European Commission

JRC SCIENCE AND POLICY REPORT

A Smart Grid for the city of Rome: a Cost Benefit Analysis

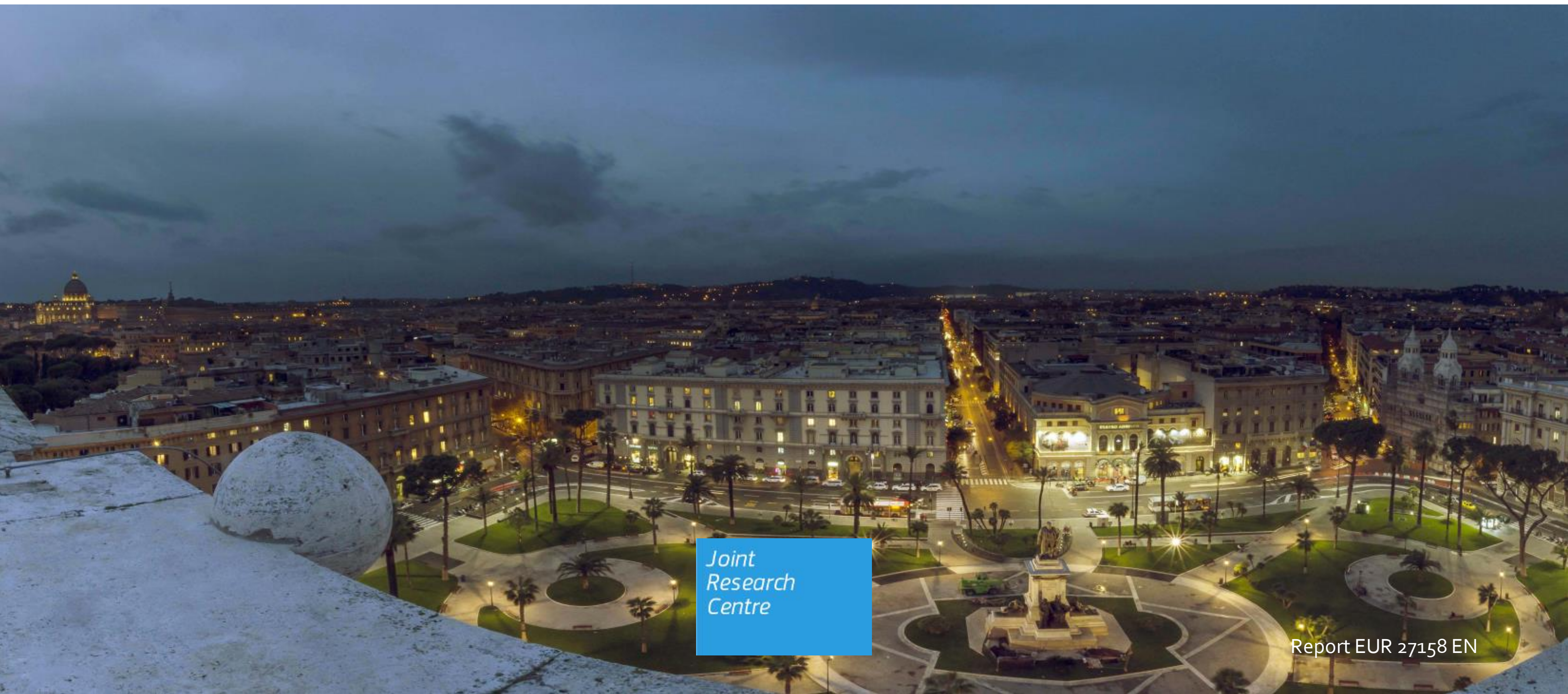
Costs and benefits of Smart Grid pilot installations and scalability options

Silvia Vitiello, Gianluca Flego, Alessandro Setti, Gianluca Fulli (JRC)

Stefano Liotta, Silvio Alessandroni, Luana Esposito (ACEA)

Davide Parisse (external consultant)

2015



Joint Research Centre

Report EUR 27158 EN

European Commission
Joint Research Centre
Institute for Energy and Transport

Contact information
Gianluca Fulli
Address: Joint Research Centre, P.O. Box 2, NL-1755 ZG Petten, The Netherlands
E-mail: gianluca.fulli@ec.europa.eu
Tel.: +31 (0)224 565656

JRC Science Hub
https://ec.europa.eu/jrc

Legal Notice
This publication is a Science and Policy Report by the Joint Research Centre, the European Commission's in-house science service. It aims to provide evidence-based scientific support to the European policy-making process. The scientific output expressed does not imply a policy position of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use which might be made of this publication.

All images © European Union 2015, except: cover photo and images (ACEA SpA)

JRC95273

EUR 27158 EN

ISBN 978-92-79-46858-2 (PDF)
ISBN 978-92-79-46857-5 (print)

ISSN 1831-9424 (online)
ISSN 1018-5593 (print)

doi:10.2790/50100 (online)

Luxembourg: Publications Office of the European Union, 2015

© European Union, 2015

Reproduction is authorised provided the source is acknowledged.

Abstract

In this work, the JRC applies its Smart Grid CBA methodology to a full-scale project rather than only to a small-size demonstrative one. To this end, the JRC and ACEA - one of Italy's biggest Distribution System Operators (DSOs), in charge of managing the distribution system of Rome - teamed up to study the merits of deploying Smart Grid technologies (preliminarily tested in a pilot project) in a big city like the Italian capital, hosting several million electricity users.
The ACEA Smart Grid Pilot Project (named "Malagrotta" after the area where pilot solutions were first realised) is the starting point for this study, as it displays many of the characteristics of emerging Smart Grids projects and interconnects several diversified generation facilities (like biogas, waste-to-electricity and PV plants) and consumption centres.
This study illustrates the outcome of the application of the JRC Cost Benefit Analysis (CBA) to a) the ACEA Smart Grids pilot project; and b) the planned deployment of Smart Grid technologies (tested in the ACEA Smart Grids pilot project) to the whole of the city of Rome. The CBA is conducted from both the private investor's and the societal perspective, in order to assess whether scaling up the Smart Grid pilot project benefits the distribution operator and the citizens.
Finally, this report shows how the JRC's CBA methodology can be effectively used to assess the financial and economic viability of real Smart Grids projects and help the investment decisions of DSOs.

