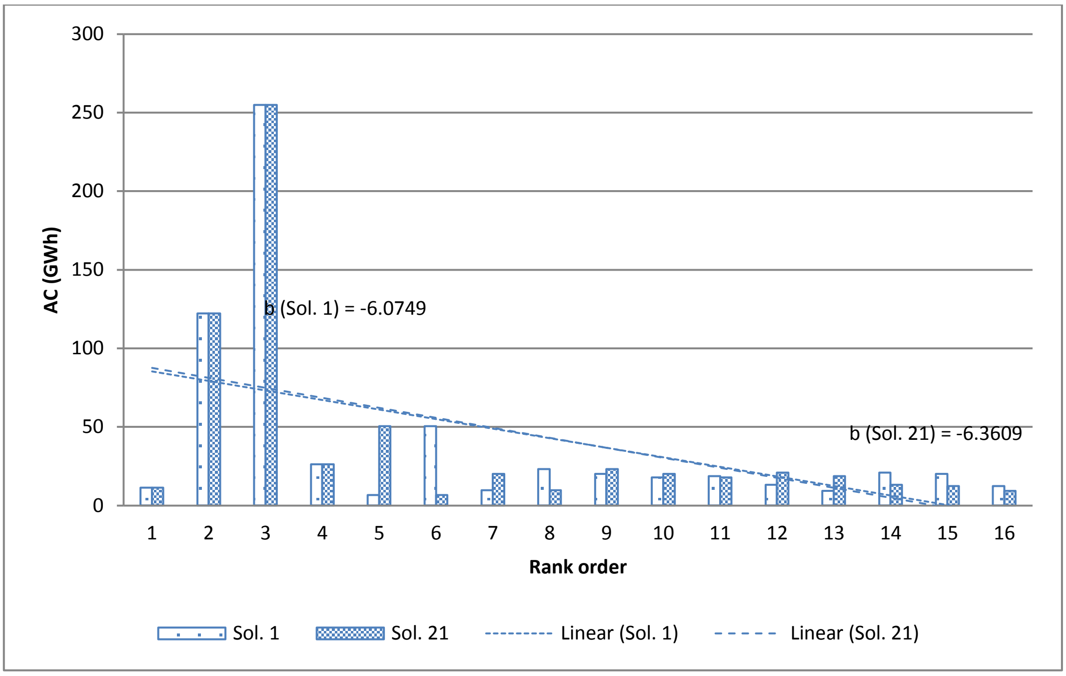


Figure 6-11 - AC values of each measure for the service and commercial segment, according to their rank order, for solutions 1 and 21, for the 1st data set.

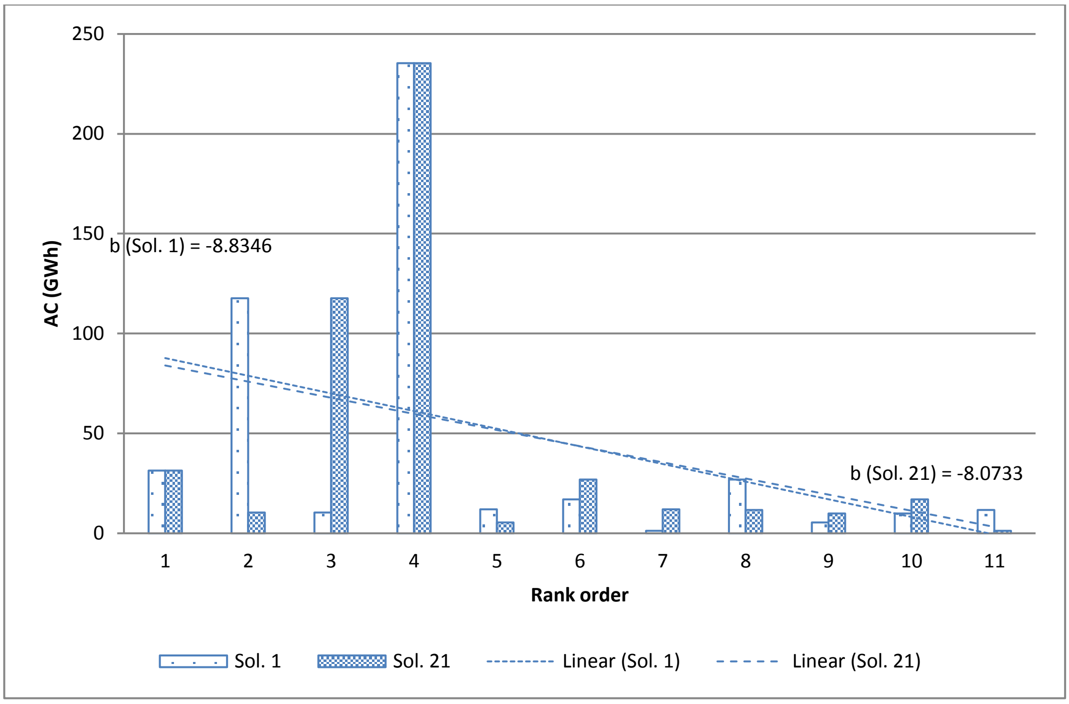


Figure 6-12 - AC values of each measure, for the industrial and agricultural consumers segment, according to their rank order, for solutions 1 and 21, for the 1st data set.

For the CSk objective, measures with higher values of CSk should be at the last positions of the rank. Therefore, the higher the slopes of the trend lines, the better. The values of the CSk, according to the rank positions of each measure, for the extreme solutions of the Pareto front, are presented in next figures (Figure 6-13 for the residential segment, Figure 6-14 for the services and commercial segment, and Figure 6-15 for the industrial and agricultural segment). For this objective, solution 21 presents better results than solution 1, for all consumer segments.

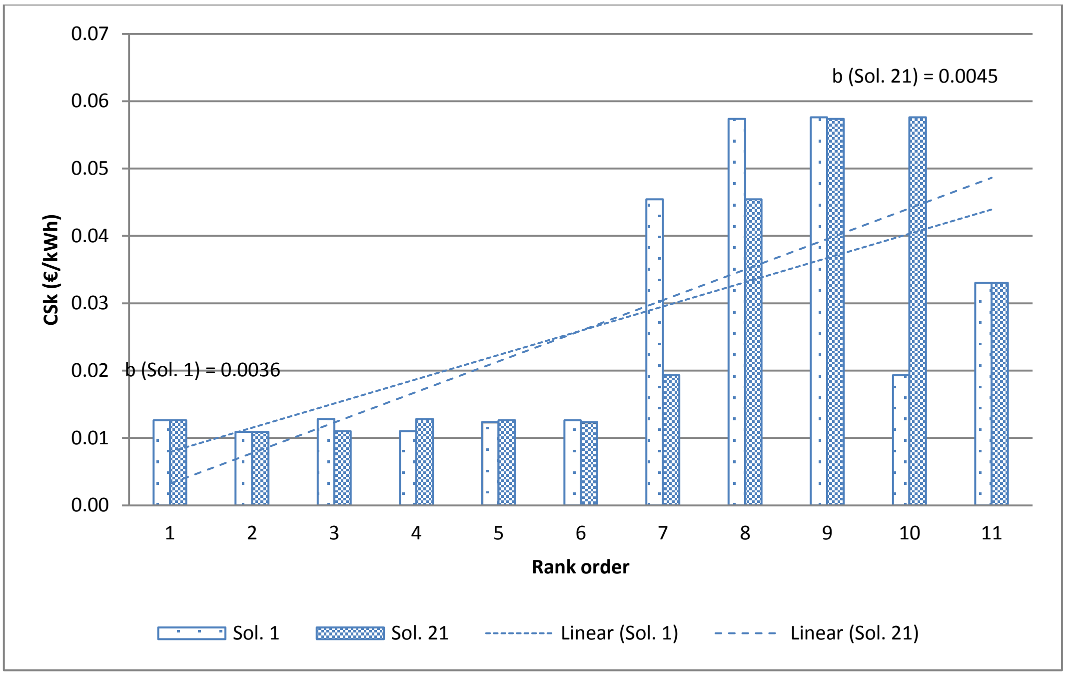


Figure 6-13 - CSK values of each measure, for the residential consumers segment, according to their rank order, for solutions 1 and 21, for the 1st data set.

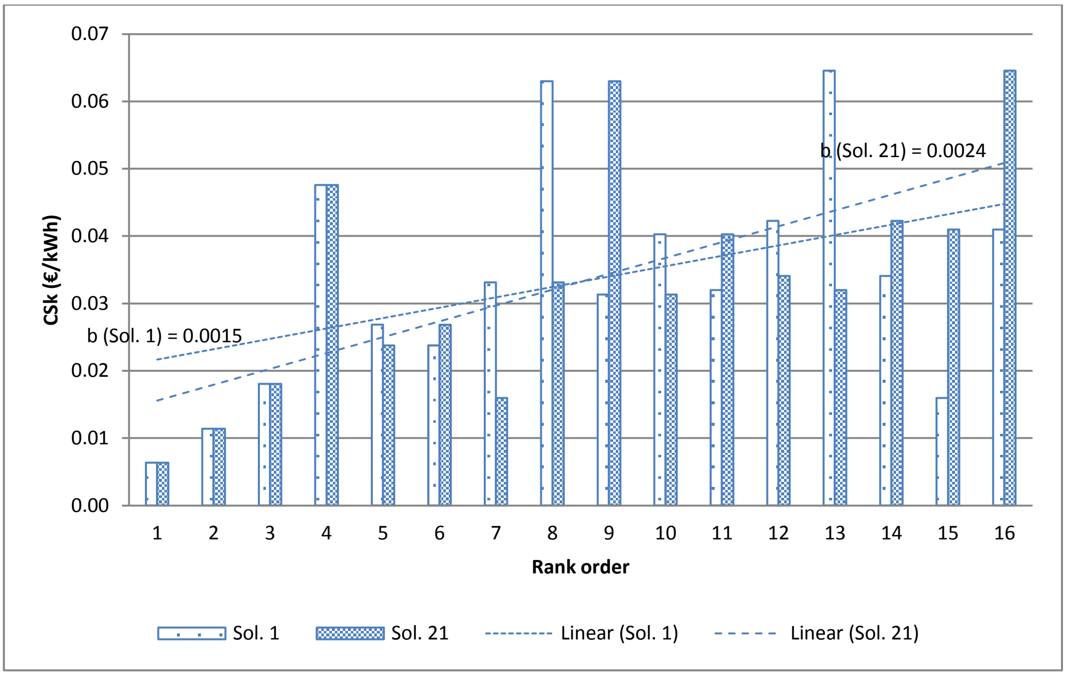


Figure 6-14 - CSK values of each measure, for the service and commercial consumers segment, according to their rank order, for solutions 1 and 21, for the 1st data set.

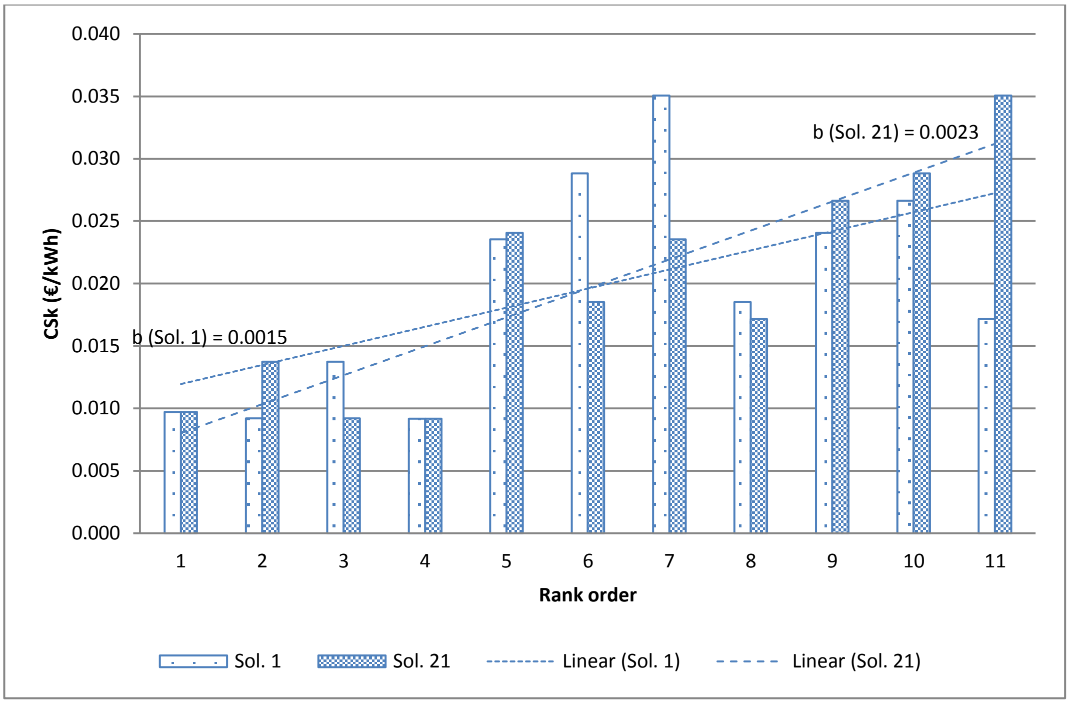
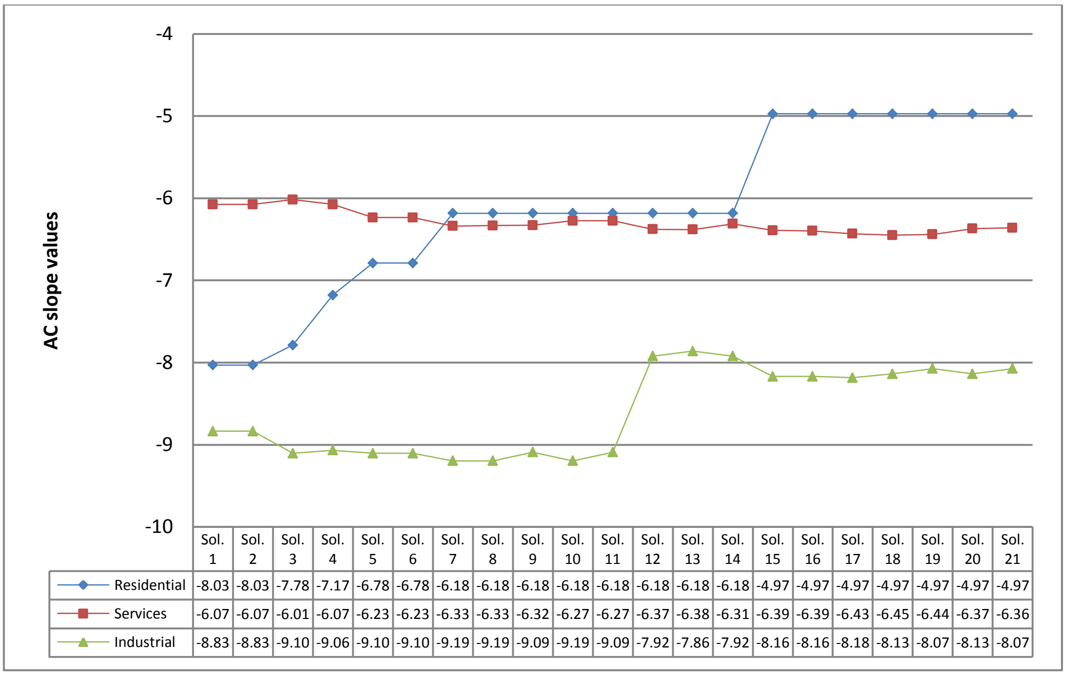


Figure 6-15 - CSK values of each measure, for the industrial and agricultural consumers segment, according to their rank order, for solution 1 and 21, for the 1st data set.

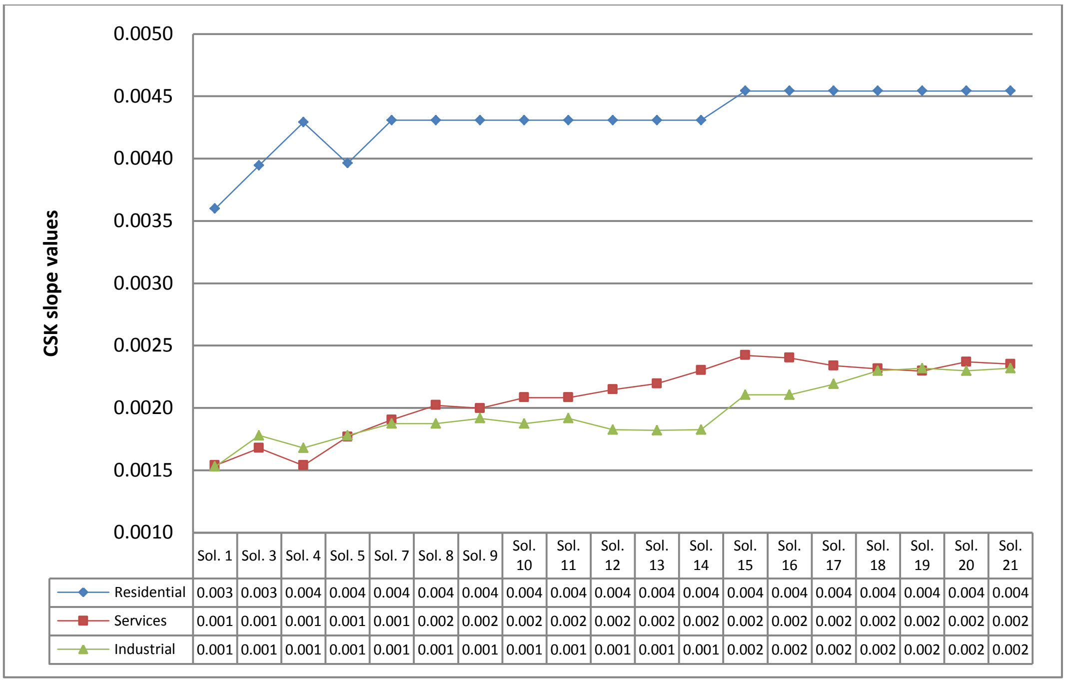
However, we are only looking at extreme solutions, and it is important to see how the intermediate solutions behave. In Figure 6-16 we can see the values of the slopes of the trend lines for the AC values according to the measures ranking position for all non-dominated solutions. More negative slope values are desirable for the AC objective and should be found near the Y-axis. In other words, from solution 1 to solution 21, slopes should be turning less negative. This is true for the residential sector, but not for the other two segments. Nevertheless, if results get worse for a segment, they get better for at least one of the others. Looking back (Figure 6-9) solutions 1 originates the same rank order that solution 2. Likewise, solutions 5 and 6 lead to the same rank of measures. Then, the slopes of the trend lines for each of those pairs of solutions will be the same, for all consumer segments, as can be observed in Figure 6-16.



	Sol. 1	Sol. 2	Sol. 3	Sol. 4	Sol. 5	Sol. 6	Sol. 7	Sol. 8	Sol. 9	Sol. 10	Sol. 11	Sol. 12	Sol. 13	Sol. 14	Sol. 15	Sol. 16	Sol. 17	Sol. 18	Sol. 19	Sol. 20	Sol. 21
Residential	-8.03	-8.03	-7.78	-7.17	-6.78	-6.78	-6.18	-6.18	-6.18	-6.18	-6.18	-6.18	-6.18	-6.18	-4.97	-4.97	-4.97	-4.97	-4.97	-4.97	-4.97
Services	-6.07	-6.07	-6.01	-6.07	-6.23	-6.23	-6.33	-6.33	-6.32	-6.27	-6.27	-6.37	-6.38	-6.31	-6.39	-6.39	-6.43	-6.45	-6.44	-6.37	-6.36
Industrial	-8.83	-8.83	-9.10	-9.06	-9.10	-9.10	-9.19	-9.19	-9.09	-9.19	-9.09	-7.92	-7.86	-7.92	-8.16	-8.16	-8.18	-8.13	-8.07	-8.13	-8.07

Figure 6-16 – Evolution of the slopes of linear trend lines of the AC values according to rank order of measures for each non-dominated solution, for the 1st data set.

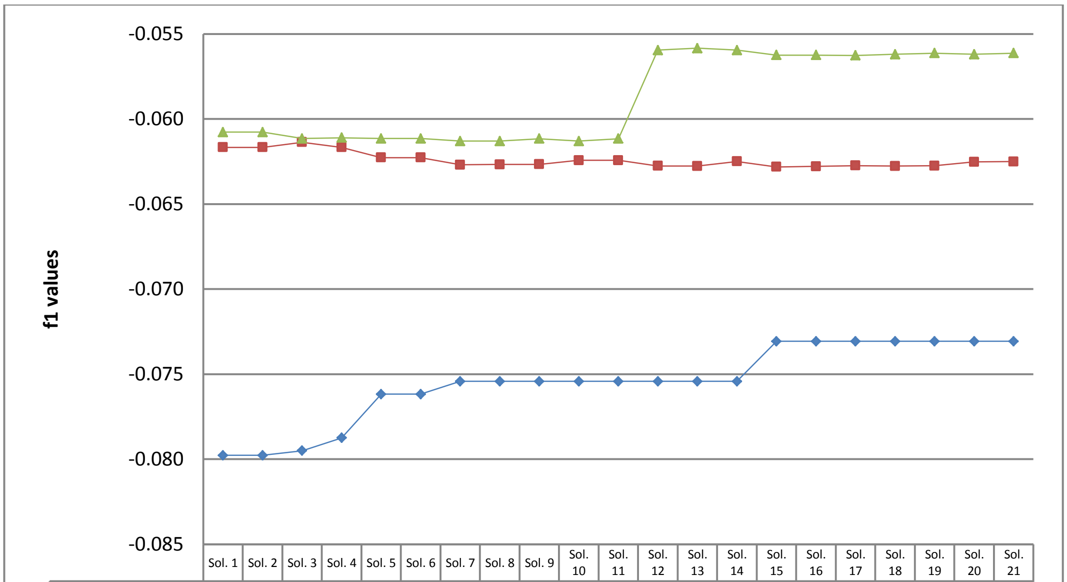
For the sake of readability, we removed solutions 2 and 6 from the figure regarding CSk slopes of the trend lines (Figure 6-17).



	Sol. 1	Sol. 3	Sol. 4	Sol. 5	Sol. 7	Sol. 8	Sol. 9	Sol. 10	Sol. 11	Sol. 12	Sol. 13	Sol. 14	Sol. 15	Sol. 16	Sol. 17	Sol. 18	Sol. 19	Sol. 20	Sol. 21
Residential	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Services	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Industrial	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002

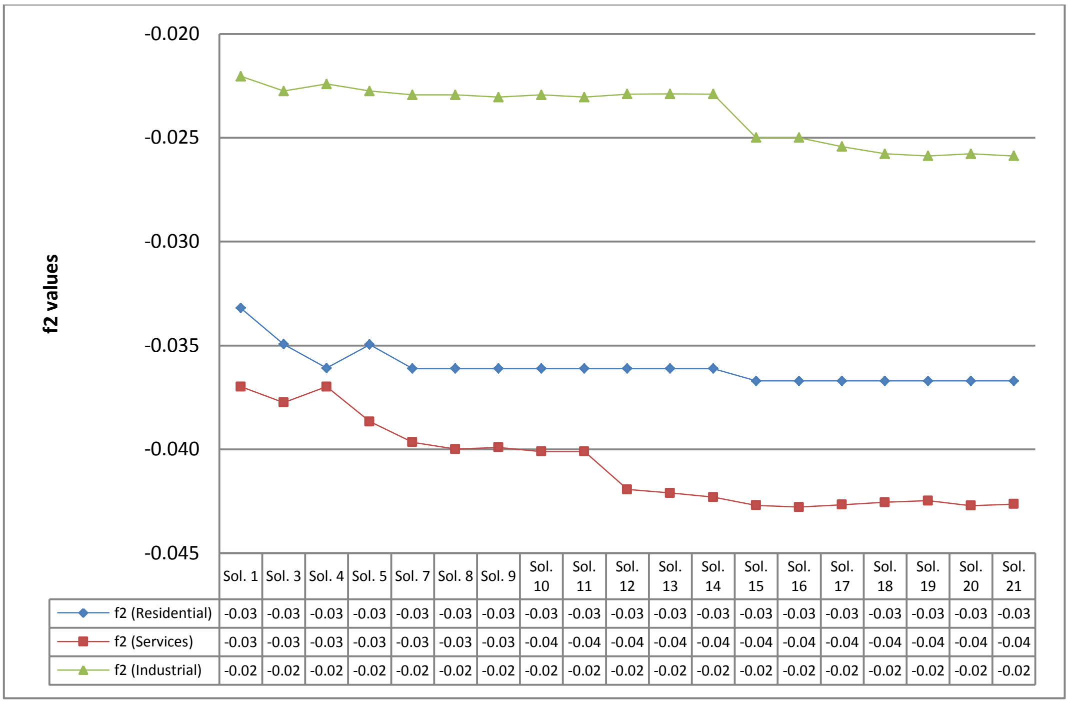
Figure 6-17 - Evolution of the slopes of linear trend lines of the CSK values according to rank order of measures for each non-dominated solution, for the 1st data set.

The rank of the measures was obtained using weighted sums as objective functions. It is therefore interesting to see how the evolution of the trend lines can be compared with the results of the weighted sums for each solution, for both objectives. The results can be found in Figure 6-18, for the AC objective, and in Figure 6-19 for the CSk objective. We can see a strong relation between the progresses of the curves of Figure 6-16 and Figure 6-18 for the AC objective, and Figure 6-17 and Figure 6-19 for the CSk objective. For the CSk objective, higher slope values (Figure 6-17) are related to lower (more negative) values of the corresponding weighted sums (Figure 6-19).



	Sol. 1	Sol. 2	Sol. 3	Sol. 4	Sol. 5	Sol. 6	Sol. 7	Sol. 8	Sol. 9	Sol. 10	Sol. 11	Sol. 12	Sol. 13	Sol. 14	Sol. 15	Sol. 16	Sol. 17	Sol. 18	Sol. 19	Sol. 20	Sol. 21
f1 (Residential)	-0.079	-0.079	-0.079	-0.078	-0.076	-0.076	-0.075	-0.075	-0.075	-0.075	-0.075	-0.075	-0.075	-0.075	-0.073	-0.073	-0.073	-0.073	-0.073	-0.073	-0.073
f1 (Services)	-0.061	-0.061	-0.061	-0.061	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062
f1 (Industrial)	-0.060	-0.060	-0.061	-0.061	-0.061	-0.061	-0.061	-0.061	-0.061	-0.061	-0.061	-0.056	-0.055	-0.056	-0.056	-0.056	-0.056	-0.056	-0.056	-0.056	-0.056

Figure 6-18 – The objective function values for the AC objective and for each consumer segment, for each non-dominated solution for the 1st set of data.