TABLE OF CONTENTS

EXECUTIVE SUMMARY - ITALIAN

La Smart Grid, la nuova generazione di reti elettriche intelligenti, rappresenta un imprescindibile ingrediente per lo sviluppo della futura rete elettrica e promette di cambiare drasticamente la maniera in cui l'energia elettrica viene generata, scambiata e commercializzata. La questione aperta riguarda come questi cambiamenti possano aiutare gli Stati Membri dell'Unione Europea (EU) nel raggiungere gli ambiziosi traguardi definiti nelle politiche energetiche UE in termini di sicurezza di approvvigionamento, sostenibilità e competitività.

Di fatto, gli investimenti in progetti pilota Smart Grid sono molto aumentati negli ultimi dieci anni, superando i €3 miliardi solo in Europa. Tuttavia, alcune questioni fondamentali restano irrisolte: vale la pena di investire in Smart Grids? C'è un business case per sviluppare in città più ampie, o in intere regioni, le soluzioni Smart Grid testate a livello locale? In che misura i cittadini beneficerebbero di tale innovazione?

Coerentemente con la propria missione di sostegno scientifico per le decisioni politiche, il JRC ha sviluppato una serie di strumenti e metodologie per osservare, simulare e valutare gli sviluppi delle Smart Grid. In particolare, dato il loro potenziale economico e i notevoli investimenti necessari, il JRC ha prodotto la prima metodologia europea per l'analisi costi-benefici (CBA) di Smart Grid. L'obiettivo più ampio della metodologia è quello di coprire anche gli impatti socio-economici dei progetti di Smart Grid, quindi non limitando l'analisi ai soli costi e benefici relativi all'attore direttamente responsabile del progetto Smart Grid.

In questo lavoro, per la prima volta, il JRC verifica e applica la sua metodologia CBA per Smart Grid a un progetto su larga scala, piuttosto che solamente a uno dimostrativo su dimensioni ridotte. A tal fine, il JRC e ACEA - uno dei più grandi operatori della rete di distribuzione in Italia (distribution system operator - DSO), responsabile della gestione del sistema di distribuzione di Roma - hanno unito le forze per studiare gli impatti di tecnologie Smart Grid (preliminarmente testate in un progetto pilota) in una grande città come la capitale italiana che ospita oltre un milione di utenti di energia elettrica.

Il progetto pilota Smart Grid di ACEA (denominato "Malagrotta", come la zona in cui le soluzioni pilota sono state realizzate) è il punto di partenza di questo studio; esso, infatti, mostra molte delle caratteristiche dei progetti Smart Grid emergenti e potrebbe essere replicato su una notevole porzione della rete di distribuzione di Roma, interconnettendo diverse strutture di generazione (come impianti a biogas, termovalorizzatori e impianti fotovoltaici) e centri di consumo.

Il progetto Smart Grid di ACEA esamina nuove soluzioni di automazione, monitoraggio e telecontrollo in diversi segmenti e a vari livelli di tensione della rete di distribuzione. Più in dettaglio, il progetto si articola in tre sottoprogetti:

a. Automazione della rete a Media tensione;
b. Monitoraggio e Telecontrollo della rete in Media e Bassa tensione;
c. Nuovi criteri di gestione della rete.

L'estensione del progetto all'intera città di Roma comporterebbe, tra l'altro, l'ampliamento dell'area di impatto dalle due cabine primarie ad Alta/Media tensione (AT/MT) testate nel progetto pilota, al totale di 70 cabine primarie AT / MT gestite da ACEA nella città di Roma.

Questo studio illustra il risultato dell'applicazione dell'analisi costi-benefici (CBA) secondo la metodologia JRC:

- al progetto pilota Smart Grid realizzato da ACEA a Malagrotta;
- alla prevista installazione di tecnologie Smart Grid (testate nel progetto pilota ACEA Smart Grid) in tutta la città di Roma.

La CBA è condotta sia dal punto di vista dell'investitore privato, sia da quello sociale al fine di valutare se un'eventuale estensione dell'investimento in Smart Grid comporterebbe importanti benefici per il complesso della cittadinanza.

I valori dei parametri scelti per la monetizzazione di costi e benefici - che si estende da tassi di sconto finanziari e sociali fino ai prezzi della CO_2 - sono spiegati e argomentati nel dettaglio. Insieme ai benefici finanziari relativi a miglioramenti nelle prestazioni in termini di gestione della rete elettrica nel progetto (come retribuite dal Regolatore), la CBA dell'investitore privato comprende anche la remunerazione degli investimenti in conto capitale (CAPEX) alle tariffe stabilite dal Regolatore italiano. Questa remunerazione, tipica delle imprese regolate nell'Unione Europea e in molti altri Paesi, ha lo scopo di incentivare il DSO ad investire nel miglioramento dell'infrastruttura che gestisce, ad esempio implementando reti intelligenti, condividendo parte del valore monetario del benessere dei consumatori che ne deriva. Potendo venire interpretata come una (pur parziale) misura monetaria di tale benessere, la remunerazione degli investimenti definita dall'autorità di regolazione competente è impiegata come fattore anche nella CBA societaria.