	Sol. 1	Sol. 3	Sol. 4	Sol. 5	Sol. 7	Sol. 8	Sol. 9	Sol. 10	Sol. 11	Sol. 12	Sol. 13	Sol. 14	Sol. 15	Sol. 16	Sol. 17	Sol. 18	Sol. 19	Sol. 20	Sol. 21
f2 (Residential)	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
f2 (Services)	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
f2 (Industrial)	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02

Figure 6-19 - The objective function values for the CSK objective and for each consumer segment, for each non-dominated solution for the 1st set of data.

6.2.2.2 Results of the 2nd data set

From all 147 different sets of criteria weights found, 50 are non-dominated (Figure 6-20). Of the 50 sets of non-dominated solutions, only 11 correspond to different rank of measures.

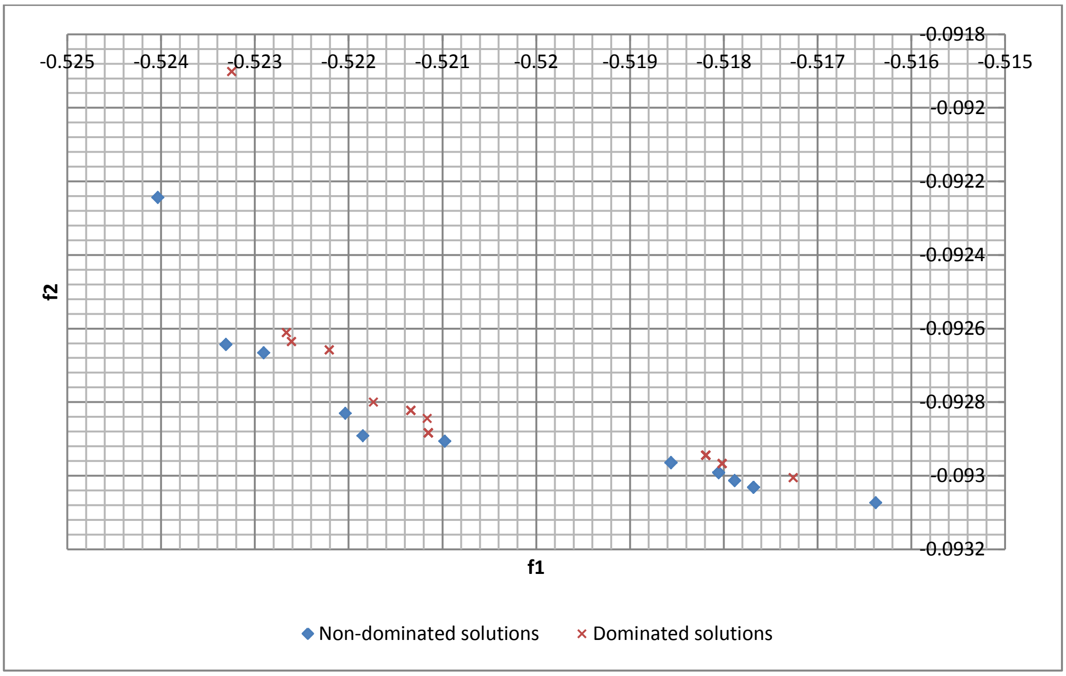


Figure 6-20 - Solutions found for the 2nd data set in the problem with 7 criteria.

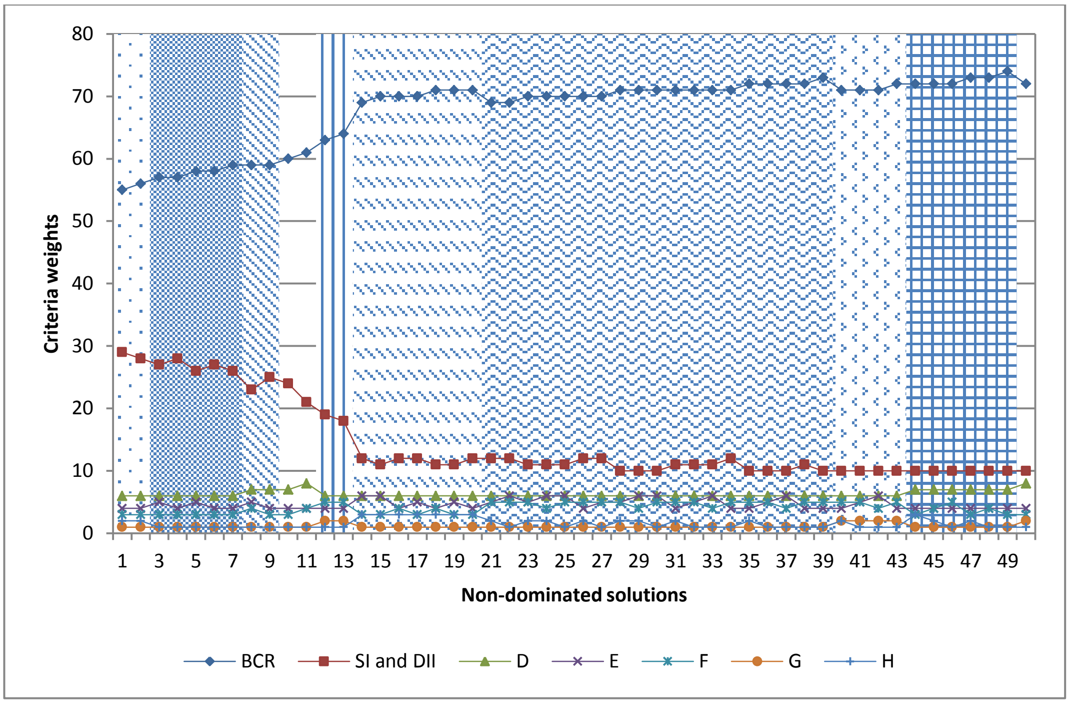


Figure 6-21 – Criteria weights of the non-dominated solutions found for the 2nd data set, with 7 criteria.

Comparing the results obtained for this data set for the problems with 8 (Figure 6-4) and 7 criteria (Figure 6-21), we can see that the number of solutions was greatly reduced. Also, the fluctuation of the weights values almost disappeared.

The extreme values found for the weights of the criteria of the non-dominated solutions are presented in Table 6-7.

Table 6-7 – Minimum and maximum values of the criteria weights found for the 2nd data set.

	a	*b+c*	*d*	*e*	*f*	*g*	*h*
Minimum value	55	10	6	4	3	1	1
Maximum value	74	29	8	6	5	2	3

Comparing the results from the 2nd data set with the ones obtained for the 1st data set, the number of non-dominated solutions more than doubles (50 for this case and 21 for the 1st data set). However, for the 2nd data set those 50 non-dominated solutions resulted in only 11 different results regarding the rank orders of measures (Figure 6-21). On the other hand, for the 1st data set, 21 non-dominated solutions resulted in 19 ranking arrangements (Figure 6-9). The ranges of the weights of the SI+DII criterion stayed very similar (Table 6-6, Table 6-7 and Figure 6-44, ahead).

The AC values of the measures according to their rank position for each consumer segment are presented in Figure 6-22, for the residential segment, Figure 6-23 for the services and commerce, and

Figure 6-24 for the industry and agriculture. For each one of them, the slopes of the trend lines indicate better results for the solution 1 than for solution 50, regarding the AC objective.

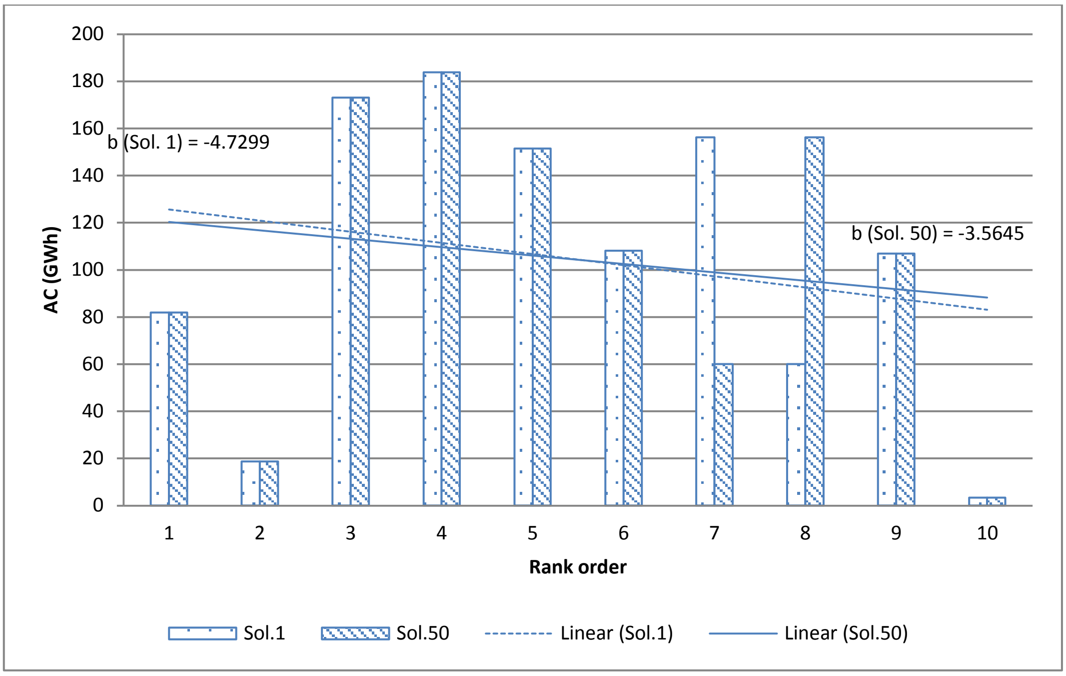


Figure 6-22 - AC values of each measure, for residential consumers, according to their rank order, for solutions 1 and 50, for the 2nd data set.

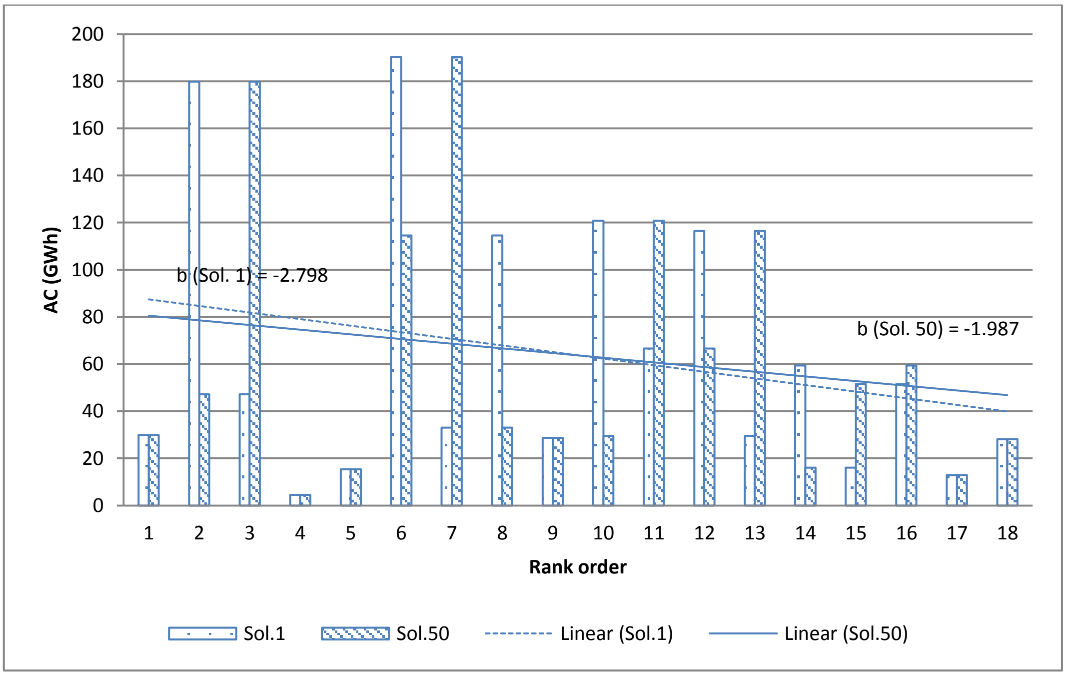


Figure 6-23 - AC values of each measure, for the service and commercial consumer segment, according to their rank order, for solutions 1 and 50, for the 2nd data set.

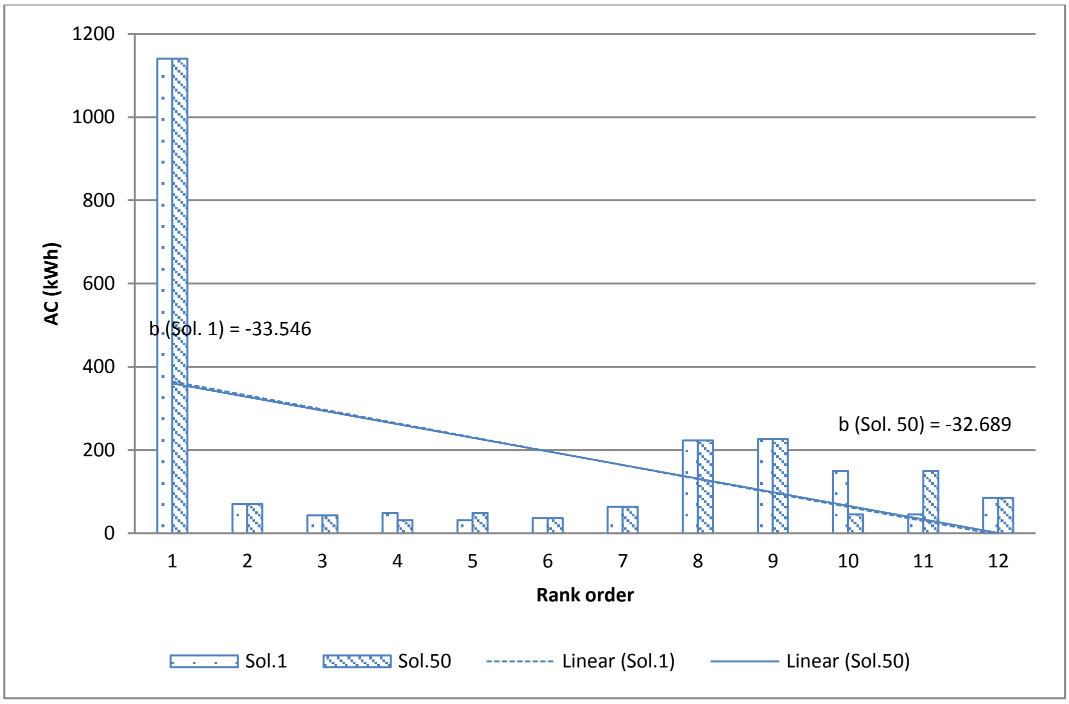
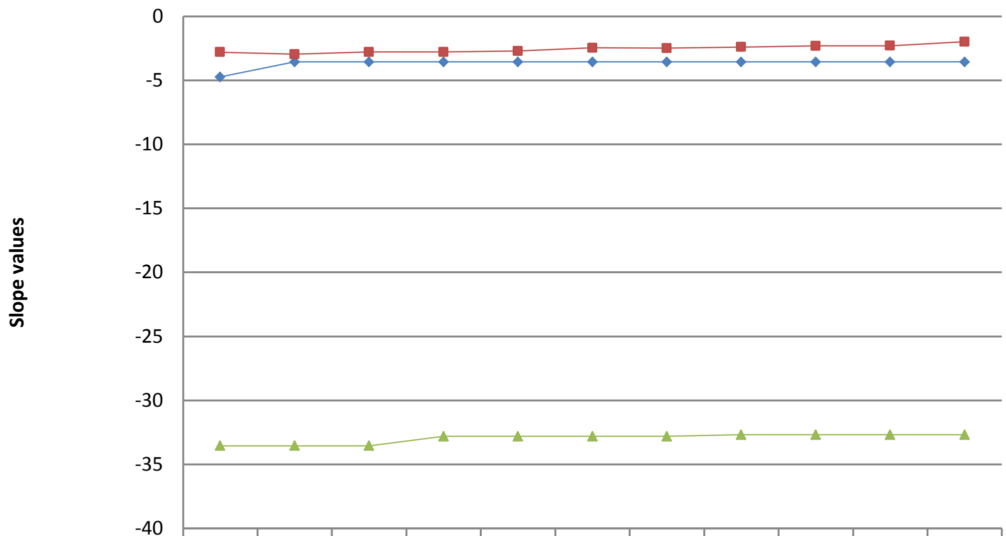


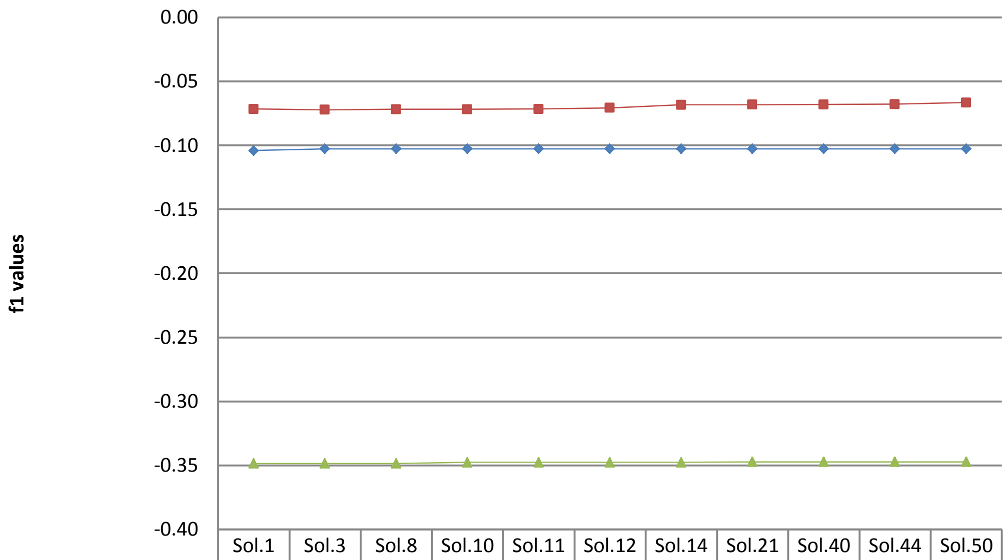
Figure 6-24 - AC values of each measure, for the industrial and agricultural consumer segment, according to their rank order, for solutions 1 and 50, for the 2nd data set.

Instead of looking only to the extreme solutions, we can observe how the slopes of the trend lines behave for all non-dominated solutions. For clarity reasons, in Figure 6-25 only the solutions that contribute with different ranking order of the measures are presented. We can see that the slopes of the trend lines have very slight variations. We can also see that these variations closely follow the variations of the weighted sums (objective functions) for each segment, and for each solution (Figure 6-26).



	Sol.1	Sol.3	Sol.8	Sol.10	Sol.11	Sol.12	Sol.14	Sol.21	Sol.40	Sol.44	Sol.50
Residential	-4.730	-3.564	-3.564	-3.564	-3.564	-3.564	-3.564	-3.564	-3.564	-3.564	-3.564
Services	-2.798	-2.967	-2.787	-2.787	-2.711	-2.465	-2.486	-2.406	-2.316	-2.297	-1.987
Industrial	-33.55	-33.55	-33.55	-32.81	-32.81	-32.81	-32.81	-32.69	-32.69	-32.69	-32.69

Figure 6-25 – Evolution of the slopes of the linear trend lines of the AC values according to the rank order of the measures, for each non-dominated solution, for the 2nd data set.



	Sol.1	Sol.3	Sol.8	Sol.10	Sol.11	Sol.12	Sol.14	Sol.21	Sol.40	Sol.44	Sol.50
f1 (Residential)	-0.1040	-0.1027	-0.1027	-0.1027	-0.1027	-0.1027	-0.1027	-0.1027	-0.1027	-0.1027	-0.1027
f1 (Services)	-0.0716	-0.0722	-0.0718	-0.0718	-0.0716	-0.0707	-0.0683	-0.0682	-0.0680	-0.0678	-0.0665
f1 (Industrial)	-0.3484	-0.3484	-0.3484	-0.3476	-0.3476	-0.3476	-0.3476	-0.3472	-0.3472	-0.3472	-0.3472

Figure 6-26 - The objective function values for the AC objective, regarding each consumer segment, for each non-dominated solution for the 2nd set of data.

As for the AC objective, for the CSk objective the slopes of the trend lines for the extreme solutions in the Pareto front are in line with the expected (Figure 6-27 for the residential, Figure 6-28 for the services and commerce, and Figure 6-29 for the industrial and agricultural segment). However, the differences are very small.

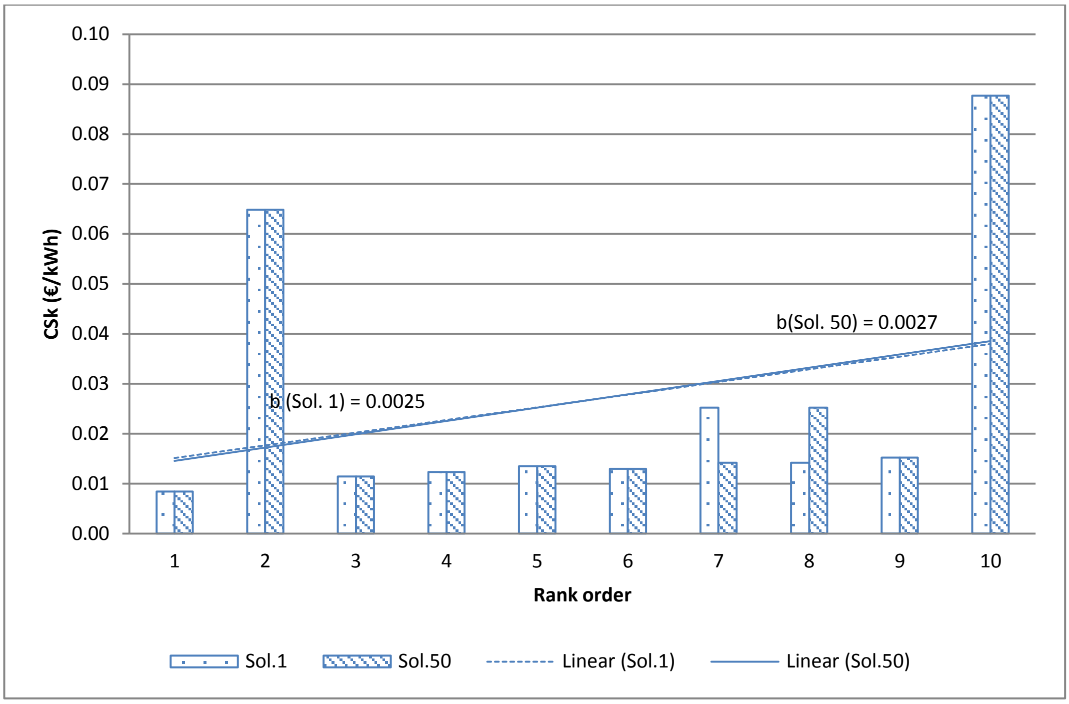


Figure 6-27 - CSk values of each measure, for the residential consumer segment, according to their rank order, for solutions 1 and 11, for the 2nd data set.

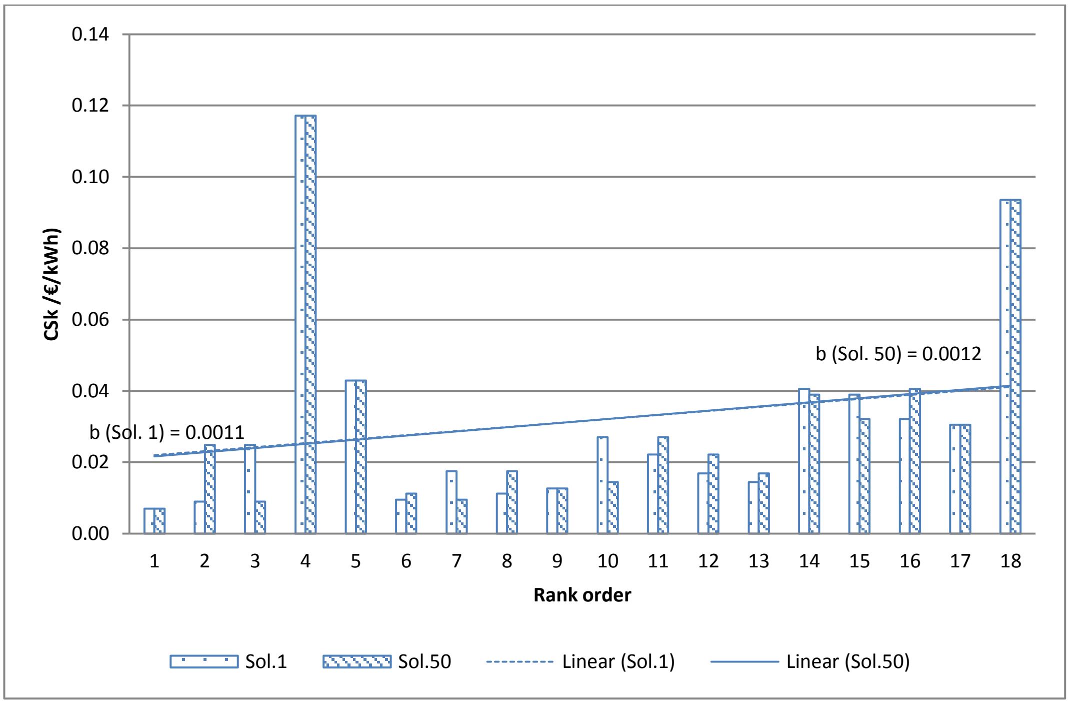


Figure 6-28 - CSk values of each measure, for the service and commercial consumer segment, according to their rank order, for solutions 1 and 11, for the 2nd data set.