Sulla base della precedente serie di ipotesi, lo studio procede nel presentare i risultati della CBA per investitori privati in termini di valore attuale netto (NPV) e tassi di rendimento interni (IRR) per il progetto Smart Grid Malagrotta e per il progetto esteso alla città di Roma. I risultati sono riportati qui di seguito:

CBA Investitore privato ***Progetto Smart Grid***	**MALAGROTTA** ***(Pilot)***	**ROMA** ***(Scale-up)***
NPV (Valore attuale netto anno 2014)	-K€ 1,262	K€ 35,972
IRR (Tasso di rendimento interno)	1.23%	16.60%

Tabella 1 Risultati della CBA per investitori privati per il progetto Malagrotta e la sua estensione a Roma (valori in K€, anno base 2014)

I risultati della CBA societaria, invece, sono presentati nella seguente tabella:

CBA Societaria ***Progetto Smart Grid***	**MALAGROTTA** ***(Pilot)***	**ROMA** ***(Scale-up)***
NPV (Valore attuale netto anno 2014)	-K€ 1,104	K€ 39,119
IRR (Tasso di rendimento interno)	1.25%	16.67%

Tabella 2 Risultati della CBA societaria per il progetto Malagrotta e la sua estensione a Roma (valori in K€, anno base 2014)

Come si può vedere, sia nella CBA per investitori privati che nella CBA sociale i risultati di base per l'intera rete di distribuzione di Roma sono positivi, mentre il progetto di Malagrotta deve affrontare le tipiche problematiche di un progetto pilota (inclusi costi irrecuperabili e rischi di innovazione) che porta a perdite di entità moderata (mantenendo comunque gli IRR positivi, seppur inferiori ai tassi di sconto). Come previsto, l'NPV e l'IRR nell'analisi sociale sono più elevati per tutti i progetti, poiché tengono in considerazione anche i benefici derivanti dal progetto all'intera cittadinanza. Ciò è dovuto alla riduzione dei valori di tasso di sconto (il tasso di sconto sociale è inferiore a quello di un investitore privato), oltre che all'introduzione di esternalità monetizzate (emissioni di CO_2 evitate).

Una completa analisi di sensibilità viene effettuata al fine di testare la robustezza dei risultati per variazioni (in particolar modo avverse) degli elementi di condizionamento. In tutta l'analisi, al variare dei parametri associati alle variabili i valori di NPV si mantengono positivi per l'estensione del progetto all'intera rete di Roma; questo vale anche per tassi d'incremento annuale piuttosto drastici dei costi CAPEX e OPEX (rispettivamente 16% e 6%), volti a simulare gli effetti di un'eventuale brusca crescita dell'inflazione importata (che potrebbe concentrare i propri effetti sull'investimento in macchinari).

Nel complesso, considerata la gamma di variazione dei parametri utilizzati per questa CBA, le prospettive per l'ammodernamento della rete elettrica di Roma tramite il progetto Smart Grids di ACEA possono dunque essere considerate molto positive.

Chiaramente, con il proseguimento della sperimentazione di Smart Grid su porzioni della rete di distribuzione di Roma (ad esempio testando l'impatto di specifiche tecnologie di stoccaggio e dei veicoli elettrici), l'analisi proposta deve essere aggiornata di conseguenza per individuare ulteriori beneficiari e nuovi vantaggi nell'impiego delle soluzioni Smart Grid.

Inoltre, vale la pena notare come i consumatori finali attivi sono ritenuti un elemento centrale per l'ampliamento in larga scala delle reti intelligenti. Questo riporta al fatto che l'impatto di ciascun progetto Smart Grid può andare oltre quanto percepito in termini monetari; per ottenere quindi un quadro più completo delle problematiche legate alla scalabilità delle Smart Grid, la CBA economico-finanziaria dovrebbe essere integrata con studi mirati sul ruolo del consumatore finale e valutazioni non monetarie sugli impatti e sulle esternalità non quantificabili (ad esempio l'impatto sociale e sulla salute, o il contributo agli obiettivi di policy).

In conclusione, il JRC continuerà a monitorare lo stato di avanzamento di questo e di altri progetti, lavorando con le parti interessate alle Smart Grid per far luce sulle possibilità e le modalità per cui le reti intelligenti rappresentino un'attività redditizia per gli investitori e benefica per la società nel suo complesso.

EXECUTIVE SUMMARY - ENGLISH

The Smart Grid, the upcoming generation of intelligent electricity networks, promises to drastically change the way power is produced, exchanged and traded. The open question is how these changes in the electricity networks can help the European Union (EU)'s Member States in achieving the ambitious security of supply, sustainability and competitiveness targets defined in the EU energy policies.

Indeed, Smart Grid investment in pilot projects has been booming over the last decade, exceeding €3 billion in Europe alone. However, key questions remain to be answered: is investing in Smart Grids worth the cost? Is there a business case for scaling up locally tested Smart Grid solutions to wider cities or regions? To what extent can citizens benefit from such innovation?

Consistent with its mission of providing science-based support to policy makers, the JRC has developed a series of tools and methodologies to observe, simulate and assess Smart Grid developments. Particularly, given the economic potential of the Smart Grid and the substantial investments required, the JRC produced the first EU Cost-Benefit Analysis (CBA) methodology for Smart Grids. The wider aim of the methodology is to cover socio-economic impacts of Smart Grid projects, thus not limiting the analysis to costs and benefits incurred by the actor(s) implementing the Smart Grid project.

In this work, for the first time, the JRC tests and applies its Smart Grid CBA methodology to a full-scale project rather than only to a small-size demonstrative one. To this end, the JRC and ACEA - one of Italy's biggest Distribution System Operators (DSOs), in charge of managing the distribution system of Rome - teamed up to study the merits of deploying Smart Grid technologies (preliminarily tested in a pilot project) in a big city like the Italian capital, hosting more than a million electricity users.

The ACEA Smart Grid Pilot Project (named "Malagrotta" after the area where pilot solutions were first realised) is the starting point for this study, as it displays many of the characteristics of emerging Smart Grids projects and interconnects diversified generation facilities (like biogas, waste-to-electricity and PV plants) and consumption centres.