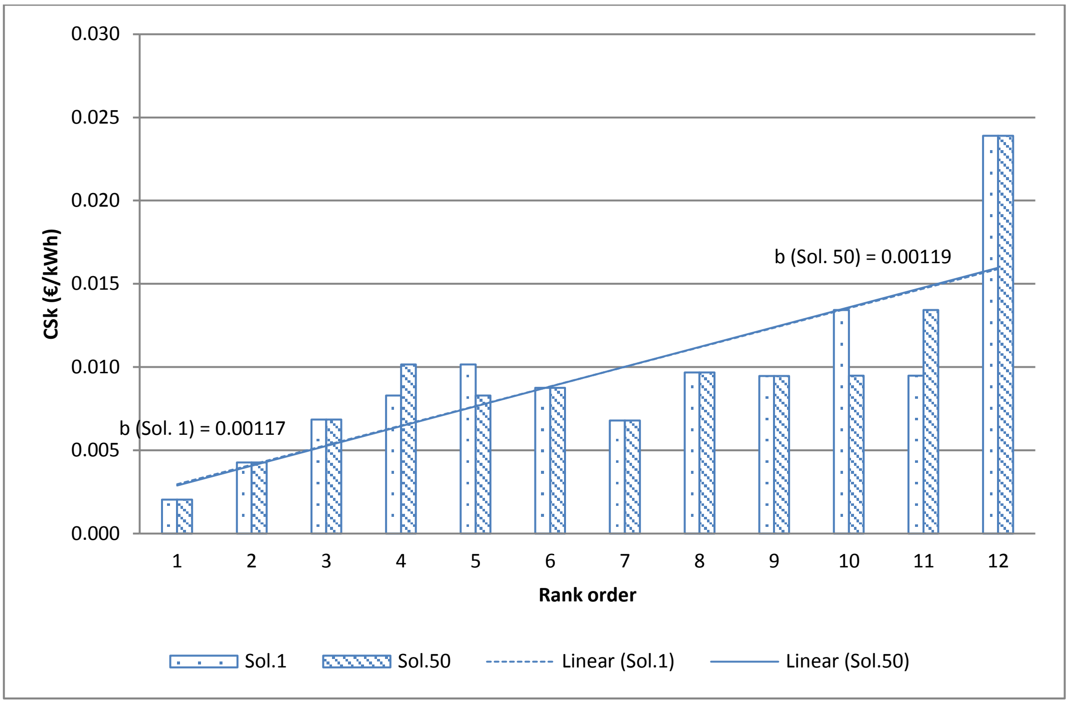
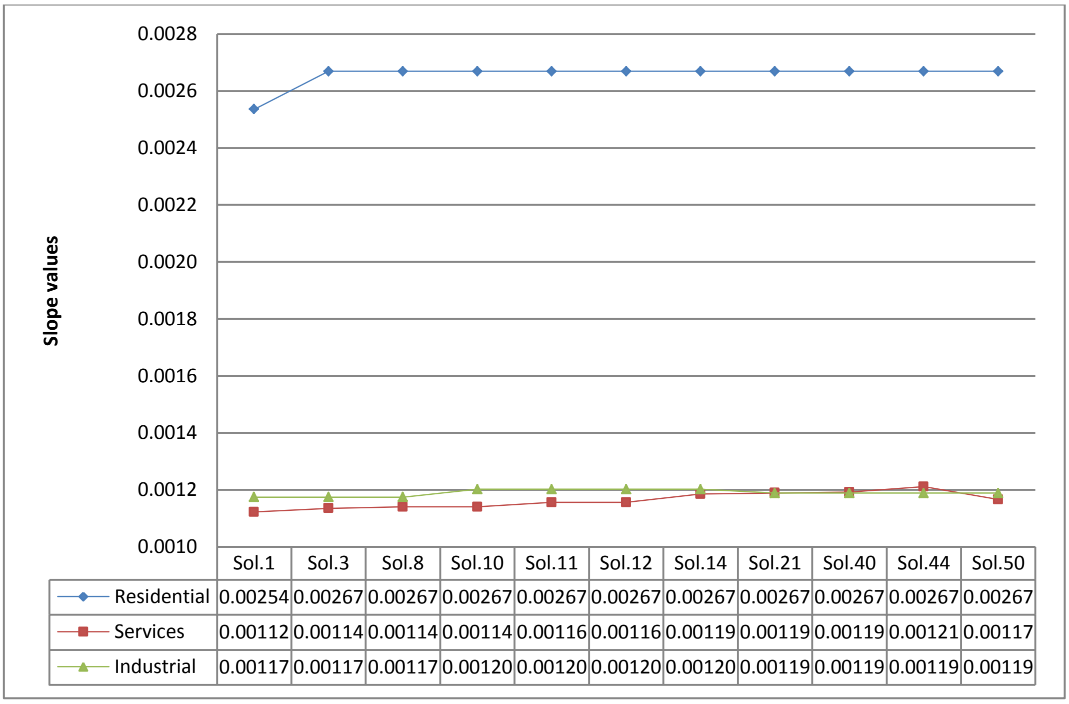


Figure 6-29 - CSk values of each measure, for the industrial and agricultural consumer segment, according to their rank order, for solutions 1 and 11, for the 2nd data set.

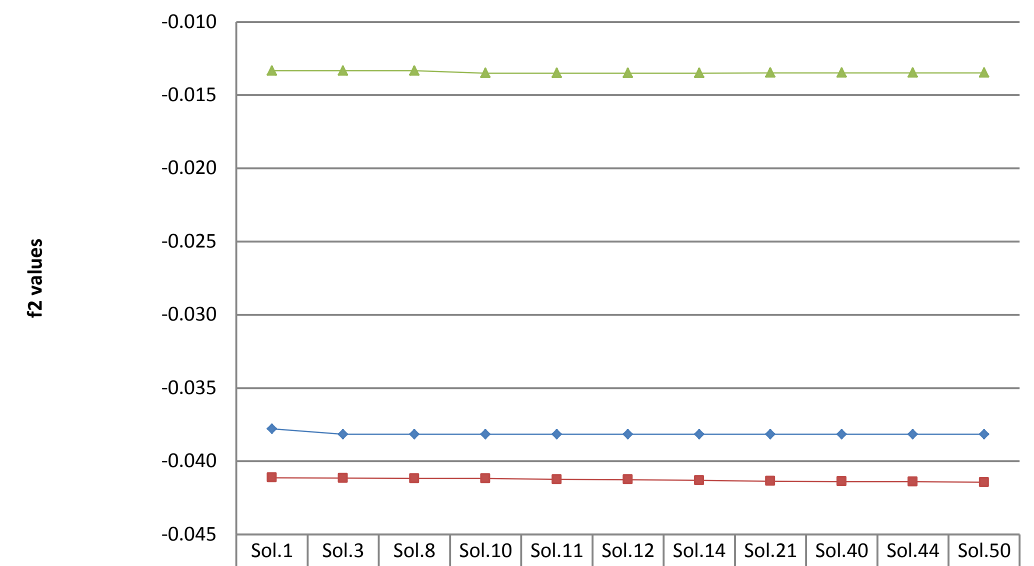
In Figure 6-30 we can see the behaviour of the slopes of the trend lines for all non-dominated solutions (that originate different rank orders).



	Sol.1	Sol.3	Sol.8	Sol.10	Sol.11	Sol.12	Sol.14	Sol.21	Sol.40	Sol.44	Sol.50
Residential	0.00254	0.00267	0.00267	0.00267	0.00267	0.00267	0.00267	0.00267	0.00267	0.00267	0.00267
Services	0.00112	0.00114	0.00114	0.00114	0.00116	0.00116	0.00119	0.00119	0.00119	0.00121	0.00117
Industrial	0.00117	0.00117	0.00117	0.00120	0.00120	0.00120	0.00120	0.00119	0.00119	0.00119	0.00119

Figure 6-30 - Evolution of the slopes of the linear trend lines of the CSk values according to the rank order of the measures for each non-dominated solution, for the 2nd data set.

The results obtained for the slopes of the trend lines are very close to the results of the weighted sums for each consumer segment (Figure 6-31).



	Sol.1	Sol.3	Sol.8	Sol.10	Sol.11	Sol.12	Sol.14	Sol.21	Sol.40	Sol.44	Sol.50
f2 (Residential)	-0.0377	-0.0381	-0.0381	-0.0381	-0.0381	-0.0381	-0.0381	-0.0381	-0.0381	-0.0381	-0.0381
f2 (Services)	-0.0411	-0.0411	-0.0411	-0.0411	-0.0412	-0.0412	-0.0413	-0.0413	-0.0413	-0.0414	-0.0414
f2 (Industrial)	-0.0133	-0.0133	-0.0133	-0.0134	-0.0134	-0.0134	-0.0134	-0.0134	-0.0134	-0.0134	-0.0134

Figure 6-31 - The objective function values for the CSk objective, regarding each consumer segment, for each non-dominated solution for the 2nd set of data.

6.2.2.3 Results of the 3rd data set

From the runs performed with the 3rd set of data, considering 7 criteria, 57 sets of criteria weights resulted, 12 of which non-dominated (Figure 6-32). From the 12 non-dominated sets of weights, only 6 originate different ranks of measures (Figure 6-33).

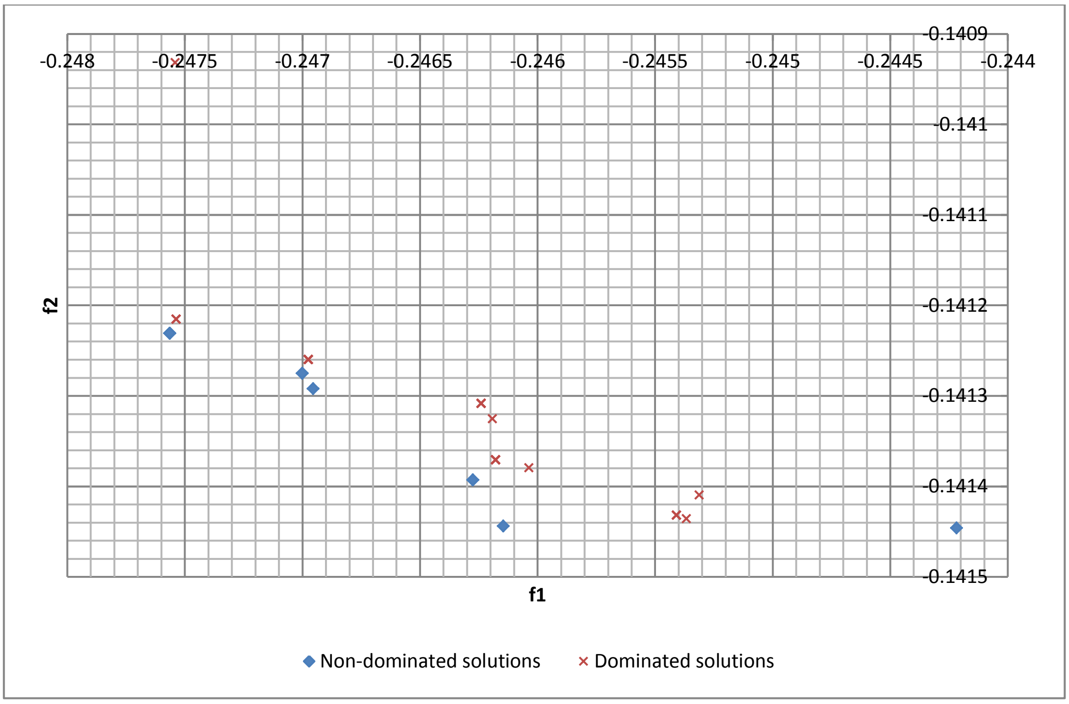


Figure 6-32 - Solutions found for the 3rd data set, considering 7 criteria.

As for the previous data sets, the number of solutions was significantly reduced when comparing the results obtained for this same case (Figure 6-33), for the 8 criteria approach (Figure 6-6). The fluctuation of the values of the criteria weights also reduced.

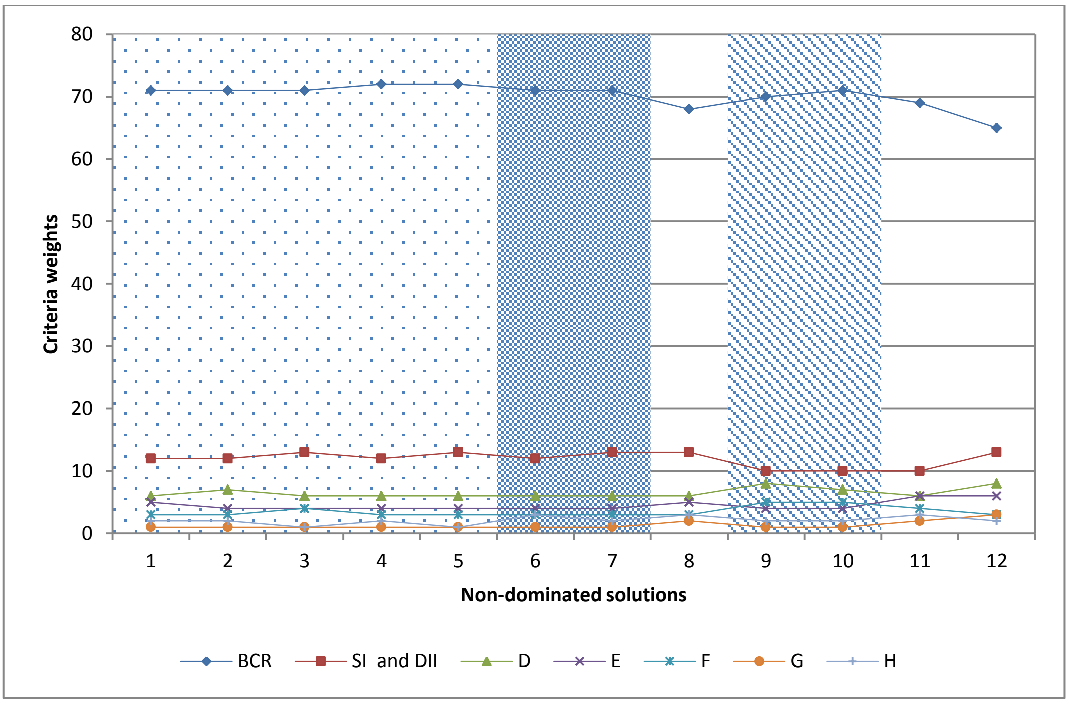


Figure 6-33 – Criteria weights of the non-dominated solutions found for the 3rd data set, with 7 criteria.

The extreme values for the weights of the criteria found are presented in Table 6-8.

Table 6-8 – Minimum and maximum values of the criteria weights found for the 3rd data set.

	a	*b+c*	*d*	*e*	*f*	*g*	*h*
Minimum value	65	10	6	4	3	1	1
Maximum value	72	13	8	6	5	3	3

In the approach with 7 criteria, the ranges of the weight values are rather small (Table 6-8). The range for the BCR weights is 8 points and for the SI+DII is only 4 points.

As was done for the previous sets of data, it is important to see the AC and CSk values according to the rank order of the measures. The AC values of the measures according to their rank position for each consumer segment, are presented in the next figures (Figure 6-34, for the residential segment, Figure 6-35 for the services and commerce, and Figure 6-36 for the industry and agriculture). For the residential sector, we can see that the measures are equally ranked for both solutions, as was expected, since all non-dominated solutions originate the same order of the measures for this consumer segment (Table B3). For the other two, the slopes of the trend lines indicate better results for solution 1 than for solution 12, regarding the AC objective.

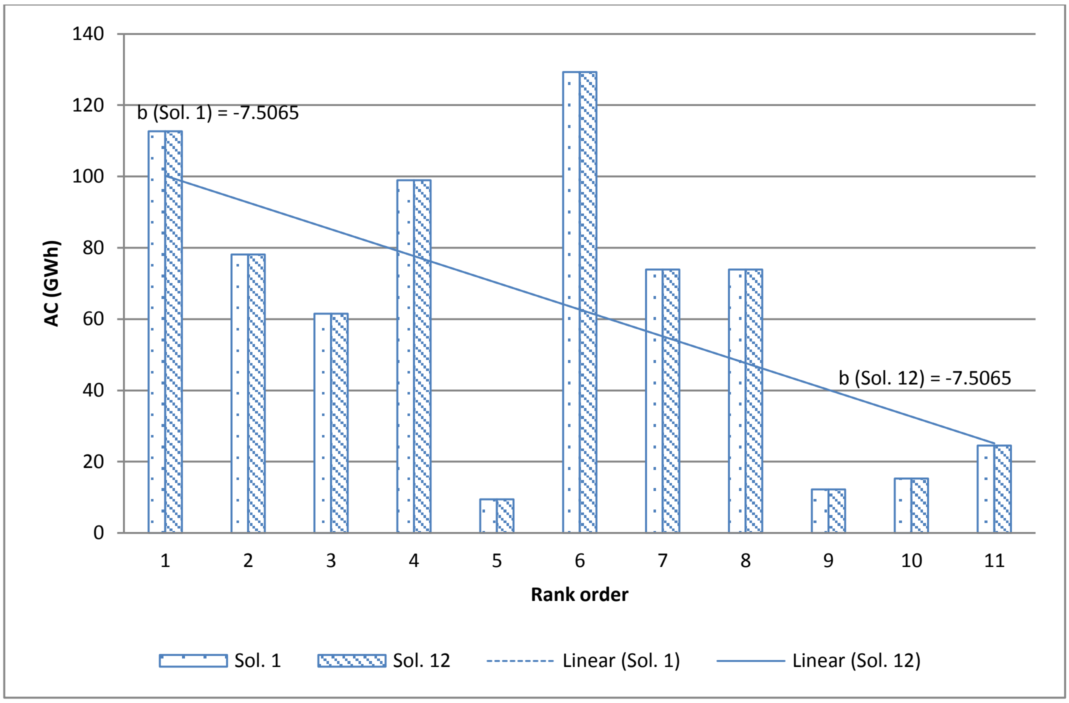


Figure 6-34 – AC values of each measure, for the residential consumer segment, according to their rank order, for solutions 1 and 12, for the 3rd data set.

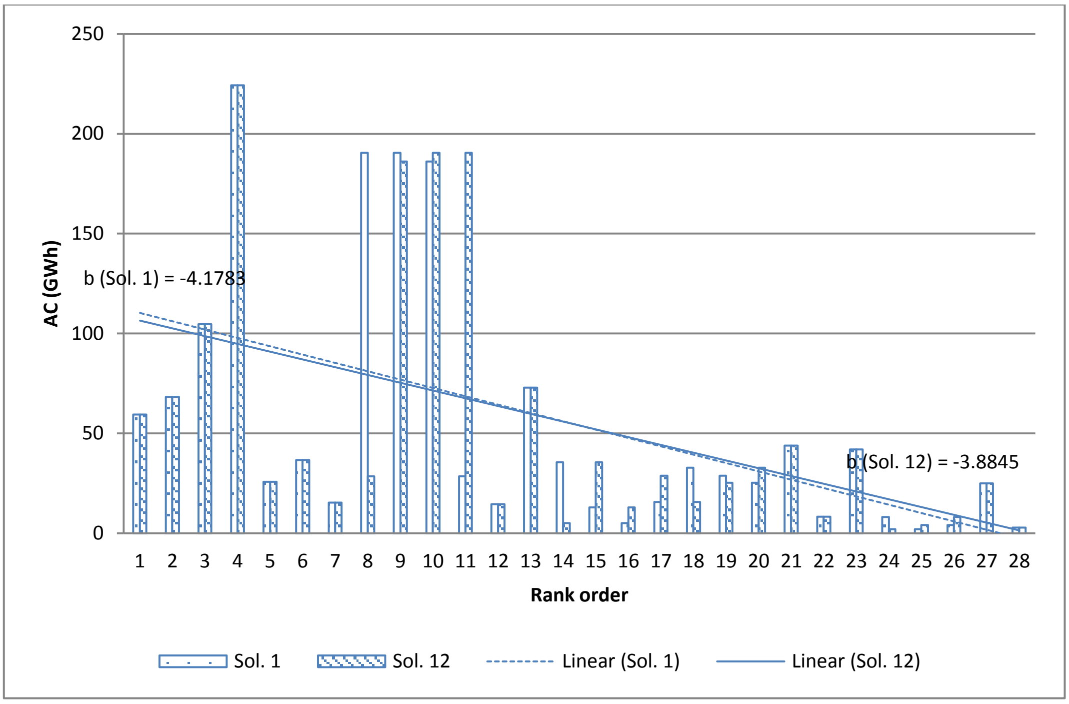


Figure 6-35 - AC values of each measure, for the service and commercial consumer segment, according to their rank order, for solutions 1 and 12, for the 3rd data set.

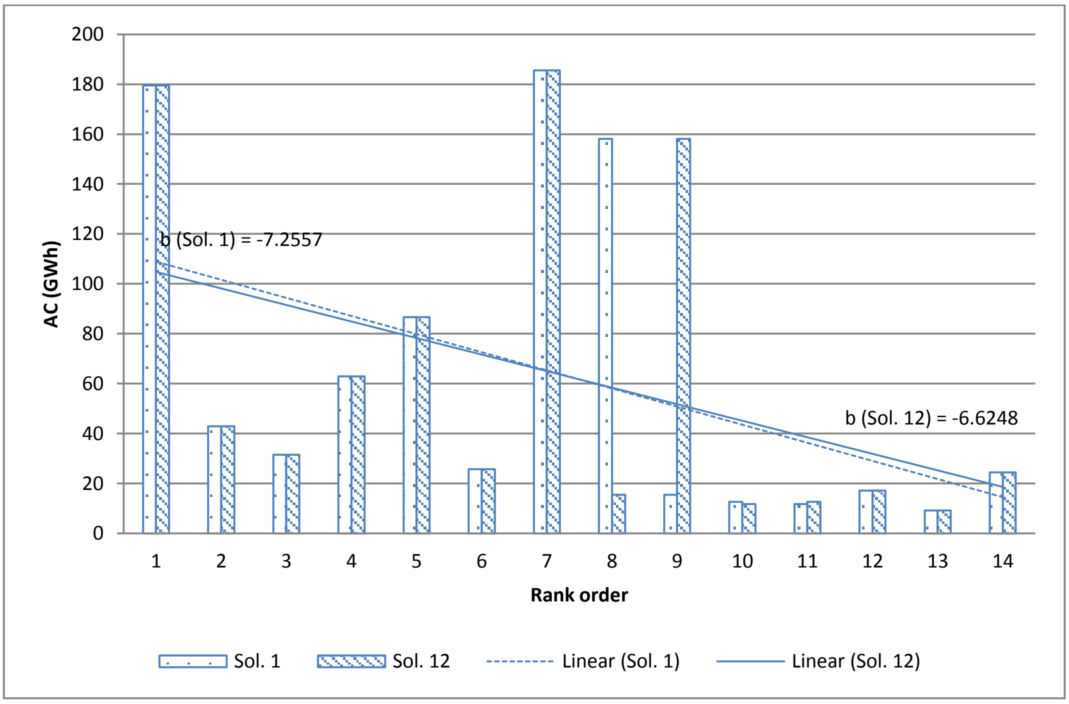
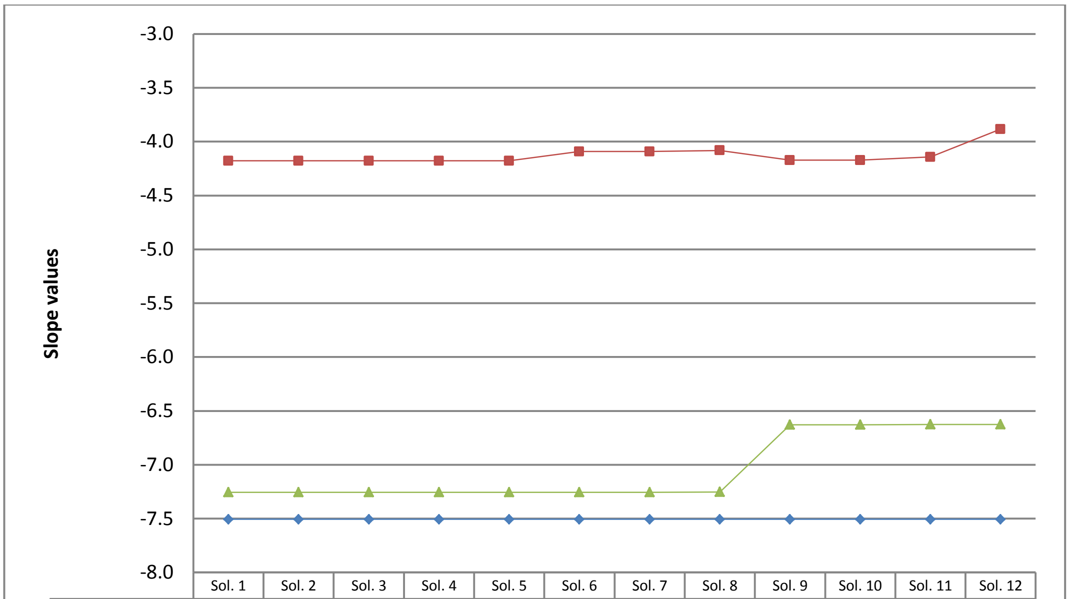


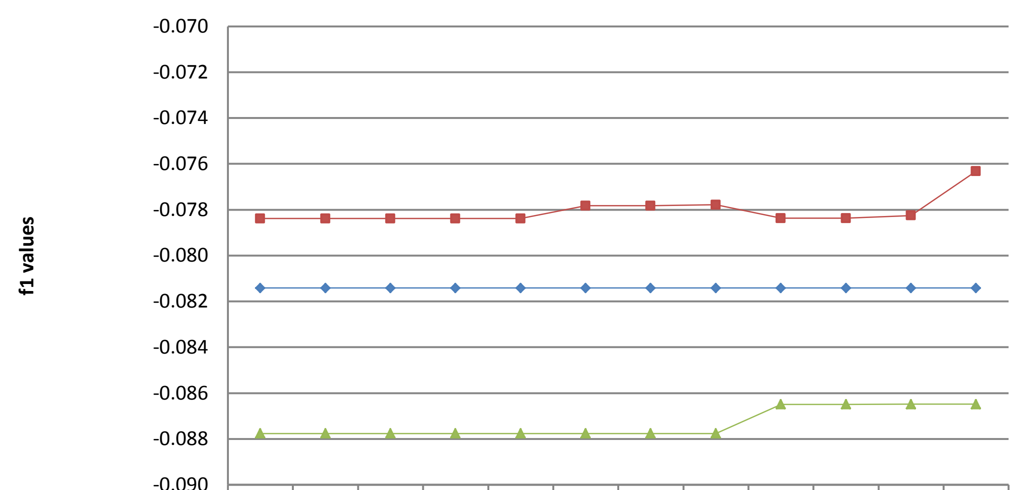
Figure 6-36 - AC values of each measure, for the industrial consumer segment, according to their rank order, for solutions 1 and 12, for the 3rd data set.