The ACEA Smart Grid Project tests novel automation, monitoring and remote control solutions on different sections and voltage levels of the distribution grid. More in detail, the project is articulated into three sub-projects:

a. Automation,
b. Medium Voltage/Low voltage Monitoring and Remote Control, and
c. New Network Management Criteria.

Scaling the project up to the city of Rome would entail, among others, expanding the impact area from the two High Voltage/Medium Voltage (HV/MV) primary substations covered by the pilot project to the whole set of 70 HV/MV primary substations operated by ACEA in the city of Rome.

This study illustrates the outcome of the application of the JRC Cost Benefit Analysis (CBA) to:

- the Smart Grids pilot project realised by ACEA in Malagrotta area;
- the planned deployment of Smart Grid technologies (tested in the ACEA Smart Grids pilot project) to the whole of the city of Rome.

The CBA is conducted from both the private investor's and the societal perspective to assess whether the Smart Grid investment might be scaled up to benefit the distribution operator and the citizens.

The parameter values chosen for cost and benefit monetisation - spanning from the financial/societal discount rates to the CO_2 price - are explained and supported in detail. Along with standard financial benefits due to project-related performance improvements in managing the grid (as remunerated by the Regulator), the private-investor CBA also includes the return on the Regulated Asset Base (RAB) of infrastructure (CAPEX) investments at the rates established by the Italian Regulator. Such remuneration, typical of regulated companies across the EU and many other Countries, aims to incentivise DSOs by allowing them to capture part of the monetary value of the consumers' welfare gains deriving from targeted innovative investments such as Smart Grids. Since they can be interpreted as an - albeit partial - monetary measure of such gains, such regulated returns are also employed to factor those gains into the Societal CBA.

Based on the previous set of assumptions, the study proceeds to present the Private-investor CBA results regarding the Net Present Values (NPV) and Internal Rates of Return (IRR) for the Malagrotta Smart Grid Project and the Rome Smart Grid upscale. These are reported below in Table 1:

Private investor CBA ***Smart Grid project***	**MALAGROTTA** ***(Pilot)***	**ROMA** ***(Scale-up)***
NPV (Net Present Value year 2014)	-K€ 1,262	K€ 35,972
IRR (Internal Rate of Return)	1.23%	16.60%

Table 1: Outcomes of the Private investor CBA for the Malagrotta project and its extension to Rome (values in K€, base year 2014)

The Societal CBA results, instead, are shown in the following Table 2:

Societal CBA ***Smart Grid project***	**MALAGROTTA** ***(Pilot)***	**ROMA** ***(Scale-up)***
NPV (Net Present Value year 2014)	-K€ 1,104	K€ 39,119
IRR (Internal Rate of Return)	1.25%	16.67%

Table 2: Outcomes of the Societal CBA for the Malagrotta project and its extension to Rome (values in K€, base year 2014)

As shown, in both Private-investor and Societal CBAs the baseline results for the whole of Rome's grid are positive, whereas the Malagrotta project faces the typical challenges of a pilot project (including sunk costs and innovation risks) leading to generating losses of moderate size (so that IRRs, though lower than the discount rates, are positive). As expected, Societal NPVs and IRRs are higher for all projects, as they take into account also the benefits accruing to the society at large. This is due to lower discount rate values (social discount rates are typically lower than those of a private investor) and to the introduction of monetised externalities (avoided CO_2 emissions).

A comprehensive sensitivity analysis is carried out in order to put to test the robustness of the results to variations (especially adverse) in the conditioning factors. For the entire range of variation of the parameter values considered, NPV figures for the whole of Rome's grid retain their positive sign; this holds as well for rather aggressive annual increase rates of CAPEX and OPEX costs (16% and 6% respectively), meant to simulate the effects of a sharp rise in imported inflation (which may concentrate its effects on machinery investment).

Therefore, considering the variation ranges of the parameters used for this CBA, the overall outlook for ACEA's Smart Grids modernisation project of Rome's electricity network may be deemed very positive.

Clearly, as the Smart Grid experimentation on portions of the distribution grid of Rome continues (e.g. by testing the impact of selected storage and Electric Vehicle technologies) the proposed analysis shall be updated accordingly to identify additional beneficiaries and merits of the Smart Grid solutions deployment.

Additionally, it is worth noting how active end-consumers are expected to be central for the large-scale roll-out of Smart Grids. This reminds one of the fact that the impact of each Smart Grid project can go beyond what can be captured in monetary terms; therefore, in order to obtain a more complete picture of the Smart Grid scalability challenges, the financial/economic CBA should be complemented with targeted studies on the end-consumer role and non-monetary appraisals of non-quantifiable impacts and externalities (e.g. social/health impacts, contribution to policy goals).

In conclusion, the JRC will continue monitoring the progress of this and other projects by working with relevant Smart Grid stakeholders in order to shed light on whether and how Smart Grids present a viable business case for investors and society as a whole.

ACRONYMS

ACEA	Azienda Comunale Elettricità e Acque (electricity Distribution System Operator of Rome)
AEEGSI	Autorità per l'Energia Elettrica, il Gas e i Servizi Idrici
CAPEX	Capital Expenditures
CBA	Cost Benefit Analysis
DG	Distributed Generation
DSO	Distribution System Operator
EC	European Commission
ETS	Emission Trading System
FDR	Financial Discount Rate
GHG	Green-House Gases
HV	High Voltage
IRR	Internal Rate of Return
JRC	European Commission – Directorate General Joint Research Centre
KPI	Key Performance Indicator
LV	Low Voltage
MV	Medium Voltage
NPV	Net Present Value
OPEX	Operating Expenditures
RAB	Regulated Asset Base
SDR	Social Discount Rate

ACKNOWLEDGMENTS

We would like to sincerely thank Catalin Felix Covrig (JRC-IET) and Andrea Rodriguez Calvo (IIT, Universidad Pontificia de Comillas) for their valuable and enthusiastic contribution to the finalisation of this report, with useful insights and suggestions during its review.