In Figure 6-37 the slopes of the trend lines of the AC values according to the ranking position of the measures are presented. Once again we can see that there is no change in the ranking order of the measures for the residential consumer segment, shown by a straight line. Regarding the other two segments we can see that solution 6 gives slightly better results for the services consumer segment, while maintaining the measures orders for the other two. The improvement in the industrial segment given by solution 9 is obtained with a small degradation of the performance regarding the services segment. This degradation of results is overcome with solution 12. The slopes of the trend lines are in line with the values of the weighted sum for each segment (Figure 6-38).



	Sol. 1	Sol. 2	Sol. 3	Sol. 4	Sol. 5	Sol. 6	Sol. 7	Sol. 8	Sol. 9	Sol. 10	Sol. 11	Sol. 12
Residential	-7.507	-7.507	-7.507	-7.507	-7.507	-7.507	-7.507	-7.507	-7.507	-7.507	-7.507	-7.507
Services	-4.178	-4.178	-4.178	-4.178	-4.178	-4.092	-4.092	-4.082	-4.173	-4.173	-4.142	-3.885
Industrial	-7.256	-7.256	-7.256	-7.256	-7.256	-7.256	-7.256	-7.252	-6.629	-6.629	-6.625	-6.625

Figure 6-37 – Evolution of the slopes of the linear trend lines of the AC values according to the measures rank order, for each non-dominated solution for the 3rd data set.



	Sol. 1	Sol. 2	Sol. 3	Sol. 4	Sol. 5	Sol. 6	Sol. 7	Sol. 8	Sol. 9	Sol. 10	Sol. 11	Sol. 12
f1 (Residential)	-0.081	-0.081	-0.081	-0.081	-0.081	-0.081	-0.081	-0.081	-0.081	-0.081	-0.081	-0.081
f1 (Services)	-0.078	-0.078	-0.078	-0.078	-0.078	-0.077	-0.077	-0.077	-0.078	-0.078	-0.078	-0.076
f1 (Industrial)	-0.087	-0.087	-0.087	-0.087	-0.087	-0.087	-0.087	-0.087	-0.086	-0.086	-0.086	-0.086

Figure 6-38 - The objective function values for the AC objective and for each consumer segment, for each non-dominated solution for the 3rd set of data.

As for the AC objective, the CSk values according to the measures ranking order, for each non-dominated solution, were also depicted. In Figure 6-39, the CSk values for the residential consumer segment are shown, where it can be seen that there was no change in the rank of the measures. For both the services and the industrial segments, the similarity of the slope values is evident (Figure 6-40, and Figure 6-41). The behaviour of the values of the 2nd objective function, for each segment (Figure 6-43), is quite similar to the behaviour of the slopes of the trend lines (Figure 6-42).

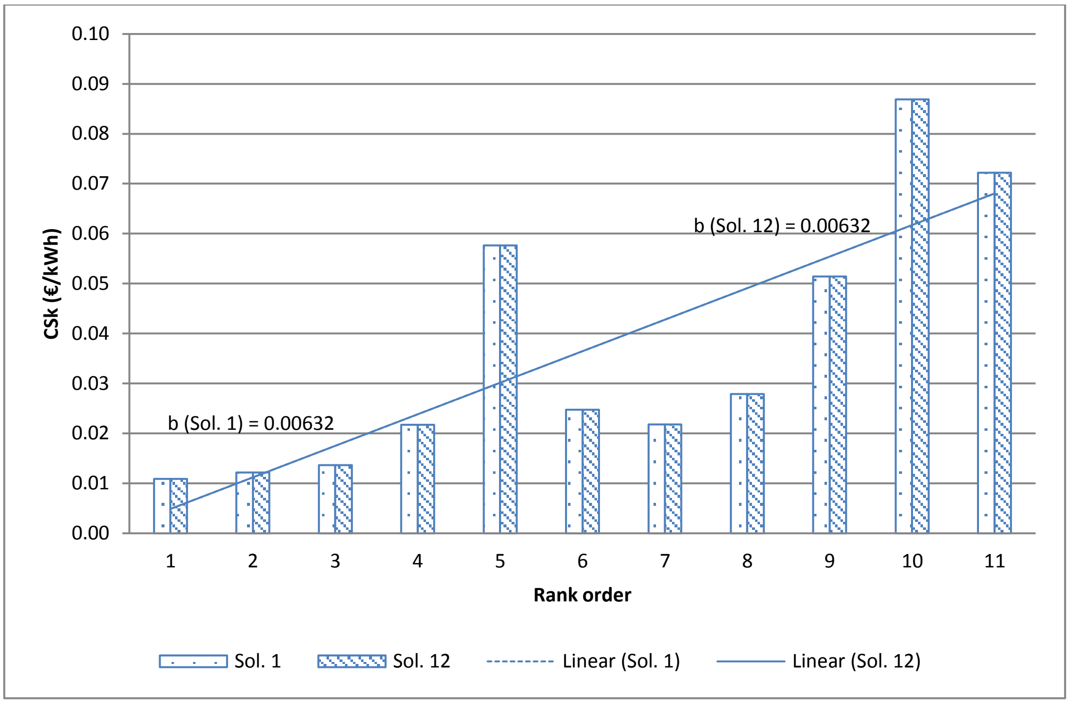


Figure 6-39 - CSk values of each measure, for the residential consumer segment, according to their rank order, for solutions 1 and 12, for the 3rd data set.

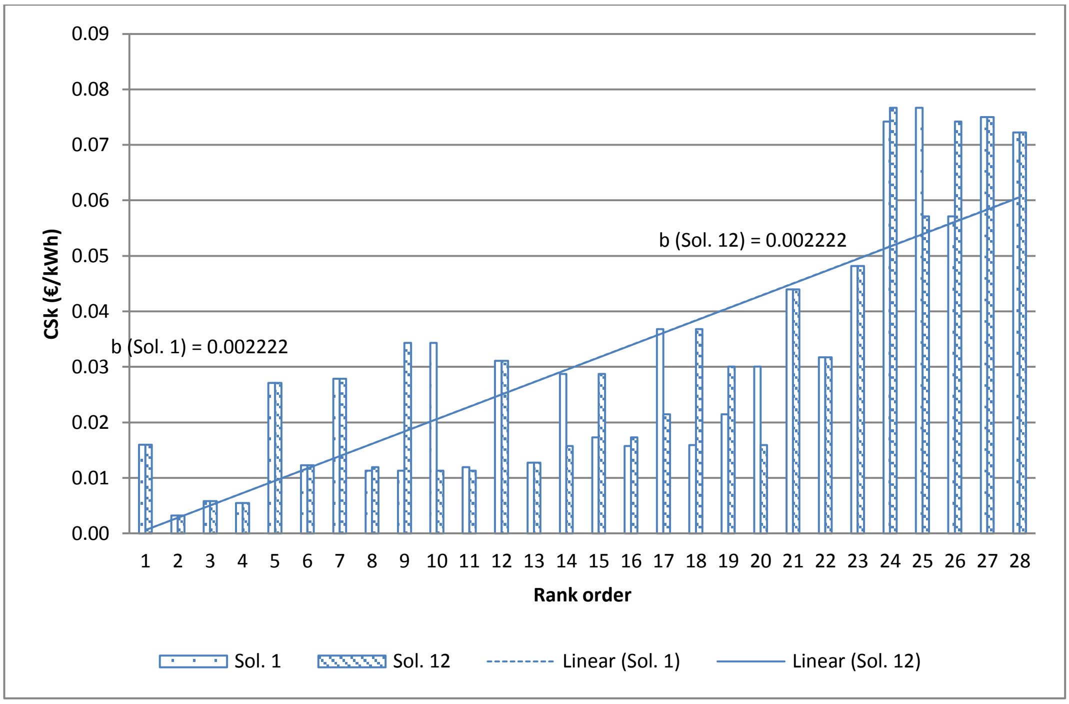


Figure 6-40 - CSk values of each measure, for the service and commercial consumer segment, according to their rank order, for solutions 1 and 12, for the 3rd data set.

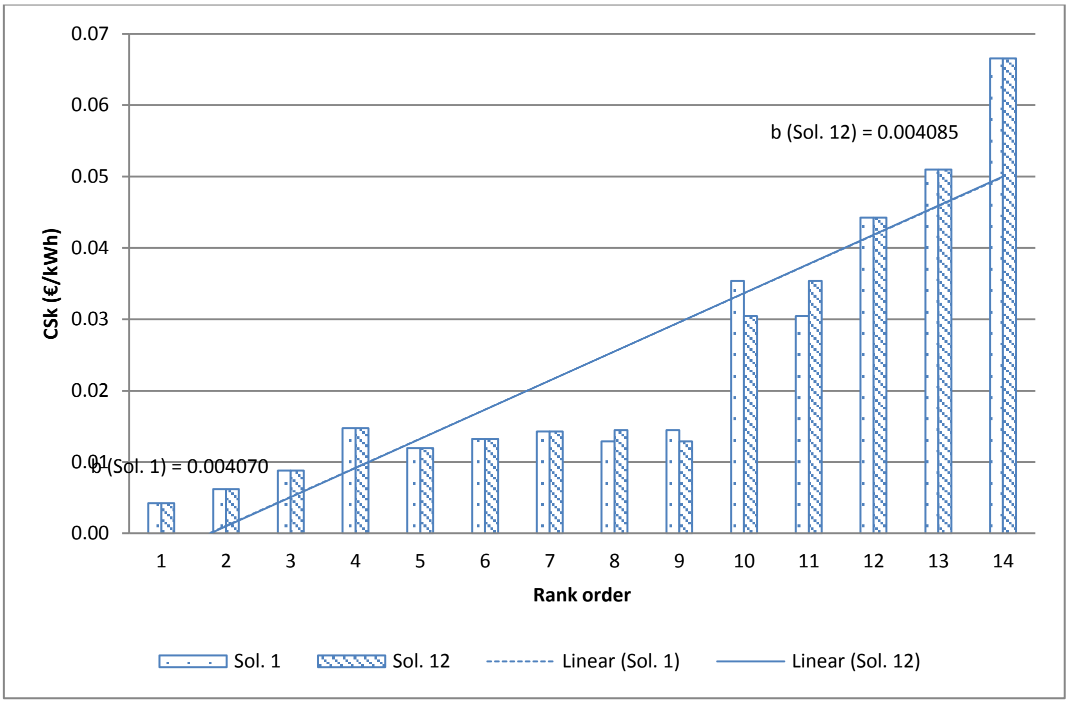
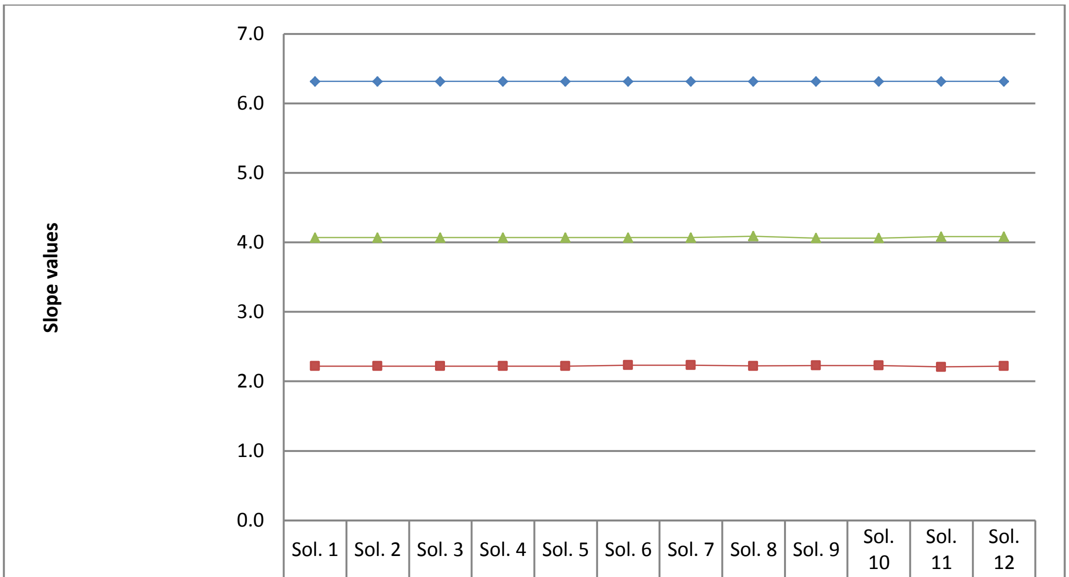
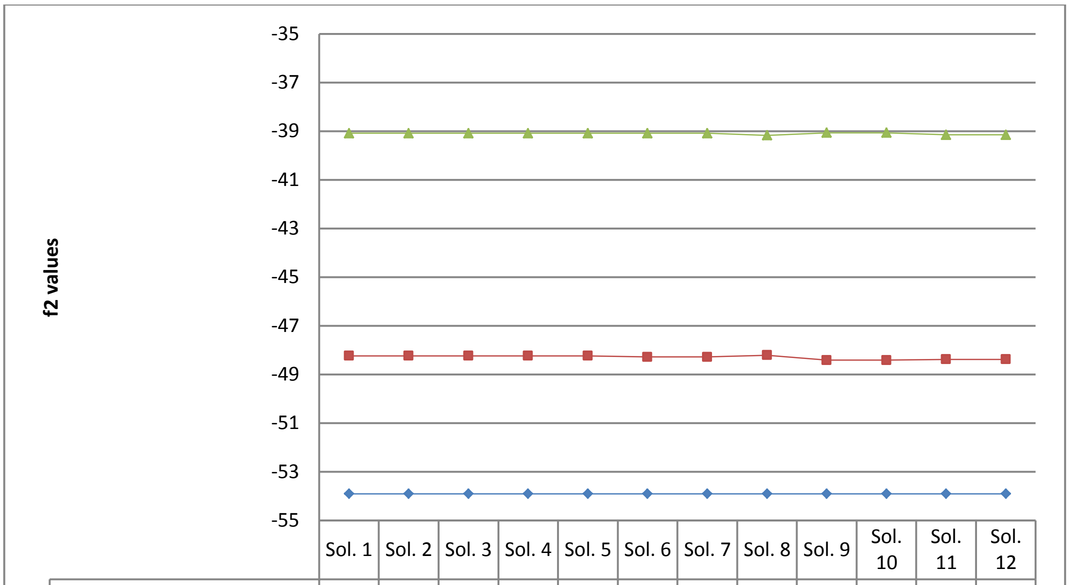


Figure 6-41 - CSk values of each measure, for the industrial and agricultural consumer segment, according to their rank order, for solutions 1 and 12, for the 3rd data set.



	Sol. 1	Sol. 2	Sol. 3	Sol. 4	Sol. 5	Sol. 6	Sol. 7	Sol. 8	Sol. 9	Sol. 10	Sol. 11	Sol. 12
Residential(*1000)	6.319	6.319	6.319	6.319	6.319	6.319	6.319	6.319	6.319	6.319	6.319	6.319
Services(*1000)	2.222	2.222	2.222	2.222	2.222	2.235	2.235	2.225	2.230	2.230	2.210	2.222
Industrial(*1000)	4.070	4.070	4.070	4.070	4.070	4.070	4.070	4.092	4.063	4.063	4.085	4.085

Figure 6-42 - Evolution of the slopes of the linear trend lines of the CSk values according to the measures rank order, for each non-dominated solution for the 3rd data set.



	Sol. 1	Sol. 2	Sol. 3	Sol. 4	Sol. 5	Sol. 6	Sol. 7	Sol. 8	Sol. 9	Sol. 10	Sol. 11	Sol. 12
f2 (Residential)(*1000)	-53.91	-53.91	-53.91	-53.91	-53.91	-53.91	-53.91	-53.91	-53.91	-53.91	-53.91	-53.91
f2 (Services) (*1000)	-48.24	-48.24	-48.24	-48.24	-48.24	-48.28	-48.28	-48.21	-48.42	-48.42	-48.38	-48.38
f2 (Industrial)(*1000)	-39.08	-39.08	-39.08	-39.08	-39.08	-39.08	-39.08	-39.17	-39.07	-39.07	-39.15	-39.15

Figure 6-43 - The objective function values for the CSk objective and for each consumer segment, for each non-dominated solution for the 3rd set of data.

6.3 Some considerations

We will now address some of the results of the tests that were presented, starting with the ranges of the BCR and SI+DII criteria for the 7 criteria approach (Figure 6-44). We can see that for both criteria, the ranges of the weights for the 2nd and 3rd data sets have a large intersection with the range of values obtained for the 1st set. However for the 3rd data set the range is much smaller. This is even more evident for the SI+DII criterion. Therefore, a predefined set of weights can hardly lead to an optimal rank of measures for all sets of measures, before knowing the measures candidates to funding.

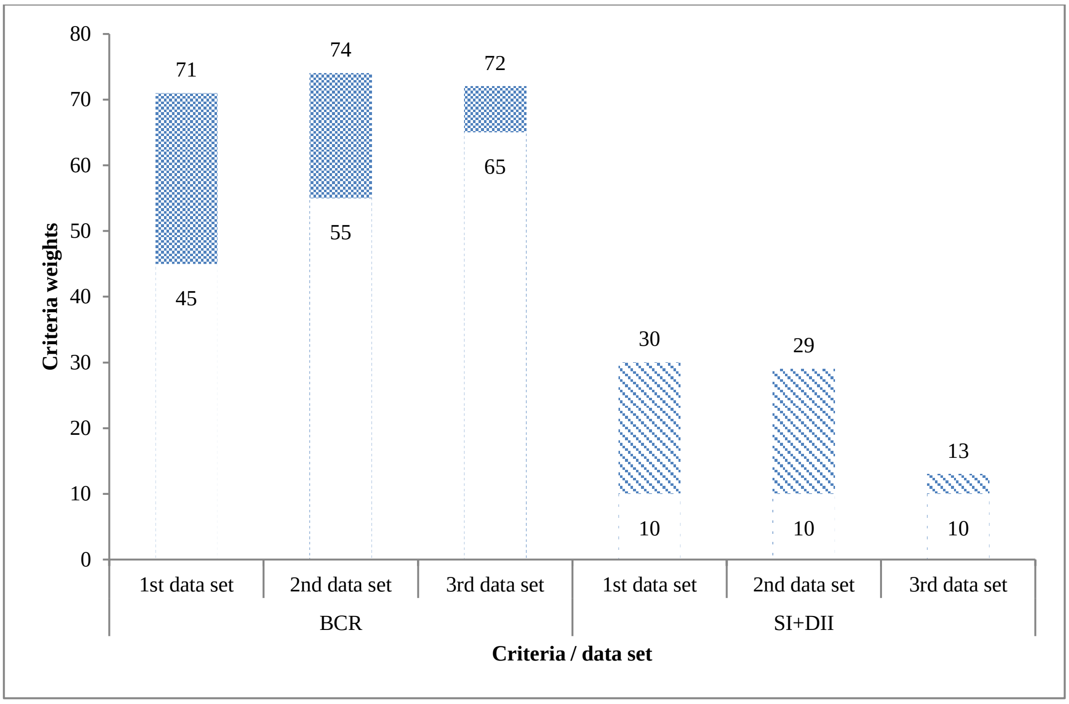


Figure 6-44 – Intervals of values obtained for the weights of the BCR and SI+DII criteria, for the three data sets.

In addition to the decrease in the range of the values for the criteria weights of the BCR and SI+DII for the 2nd and 3rd data sets there also seems to exist a change in the relation between the objectives and the criteria. Take, for instance the 1st data set and 2nd data set (Figure 6-9 and Figure 6-21). Generally speaking, higher values of the BCR weight seem to be associated to better results for the CSk objective (smaller values in top ranking positions). Also, higher values of the AC objective are obtained with higher values for the weight of the SI+DII criterion. However, for the 3rd data set, the situation is reversed, although the variation is very small. Scatter charts can help us find a possible reason for this behavior. In Figure 6-45 and in Figure 6-46 the relations between AC and BCR, and between CSk and BCR, for each data set, are respectively presented. The relations between these two pairs of sets of data are poor as can be seen by the R^2 values near each trend line. However, the sign of the slopes of the trend lines indicate that higher values of BCR are more closely related to higher values of AC (Figure 6-45) and to lower values of CSk (Figure 6-46). The slopes vary from one data set to the other, but the sign remains the same.

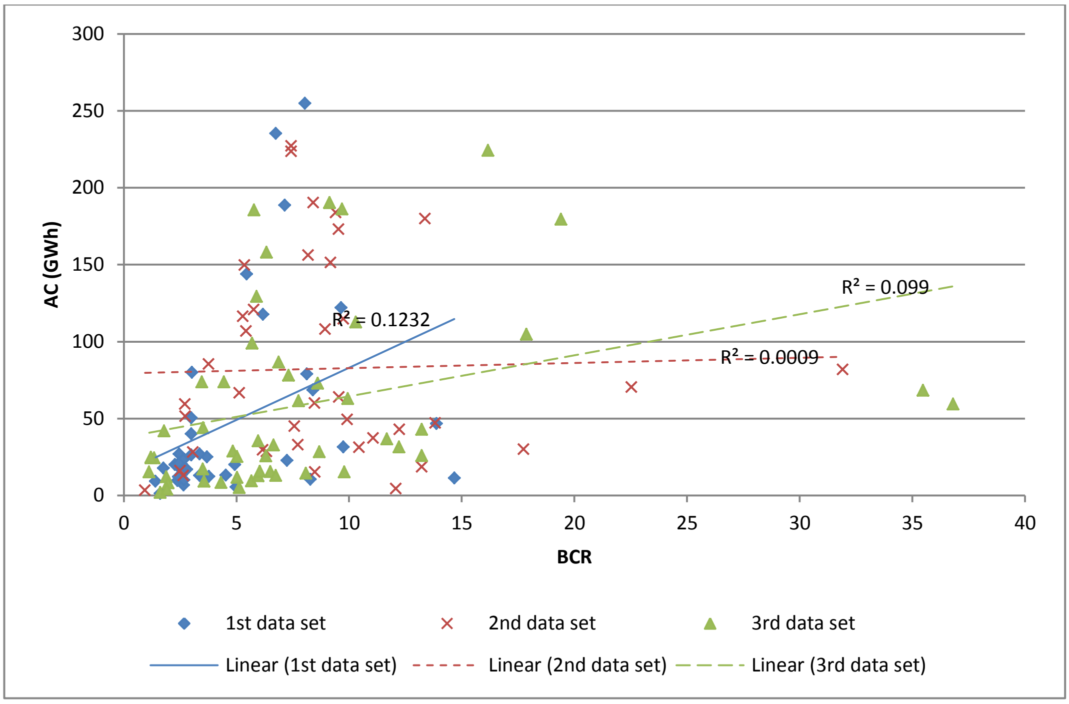


Figure 6-45 - Relations between AC and BCR for all data sets.

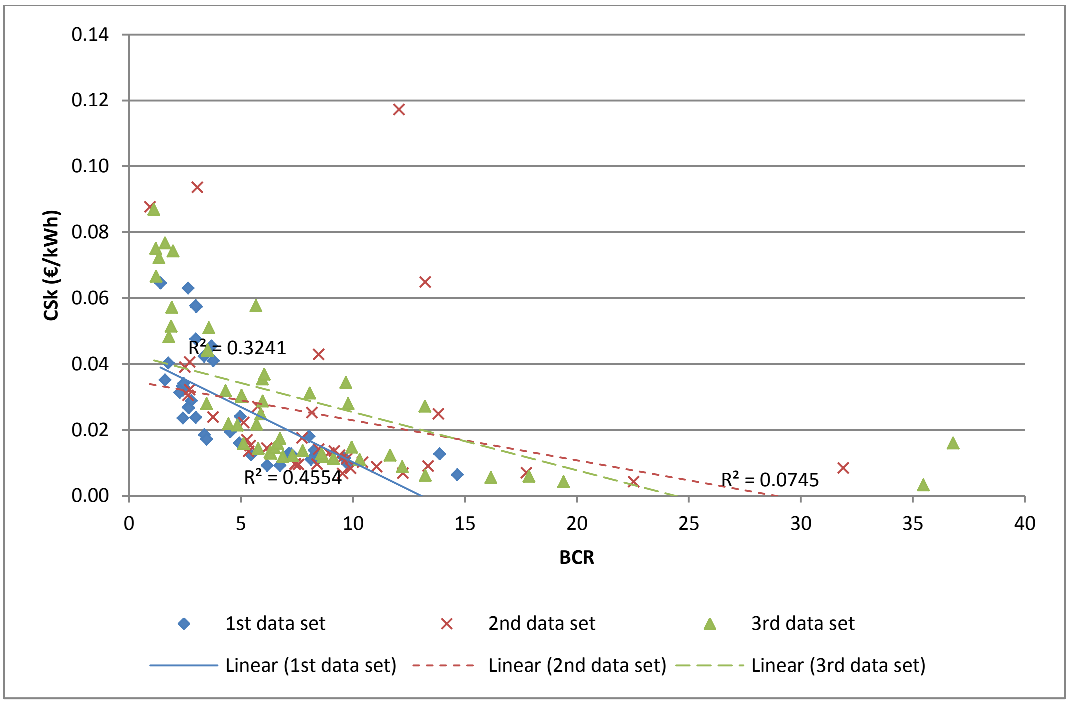


Figure 6-46 – Relations between CSk and BCR for all data sets.

For the relation between AC and CSk with SI+DII (Figure 6-47 and Figure 6-48), we can see that for the 3rd data set the slope of the relation between SI+DII criterion and both AC and CSK reverses. This means, generally speaking, that for the 1st and 2nd data sets, smaller values of SI+DII tend to correspond to smaller values of CSk, and for the 3rd data set smaller values of CSk are related to higher values of

SI+DII. For the 2nd and 3rd data set two measures (I1 and S28, respectively) were removed, to what this analysis is concerned, since they were clear outliers (Table A2 and Table A3). Once again we stress the weak relation between these characteristics of the measures.

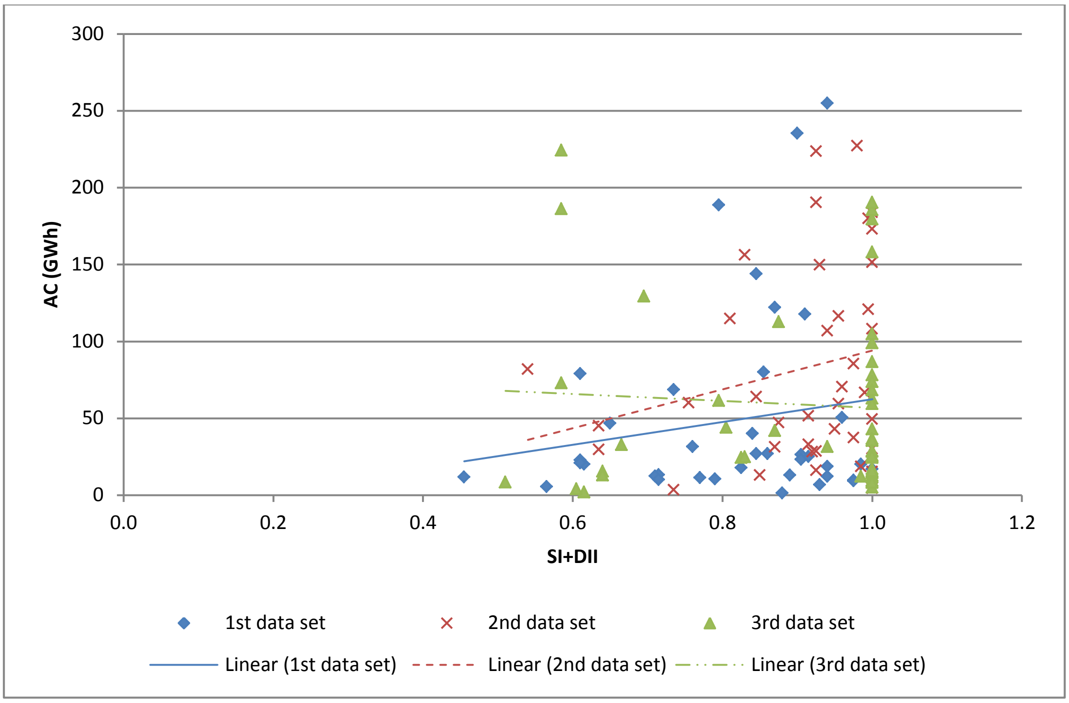


Figure 6-47 – Relations between AC and SI+DII for all data sets.

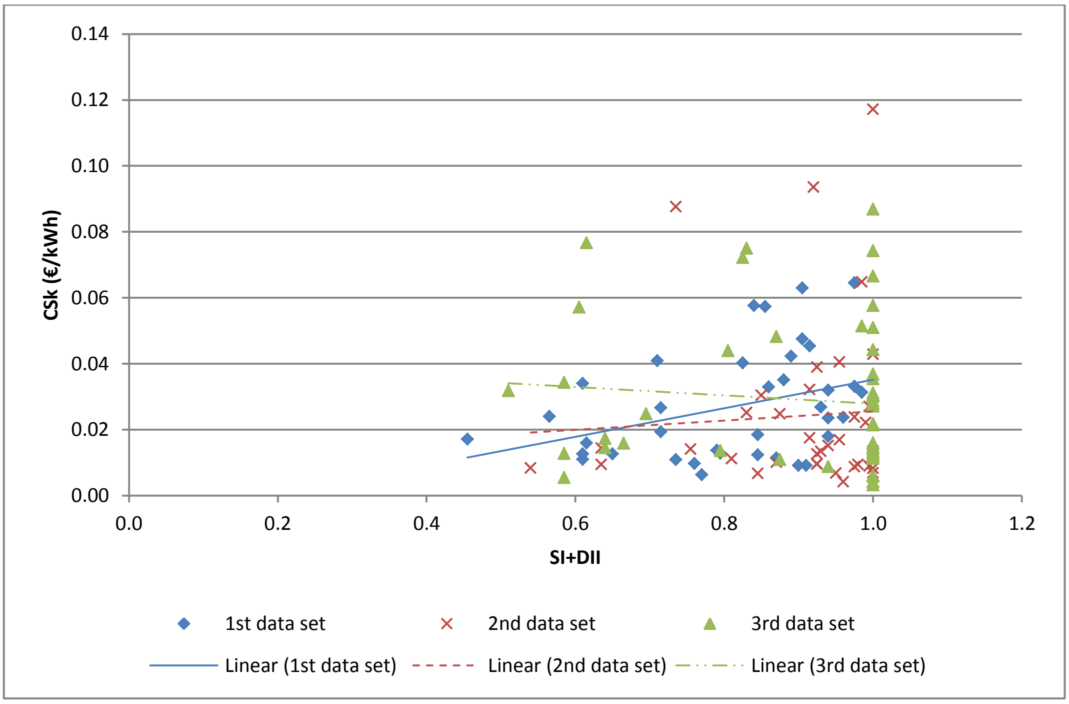


Figure 6-48 – Relation between CSk and SI+DII for all data sets.

An additional feature that can be observed in these figures is the very small diversity of the SI+DII values in the measures for the 2nd data set and, even more, for the 3rd data set. More than the lack of diversity we can point out the high concentration of measures with a value of 1 for this criterion (Table 5-1). Being SI+DII an average of the SI and DII, then a large group of the measures have a value of 1 for these two criteria (Table A-3 and Table A-4). As was previously pointed out, the number of non-dominated solutions that give rise to different rank of measures is also smaller for the 2nd and 3rd data set. This could be a result of the lack of variety in SI+DII values. This could also be the reason for the fluctuation that was found in the weights of the SI and DII criteria in the approach with 8 criteria (see Figure 6-4 and Figure 6-6). From one PPEC call to the next, SI and DII seem to have lost characteristics of a natural evaluation criteria and assumed markedly the characteristic of screening criteria (binary).

6.4 Post-processing analysis: From ranking to selecting measures

The selection of measures is subject to budgetary constraints. We do not intend to compare the results obtained with the proposed methodology to the ones that resulted from each PPEC edition. This comparison would only be legitimate if the objectives behind the criteria weights were the same, which may not be the case. Therefore, we consider the same budget amounts for all sets of measures (Table 6-9). These amounts are similar to the ones of the last PPEC call, exception made for the segment of industrial and agricultural consumers. We forced a smaller budgetary amount available for this segment in the last PPEC call (5.762.084€) since, as it was, it would suffice to co-finance all measures of the 1st data set. Thus, no selection would have taken place, which was not interesting from this research point of view.

Table 6-9 - Budget amounts used for each consumer segment.

Consumer segment	***Amount (€)***
Residential	5 300 000
Services and commerce	5 000 000
Industry and agriculture	4 500 000

In this section we will use the 1st set of data to detail the explanation and comments on the results.

The selection of measures is made by increasing order of the rank position, until the budget amount is exhausted. When the available budget is not enough to fully fund the next measure in the rank, this measure is resized to a percentage of its initial size. This percentage is calculated based on the budget available and the PPEC cost of the measure. Here we are considering that all costs of the measure applying for funding, whether fixed costs or investment costs, are equally reduced. This procedure will equally change the avoided consumption (AC), and the societal costs. Since the cost of each saved kWh is the ratio between societal costs and AC, their values will not change for the resized measures. Only for illustrative purposes, the percentage of financing of the measures in the 1st data set, for each consumer segment, is presented in Table A-8. The rank position is shown in the 1st column. Each cell of the Table A-8 contains the percentage of financing of the measure whose code is presented in the same corresponding cell in Table A-5. From all 21 solutions only 19 different groups of selected measures are obtained.

In Table 6-10 the values of AC, Societal costs, and CSk, for each arrangement of selected measures, are presented. The best results for each objective are highlighted in bold numbers. Remembering that the best solution to the AC objective is solution 1 and for the CSk is solution 21, the results are not what were expected. Nevertheless, the relative differences between the better and the worse values, regarding the best possible option for each objective, are less than 0.5% for the avoided consumption objective, corresponding to an additional 7 GWh, and around 1.6% for the cost of each saved kWh, corresponding to a little over 0.2 euro per MWh smaller than the worst.

Table 6-10 - AC, Societal costs and CSk obtained for the non-dominated solutions, for the 1st data set.

	Sol. 1 to 4	*Sol. 5 and 6*	*Sol. 7, 8, 9, 12 and 13*	*Sol. 10, 11, and 14*	*Sol. 15, and 16*	*Sol. 17*	*Sol. 18, and 20*	*Sol. 19, and 21*
AC (GWh)	1379	1380	1380	1380	1381	1384	**1385**	1382
Societal costs (k€)	19168	19180	19062	18881	19067	19202	19182	19073
CSk (€/kWh)	0.01390	0.01389	0.01381	**0.01369**	0.01381	0.01388	0.01385	0.01380

The highest contribution for the highest AC value, for solutions 18 and 20, is mostly due to the industrial consumer segment (Figure 6-49). The difference between AC amounts for sol. 1 and sol. 18 is 6 GWh, and the industrial segment contributes with 4.83 GWh. Although the search for the criteria weights is dependent on the measures from all segments, we will analyse the effect of the selection process for this particular case, and only as an example.

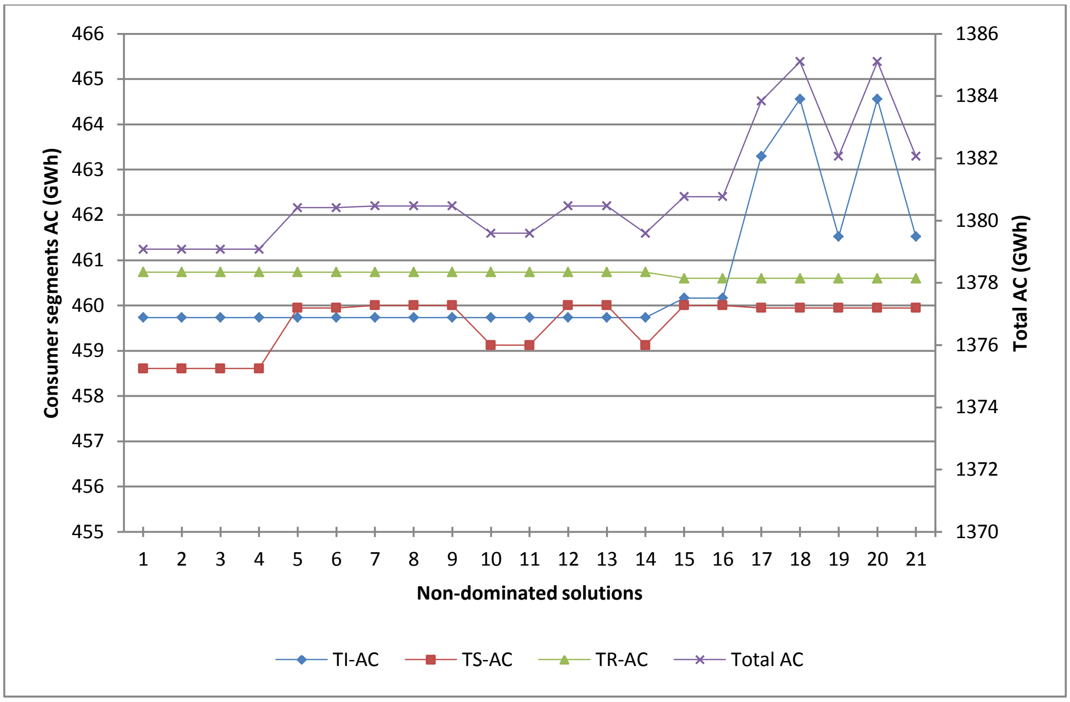


Figure 6-49 – AC values for each consumer segment and for the whole set of selected measures, for each non-dominated solution.

Measures *I7- Monitoring of cleaning of bag filters for differential pressure*, *I10 – High efficiency motors*, and *I11 – Industrial compressed air*, that are totally or partially financed, regarding sol. 1, see their funding share reduced or eliminated due to their higher CSk values, in sol. 18 (Table 6-11). Solution 1 selects 10 measures and solution 18 selects 9. On the other hand, measure *I8 – Pressure regulators in direct exits to the atmosphere of compressed air system*, that is not selected, in sol. 1, is totally funded, in sol. 18. Amongst those measures with lower CSk value, I8 has an AC value higher than the sum of the values of I10 and I11, thus contributing to a higher AC value for all selected measures using sol. 18.

Table 6-11 – Industrial segment measures that make a difference between Sol. 1 and Sol. 18.

Measures	***AC (GWh)***	***CSk (€/kWh)***	***Sol. 1 Funding (%)***	***Sol. 1 Rank position***	***Sol.18 Funding (%)***	***Sol. 18 Rank position***
I7	16.93	0.0288	100%	6	79%	9
I8	11.75	0.0172	0%	11	100%	8
I10	1.37	0.0351	100%	7	0%	11
I11	10.00	0.0266	20%	10	0%	10

A similar analysis can be done to the CSk objective.

After applying budgetary restrictions, the DM has to decide between two solutions, regarding the pursued objectives, and five sets of criteria weights (Table 6-12).

Table 6-12 - Criteria weights of the non-dominated solutions after the selection of the measures for the 1st data set.

Solution	***BCR***	***SI+DII***	***D***	***E***	***F***	***G***	***H***	***AC(GWh)***	***CSk (€/kWh)***
10	49	30	8	4	5	1	3	1380	**0.01369**
11	50	29	8	4	5	1	3	1380	**0.01369**
14	57	25	7	4	3	1	3	1380	**0.01369**
18	71	10	7	4	5	1	2	**1385**	0.01385
20	70	10	7	4	5	1	3	**1385**	0.01385

For the 2nd data set, from all 50 non-dominated solutions for the ranking of measures only two arrangements of selected measures were found (Table 6-13). The least favourable option regarding both objectives is 0.02% (around 520 MWh) below the AC objective best value and 0.2% (around 0.015 € per MWh) above for the CSk objective. Here, the differences are so small that the DM decision could be more related to regulatory matters, since the weights of the criteria can act as signs to the proponents.

Table 6-13 - AC, Societal costs and CSk for the non-dominated solutions for the 2nd data set.

	Sol. 1 to 43	***Sol. 44 to 50***
AC (GWh)	2861.4	**2861.9**
Societal costs (k€)	22619	22581
CSk (€/kWh)	0.00790	**0.00789**

In Table 6-14 we can see all 7 sets of criteria weights. We can also see that the changes in the weight values of the criteria are very small.

Table 6-14 - Criteria weights of the non-dominated solutions after the selection of the measures for the 2nd data set.

Solution	*BCR*	*SI+DII*	*D*	*E*	*F*	*G*	*H*	*AC (GWh)*	*CSk (€)*
44	72	10	7	4	3	1	3	**2861.9**	**0.00789**
45	72	10	7	4	4	1	2	**2861.9**	**0.00789**
46	72	10	7	4	5	1	1	**2861.9**	**0.00789**
47	73	10	7	4	3	1	2	**2861.9**	**0.00789**
48	73	10	7	4	4	1	1	**2861.9**	**0.00789**
49	74	10	7	4	3	1	1	**2861.9**	**0.00789**
50	72	10	8	4	3	2	1	**2861.9**	**0.00789**

For the 3rd data set, the 12 non-dominated solutions originate 4 arrangements of selected measures (Table 6-15). For this group of data, the worse solution regarding the AC objective is 0.6% (representing around 12.9 GWh) above the best one. For the CSk objective this difference amounts to more than 17% (representing around 2.11 € per MWh). Here the difference is not negligible.

Table 6-15 - AC, Societal costs and CSk for the non-dominated solutions for the 3rd data set.

	Sol. 1 to 8	*Sol. 9 to 10*	*Sol. 11*	*Sol. 12*
AC (GWh)	2039.1	2038.8	**2051.7**	2051.6
Societal costs (k€)	24362	24382	28818	28834
CSk (€/kWh)	**0.01195**	0.01196	0.01405	0.01405

As for the 2nd data set, the changes in criteria weights between solutions are very small (Table 6-16).

Table 6-16 - Criteria weights of the non-dominated solutions after the selection of the measures for the 3rd data set.

Solution	*BCR*	*SI+DII*	*D*	*E*	*F*	*G*	*H*	*AC (GWh)*	*CSk (€/kWh)*
1	71	12	6	5	3	1	2	2039.1	**0.01195**
2	71	12	7	4	3	1	2	2039.1	**0.01195**
3	71	13	6	4	4	1	1	2039.1	**0.01195**
4	72	12	6	4	3	1	2	2039.1	**0.01195**
5	72	13	6	4	3	1	1	2039.1	**0.01195**
6	71	12	6	4	3	1	3	2039.1	**0.01195**
7	71	13	6	4	3	1	2	2039.1	**0.01195**
8	68	13	6	5	3	2	3	2039.1	**0.01195**
11	69	10	6	6	4	2	3	**2051.7**	0.01405

For almost all arrangements of selected measures there is more than one alternative for the weights of the criteria. The differences in the weights of the criteria are very small from one solution to the other. When the DM is placed before more than one arrangement for the selected measures, he/she only has to decide which objective is more important to him/ her. This preference can be expressed before the search for the criteria weights in order to increase the transparency of the selection procedure.

6.5 Conclusions

Decisions based on weighted sum with previously fixed criteria weights can, without any doubt, contribute to a transparent procedure. It also sends signals to proponents about those characteristics of measures that are valued and those that are not. Nevertheless, the weights of the criteria may not lead to the best solution, or to a good compromise solution, according to the objectives behind the definition of the criteria and their weights.

In this thesis a ranking problem applied to energy efficiency measures was address. We used data from three previous calls for proposals of a tender mechanism (PPEC) managed by the Portuguese energy regulator. This tender mechanism intends to select energy efficiency measures to be co-financed. Besides data from measures candidates to PPEC calls, we also used the same criteria as the regulator. However, our procedure is based on explicitly assumed societal objectives and on defined ranges of values for each criterion weight. These objectives should reflect the DM interests. In this case, we choose avoided consumption and cost of each saved kWh, considered as important variables to the societal mission of the regulator. We wanted to find the appropriate set, or sets, of criteria weights that should be used so that measures were ranked according to those societal objectives. We used a genetic algorithm, NSGA-II with adaptive crossover and mutation probabilities to search for the non-dominated solutions of this bi-objective problem. This results in sets of criteria weights that represent good compromise solutions in face of the measures to be ranked.

We verified that, for the pursued objectives, the application of some criteria have effects that change from one call to the other. This change resulted in the improvement of the candidate measures performance on these criteria. This can be seen as a success of the mechanism, from the regulatory point of view. However, these criteria progressively loose the characteristics required of an evaluating criteria. If the DM considers that those are important criteria, he/she can use them as screening criteria. Hence, other more suitable evaluating criteria can be added without overly burdening the process both for the regulator and for the proponents. Our methodology can, then, assist in the selection of criteria, besides the determination of their weights.

We also found out that the ranges of values for the BCR criterion in the non-dominated solutions narrows from the 1st set of data to the last. For the SI+DII criterion the range of values of their weights dramatically reduces from the 2nd to the 3rd data set. Altogether, hardly a predefined set of criteria is equally suitable for different sets of measures. So, instead of using a fixed solution known previously to the call for proposals, we can set a range of values for each criterion. These ranges of values could be set according to the DM preferences, and used to send signals to the promoters. This could represent a good compromise between process transparency and being able to use the most suitable set of criteria weights in face of a set of measures.

An additional contribution of our approach is the use of external references for the performance of the measures on each criterion. The use of “Good” and “Neutral” reference values helps increasing the standards of performance of measures from one edition of the mechanism to the next.

Altogether, we believe that our proposal can assist in finding the best possible use of public, ratepayer money in the pursuit of explicitly assumed societal objectives.

Chapter 7. Conclusions

The promotion of EE/DSM measures by electric utilities is an activity that lasts for about 40 years. Along the time these activities have been driven by high prices of primary energy, by the need to limit environmental impact of the energy industry, by financial/economic constraints, among others. In a highly diversified set of regulatory environments, ranging from industry structures with full vertical integration to completely unbundled business areas, with state-owned or investor-owned companies, with buyer/seller privileges or in a fully competitive environment, it has been possible to find cases of utilities promoting EE at the end-uses. Energy Efficiency measures promoted by utilities have been funded by SBC or other similar charges, by environment taxes, by budgetary allocation from governments, by utilities revenues, by ratepayers, by donor organizations, and other funds. Experiences were found as part of voluntary initiatives of the utilities or by regulatory impositions. It was possible to find utilities investing in the promotion of EE measures in countries/jurisdictions where they are not under any obligation. However, higher commitment of utilities in EE promotion is definitely more common under regulatory obligations.

In this thesis several countries around the world were studied, regarding the involvement of electric utilities in the promotion of EE measures and the regulatory environment they were in. The regulatory mechanisms that were identified, among these studied countries that foster energy providers to promote EE at the end-use, are EEO, IRP, funding strategies, and performance incentives. Some involvement of independent energy efficiency delivery providers was not found in such a quantity that a particular treatment was advisable. The most common situations found were EEO, followed by performance incentives. In the end, the promotion of EE, mainly under the societal perspective, needs some regulatory stimulus. IRP was only found in the US, although there were references to previous experiences in European countries. Most of the countries with EEO do not seem to maintain an ex-ante evaluation of the portfolio of programmes to be implemented by utilities. The implementation of portfolios of measures, sometimes without any ex-ante selection by the regulatory authorities, may not reflect entirely the societal interest of EE promotion, leading to the need of some extra care by the regulatory authorities (as was the case of the UK). This situation becomes more important when EE measures are paid by all customers.

With this work it is possible to verify the existence, throughout the world, of electric utilities involved in the promotion of energy efficiency. Also, most of them are under regulatory obligations that demand the implementation of EE programmes and/or the accomplishment of savings targets, supported by performance incentives and/or lost revenue recovery strategies. The pursuit of societal objectives by electric utilities is possible but must be encouraged or enforced.

There has been a discussion on which should be the main actors of the EE promotion at the demand-side: distribution system operators or suppliers. It is argued that distributors are less dependent on the volume of energy sold, thereby being more suited to promote EE. On the other hand, suppliers are closer to the customer, thereby more capable of influencing the market and the consumer behaviours. A line of action for future work may explore the consequences so far for the suppliers business in those situations where these are subject to EEO, what are the regulatory safeguards adopted regarding the preservation of the financial health of the agents of this type and, additionally, what are the differences, if any, of the regulatory features and constraints affecting suppliers on one side and distributors on the other side, when it comes to EEO. Finally, from the regulators perspective, is cost-effectiveness EE programmes affected in any way by the obvious differences between suppliers and distributors?

An additional outcome of this thesis, that also opens the way for further research, is the identification of the “trend”, in some environments, towards a less regulated ex-ante assessment of programmes portfolios. At least a question arises when the selection of measures is made by the utilities without, or with minimal intervention of the regulator: are the societal interests taken care of, and if so, how are they taken care of, in the cost-effectiveness assessment of the portfolios? It is also an open question to compare the costs and the benefits of these apparently “less” regulated involvements with the more regulated alternatives.

An additional line of future action consists of drawing a picture of actual programme costs, split among the different sources – taxpayer, ratepayer, utility – and of the actual importance of the lost revenues issue. Assessing these amounts would be of great value for an informative picture of the potential and the possible pitfalls associated to EE fostering.

Associated to the precedent matter, a complementary stream of research consists of assessing the total verified energy savings due to EE utility-driven programmes and the respective impacts on tariffs, as this would clarify the degree of societal interest of EE programmes from the ratepayer perspective. The Portuguese regulator uses a tender mechanism for the selection of EE measures, proposed by several organizations, including electric utilities. This mechanism has proven to be a regulatory success taking into account the growing number of candidate measures and proponents. Nowadays, without any compensation for the revenues and even without recovering all the costs, utilities seem to be engaged in the participation in the programme. The use of an additive value function with some criteria and weights, established well before the tender receives any measure proposal, provides transparency to the procedure, but also inhibits a desirable flexibility to adapt the weighting factors. The methodological approach made in this work suggests the use of societal objectives in the search for the most suitable sets of weights. Allowing some flexibility, the regulator does not stay tied to a set of weights that reflects a static preference structure, becoming able to explicitly address a set of unquestionable societal objectives. The proposed methodology also suggests the use of external references to the performance of the measures regarding each criterion. Besides avoiding the sensitivity of the evaluation process to the parameters of the proposed measures, external references allow sending signals to the potential proponents on what is considered a "good" and "not so good" performance value, therefore marking out some performance standards for the measures.

Overall, the proposed methodological approach can help the proponents in the design of more cost-effective and societally interesting measures, and the regulator in adopting an even more influential role in the characteristics of EE measures.

Even maintaining the ex-ante assessment method of using an additive value function, as it is an intuitive procedure, additional criteria can be considered for exploring their effect on the chosen societal objectives. Additionally, besides setting upper and lower bounds to the weighting factors, an alternative to explore consists of assigning some kind of precedence of some criteria over others. This would eventually reduce the transparency in the tender if not disclosed in advance, but would probably result in a higher number of alternative suitable solutions, regarding the elected societal objectives.

Another outcome of this thesis is the possibility of using societal objectives as explicit drivers in the selection of EE measures, as well as the use of external reference values to assess the performance of the measures, that allows to know "how good the measures are" beyond the group of candidates they belong to, in a particular call. A methodological approach was proposed using societal objectives as drivers in the selection of EE measures, based in an additive value function.

Chapter 8. Epilogue – a personal opinion

Unlike the energy crises of the 1970s, when the concerns with energy consumption were temporary, and vanished (also temporarily) with the reduction of oil prices, the present situation seems to be different. Mainly due to the concern with global warming that crosses all sectors of the contemporary society, and in particular due to the responsibility of energy consumption in GHG emissions, the attention to energy efficiency seems to have "been here to stay". At least on the agenda…

Several organizations, at local, regional, national, transnational and even at global level, from all sectors of society, have been addressing the issue of energy efficiency. Driven by regulatory impositions, by financial/economic reasons, or by "environmental friendly" kind of labels, many organizations have been more or less actively promoting EE.

Utilities involvement in the promotion of EE

Electric utilities are not an exception. Some retrieve the experience acquired during the oil crises of the 1970s. However, the electric sector has been subject to changes around the world, with activity unbundling and privatisations of previously state-owned companies or assets. The introduction of competition without a key change in the business structure built a barrier to the interests of private companies in fostering EE on the demand-side. As a matter of fact, the involvement of electric utilities, with private interests, in the promotion of EE in the demand-side is mostly due to three types of reasons: regulatory impositions, marketing interests, and economic interests.