1. Introduction

The JRC started investigating what Smart Grids can deliver in the current European landscape by creating the first European Smart Grids projects inventory. This annual outlook, today at its 4^{th} edition, not only features the type of Smart Grid application tested, but also includes data on investments and funding for each project, and indicates that cumulated investment amounts to €3.19 billion from 2002 until today (JRC, 2014).

Is investing in Smart Grids worth the cost? They are often considered as solutions still in a testing phase that will come to commercial maturity only at a future time. Consistent with its mission of providing science-based support to policy makers, the JRC wanted to shed light on whether Smart Grids represent a viable business already today.

Given the economic potential of the Smart Grid and the substantial investments required, there is a need for a methodological approach to estimate the costs and benefits of Smart Grids, based as much as possible on data from Smart Grid pilot projects.

The JRC developed a series of tools to assess Smart Grids projects, starting from the first EU Cost-Benefit Analysis methodology (JRC, 2012). However, a detailed and fact-based evaluation must rely on real solutions tested in existing distribution grids.

The challenge of a formal assessment framework for Smart Grid projects is linked to three main reasons (Jackson, 2011):

- Smart Grid projects are typically characterised by high initial costs and benefit streams that are uncertain and often long-term in nature. In fact, many Smart Grid benefits are systemic in nature, i.e. they only come into play once the entire smart electricity system is in place and new market players have successfully assumed their roles.

- Smart Grid assets provide different types of functions to enable Smart Grid benefits. A variety of technologies, software programmes and operational practices can all contribute to achieving a single Smart Grid benefit, while some elements can provide benefits for more than one Smart Grid objective in ways that often impact each other.

- The active role of customers is essential for capturing the benefits of many Smart Grid solutions. Especially at this early stage of the Smart Grid development, consumers' participation and response are still uncertain and relevant behavioural information (e.g. load profiles) is often not (yet) accessible to utility companies.

The JRC and ACEA - one of Italy’s biggest DSOs, in charge of managing the MV/LV grid of Rome - teamed up to consolidate the evaluation of Smart Grids solutions as a viable investment for distribution operators. ACEA and the JRC signed a specific Letter of Intents on this topic back in 2012, and have since worked together to study the opportunity to scale up a Smart Grid from a pilot project to the dimension of a big city like Rome, with more than four million inhabitants.

ACEA was selected as the perfect case study for many concurrent reasons: the "Malagrotta" project, named after the area where the pilot solutions were first realised, features many of the characteristics of innovative and comprehensive Smart Grids projects: it entails automation, monitoring, and remote control of the different sections and different voltage levels of the distribution grid, adding also more innovative features like storage and electric vehicles. The project has been realised on a grid linking several generation facilities, like biogas, waste and PV plants, and supplying refineries and other important consumption centres.

The project is at the same time innovative and of considerable dimensions, and has been selected by the National Regulatory Authority of Italy (AEEGSI) as one of the eight Smart Grids projects benefiting from a premium remuneration of the capital invested, thanks to specific characteristics of potential benefits and scalability[1].

1.1. Goals of the report

The goals of this report are:

- to confirm the robustness of the JRC cost benefit analysis methodology for a concrete evaluation of financial and economic impacts of Smart Grid projects, and to illustrate its application on ACEA's Malagrotta Smart Grid project;
- to apply the methodology for the first time to an entire MV/LV distribution grid, providing recommendations for the evaluation of Smart Grid scalability options, through the assessment of the expected expansion of the Smart Grids solutions (tested in Malagrotta project) to the distribution grid serving the whole city of Rome.
- to provide evidence on how ACEA's Smart Grids investment decisions included into the 2014-2018 business plan can maximise benefits, when scalability to the city level is implemented.

1.2. European overview of Smart Grid projects

A smart electricity grid opens the door to new applications with far-reaching impacts: providing the capacity to safely integrate more renewable energy sources (RES), electric vehicles and distributed generators into the network; delivering power more efficiently and reliably through demand response and comprehensive control and monitoring capabilities; using automatic grid reconfiguration to prevent or restore

[1] AEEGSI (2011).

outages (self-healing capabilities); enabling consumers to have greater control over their electricity consumption and to actively participate in the electricity market.

All these capabilities are being tested in Smart Grid pilot projects around the world, shedding light on how to move forward in the transition towards the electricity system of the future. A significant number of such projects are situated within the EU, making the EU probably the world's most active area for Smart Grid testing and development.

Spread across the 28 EU member countries, at the moment there are in Europe 459 different projects, divided between R&D and Demo & Deployment. About 63% of these projects are only developed in a single country, certifying the importance of individual players in the phase of testing and development of new solutions for the generation and distribution of electrical energy.

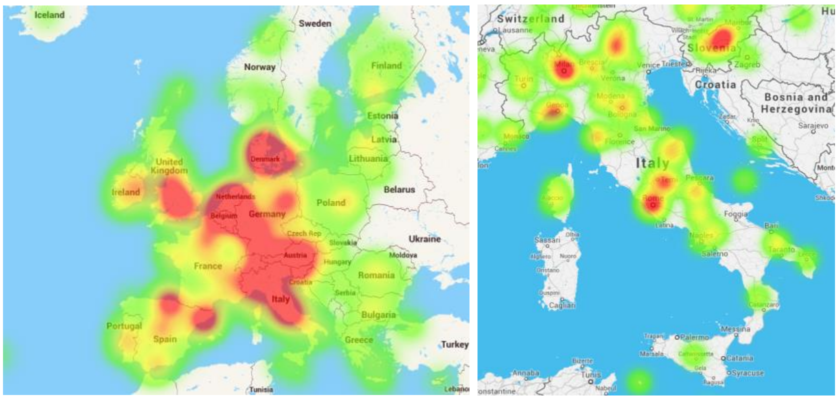


Figure 1: Overview of Smart Grid sites in Europe and Italy

Cities such as Paris (FR), London (UK) and Rome (IT) show a high concentration of projects and investments in Smart Grids, with total allocated resources that overcome €100 million. Investments mainly focus on applications like the integration of distributed generation into the grid, as well as the integration of large scale RES, and smart network management, with the goal of improving the observability and controllability of the network through substation automation, grid monitoring and remote grid control.