Economic interests are mostly present in the case of utilities in developing countries, with electric sectors characterized by old, unreliable, fragmented assets, and unable to satisfy the demand, with high costs and technical and commercial losses. With tariffs usually highly subsidized, the promotion of EE at the demand-side is viewed as an opportunity to ease the stress upon the need to more investments in the system and also reduce the losses due to lower energy demands and lower energy bills. In developed countries, the volatility of primary energy prices, the increasing environmental constraints regarding the use of land and GHG emissions, among others, are factors that influence decision making.

The relationship between utilities and customers must be strengthened, and bonds must be built in order for the customer to keep with the same energy provider. The promotion of EE measures where the benefits for the customer are evident and there is availability to inform and help can increase the trust of the customer in his supplier. These are opportunities that utilities should not neglect in a competitive environment. Also the cooperation with other energy suppliers may be required to increase the savings through fuel substitution alternatives.

The design of EE programmes that take advantage of any other regulatory measures, such as labelling, MEPS, buildings code, etc., can enhance the outcomes of the programmes. However, this procedure raises some issues about the double accounting of the savings, in an ex-post evaluation.

Regulatory impositions are, without doubt, the main driver of the involvement of electric utilities in the promotion of EE at end-uses. The imposition of energy saving targets together with a clear and stable funding structure may foster utilities in promoting cost-effective EE measures.

Energy efficiency procurement strategies

The Portuguese regulator has developed a mechanism that allows the participation of utilities and other organizations in the promotion of EE.

In the Portuguese approach to EE procurement, the regulator must continue to involve all stakeholders in the decision process, even if the framework changes due to the possible enforcement of energy efficiency obligations. It is of extreme importance to understand how the utilities, and other promoters, intend to deal with the fact that the “easy to get” savings are almost exhausted, due to the fact that the market is actually almost or already transformed. The promotion of measures for CFL replacement is likely no longer a good option. For instance, it would be interesting to find out how distant is the number of CFL per household from the number of fixtures. Most likely, increasing the number of distributed CFL would not have the estimated effect on savings, due to the fact that those newly distributed CFLs would become part of a stockpile. It is interesting to remember the already mentioned case of the UK, where the number of distributed CFL per household was nine and the estimated average number of fixtures was between 8 and 10. Also, the promotion of LED in the residential and service sectors will in some cases inhibit the full achievement of the projected savings due to previous CFL campaigns. The need to call upon measures with lower BCR, measures that need higher investments, and with longer payback periods, may become a challenge. It is important to remember that there is in Portugal no cost recovery mechanism, nor loss of revenues compensation mechanism, nor even incentives to shareholders, as there are in some other countries. In order to keep the win-win situation where all parties involved in PPEC win (Apolinário, et al., 2012) it is important to utilities to seek the “right” customers, since the cost of the public image will rise. Utilities must invest on a stronger relation with their customers.

The possibility of coordinating different regulatory schemes could be advantageous. For instance, it would be beneficial that consumers under the Management System of Intensive Energy Consumption (SGCIE) and utilities could co-operate in the design of new EE measures, in spite of the potential for some contradictory interests. Not only this would favour customers that are by law obliged to improve their energy efficiency, but the unit cost reduction of the service/product they provide would increase the competitiveness of the company, in the interest of the economy and of the society. A possible lower limit of the PPEC support for these situations could be considered. Similarly, the cooperation between promoters and interested parties in obtaining the buildings certification under the National System for the Energy and Air Quality in the Interior of Buildings Certification (SCE) could also be considered.

In order to bring down EE implementation costs, utilities should also develop stronger relationships with specialized contractors, who can help obtaining the expected EE savings and develop replicable procedures and techniques, thereby increasing the spillover effect. The regulator may evaluate the opportunity to foster the development of these specialized contractors.

Some countries chose to have mandatory EE actions, or set a list of standard measures for the obliged parties to select and implement. This approach has lower costs associated to ex-ante evaluation, but probably fails to provide incentive for innovative measures. Similarly, the selection of portfolios of measures instead of individual measures can have the same undesirable effect on innovation, which must be stimulated although permanently ensuring that societal interests are preserved.

In this context, the proposed methodology can be useful in selecting a set of measures in accordance with societal objectives considered relevant by the regulator, as well as in the definition of the corresponding evaluation criteria.

In the end…

Regulatory conditions should be created to foster the promotion of EE by electric utilities. Societal objectives must always influence decisions on the management of energy resources, bearing in mind that energy efficiency at the consumer side of the meter is a highly valuable resource.

Appendices

Appendix A

The countries that were analysed are presented in this appendix divided according to the presence of private interests in the electricity sector. These lists resulted from the consultation of REEEP (2012), Nagayama (2011), and United Nations Economic Commission for Europe (2010).

Table A - 1 – Countries with different private interests in the electric sector.

Countries without private interest in the electric sector	***Countries with single buyer***	***Countries with private interest in the electric sector, besides generation***
Afghanistan	Algeria	Albania
Angola	Armenia	Antigua and Barbuda
Azerbaijan	Bahrain	Argentina
Belarus	Bangladesh	Australia
Benin	Botswana	Austria
Bhutan	Cambodia	Bahamas
Brunei Darussalam	Central African Republic	Barbados
Burkina Faso	Costa Rica	Belgium
Burundi	Croatia	Belize
Chad	Cuba	Bolivia
Comoros	Dominica	Bosnia and Herzegovina
Cook Islands	Ecuador	Brazil
Democratic Rep. of Congo	Egypt	Bulgaria
Democratic Rep. of Timor Leste	Fiji Islands	Cameroon
Eritrea	Gabon	Canada
Federal State of Micronesia	Gambia	Cape Verde
Guinea	Ghana	Chile
Independent State of Samoa	Guinea Bissau	China
Iran	Guyana	Colombia
Iraq	Haiti	Czech Republic
Israel	Honduras	Denmark
Jordan	Indep. State of Papua New Guinea	Djibouti
Kiribati	Kenya	Dominican Republic
Kuwait	Lao	El Salvador
Lesotho	Latvia	Equatorial Guinea
Liberia	Lebanon	Estonia
Libya	Madagascar	Ethiopia
Malawi	Malaysia	Finland
Marshall Islands	Maldives	France
Mauritania	Mali	Georgia
Mozambique	Mauritius	Germany
Namibia	Mexico	Greece
Niue and Tokelau	Mongolia	Grenada
Paraguay	Nepal	Guatemala
Republic of Congo	Niger	Hungary
Rwanda	Oman	India
Saint Vincent	Pakistan	Indonesia
São Tome and Principe	Panama	Ireland
Seychelles	Republic of Palau	Italy
Sierra Leone	Republic of the Philippines	Ivory Coast
Syria	Romania	Jamaica
The Republic of Nauru	Saudi Arabia	Japan
Togo	Senegal	Kazakhstan
Tonga	Serbia and Montenegro (?)	Kyrgyzstan
Turkmenistan	Solomon Islands	The Republic of Korea
Tuvalu	South Korea	Lithuania
Union of Myanmar	Sri Lanka	Luxemburg
United Arab Emirates	Sudan	Macedonia

Countries without private interest in the electric sector	***Countries with single buyer***	***Countries with private interest in the electric sector, besides generation***
Venezuela	Swaziland	Moldova
Yemen	Tanzania	Morocco
	Thailand	The Netherlands
	Trinidad and Tobago	New Zealand
	Tunisia	Nicaragua
	Uruguay	Nigeria
	Uzbekistan	Norway
	Vietnam	Palestine
	Zimbabwe.	Peru
		Poland
		Portugal
		Qatar
		Russia
		Saint Kitts and Nevis
		Saint Lucia
		Singapore
		Slovak Republic
		Slovenia
		Somalia
		South Africa
		Spain
		Suriname
		Sweden
		Switzerland
		Taiwan
		Tajikistan
		Turkey
		Uganda
		Ukraine
		United Kingdom
		United States of America
		Vanuatu
		Zambia

Appendix B

The measures considered in the thesis are listed in this appendix. In the following tables, measures are identified by an alphanumeric code where the letter presented in the 1st column stands for the consumer segment they belong to (R for residential, S for service and commerce, and I for industry and agriculture). The number in the code is a way of enumerating the measures in each segment.

Table A - 2 – Some characteristics of the energy efficiency measures from the 1st data set (ERSE, 2007b).

Code	*Measures*	*BCR*	*SI*	*DII*	*D*	*E*	*F*	*G*	*H*	*PPEC costs (€)*	*AC (GWh)*	*CSk (€/kWh)*
R1	100% efficient lighting in the autonomous region of Azores	13.88	0.57	0.73	1.00	0.50	1.00	0.33	0.67	309276	46.81	0.0126
R2	Efficient lighting in housing estates	8.40	0.67	0.80	0.86	0.40	1.00	0.00	0.67	731327	68.66	0.0109
R3	Replacement of incandescent bulbs for LED lighting	5.46	0.80	0.89	0.86	0.50	0.75	0.00	0.67	1780500	143.89	0.0124
R4	CFLs	8.13	0.53	0.69	0.86	0.50	0.75	0.00	0.67	870000	78.93	0.0110
R5	Replacement of incandescent bulbs for efficient lighting	7.14	0.74	0.85	0.71	0.50	0.75	0.00	0.67	2422360	188.64	0.0128
R6	Efficient lighting in historic districts	7.24	0.53	0.69	0.57	0.50	0.75	0.33	0.67	282821	22.89	0.0126
R7	Promotion of efficient freezers	3.69	0.89	0.94	0.71	0.50	1.00	0.00	0.67	510000	25.11	0.0454
R8	Power strips	4.53	0.65	0.78	0.57	0.50	1.00	0.00	1.00	255000	13.19	0.0193
R9	Solar heating (2Y)	3.02	0.82	0.89	0.71	0.50	1.00	0.33	0.67	1747381	80.00	0.0574
R10	Solar heating (1Y)	2.99	0.80	0.88	0.71	0.50	1.00	0.33	0.67	905000	40.00	0.0576
R11	Efficient heat pumps	2.45	0.82	0.90	0.71	0.50	1.00	0.00	0.67	745000	27.03	0.0330
S1	Compact Fluorescent Lamps	14.67	0.71	0.83	0.86	0.60	1.00	0.33	0.67	72000	11.34	0.0064
S2	Replacement of conventional lighting for LED lighting	8.04	0.92	0.96	0.57	0.20	0.50	0.33	0.33	2349675	254.84	0.0180
S3	Free-cooling as a complement to air-conditioning systems	9.64	0.83	0.91	0.71	0.20	0.50	0.00	0.33	899946	122.17	0.0114
S4	ENER-Hall: Monitoring internet use of electric energy in municipal buildings	4.93	0.54	0.69	0.71	0.20	0.50	0.00	0.33	286524	20.13	0.0159
S5	Maximum demand control systems	3.36	0.86	0.92	0.71	0.20	0.50	0.00	0.33	269204	13.06	0.0423
S6	Use of natural lighting: lighting installation with flux regulators	3.77	0.64	0.78	0.57	0.20	0.50	0.33	0.33	231685	12.31	0.0410
S7	Reflux - Installation of flow regulators in bright lighting	2.99	0.88	0.93	0.86	0.60	1.00	0.67	0.33	622952	26.23	0.0476
S8	LEDs in traffic lights	2.64	0.97	0.84	0.71	0.50	1.00	0.33	0.67	680000	23.18	0.0630
S9	LED traffic lights	2.42	0.92	0.96	0.71	0.20	1.00	0.00	0.67	597000	18.66	0.0320
S10	Lighting - Vila Nova de Gaia	2.99	0.99	0.93	0.86	0.40	1.00	0.00	0.67	1169660	50.40	0.0238
S11	Systems for regulating the flow in street lighting	2.27	0.98	0.99	0.71	0.30	1.00	0.00	1.00	627217	20.03	0.0313
S12	Regulators with flow monitoring and control by microprocessor	2.65	0.92	0.94	0.71	0.50	1.00	0.67	1.00	180543	6.73	0.0268
S13	Installation of LED lighting	2.39	0.97	0.98	0.71	0.50	1.00	0.00	1.00	319336	9.64	0.0331
S14	Replacement of ferromagnetic ballasts by electronic in fluorescent lighting	2.44	0.58	0.64	0.86	0.50	1.00	0.00	0.67	577615	20.97	0.0341
S15	VSD on trade and services	1.76	0.98	0.67	1.00	0.50	1.00	0.00	0.67	714880	17.76	0.0403
S16	Replacement of fixture and light bulbs in street lighting	1.41	0.97	0.98	0.57	0.40	0.75	0.33	0.33	595000	9.21	0.0646
I1	Variable Speed Drives	9.75	0.73	0.79	1.00	0.50	1.00	0.67	0.67	183300	31.44	0.0097
I2	Efficient transmission systems	8.28	0.75	0.83	0.71	0.60	0.75	0.33	0.67	72000	10.48	0.0137
I3	Variable speed drives in the industry	6.75	0.99	0.81	0.71	0.60	0.75	0.00	0.67	1936394	235.35	0.0092
I4	Variable speed drives in industry and agriculture	6.18	0.99	0.83	1.00	0.50	1.00	0.33	0.67	1083058	117.68	0.0092
I5	GEO-INDUSTRY - Replacement of	4.98	0.71	0.42	0.71	0.30	1.00	0.00	1.00	62033	5.43	0.0241

Code	Measures	BCR	SI	DII	D	E	F	G	H	PPEC costs (€)	AC (GWh)	CSk (€/kWh)
	air conditioning systems for geothermal systems											
I6	Promotion of maximum demand control systems	3.37	0.80	0.89	0.71	0.30	1.00	0.00	0.67	430974	26.96	0.0185
I7	Monitoring of cleaning of bag filters for differential pressure	2.79	1.00	1.00	0.57	0.40	0.75	0.33	0.67	344768	16.93	0.0288
I8	Pressure Regulators of compressed air system in direct exits to the atmosphere	3.47	0.86	0.05	0.71	0.20	1.00	0.00	0.67	173250	11.75	0.0172
I9	Installation of flow regulators with monitoring and control by microprocessor	2.42	0.93	0.95	0.86	0.50	1.00	0.67	0.67	285117	12.11	0.0235
I10	High-efficiency motors	1.62	1.00	0.76	0.86	0.60	0.75	0.67	0.67	48020	1.37	0.0351
I11	Industrial compressed air	2.67	0.68	0.75	0.71	0.60	0.75	0.67	0.67	266460	10.00	0.0266

Table A - 3 – Some characteristics of the energy efficiency measures from the 2nd data set (ERSE, 2009b).

Code	Measures	BCR	SI	DII	D	E	F	G	H	PPEC costs (€)	AC (GWh)	CSk (€/kWh)
R1	Installation of efficient light equipment	31.91	0.70	0.38	0.86	0.30	1.00	0.33	1.00	263685	81.92	0.0084
R2	Solar water heating panels	13.23	1.00	0.97	0.86	0.30	1.00	0.33	0.67	92500	18.70	0.0648
R3	Exchange of compact fluorescent lamps (CFL) in low-income households	9.53	1.00	1.00	0.71	0.90	1.00	0.33	1.00	1576000	173.01	0.0114
R4	Exchange of CFL in supermarkets	9.41	1.00	1.00	0.86	0.30	1.00	0.00	1.00	1695750	183.83	0.0123
R5	CFL exchange campaign	9.18	1.00	1.00	0.71	0.30	1.00	0.33	1.00	1430800	151.39	0.0135
R6	Offering CFL in shops and agents	8.94	1.00	1.00	0.71	0.30	1.00	0.00	1.00	1050000	108.13	0.0129
R7	Installation of occupancy detectors in elevators	8.47	0.69	0.82	0.71	0.50	1.00	0.33	0.67	550000	60.05	0.0142
R8	CFLs Pack - "Take two and pay only one"	8.18	0.84	0.82	0.71	0.30	1.00	0.00	1.00	1657500	156.19	0.0252
R9	Insulation screen for blind box	5.42	0.93	0.95	0.86	0.40	1.00	0.67	0.67	1290312	106.92	0.0152
R10	Promotion of X10 equipment and insulation screen for blind box for visually handicapped	0.94	0.73	0.74	0.71	0.60	1.00	0.67	0.67	233000	3.36	0.0877
S1	Phase out of incandescent lighting	17.75	1.00	1.00	1.00	1.00	1.00	0.33	0.67	162000	30.01	0.0070
S2	Efficient halogen lighting	12.07	1.00	1.00	1.00	0.50	1.00	0.67	0.67	48000	4.51	0.1172
S3	T5 lamps in schools	13.82	0.96	0.79	0.71	0.50	0.75	0.00	1.00	238280	47.17	0.0248
S4	Compact fluorescent lamps	13.37	1.00	0.99	0.71	0.30	1.00	0.00	0.67	1289600	179.89	0.0090
S5	7W LEDs	8.48	1.00	1.00	1.00	0.50	1.00	0.67	0.67	135000	15.37	0.0429
S6	eCube: refrigeration systems in supermarkets	8.41	1.00	0.85	1.00	0.50	0.75	0.67	0.67	1453600	190.37	0.0095
S7	Astronomical clocks	9.74	1.00	0.62	0.57	0.50	1.00	0.33	0.67	1026500	114.69	0.0112
S8	Freecooling in technical areas	7.73	0.98	0.85	1.00	0.60	1.00	0.67	1.00	305261	33.07	0.0175
S9	eCube: companies with refrigeration needs	6.34	1.00	0.85	1.00	0.50	0.75	0.67	0.67	290720	28.69	0.0127
S10	LED traffic lights	5.76	1.00	0.99	0.57	0.50	1.00	0.67	0.67	1632750	120.84	0.0270
S11	Advertising with efficient lighting (led)	5.13	1.00	0.98	0.71	0.50	0.50	0.67	0.67	1034762	66.72	0.0222
S12	Smart SME - Commerce and services	6.16	0.57	0.70	0.86	0.30	1.00	0.33	0.67	342621	29.60	0.0145
S13	Free-cooling in service buildings	5.28	1.00	0.91	0.43	0.50	0.75	0.67	0.67	1576000	116.55	0.0169
S14	Public lighting - Flux regulation	2.71	1.00	0.91	0.71	0.50	1.00	0.33	0.67	1565791	59.45	0.0405
S15	Thin film for glazing in buildings	2.72	0.99	0.84	0.86	0.30	0.75	0.67	0.67	1326705	51.59	0.0322
S16	LEDs in traffic control systems	2.50	0.90	0.95	0.79	0.50	1.00	0.67	0.67	499950	16.04	0.0390
S17	Insulation screen for store box	2.64	0.83	0.87	0.71	0.40	1.00	0.67	0.67	316560	12.99	0.0305
S18	Solatubes	3.06	0.91	0.93	0.07	0.50	0.75	0.67	0.33	645000	28.26	0.0936
I1	eCube: refrigeration systems (food industry)	31.71	1.00	0.72	1.00	0.50	0.75	0.67	0.67	1860226	1140.50	0.0020
I2	Efficient transmission systems (motors)	22.54	0.97	0.95	0.86	0.30	1.00	0.00	0.67	235750	70.54	0.0043
I3	Binary control in motors	12.23	0.96	0.94	1.00	0.60	1.00	0.33	0.67	201500	42.91	0.0069
I4	Variable Speed Drives (VSD) in pumping systems	9.91	1.00	1.00	1.00	0.60	1.00	0.33	1.00	286300	49.38	0.0083
I5	Installation of voltage regulators for	10.44	0.91	0.83	1.00	0.60	1.00	0.33	0.67	172750	31.41	0.0102

Code	*Measures*	*BCR*	*SI*	*DII*	*D*	*E*	*F*	*G*	*H*	*PPEC costs (€)*	*AC (GWh)*	*CSk (€/kWh)*
	lighting											
I6	Compact fluorescent lamps	11.06	0.97	0.98	0.71	0.30	0.75	0.00	0.67	260545	37.34	0.0088
I7	eCube: industrial refrigerating systems (processed food)	9.55	0.98	0.71	1.00	0.50	0.75	0.67	0.67	346626	63.99	0.0068
I8	Electronic speed drives	7.43	1.00	0.85	1.00	0.50	1.00	0.33	1.00	1728825	223.58	0.0097
I9	T5 - discharge lamps	7.43	1.00	0.96	0.71	0.50	0.75	0.00	1.00	1718785	227.09	0.0095
I10	Energy efficient motors with electronic speed drivers	5.35	1.00	0.86	1.00	0.50	1.00	0.33	1.00	1608304	149.74	0.0134
I11	Smart SME - agriculture and industry	7.57	0.57	0.70	0.86	0.30	1.00	0.33	0.67	342621	45.15	0.0095
I12	Energy efficiency solutions in compressed air systems	3.76	1.00	0.95	1.00	0.50	0.75	0.67	0.67	1633137	85.50	0.0239

Table A - 4 – Some characteristics of the energy efficiency measures from the 3rd data set (ERSE, 2010).

Code	*Measures*	*BCR*	*SI*	*DII*	*D*	*E*	*F*	*G*	*H*	*PPEC costs (€)*	*AC (GWh)*	*CSk (€/kWh)*
R1	Distribution of 4 CFL to solidarity institutions	10.30	0.84	0.91	0.71	0.90	1.00	0.33	1.00	983906	112.69	0.0109
R2	Efficient home Kit (LED + Standby killer)	7.31	1.00	1.00	0.86	0.50	1.00	0.67	1.00	759552	78.10	0.0122
R3	Installation presence detectors in elevators	7.76	0.74	0.85	0.71	0.50	1.00	0.33	0.67	615000	61.54	0.0136
R4	Promotion of efficient lights - LEDS	5.70	1.00	1.00	0.71	0.50	1.00	0.67	1.00	1136000	98.95	0.0217
R5	LEDs in residential	5.67	1.00	1.00	0.79	0.50	1.00	0.67	0.67	109000	9.45	0.0577
R6	Knowatt	5.89	0.62	0.77	0.86	0.60	0.50	1.00	0.33	1703332	129.28	0.0248
R7	Standby killer - remote control	4.45	1.00	1.00	0.86	0.50	1.00	0.67	1.00	1287750	73.87	0.0218
R8	Elimination Standby consumption	3.47	1.00	1.00	0.86	0.50	1.00	0.67	1.00	1649440	73.87	0.0279
R9	Consumption management	1.88	0.98	0.99	0.86	0.60	1.00	1.00	0.67	503918	12.25	0.0514
R10	Promotion of consumption management	1.12	1.00	1.00	0.86	0.60	0.75	1.00	0.67	1063800	15.31	0.0869
R11	E2D - Energy efficiency in the residential sector	1.34	0.83	0.82	0.71	0.60	0.75	1.00	0.67	1414000	24.49	0.0722
I1	Variable speed drives	19.41	1.00	1.00	0.86	0.60	1.00	0.33	1.00	531300	179.56	0.0042
I2	Driving force control systems	13.23	1.00	1.00	0.71	0.60	1.00	0.33	1.00	186300	42.91	0.0062
I3	Variable frequency drives	12.21	1.00	0.88	0.71	0.60	1.00	0.33	1.00	148388	31.54	0.0088
I4	Energy efficiency motors	9.95	1.00	1.00	0.86	0.50	1.00	0.33	1.00	363362	62.96	0.0147
I5	VSD in ventilation systems	6.88	1.00	1.00	0.86	0.50	1.00	0.33	1.00	723600	86.69	0.0119
I6	VSD in refrigeration systems	6.31	1.00	1.00	0.86	0.50	1.00	0.33	1.00	234251	25.73	0.0132
I7	Replacement of discharge lamps by T5 tubular lamps	6.33	1.00	1.00	0.71	0.30	0.75	0.00	0.67	1405392	158.16	0.0129
I8	VSD in pumping systems	5.78	1.00	1.00	0.86	0.50	1.00	0.33	1.00	1844500	185.57	0.0143
I9	Replacement of high pressure discharge lamps by fluorescent lamps	5.96	1.00	1.00	0.71	0.30	1.00	0.00	0.67	120000	12.71	0.0354
I10	Smart SME - Agriculture and industry	6.50	0.72	0.56	0.86	0.30	1.00	0.33	0.67	136979	15.51	0.0145
I11	Light flux regulators	5.03	1.00	1.00	0.71	0.60	1.00	0.33	1.00	135000	11.83	0.0304
I12	Energy efficiency solutions for compressed air systems	3.51	1.00	1.00	0.86	0.50	1.00	0.67	0.67	300000	17.17	0.0443
I13	Replacement of T8 lamps by T5 tubular lamps	3.57	1.00	1.00	0.71	0.30	1.00	0.00	0.67	145894	9.25	0.0510
I14	Energy Management systems	1.21	1.00	1.00	0.86	0.50	1.00	0.33	0.67	1124829	24.49	0.0666
S1	Phase Out HG -Energy efficiency in public lighting in rural and historical villages	36.81	1.00	1.00	0.86	0.70	1.00	0.00	0.67	142500	59.42	0.0160
S2	Astronomical clocks in public light	35.48	1.00	1.00	0.57	0.30	1.00	0.00	1.00	168000	68.33	0.0032
S3	CFLs in solidarity institutions	17.87	1.00	1.00	0.57	0.90	1.00	0.33	1.00	480000	104.76	0.0058
S4	LED monumental - replacement of conventional lamps by LED in monuments and historical buildings	13.22	1.00	1.00	0.86	0.50	1.00	0.67	0.67	140300	25.84	0.0272
S5	Replacement of halogen lamps by LED in 24/7 installations	9.79	1.00	1.00	0.86	0.50	1.00	0.67	1.00	139767	15.33	0.0279
S6	Refrigeration optimization in big suppliers - Installation of evaporative condensing systems	16.17	0.50	0.67	1.00	0.50	1.00	0.33	0.33	989406	224.30	0.0055

Code	*Measures*	*BCR*	*SI*	*DII*	*D*	*E*	*F*	*G*	*H*	*PPEC costs (€)*	*AC (GWh)*	*CSk (€/kWh)*
S7	LED in traffic lights	11.67	1.00	1.00	0.57	0.50	1.00	0.33	0.67	216041	36.73	0.0123
S8	Installation of flux regulators in public lights in urban areas	9.13	1.00	1.00	0.86	0.30	1.00	0.00	1.00	1488475	190.44	0.0113
S9	Free-cooling	8.68	1.00	1.00	0.86	0.50	1.00	0.67	0.67	234150	28.50	0.0119
S10	Installation of flux regulators in public lights in road access	9.13	1.00	1.00	0.86	0.30	1.00	0.00	1.00	1488475	190.44	0.0113
S11	Replacement of halogen lamps by LED in semi-permanent installations	8.08	1.00	1.00	0.86	0.50	1.00	0.67	1.00	156931	14.54	0.0311
S12	LED in monuments	9.69	0.50	0.67	0.86	0.60	1.00	0.67	0.33	1341208	186.19	0.0344
S13	eCube	5.12	1.00	1.00	1.00	0.50	1.00	0.67	1.00	64980	5.18	0.0157
S14	Traffic LED - Replacement of incandescent lights by LEDS in traffic lights	5.97	1.00	1.00	0.86	0.50	1.00	0.33	0.67	408400	35.53	0.0287
S15	Replacement of T8 lamps by T5 tubular lamps	6.04	1.00	1.00	0.71	0.30	1.00	0.00	0.67	182368	15.77	0.0368
S16	Refrigeration optimization in big suppliers - Installation of VSD	8.61	0.50	0.67	0.86	0.50	1.00	0.33	0.33	604559	73.00	0.0127
S17	VSD in pumping systems	4.84	1.00	1.00	0.86	0.50	1.00	0.33	1.00	426034	28.92	0.0214
S18	LEDs to replace "Focus" in commerce	5.03	1.00	1.00	0.71	0.50	0.75	0.67	1.00	419430	25.34	0.0301
S19	SMART SME - Commerce and services	6.74	0.72	0.56	0.86	0.30	1.00	0.33	0.67	136979	12.95	0.0173
S20	Installation of flux regulators in public lights in Madeira Autonomous Region	6.64	0.62	0.71	0.57	0.30	1.00	0.00	0.67	417306	32.82	0.0159
S21	Replacement of conventional lamps by LED	3.52	0.75	0.86	0.86	0.50	1.00	0.67	1.00	1040060	43.96	0.0440
S22	Installation of T8 lamps in schools	1.97	1.00	1.00	0.57	0.30	0.75	0.00	1.00	354000	8.22	0.0742
S23	SEMALED - replacement of incandescent lamps by LED in traffic lights	1.78	0.83	0.91	0.86	0.50	1.00	0.33	0.67	1619217	41.99	0.0482
S24	Replacement of halogen lamps by LED in Madeira Autonomous Region	4.31	0.47	0.55	0.71	0.50	1.00	0.67	1.00	192399	8.42	0.0318
S25	IPLED - LED public lights	1.20	0.78	0.88	0.71	0.40	1.00	0.67	0.67	1497204	24.95	0.0750
S26	"+ LED" - Replacement of halogen lamps by LED in hotel units	1.61	0.53	0.70	0.86	0.50	1.00	0.67	0.67	123950	2.02	0.0767
S27	Replacement of incandescent lamps by LED in traffic lights, in Madeira Autonomous Region	1.91	0.52	0.69	0.71	0.50	1.00	0.33	0.67	174861	4.11	0.0572
S28	CMLED	1.24	0.01	0.00	0.71	0.50	0.75	0.67	0.33	168781	2.92	0.0722

Appendix C

In this appendix the table with the rank order of measures that results from non-dominated solutions for the 1st data set is presented (Table A-5), as well as for the 2nd (Table A-6) and the 3rd (Table A-7). In Table A-6, due to the high number of non-dominated solutions, only those that correspond to different ranks of measures are presented. When a solution (column) has measure codes underlined and bold, it means that the corresponding measures have different rank orders from the one they have in the contiguous solution (column) on the left.