Within this vivid EU-wide urban development of advanced solutions for electricity networks, ACEA started in 2011 a Smart Grid pilot project in Malagrotta, Rome, focusing on distribution and automation of the MV/LV network. The aim is to quantify the benefits of the operated improvements to the grid, and to eventually extend the project to the entire area of Rome. The main areas of intervention, as well as the issues connected to the project, are described in the following chapters.

1.3. Description of the Malagrotta project

The goal of ACEA's pilot project is to set up a prototype of real Smart Grid which may be replicated over the whole of Rome's electricity network, in order to accommodate a prospectively increasing flow of Distributed Generation (DG) injected into the system, while keeping stable or even improving the quality of distribution service. DG is known to raise a number of issues to be addressed for electricity grids, such as:

- Capacity of cables, conductors and equipment;
- Short circuit power levels of the grid;
- Slow or rapid voltage variations;
- Variations of other voltage quality parameter (harmonics, symmetry);
- Reverse power flow at HV/MV transformers or at single MV lines;
- Unwanted islanding.

However, some advantageous opportunities may arise from DG, including:

- Voltage stability improvement at some nodes;
- Reduction of energy losses in the lines;
- Improvement of continuity of supply;
- Postponement of grid development or substitution interventions.

Such features pose new challenges to grid management, which need to be met through improvements in remote monitoring, diagnostics and automation.

ACEA's Malagrotta pilot project started in January 2011, with the involvement of local and international electricity suppliers. The planned installation activities have been concluded in December 2013, while monitoring and data gathering of the entire project went on until December 2014. The installations involve an electricity grid already operational in the Malagrotta-Ponte Galeria area, which includes two primary substations (Raffinerie and Ponte Galeria), 76 secondary substations, 69.5 km in MV, four electricity generation plants, six users connected to the MV grid and 1,200 consumers to the LV grid.

Figure 2: High Voltage switch and High Voltage disconnector at the primary substation Raffinerie

The project addresses three main areas of intervention, or sub-projects:

1) Advanced MV-grid automation;
2) Monitoring and Remote Control of MV/LV grid;
3) New management criteria of MV grid.

It is very important to note that the three sub-projects are additive, therefore it would not make sense to realise e.g. sub-project 2 without having realised sub-project 1: they represent 3 subsequent phases of a unique project, which has been divided into three chunks in order to evaluate more carefully each one's contribution in recovering the initial investment. Realising e.g. sub-project 2 without having realised sub-project 1 would not make sense for ACEA, as many benefits stemming from this project (as for most Smart Grids projects, as previously mentioned) can be reaped only if the complete Smart Grid system is set up.

The sub-projects on Automation (1) and Monitoring (2) represent the development of innovative solutions at the peripheral level. Specifically, the advanced automation of the grid has entailed the creation of three alternative solutions for the automatic identification of the grid segment where a failure takes place: SLP (S*electtività Logica Palindroma*, "palindromic logical selectivity"), chronometric selectivity, and fast FRG (*Funzione Rivelatore di Guasto*, "fault detection function")[2].

The first involves the installation of distributed intelligence on the nodes, and their mutual connection through a low latency radio signal (HiperLAN), in order to obtain the selection of the failed segment in an interval of hundreds of milliseconds.

The other two, instead, involve the installation of distributed intelligence on autonomously operating nodes, with a longer overall response time (in the order of seconds). This approach, however, is easier to replicate on a larger scale, and operatively more stable.

Figure 3: Medium voltage switchgear installed at ACEA's test field, with instruments for the selection of MV lines failed segments

[2] More details on the technical aspects of the project may be found in ACEA (2013) (in Italian).

The sub-project on Monitoring of MV and LV grids has prompted the development and the installation of a solution for real-time measurement of electric and environmental variables directly at the secondary substation, and for their transmission to the central information system, both through the public network (GSM/GPRS) and a through dedicated private line (TETRA).

A solution for the remote control of LV grid switches was also developed considering two approaches: one involved the substitution of the existing switch, while the other only required its upgrade (it is worth remarking that the distribution grid of Rome includes more than 60,000 LV switches).

After the completion of the project, all this equipment allows to continuously monitor and remote-control the LV grid. So far, this has only been done through on-site interventions prompted by direct customer request.

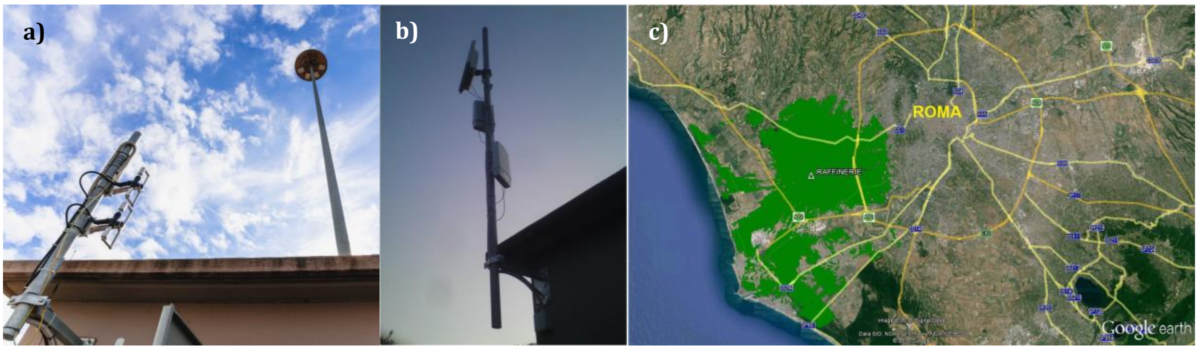


Figure 4: a) HiperLAN and Tetra equipment installed on a secondary substation of the pilot project; b) detail of the HiperLAN antenna; c) TETRA coverage of the project area

The sub-project on New Management Criteria for MV grids (3) represents a first step towards the development of a stronger central information system, with several more control options than the existing one. The project implied the development of an algorithm, resident in the SCADA system of ACEA, which models the electric state of the entire grid through data coming from the MV grid nodes and establishes the optimal set points to be sent to on-site operative equipment (devices for voltage variation on MV lines, distributed generators on MV). Electricity losses can thus be minimised, while respecting the predefined conditions on voltage profiles.