Table A - 5 - Rank order of measures resulting from non-dominated solutions, for the 1st set of data.

Rank	*Sol.1*	*Sol.2*	*Sol.3*	*Sol.4*	*Sol.5*	*Sol.6*	*Sol.7*	*Sol.8*	*Sol.9*	*Sol.10*	*Sol.11*	*Sol.12*	*Sol.13*	*Sol.14*	*Sol.15*	*Sol.16*	*Sol.17*	*Sol.18*	*Sol.19*	*Sol.20*	*Sol.21*
	Residential																				
1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1
2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2
3	R5	R5	R5	R5	***R4***	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4
4	R4	R4	R4	R4	***R5***	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5
5	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	***R6***	R6	R6	R6	R6	R6	R6
6	R6	R6	R6	R6	R6	R6	R6	R6	R6	R6	R6	R6	R6	R6	***R3***	R3	R3	R3	R3	R3	R3
7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	***R8***	R8	R8	R8	R8	R8	R8
8	R9	R9	R9	***R8***	***R9***	R9	***R8***	R8	R8	R8	R8	R8	R8	R8	***R7***	R7	R7	R7	R7	R7	R7
9	R10	R10	***R8***	***R9***	***R8***	R8	***R9***	R9	R9	R9	R9	R9	R9	R9	R9	R9	R9	R9	R9	R9	R9
10	R8	R8	***R10***	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10
11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11
	Services and Commerce																				
1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
2	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3
3	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
4	S7	S7	***S12***	***S7***	S7	S7	***S10***	S10	S10	S10	S10	S10	S10	S10	S10	S10	***S7***	S7	S7	S7	S7
5	S12	S12	***S7***	***S12***	***S10***	S10	***S7***	S7	S7	***S12***	S12	***S7***	S7	***S12***	***S7***	S7	***S10***	S10	S10	S10	S10
6	S10	S10	S10	S10	***S12***	S12	S12	S12	S12	***S7***	S7	***S12***	S12	***S7***	***S12***	S12	***S4***	S4	S4	***S12***	S12
7	S13	S13	S13	S13	S13	S13	S13	S13	S13	S13	S13	S13	S13	S13	***S4***	***S13***	***S12***	S12	S12	***S4***	S4
8	S8	S8	S8	S8	S8	S8	S8	***S11***	S11	S11	S11	***S8***	S8	***S11***	***S13***	***S4***	***S8***	S8	S8	***S13***	S13
9	S11	S11	S11	S11	S11	S11	S11	***S8***	S8	S8	S8	***S11***	S11	***S8***	S8	S8	***S13***	S13	S13	***S8***	S8
10	S15	S15	***S9***	***S15***	***S9***	S9	***S15***	***S9***	***S15***	***S9***	S9	S9	***S4***	***S9***	***S11***	S11	S11	S11	S11	S11	S11
11	S9	S9	***S15***	***S9***	***S15***	S15	***S9***	***S15***	***S9***	***S15***	S15	***S4***	***S9***	***S4***	***S9***	S9	S9	***S14***	***S15***	***S14***	***S15***
12	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	***S15***	S15	S15	***S5***	***S15***	***S14***	***S15***	***S14***	***S15***	***S14***
13	S16	S16	S16	S16	***S4***	S4	S4	S4	S4	S4	S4	***S5***	S5	S5	***S15***	***S14***	***S5***	***S9***	S9	S9	S9
14	S14	S14	S4	S14	***S16***	S16	***S14***	S14	S14	S14	S14	S14	S14	S14	S14	***S5***	***S15***	***S5***	S5	S5	S5
15	S4	S4	***S14***	***S4***	***S14***	S14	***S16***	S16	S16	S16	S16	***S6***	S6	S6	S6	S6	S6	S6	S6	S6	S6
16	S6	S6	S6	S6	S6	S6	S6	S6	S6	S6	S6	***S16***	S16	S16	S16	S16	S16	S16	S16	S16	S16
	Industry and agriculture																				
1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1
2	I4	I4	I4	I4	I4	I4	I4	I4	I4	I4	I4	***I2***	I2	I2	I2	I2	I2	I2	I2	I2	I2
3	I2	I2	I2	I2	I2	I2	I2	I2	I2	I2	I2	***I4***	I4	I4	I4	I4	I4	I4	I4	I4	I4
4	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3
5	I9	I9	I9	I9	I9	I9	I9	I9	I9	I9	I9	I9	***I5***	***I9***	***I5***	I5	I5	I5	I5	I5	I5
6	I7	I7	I7	I7	I7	I7	***I6***	I6	I6	I6	I6	***I5***	***I9***	***I5***	***I6***	I6	I6	I6	I6	I6	I6
7	I10	I10	***I6***	I6	I6	I6	***I7***	I7	***I5***	***I7***	***I5***	***I6***	I6	I6	***I9***	I9	I9	I9	I9	I9	I9
8	I6	I6	***I5***	***I10***	***I5***	I5	I5	I5	***I7***	***I5***	***I7***	I7	I7	I7	I7	I7	I7	***I8***	I8	I8	I8
9	I5	I5	***I10***	***I5***	***I10***	I10	I10	I10	I10	I10	I10	I10	I10	I10	***I11***	I11	***I8***	***I7***	***I11***	***I7***	***I11***
10	I11	I11	I11	I11	I11	I11	I11	I11	I11	I11	I11	I11	I11	I11	***I8***	I8	***I11***	I11	***I7***	***I11***	***I7***
11	I8	I8	I8	I8	I8	I8	I8	I8	I8	I8	I8	I8	I8	I8	***I10***	I10	I10	I10	I10	I10	I10

Table A - 6 - Rank order of measures resulting from non-dominated solutions for the 2nd set of data.

Rank	*Sol.1*	*Sol.3*	*Sol.8*	*Sol.10*	*Sol.11*	*Sol.12*	*Sol.14*	*Sol.21*	*Sol.40*	*Sol.44*	*Sol.50*
						Residential					
1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1
2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2
3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4
5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5
6	R6	R6	R6	R6	R6	R6	R6	R6	R6	R6	R6
7	R8	***R7***	R7	R7	R7	R7	R7	R7	R7	R7	R7
8	R7	***R8***	R8	R8	R8	R8	R8	R8	R8	R8	R8
9	R9	R9	R9	R9	R9	R9	R9	R9	R9	R9	R9
10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10
						Services and commerce					
1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
2	S4	S4	S4	S4	S4	S4	***S3***	S3	S3	S3	S3
3	S3	S3	S3	S3	S3	S3	***S4***	S4	S4	S4	S4
4	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
5	S5	S5	S5	S5	S5	S5	***S7***	S7	S7	S7	***S5***
6	S6	S6	S6	S6	S6	***S7***	***S5***	S5	S5	S5	***S7***
7	S8	***S7***	S7	S7	S7	***S6***	S6	S6	S6	S6	S6
8	S7	***S8***	S8	S8	S8	S8	S8	S8	S8	S8	S8
9	S9	S9	S9	S9	S9	S9	S9	S9	S9	S9	S9
10	S10	S10	S10	S10	S10	S10	S10	S10	S10	***S12***	S12
11	S11	S11	S11	S11	***S12***	S12	S12	S12	S12	***S10***	S10
12	S13	S13	***S12***	S12	***S11***	S11	S11	S11	S11	S11	S11
13	S12	S12	***S13***	S13	S13	S13	S13	S13	S13	S13	S13
14	S14	S14	S14	S14	S14	***S16***	***S14***	S14	***S16***	***S14***	***S16***
15	S16	S16	S16	S16	S16	***S14***	***S16***	S16	***S14***	***S16***	***S15***
16	S15	S15	S15	S15	S15	S15	S15	***S17***	S17	***S15***	***S14***
17	S17	S17	S17	S17	S17	S17	S17	***S15***	S15	***S17***	S17
18	S18	S18	S18	S18	S18	S18	S18	S18	S18	S18	S18
						Industry and agriculture					
1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1
2	I2	I2	I2	I2	I2	I2	I2	I2	I2	I2	I2
3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3
4	I4	I4	I4	I4	I4	I4	I4	***I5***	I5	I5	I5
5	I5	I5	I5	I5	I5	I5	I5	***I4***	I4	I4	I4
6	I6	I6	I6	I6	I6	I6	I6	I6	I6	I6	I6
7	I7	I7	I7	I7	I7	I7	I7	I7	I7	I7	I7
8	I8	I8	I8	I8	I8	I8	I8	I8	I8	I8	I8
9	I9	I9	I9	I9	I9	I9	I9	I9	I9	I9	I9
10	I10	I10	I10	***I11***	I11	I11	I11	I11	I11	I11	I11
11	I11	I11	I11	***I10***	I10	I10	I10	I10	I10	I10	I10
12	I12	I12	I12	I12	I12	I12	I12	I12	I12	I12	I12

Table A - 7 - Rank order of measures resulting from non-dominated solutions, for the 3rd set of data.

Rank	*Sol. 1*	*Sol. 2*	*Sol. 3*	*Sol. 4*	*Sol. 5*	*Sol. 6*	*Sol. 7*	*Sol. 8*	*Sol. 9*	*Sol. 10*	*Sol. 11*	*Sol. 12*
						Residential						
1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1
2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2
3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4
5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5
6	R6	R6	R6	R6	R6	R6	R6	R6	R6	R6	R6	R6
7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7
8	R8	R8	R8	R8	R8	R8	R8	R8	R8	R8	R8	R8
9	R9	R9	R9	R9	R9	R9	R9	R9	R9	R9	R9	R9
10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10
11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11	R11

Rank	*Sol. 1*	*Sol. 2*	*Sol. 3*	*Sol. 4*	*Sol. 5*	*Sol. 6*	*Sol. 7*	*Sol. 8*	*Sol. 9*	*Sol. 10*	*Sol. 11*	*Sol. 12*
	Services and Commerce											
1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3
4	S6	S6	S6	S6	S6	S6	S6	S6	S6	S6	S6	S6
5	S4	S4	S4	S4	S4	S4	S4	S4	S4	S4	S4	S4
6	S7	S7	S7	S7	S7	S7	S7	S7	S7	S7	S7	S7
7	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5
8	S8	S8	S8	S8	S8	S8	S8	S8	S8	S8	***S12***	***S9***
9	S10	S10	S10	S10	S10	S10	S10	S10	S10	S10	***S8***	***S12***
10	S12	S12	S12	S12	S12	***S9***	S9	S9	***S12***	S12	***S10***	***S8***
11	S9	S9	S9	S9	S9	***S12***	S12	S12	***S9***	S9	S9	***S10***
12	S11	S11	S11	S11	S11	S11	S11	S11	S11	S11	S11	S11
13	S16	S16	S16	S16	S16	S16	S16	S16	S16	S16	S16	S16
14	S14	S14	S14	S14	S14	S14	S14	S14	S14	S14	S14	***S13***
15	S19	S19	S19	S19	S19	S19	S19	***S13***	***S19***	S19	***S13***	***S14***
16	S13	S13	S13	S13	S13	S13	S13	***S19***	***S13***	S13	***S19***	S19
17	S15	S15	S15	S15	S15	S15	S15	S15	S15	S15	S15	***S17***
18	S20	S20	S20	S20	S20	S20	S20	***S17***	***S20***	S20	***S17***	***S15***
19	S17	S17	S17	S17	S17	S17	S17	***S18***	***S17***	S17	***S20***	***S18***
20	S18	S18	S18	S18	S18	S18	S18	***S20***	***S18***	S18	S18	***S20***
21	S21	S21	S21	S21	S21	S21	S21	S21	S21	S21	***S24***	***S21***
22	S24	S24	S24	S24	S24	S24	S24	S24	S24	S24	***S21***	***S24***
23	S23	S23	S23	S23	S23	S23	S23	S23	S23	S23	S23	S23
24	S22	S22	S22	S22	S22	S22	S22	S22	***S26***	S26	S26	S26
25	S26	S26	S26	S26	S26	S26	S26	S26	***S27***	S27	S27	S27
26	S27	S27	S27	S27	S27	S27	S27	S27	***S22***	S22	S22	S22
27	S25	S25	S25	S25	S25	S25	S25	S25	S25	S25	S25	S25
28	S28	S28	S28	S28	S28	S28	S28	S28	S28	S28	S28	S28
	Industry and Agriculture											
1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1	I1
2	I2	I2	I2	I2	I2	I2	I2	I2	I2	I2	I2	I2
3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3	I3
4	I4	I4	I4	I4	I4	I4	I4	I4	I4	I4	I4	I4
5	I5	I5	I5	I5	I5	I5	I5	I5	I5	I5	I5	I5
6	I6	I6	I6	I6	I6	I6	I6	I6	I6	I6	I6	I6
7	I8	I8	I8	I8	I8	I8	I8	I8	I8	I8	I8	I8
8	I7	I7	I7	I7	I7	I7	I7	I7	***I10***	I10	I10	I10
9	I10	I10	I10	I10	I10	I10	I10	I10	***I7***	I7	I7	I7
10	I9	I9	I9	I9	I9	I9	I9	***I11***	***I9***	I9	***I11***	I11
11	I11	I11	I11	I11	I11	I11	I11	***I9***	***I11***	I11	***I9***	I9
12	I12	I12	I12	I12	I12	I12	I12	I12	I12	I12	I12	I12
13	I13	I13	I13	I13	I13	I13	I13	I13	I13	I13	I13	I13
14	I14	I14	I14	I14	I14	I14	I14	I14	I14	I14	I14	I14

Appendix D

The percentage of financing of the measures in the 1st data set, for each consumer segment, is presented in Table A-8. The rank position is shown in the 1st column. The percentage in each cell of the table A - 8 corresponds to the measure which code is presented in the same cell in table A - 5.

Table A - 8 – Percentage of funding of measures according to their rank order for the 1st data set.

Rank	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*
	Residential																				
1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
4	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
5	54	54	54	54	54	54	54	54	54	54	54	54	54	54	100	100	100	100	100	100	100
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	38	38	38	38	38	38
	Services and Commerce																				
1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
4	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
5	100	100	100	100	90	90	81	81	81	100	100	81	81	100	81	81	90	90	90	90	90
6	74	74	74	74	0	0	0	0	0	52	52	0	0	52	0	0	0	0	0	0	0
	Industry and Agriculture																				
1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
4	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
5	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
6	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
7	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
8	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	38	38	59	79	100	79	100
10	20	20	20	20	20	20	20	20	20	20	20	20	20	20	0	0	0	0	2	0	2

Annexes

In the following annexes are presented the partial versions of the California Standard Practice Manual (CPUC and CEC, 2001), and of the versions 2 (CPUC, 2003) and 4 (CPUC, 2008) of the Energy Efficiency Policies Manuals. In order to highlight what was considered to be probably useful for the reader in the context of this work, while minimizing potential risk of changing the original context, only minor changes to the original text were made. For a detailed understanding of those manuals, the original versions are highly recommended.

Also the cost-effectiveness tests performed in US states are presented in Annex D.

Annex A – California Standard practice for the economic analysis of DSM programmes

The Standard Practice for Cost-Benefit Analysis of Conservation and Load Management Programs, February 1983, intended to define guidelines for cost-efficiency analysis of utility-sponsored programmes. This Standard Practice Manual (SPM) was revised in 1987-88, and 2001 (CPUC and CEC, 2001). This manual defines a set of cost-effectiveness tests and identifies the costs and the benefits of each one of them. Each test shows a different perspective: Participant, Ratepayer Impact Measure (RIM), Program Administrator Cost (PAC)[1], and Total Resource Cost (TRC)[2]. The results of each test can be presented in several ways, but in all cases it is suggested to compute the net present value (NPV) of impacts of the programme over the lifecycle of those impacts. In Table B-1 the primary and secondary indicators for each of the cost-effectiveness tests are presented.

[1] Formerly designated "Utility Cost" test (UC).

[2] There is a "Societal" test, derived from the TRC, which accounts for externalities.

Table B-1 – Primary and secondary indicators for each of the cost-effectiveness tests (CPUC and CEC, 2001).

Primary	Secondary
Participant	
NPV (all participants)	Discounted payback (years) Benefit-cost ratio (BCR) NPV (average participant)
Ratepayer Impact Measure	
Lifecycle revenue impact (LRI) per unit of energy or demand NPV	Lifecycle revenue impact (LRI) per unit Annual revenue impact (by year, per kWh, kW, therm, or customer) First-year revenue impact (per kWh, kW, therm, or customer) BCR
Total Resource Cost	
NPV	BCR Levelized cost (cents or dollars per unit of energy or demand) Societal (NPV; BCR)
Program Administrator Cost	
NPV	BCR Levelized cost (cents or dollars per unit of energy or demand)

The primary indicators are the ones that were considered the most useful for comparing DSM programmes cost-effectiveness. The secondary indicators are considered supplemental and can be useful for some programmes, proceedings, or reports.

Since these tests reflect different perspectives they are not supposed to be used individually or in isolation. Under this multi-perspective approach program administrators must consider trade-offs between the various tests. In the next sections each perspective is presented.

The Participant Test

The Participant test is the measure of the quantifiable benefits and costs to the participant due to his/her participation in the programme. Since the variables used to the customers to make a decision may not be all quantifiable, this test cannot be a complete measure of the benefits and costs faced by the customer, when participating in the programme. Some of the benefits for the customer may be the reduction of the bill, any incentive paid by the utility or any other market agent, and any tax credit received. Costs due to participation in the programme may include the costs of any equipment or materials purchased, any operational and maintenance costs, any removal costs, and the value of the customer's time for the implementation of the measure (CPUC and CEC, 2001).

The results of this test can be expressed, primarily through the net present value (NPV) for the total programme. However three other secondary tests are possible: a NPV per average participant, a

BCR or discounted payback (DP). The DP is the number of years necessary for the cumulative discounted benefits to equal or exceed the cumulative discounted costs. The shorter the DP the more beneficial the programme is to the participants. NPV gives the net dollar benefit of the programmes to an average participant or to all participants discounted over some specified time period. NPV must be positive in order for the programme to be beneficial for the participants. The BCR is the ratio between the total benefits and the total costs of the programme, discounted over some specified period of time. The BCR gives a measure of the rough rate of return of a programme and is also a risk indicator. A beneficial programme must have a BCR above 1.

The Participant Test is particularly useful since it can provide an indication of the interest in the programme, helping in the design, in establishing incentive levels to induce desirable participation goals, in programme penetration analysis, helping also to minimize adverse ratepayer impacts and maximize benefits. Since not all customer decisions are based in quantifiable variables, this test is incapable of accurately identifying all the complexities of the customers decision-making process. Therefore the role of the Participants Test should have a supportive role in the assessment of the programmes as alternatives to supply-side projects.

The Ratepayer Impact Measure Test

The Ratepayer Impact Measure (RIM) test is a measure of the effect of the utility revenues and operating costs, due to the programme, on rates and customer bills. The benefits from this test are the savings from the avoided supply costs. These avoided supply costs include reduction in generation, transmission, distribution, and capacity costs for periods when load has been reduced and the increase in revenues for the periods in which load has increased. The costs for the RIM test are the programme costs incurred by the utility (and/or any other entities incurring costs), the incentives paid to the participant, the decrease in revenues due to load decrease and the increase supply costs for any periods when load increased. The utility costs due to the programme include initial and annual costs, such as the cost associated to equipment, operation and maintenance, installation, programme administration, and customer dropout and removal of equipment (less salvage values). If the lost revenues and the utility costs are lower than the avoided costs experienced by the utility, the rates will decrease, and vice-versa. This test gives information about the direction and the magnitude of the change in customer bills or rate levels.

The results of this test could be presented, primarily, through the lifecycle revenue impact (LRI), expressed as a change in rates (cents per kWh, dollars per kW, and cents per therm for natural gas) and the NPV. The secondary indicators of the test results are the LRI per customer, first-year and annual revenue impacts, and the BCR.

The LRI is the one-time change in rates or the bill change over the life of the programme needed to bring total revenues in line with revenue requirements over the life of the programme. The change in the rate is expected to be implemented in the first year of the programme. Any successive rate changes are made from there. The first-year revenue impact (FRI) is the change in rates in the first year of the programme or the bill change needed to get total revenues to match revenue requirements only for that year. The annual revenue impact (ARI) is a series of differences between revenues and revenue requirements in each year of the programme. These series shows the cumulative rate change or bill change in a year needed to match revenues to revenue requirements. Thus, the ARI_{RIM} for year six per kWh is the estimate of the difference between present rates and the rate that would be in effect in year six due to the programme. For results expressed as lifecycle annual, or first-year revenue impacts, negative results indicate favourable effects on the bills of the ratepayers or reductions in rates. Positive values for results of the tests indicate adverse bill impacts or rate increases.

The NPV_{RIM} gives the discounted dollar net benefit of the programme from the perspective of rate levels or bills over some specified time period. Positive NPV_{RIM} correspond to lower rates and bills. The BCR_{RIM} is the ratio between the total benefits of the programme and the total costs discounted over some specified time period. A BCR_{RIM} above one indicates that the programme will lower rates and bills.

The loss of revenues due to DSM programmes has to be compensated by ratepayers. The RIM test is the only test that reflects the revenue shift along with the other costs and benefits due to the programme. This is an important outcome from the test. Another important characteristic of the RIM test is that it can be applied to all DSM programmes (conservation, load management, fuel substitution, and load building). This particularity of the RIM test allows the impacts among DSM options to be compared.

A weakness of the RIM test is that its results are probably less accurate than those from the other tests because it is sensitive to both the differences between long-term projections of marginal costs and the long-term projections of rates, two costs streams that are difficult to accurately quantify. Besides, RIM test results are also sensitive to assumptions regarding the financing of programme costs. Sensitivity analyses and interactive analyses that capture the feedback effects between system changes, rate design options, and alternative means of financing generation and non-generation options can help overcome these limitations. However, these types of analyses may be difficult to implement. The RIM test should be carefully applied when evaluating fuel substitution programmes with multiple end-use efficiency options. For example, when the marginal costs are less than the average costs, a programme that promotes an inefficient appliance may give a more favourable result than a programme that promotes an efficient appliance. Though the results of the RIM test accurately reflect rate impacts, the implications for long-term conservation programmes need to be considered.

Total Resource Cost Test

The Total Resource Cost (TRC) Test measures the net costs of a DSM programme as a resource option based on total costs of the programme, including both the participants and the utility's costs. The TRC test is applicable to conservation, load management and fuel substitution programmes.

The Societal test (a societal version of the TRC) differs from the TRC test since it includes the effects of externalities (such as environmental, national security), excludes tax credit benefits, and uses a different (a societal) discount rate.

The TRC test represents a combination of the effects of a programme on both the participants and the non-participants in the programme. The benefits calculated in the TRC test are the avoided supply costs, the reduction in generation, transmission, distribution, and capacity costs valued at marginal cost for the periods when there is a load reduction. The avoided supply costs should be calculated using net programme savings (savings net of changes in energy use that would have happened regardless of the programme). The costs accounted for in the TRC are the programme costs paid by the utility and the participants plus the increase in supply costs for the periods in which load has increased. Thus all equipment costs, installation, operation and maintenance, cost of removal (less salvage value), and administration costs, regardless who pays for them, are included in this test. Any tax credits are considered as reduction to the costs in the test.

The TRC test results can be expressed by the NPV. Other secondary measures are the BCR, and the levelized costs. The Societal version expressed in terms of NPV, BCR, or levelized costs is also considered a secondary indicator of TRC test results.

The NPV_{TRC} is the discounted value of the net benefits to this test over a specified period of time. NPV_{TRP} measures the change in the total resource costs due to the programme. A positive NPV indicates that the programme is a less expensive resource than the supply option upon which the marginal costs are based.

The BCR_{TRC} is the ratio between the discounted total benefits of the programme and the discounted total costs over some specified time period. It gives an indication of the rate of return of this programme to the utility and its ratepayers. A BCR above one indicates that the programme is beneficial to the utility and its ratepayers on a total resource cost basis.

The levelized cost is a measure of the total costs of the programme in a form that is sometimes used to estimate costs of utility-owned supply additions. It presents the total costs of the programme to the utility and its ratepayers on a per kW, per kWh, or per term basis levelized over the life of the programme.

The Societal test is structurally similar to the TRC test. It attempts to quantify the change in the total resource costs to the society as a whole rather than to only the service territory (the utility and its ratepayers), as does the TRC. In taking the society's perspective, the Societal test utilizes essentially the same input variables as the TRC test, but they are defined with a broader societal point of view. More specifically, the Societal test differs from the TRC test in at least one of five items. Firstly, the Societal test may use higher marginal costs than the TRC test if a utility faces marginal costs that are lower than other utilities in the state or than its out-of-state suppliers. Marginal costs used in the Societal test would reflect the cost to the society of more expensive alternative resources. Second, tax credits are treated as a transfer payment in the Societal test, and thus are left out. Third, in the case of capital expenditures, interest payments are considered a transfer payment since society actually expends the resources in the first year. Therefore, capital costs enter the calculations in the year in which they occur. Fourth, a societal discount rate should be used. Finally, marginal costs used in the Societal test would also contain externality costs of power generation not captured by the market system. The values of some externalities are also referred to as "adders" designed to capture or internalize such externalities. Some potential adders would include for example: the benefit of avoided environmental damage; the benefit of avoided transmission and distribution costs; the benefit of avoided generation costs; the benefit of increased system reliability; non-energy benefits; non-energy benefits for low income programmes; benefits of fuel diversity.

An important outcome of the TRC test is its scope. The test includes total costs (participants plus programme administrator) and also has the potential for capturing total benefits (avoided supply costs plus, in the case of the Societal test, externalities). The TRC test provides a useful basis for comparing demand- and supply-side options.

The treatment of revenue shifts and incentive payments as transfer payments can both be a strength and a weakness of the TRC test. While it is true that most supply-side cost analyses do not include such financial issues, it can be argued that DSM programmes should include these effects since, in contrast to most supply-side options, DSM programmes do result in lost revenues. In addition, the costs of the DSM as a resource in the TRC test are based on the total costs of the programme, including the ones incurred by the participant. Supply-side resource options are typically based only on the costs incurred by the power suppliers. Finally, the TRC test cannot be applied meaningfully to load building programmes, thereby limiting the ability to use this test to compare the full range of DSM options.

Program Administrator Cost Test

The Programme Administrator Cost (PAC) Test measures the net costs of a DSM programme as a resource option based on the costs incurred by the programme administrator (including incentive costs) and excluding any net costs incurred by the participant. The benefits are similar to the TRC test benefits.

The benefits for the PAC test are the avoided supply costs of energy and demand, the reduction in transmission, distribution, generation and capacity valued at marginal costs for the periods when there is a load reduction. The avoided supply costs should be calculated using net programme savings, savings net changes in energy use that would have happened regardless of the programme. The costs for the PAC test are the programme costs incurred by the administrator, the incentives paid to the customers, and the increased supply costs for the periods in which the load increased. Programme administrator costs include initial and annual costs, such as the cost of utility equipment, installation, operation and maintenance, programme administration, and the customer dropout and removal of the equipment (less salvage value).

In the PAC test, the revenue shifts are viewed as a transfer payment between participants and all ratepayers. Although a shift in the revenues affects rates, it does not affect revenue requirements, which are defined as the difference between the net marginal energy and capacity costs avoided and programme costs. Thus, if $NPV_{PAC} > 0$ and $NPV_{RIM} < 0$, the administrator´s overall total costs will decrease, although rates may increase because the sales base over which revenue requirements are spread has decreased.

This test should primarily be expressed by the NPV. The secondary indicators for this test are BCR and levelized costs.

The NPV_{PAC} is the benefit of the programme minus the administrator's costs, discounted over some specified period of time. A NPV_{PAC} above zero indicates that this DSM programme would decrease costs to the administrator and the utility. The BCR_{PAC} is the ratio of the total discounted benefits of a programme to the total discounted costs for a specified time period. A BCR_{PAC} above one indicates that the programme would benefit the combined administrator and utility's total cost situation. The Levelized cost is a measure of the costs of the programme to the administrator in a form that is sometimes used to estimate costs of utility-owned supply additions. It presents the costs of the programme to the administrator and the utility on per kW, per kWh, or per therm basis levelized over the life of the programme.

The PAC test treats revenue shifts as transfer payments, meaning that test results are not complicated by the uncertainties associated with long-term rate projections and associated rate design assumptions. The PAC test includes only the portion of the participant's equipment costs that is paid for by the administrator in the form of an incentive. Therefore, for purposes of comparison, costs in the PAC test are defined similarly to those supply-side projects which also do not include direct customer costs.

Being the device costs those incurred exclusively by the administrator, the PAC test results reflect only a portion of the full costs of the resource. The PAC test shares two limitations with the TRC test: (1) by treating revenue shifts as transfer payments, the rate impacts are not captured, and (2) the test cannot be used to evaluate load building programmes.

The PAC test was formerly named Utility Cost test (UC). The change allowed the use of this test of the assessment of programmes managed by other non-utilities entities.

The PAC test is usually used by jurisdictions that want to increase the investments in EE, since it compares EE as a utility investment, as does with other resources.

Annex B - Energy Efficiency Policy Manual – version2

The Energy Efficiency Policy Manual, Version 2 (CPUC, 2003) defines a set of rules for the ranking of measures that should be funded by a PGC. The programmes are ranked in accordance with their performance assessed with a set of evaluating criteria (primary criteria). The policy objective is to finance programmes that are cost-effective, that achieve maximum energy and peak demand savings, that are able to provide access to all customers, that are able to overcome market barriers, and that take advantage of coordination with existing programmes. Each criterion is valued differently by the Commission. The EE programmes can be divided in two groups (1) PGC "hardware" and incentive programmes and (2) Information-only and Statewide Marketing and Outreach Programs.

For the Primary criteria for PGC "Hardware" and Incentive Programs, the criteria used and the assigned scores are:

1. Cost-effectiveness - The cost-effectiveness criterion is valued with 40 points, divided in two different measures: the program net benefits, valued with 30 points, and the benefit-cost ratio, valued with 10 points. The Commission considers that two cost-effectiveness tests are important in evaluating the EE programmes. The first is the Societal version of the TRC test, and the other is the Participant test. The Societal test intends to measure the overall cost-effectiveness of EE programmes from the societal perspective, accounting for the benefits and costs from more than just an individual perspective. As previously pointed out, the TRC is one criterion among others to support the funding decision, however this will be the one preferred by the Commission to assess the programme cost-effectiveness. The Participant test is used to evaluate programmes that intend to induce individual customers to make EE decisions. It measures the cost-effectiveness of the programmes from the perspective of the consumers participating in the programme. The EE programmes that will provide financial incentives to the customers should include the results of both the TRC and the Participant test.
2. Long-term Annual Energy Savings – This criterion is valued with 20 points and intends to create permanent and verifiable energy savings over the life cycle of programme.
3. Electric peak demand savings – This criterion is valued with 15 points, and intends to foster the implementation of measures that contribute to long-term and permanent peak demand savings.
4. Equity - The criterion Equity is valued with 10 points. With this criterion the Commission intends to prioritize programmes that provide access to EE alternatives to all customers,

mainly those “underserved” and “hard-to-reach markets”. Since the PGC is equally paid by all customers, it is fair that all can benefit from the alternatives.

5. Ability to overcome market barriers - This criterion is valued by the Commission with 5 points. A list of barriers to be addressed or overcome by the measure is provided by the Commission, in order of importance such as:
    - Higher initial costs for high-efficiency measures relative to standard-efficiency measures;
    - Lack of consumer information on energy efficiency;
    - Lack of financing for EE improvements;
    - Split incentives (such as between owners/landlords and tenants);
    - Lack of a viable and competitive set of providers of EE services in the market;
    - Barriers to the entry of new energy efficiency service providers;
    - Lack of availability of high-efficiency products.
6. Innovation - The Innovation criterion is valued with 5 points. With this criterion the Commission intends to value programmes that are based on new ideas, new delivery mechanisms, new providers or EE services, or even new and emerging technologies to address new programmes areas, to overcome existing shortcomings, or to improve the effectiveness of existing programmes.
7. Coordination with programmes run by other entities - This criterion is valued with 5 points and intends to encourage programmes that benefit from the coordination with other existing programmes, including those run by other state agencies, private entities, municipal utilities, or the federal government.

The programmes belonging to the category of Information-only and Statewide marketing and outreach programs are primarily evaluated in accordance with the criteria Ability to overcome market barriers, Equity, Innovation and Coordination with other programme implementers, valuing 25 points each.

A secondary set of criteria is also used for both kinds of programmes. The criteria and the score assigned to each one are:

1. Quality and viability – 30 points
2. Distribution and reasonableness of budgets – 20 points
3. Programme objectives and tasks clearly identified – 20 points
4. Experience with successful delivery of similar programmes – 20 points

5. Alleviates transmission constraints in an area identified by the California Independent System Operator – 10 points

The evaluation and selection of the proposals follows the next steps:

1. Each proposal is evaluated using the primary and secondary sets of criteria;
2. The proposals are ranked in order of their performance values on the primary criteria, in order to create a short list with the highest ranking proposals;
3. The proposal on the short list are ranked using a combination of the primary and secondary criteria performance values;
4. A portfolio of programmes will be assembled from this smaller pool of proposals.

The portfolio must comply with the available funding by the utility territory and have a TRC ratio greater than one. The compiled portfolio of programmes must balance the following goals:

- Maximized energy savings;
- Strong cost-effectiveness;
- Equitable geographic distribution;
- Diversity of target markets;
- Equity by rate class;
- Equity between gas and electric programme offerings and energy savings;
- Diversity of programme offerings;
- Multiple languages offered to programme participants.

The portfolios are then submitted to the Commission's approval for funding. The measures that are considered for PGC funding are those that contribute to a permanent replacement of energy equipment for more efficient models or those that support information or education activities.

Annex C - Energy Efficiency Policy Manual – version 4

The version 4 of the EEPM was intended to be applied to all EE activities initiated in 2006 and beyond (CPUC, 2008). The Commission and the state policy expressed, as before, the intention of making energy efficiency the utilities highest priority procurement resource. Cost-effective energy efficiency alternatives should be the first “resource” to meet customers’ energy needs. The Commission’s main goal is to pursue all cost-effective energy efficiency opportunities over the long- and short-term. Then annual and cumulative savings goals are set for each utility service territory. Each Programme Administrator should develop a portfolio of programmes to meet or exceed these annual and cumulative savings targets. These portfolios should be managed in a way that the most cost-effective EE programmes are pursued first, while minimizing the lost opportunities. Lost opportunities are those EE alternatives that offer a long-lived, cost-effective savings, and if not exploited promptly or simultaneously with other alternatives, are lost irretrievably or become much more costly to achieve. When looking for the most cost-effective alternatives it may leave other cost-effective options behind and may lead to lost opportunities, which is called cream-skimming.

The primary indicator of the cost-effectiveness of the energy efficiency programme is the TRC, following the Commissions opinion that ratepayer-funded EE measures should focus in programmes that serve as resource alternatives to supply-side options. The TRC test measures the net resource benefits from the perspective of all ratepayers by combining the net benefits of the programme to participants and non-participants. The benefits are the NPV of the avoided costs of the supply-side resources avoided or deferred. The TRC test costs contain the NPV of the costs participants incur for the measure/equipment installed over the measure lifetime and the costs incurred by the programme administrator. A discount rate is used in the TRC computation that reflects the utilities’ weighted average cost of capital, as adopted by the Commission.

Besides the TRC, the Programme Administrator Cost (PAC) test of cost-effectiveness could also be considered in evaluating programme and portfolio cost-effectiveness. The programme benefits are the same for both the TRC and the PAC test, however, the costs included in the PAC test are the NPV of the costs incurred by the programme administrator (including financial incentives or rebates paid to participants), but not the cost incurred by the participating customer. Also a discount rate should be used when computing the PAC test, reflecting the utilities’ weighted cost of capital.

The application of both the TRC and the PAC tests is called “Dual-Test”. Very often, when an EE programme passes the TRC test, it also passes the PAC test. However, if the programme requires rebates or other financial incentives to participants, that exceeds the measure cost, than the programme may pass the TRC test, but fail the PAC test. The use of the Dual-Test ensures that no more money is spent in financial incentives than the necessary to achieve the TRC net benefits.

A threshold condition for the eligibility of the portfolio for ratepayer funds results from using the Dual-Test for the entire portfolio. In this cost-effectiveness test should be included the individual programmes, plus all costs not assignable to individual programmes, such as overhead, planning, evaluation, measurement verification and administrator compensation and performance, when applicable, the costs for shareholders incentives that are projected to be paid for the performance of the portfolio under the energy efficiency incentive in effect at the time. The evidence that this threshold requirement is met must be demonstrated in the application for funding.

Competition in energy efficiency procurement should focus on soliciting new program ideas to achieve or exceed the Commission's savings goals, rather than just allocating a specific percentage of program funding to particular implementers. The Programme Administrators will identify a minimum of 20% of the funding for the entire portfolio that will be put out to competitive bid to third-parties for the purpose of soliciting innovative ideas and proposals for improved portfolio performance. The participation of non-IOUs as designers and deliverers of programmes (rather than implement IOU-designed programs) should be made if there is an evaluation that the program designs and delivery mechanisms proposed by non-IOUs are superior to those currently being implemented or planned for the future, in achieving overall portfolio savings goals.

Annex D – Cost-effectiveness tests used in some US states

Brief description of the cost-effectiveness procedures used by some US states for screening EE/DSM programmes.

Arizona requires the use of the Societal test. The test considers costs and benefits associated with reliability, improved system operations, environmental impacts, and customer service. It also considers the savings for both natural gas and electricity and any uncertainty about future trends of costs or benefits (RAP, 2011a).

In Arkansas, all four tests are required to perform the screening of EE programs: the Participant test, the RIM test, the TRC test, and the PAC test. A cost-effective programme is defined as "one that has a high probability of providing aggregate ratepayer benefits to the majority of utility customers." Even without any preference between the tests being established, some utilities seem to have been interpreting as meaning that the TRC test has preference; utility programs being implemented have all had positive (>1.0) results under the TRC test (RAP, 2011d).

In Colorado, the COPUC established the use of a modified TRC test for the evaluation of DSM programmes cost-effectiveness. The modification resulted from the introduction of the valuation of the avoided emissions and non-energy benefits (Nowak et al., 2011; RAP, 2011a).

Also in Connecticut, electric distribution companies are required to procure cost-effective energy efficiency alternatives as their first-priority resource (Nowak etal., 2011). The 2010 Conservation and Load Management Plan of the electric and gas utilities used both the UTC test and the TRC test for screening DSM alternatives. The TRC test includes water benefits, emission benefits, avoided fossil fuel use, and other non-resource benefits such as reduced maintenance (RAP, 2011b).

In District of Columbia, the Sustainable Energy Utility (SEU) programs as a whole should meet the Societal test on an annual and contract-term basis, although no definition is done for this test (RAP, 2011c).

In Florida, the statute requires conservation programs to be cost-effective, and utilities must check the cost-effectiveness using the Participant test, the RIM test, and the TRC test. Traditionally the RIM test is the most heavily weighted. However, in the goal-setting process for electric utilities that occurred in 2009, the PSC established goals based on the Enhanced Total Resource Cost test (E-TRC). The E-TRC includes estimated costs of GHG emissions, as well as numeric adders associated to residential measures that have a two-year or less payback (RAP, 2011d) (FPSC, 2011).

In Georgia, the TRC and Societal Cost tests are eligible for use, but through 2004, all EE programs were required to pass the RIM test (RAP, 2011d).

Hawaii's IRP Framework, enacted in 1992, requires five tests to be used to evaluate EE programs, with greatest weight being given to the TRC Test. New regulations being prepared on the operation of the EE portfolio standards may change how EE programs are evaluated (RAP, 2011a).

In Idaho, in 2001, the PUC ordered Idaho Power to use the TRC test, Utility Cost test (now the PAC test), and Participant test in assessing the cost-effectiveness of its DSM programs. In 2009 the Commission recognized that the cost-effectiveness from the TRC perspective was an important criterion for assessing the appropriateness of utility DSM. However the Commission has not specifically defined the TRC or the other tests it requires. Avista Utilities' and Rocky Mountain Power's assessment of their DSM programs consistently include cost-effectiveness evaluations using all three tests (RAP, 2011a).

In Illinois, all EE measures must have a BCR greater than one over the lifetime of the measure according to the TRC test. Low-income programs do not have to meet the TRC test (RAP, 2011e).

In Indiana, in late 2009, the Commission ordered all utilities to establish core DSM programs. The TRC, the participant, the RIM, and the PAC tests are used to evaluate measures proposed in an IRP (RAP, 2011e; IAC, Not dated).

In Iowa, EE plans as a whole are required to be cost-effective, and require the use of the Societal test, RIM test, UC test (now PAC test), and Participant tests. As in Illinois, EE programs for low-income customers and other specific programs do not need to be cost-effective (RAP, 2011e).

In Kansas, utilities should submit five benefit-cost tests with their DSM or DR program applications and that emphasis would be placed by the Commission on the TRC and RIM tests (RAP, 2011e).

In Kentucky no specific test is required, although it is required for the utilities to perform tests on their proposals (RAP, 2011c).

Louisiana has not established a cost benefit test for program evaluation. However the City of New Orleans has moved forward with Entergy New Orleans utility to establish EE priorities and program implementation. The Entergy New Orleans uses the TRC test. Regulation, not yet in place, authorizes use of the range of California SPM tests, with TRC as the conclusive test (RAP, 2011d).

Maine uses a Modified Societal Test to evaluate EE programs. The test is required to include non-resource benefits, including environmental benefits to the extent such benefits can be reasonably quantified and valued. Under certain conditions a program can be implemented without satisfying the modified Societal Test (RAP, 2011b).

In Maryland, utilities are required to use the Societal, the PAC, the Participant, and the TRC tests, and the Commission will consider and weigh all of them (Order NO. 81637, 2007; RAP, 2011c).

In Massachusetts, in 2008, the Green Communities Act (GCA) required that gas and electric utilities to pursue all cost-effective energy efficiency (RAP, 2011b; Nowak et al., 2011). The TRC test is the only cost-effectiveness test used to evaluate EE programs. The TRC is performed at the program level, except with hard-to-measure efficiency programs, for which the TRC is computed at the sector level. The costs of complying with reasonably foreseeable environmental laws and regulations are included in the TRC, but environmental externalities are not (RAP, 2011b).

In Michigan, energy optimization plans must use the Utility System Resource Cost Test, analogous to the PAC test. The test is defined by regulation, and incorporates future carbon taxes into the benefits (RAP, 2011e; Nowak et al., 2011).

In Minnesota, since 2010, utilities have to save 1.5% of their retail sales. The first 1% has to be obtained directly from energy efficiency or conservation programmes. The Societal Test is the one predominantly used to measure the cost-effectiveness of the programmes, since it is considered by the Office of Energy Security to combine the impact on the utility, the participants in the programme, non-participants ratepayers, and the environmental benefits (Nowak et al., 2011; RAP, 2011e).

There were no requirements in Mississippi that specify the use of cost-effectiveness tests to the development and implementation of energy efficiency programs (RAP, 2011d).

Missouri requires the use of the TRC test to evaluate EE programs as part of its resource planning process. According to the Commission rules, the TRC compares the sum of avoided utility costs and avoided probable environmental compliance costs to the sum of all incremental costs of end-use measures that are implemented due to the program (RAP, 2011e).

In Montana, the cost-effectiveness of the resources considered in the IRP process is evaluated with the Societal test. This test is defined as consisting of all costs to the utility plus all external costs which are imposed on the global society; and attributes of the test may include, but may not be limited to: environmental externalities, efficiency of the resource, administrative costs, cost effectiveness in the context of the utility system, risk and uncertainty, reliability, and associated transmission costs (RAP, 2011a).

In Nebraska, EE measures are evaluated using four tests, with the TRC test being the one used to evaluate which measures to include in a portfolio (RAP, 2011e).

Nevada rules require that a utility should include a life-cycle analysis of the programs using the TRC test, in its DSM plan, which is part of the IRP. The TRC test determines the overall economic efficiency of a demand management program by measuring the net costs of the program based on its total costs, including, without limitation, the costs to both participants and the utility. The environmental costs of a DSM plan must be quantified for air emissions, water, and land use (RAP, 2011a).

The Commission required Public Service of New Hampshire to use the TRC test to determine the cost-effectiveness of EE programs since 2009. The Commission will not approve the addition of an environmental adder to the TRC test, but the utility must prepare a sensitivity analysis of the TRC using a higher-than-market value of carbon dioxide (RAP, 2011b).

In New Mexico, the TRC test is used to evaluate EE programs. (RAP, 2011a).

New York uses the TRC test. The incentive payments, or rebates, used to encourage customer adherence to the programmes, are not considered into the TRC test (RAP, 2011c).

In North Carolina, utilities are required to provide economic justification for each proposed EE or DSM measure or program. At a minimum, cost-effectiveness evaluations should include the TRC, the Participant test, the Utility Cost test (now the PAC test), and the RIM test (RAP, 2011d).

In North Dakota although no tests are required, utilities usually use a variety of tests, giving most weight to RIM (RAP, 2011e).

In Ohio, all electric utilities are required to implement EE programs, and use the TRC test to evaluate programs (RAP, 2011e).

Oklahoma requires regulated utilities to operate Demand Programs, which include EE as a resource. The cost-effectiveness of the program evaluated based on tests found in the California SPM, which includes the TRC. However, the results of the RIM test should include an estimate of the impact on average customer bills (OSS, 2010; RAP, 2011e).

The Energy Trust of Oregon (ETO) uses the Utility System test and the Societal test as the primary tests to evaluate EE programs. The economic comparison will be made using the BCR. Whenever there is available data, both tests must be computed and the programme must pass in both. The Societal test includes all costs and savings of program participants and others that were influenced by the programme. The Utility System test includes the costs incurred by the Energy Trust and the savings of participants and others influenced by the programmes (Energy Trust of Oregon, 2011; RAP, 2011a).

In Pennsylvania, the EE programmes must have a BCR above one, measured by the TRC test. The TRC test is considered a standard test that is met if, over the effective life of each plan not to exceed 15 years, the net present value of the avoided monetary cost of supplying electricity is greater than the net present value of the monetary cost of EE conservation measures (RAP, 2011c).

Rhode Island requires that utilities should use the TRC test to assess measures, programmes, and portfolios cost-effectiveness. The test must include the costs of CO_2 mitigation under RGGI and other factors proposed by the utility, including non-energy benefits for its Residential Low Income programs (RAP, 2011b).

In South Carolina, the definition of IRP requires that the plan should include a brief cost-benefit analysis, if available, for each option. The PSC does not currently require any particular test (RAP, 2011d).

In South Dakota, Commission places the most emphasis on TRC with some on the RIM test (RAP, 2011e).

In Tennessee, since 2010 the TRC, UC, and RIM tests are used to evaluate scenarios (RAP, 2011d).

In Texas the PAC test is used to evaluate the cost-effectiveness of an EE program. The programme is considered cost-effective if the costs (including incentives, M&V, R&D, and administrative costs) to the utility are lower than the benefits (including the value of the demand reductions and energy savings, measured in accordance with the avoided costs given in the rules) (RAP, 2011a).

In Utah, several tests are required for the evaluation of EE programs: TRC, Utility cost test, Participant test, and the RIM test (RAP, 2011a).

In Vermont, the cost-effectiveness of the programmes is measured through the Societal Test, and VEIC imposes a minimum of 1.2:1 factor of gross electric benefits to invest. Since the Efficiency Vermont has flexibility to change the programmes in order to achieve their goals, and they are allowed to invest in measures which give them most long-term savings for each dollar invested (Nowak et al., & Witte, 2011).

In Virginia, the cost-benefit ratio of any proposed program is analysed separately using, at a minimum, the Participants test, the Utility Cost test, the RIM test, and the TRC test. Approval may be sought for programs individually or as a package. Since 2009 all tests will still be considered but higher weight will be given to the RIM test, followed by the TRC test. (RAP, 2011c).

Washington requires the use of a modified TRC to evaluate EE programs, in order to include quantifiable non-energy benefits, a risk adder, and a 10% conservation benefit adder that increases the avoided costs by 10% (RAP, 2011a).

In Wisconsin, the Commission defined a modified TRC and expanded TRC. A modified TRC is used to determine the effectiveness of EE measures and portfolios of programs. The modified TRC includes additional benefits due to costs avoided as a result of the programs, including the value of avoided emissions for which active offset markets currently exist (SOx, NOx, and CO_2). An Expanded Net Economic Test is used at the portfolio level. The costs included in the Expanded test are the same as the modified TRC test, but also include non-economic externalities, such as mercury, and economic non-energy benefits and costs, such as water savings and improved productivity. Recently, regulation was issued that embraced the uses of the modified and expanded cost tests, and additionally required that programmes must pass the PAC test (RAP, 2011e).

In Wyoming, the Commission has previously accepted all of the standard tests, including TRC, without any specific test requirement (RAP, 2011a).

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