The Smart Grid project has resulted on the development of innovative solutions at the peripheral grid level (Advanced automation of MV grid and Monitoring and Remote Control of LV grid), which are replicable on a large scale for the entire grid owned by ACEA.

2. Cost Benefit Analyses for a SG in the city of Rome: methods and results

2.1. The JRC CBA methodology for Smart Grids projects

The aim of the CBA methodology described in the Guidelines (JRC 2012) was to define a way to include also socio-economic impacts of Smart Grid projects into the evaluation, thus not limiting the analysis to financial costs and benefits incurred by the actor(s) implementing the Smart Grid project. The JRC therefore aims to analyse projects from a societal perspective, considering each project's impact on the entire value chain and on society at large.

The proposed approach also recognises that the impact of each Smart Grid project goes beyond what can be captured in monetary terms, and therefore the CBA economic analysis (monetary appraisal of costs and benefits on behalf of society) may be complemented with qualitative impact analyses (non-monetary appraisal of non-quantifiable impacts and externalities, e.g. social impacts, contribution to policy goals) and Key Performance Indicators (KPIs), capturing only the specific technical aspects affected by the implementation of the selected Smart Grid project.

The economic analysis takes into account all costs and benefits that can be expressed in monetary terms, considering a societal perspective. In other words, the analysis tries to include all costs and benefits that spill over from the Smart Grid project into the electricity system at large (e.g. enabling the future integration of distributed energy resources, impact on electricity prices and tariffs, etc.) and into society at large (e.g. environmental costs).

The JRC's approach to CBA comprises three main parts:

a. Defining the *boundary conditions*, i.e. the parameters defining the context underlying the realisation of the project (e.g. demand growth forecast, discount rate, local grid characteristics) and the *implementation choices* (e.g. roll-out time, chosen functionalities);

b. Identifying costs and benefits accruing from the project over the chosen time lapse, discounting them and summing them up to obtain an _NPV_;
c. Performing a _sensitivity analysis_ to test the robustness of the CBA outcome, when subject to variations in the key variables/parameters set in step a.

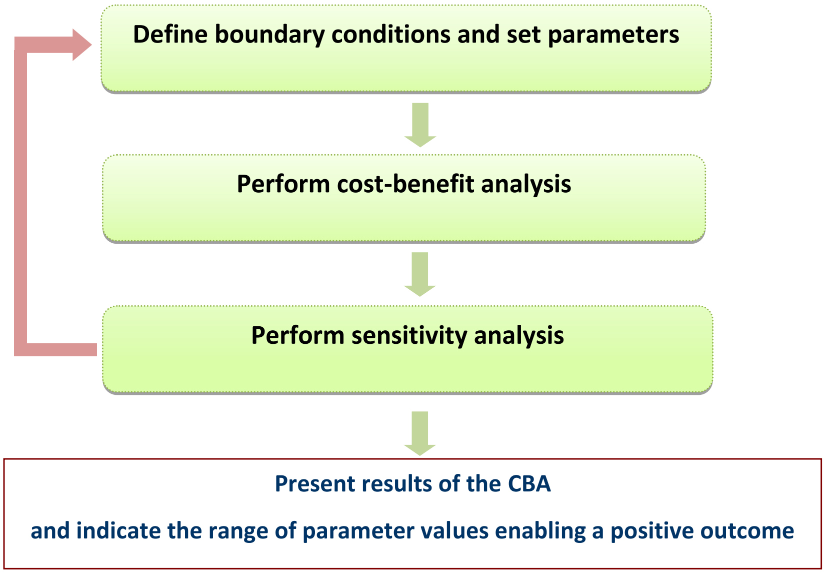


Figure 5: Cost-benefit analysis framework

The methodology (JRC, 2012) also provides guidance on the identification of those externalities and social impacts that can result from the implementation of Smart Grid projects but cannot be easily monetised and factored into the cost-benefit computation.

As mentioned, the economic appraisal needs to be integrated with both a qualitative impact analysis to assess externalities that are not quantifiable in monetary terms and Key Performance Indicators to include technical impacts that would be otherwise difficult to monetise. These include the costs and the benefits derived from broader social impacts like security of supply, consumer participation and improvements in market functioning.

Analysing the Malagrotta project and its scalability options to the broader Rome-wide network, the main monetised societal impacts are related to improvement in terms of avoided CO_2 emissions thanks to a more efficient integration of RES into the distribution grid.

Of course, many other positive impacts can be recognised for the society as a whole, such as improvements in health conditions of Rome's citizens, or environmental benefits deriving from the deployment of electric vehicles, among others. However, in this analysis such benefits are only discussed at a qualitative level, while the monetisation of impacts relies on clearly quantifiable items, such as the market price of CO_2 emissions in the European Trading System (ETS).

2.1.1. Economic analysis — monetary appraisal

The goal of the economic analysis is to identify the range of parameter values enabling a positive outcome of the CBA, and to define actions useful to keep these variables in that range. The indicators for such analysis include:

- economic net present value (NPV) — the difference between the discounted social benefits and costs;
- economic internal rate of return (IRR) — the discount rate that produces a zero value for the NPV;
- B/C ratio, i.e. the ratio between discounted economic benefits and costs.

As stated above, the goal of this analysis is to provide an assessment of the Smart Grid project of the city of Rome from the point of view of society. This does obviously not replace, but instead encompasses the assessment of the investment from the perspective of a private investor.

Therefore, in the CBA discussed in chapter 2 we first perform an evaluation from the latter's viewpoint, to subsequently add our estimates of the monetised societal benefits and costs. This will be first applied to the data pertaining to the Malagrotta pilot project, and then extended to the projected investments involving the whole city of Rome, based on their expected costs and benefits. Both analyses, however, require assumptions on a set of values, which the next section proceeds to spell out.

2.2. Assumptions on specific values

Cost-Benefit Analyses make use of a number of parameters, whose assumed values are critical to the accuracy and meaningfulness of the results. We proceed here to argue for our choices for such values.

2.2.1. Discount rate

The discount rate takes into account the time value of money (the idea that the money available now is worth more than the same amount of money available in the future because it could be earning interest) and the risk or uncertainty of anticipated future cash flows (which may be less than expected).

The discount rate typically has a significant impact on the assessment of the Smart Grid project. This is because (1) investment costs are incurred predominantly at the beginning of the scenario and are typically infrastructure-related costs – defined as "sunk" as they cannot be recovered after being incurred – while (2) Smart Grid interventions often provide benefits only in the long run. Two different interest rates are used in calculating NPVs: the weighted average cost of capital (WACC) for the private investor's CBA, and the social discount rate for the societal CBA.

The rationale for choosing a public policy discount rate is to recognise the societal value of Smart Grid investments, the impacts of which go beyond project developers and affect a wide range of stakeholders and society at large.

Discounting costs and benefits at this social discount rate would provide the value that the project gives to society, regardless of the actual costs of raising funds for the project. For example, in most countries where weighted average cost of capital for utilities is higher than the societal discount rate, the cost of remuneration of this new investment (rate of return over an increased remunerated asset base) and variations in operational costs impacting the regulated tariff may be included as an additional cost of the project in the CBA.

While discussing the proper way to impute values for the social discount rate (SDR) for CBA's, EC (2008) expresses the view that "consensus is growing around the social time preference rate (STPR) approach. This approach is based on the long term rate of growth in the economy and considers the preference for benefits over time, taking into account the expectation of increased income, or consumption, or public expenditure."[3] An approximate formula flowing from this approach is the following:

$$r = eg + p$$

where r is the real social discount rate of public funds expressed in an appropriate currency (e.g. Euro); g is the growth rate of public expenditure; e is the elasticity of marginal social welfare with respect to public expenditure, and p is a rate of pure time preference (STPR)[4].

The official guidelines for CBA have long suggested a SDR value of 5%. This was originally proposed by the Conference of the Presidents of Regions and Autonomous Provinces in a document of 2001[5], which is still the reference for the Italian Regions' feasibility studies[6] and was adopted by the Italian Economic Ministry and the EC (2002, p. 104)[7]. However, as noted by Percoco (2008), this rate "does not have any background empirical analysis, nor has it any strong supportive argument".

Therefore, in order to choose an appropriate social discount rate for this analysis, one should further consider that expectations on Italy's economic growth rate (g)

---

3 The theoretical superiority of STPR is also claimed by Evans (2006, p. 3), quoting policy (HM Treasury, 1997) and academic (Spackman, 2004) papers. In short, the rationale for taking into account the expected GDP growth rate is its presumable positive impact on consumption. Based on standard economic theory, if I expect to consume more in the future, the additional SG benefits will be given a lower value than if I have less positive expectations. This is as much as saying that high (consumption) growth expectations determine high discount rates, and vice versa.

4 The algebra for this equation is set out in Feldstein (1965).

5 Conferenza dei Presidenti delle Regioni e delle Province Autonome (2001, 2003).

6 Cf. f.i. the regulation of the Regional Project Assessment Group of Tuscany (Regione Toscana, 2013).

7 EC (2002).

have deteriorated in recent years, and this should be mirrored in SDR. Indeed, even the pre-crisis estimates of EC (2006)[8] - i.e. DG REGIO's CBA guidelines - suggested a lower value of 3.5% for Italy's SDR. This document is the methodological reference of EC (2008), where 3.3% is suggested as a value of reference for Italy; nevertheless, each member state is exhorted to assess its own SDR. These figures are quite in line with Evans (2006) (who argued that a rate close to 3% was defendable as a European benchmark), and with Percoco's (2008) own estimate of 3.69-3.83% (which depends on usage of the 1980-2004 average of real GDP growth rates, equalling 2.1%). SDR values are further lowered in Florio and Sirtori (2013), who estimate an appalling 1.13%, flowing from their assumption of 0.1% yearly GDP growth (based on a long-run average of 2000-2018 data and forecasts).

Considering the time frame of our period of interest, it is our opinion that the 1980-2004 mean value for g could not pertinently represent the current and future situation. On the other hand, estimates based on 2000-2018 rates seem excessively tied to global and Euro crisis circumstances to be extended all the way to 2029. While gauging current growth expectations, moreover, the plain application of values relative to past performances seems rather unwarranted, except of course to the extent that – in people's minds – the latter concur to shape the former.

It seems that a better approach is to refer to long-term growth forecasts for Italy by international economic institutions, as an element to feed into computations of STPR. On this regard, IMF forecasts[9] are 0.9% for 2015 and 1.1% for 2019, while the OECD[10] estimates an average of 1.5% for the 2014-2030 period, and Banco de España (2012, p. 18) imputes a value of 1.4% for 2012-2021 and 1.1% for 2022-2031.

[8] EC (2006).

[9] IMF (2014, p. 181).

[10] OECD (2014, p. 224).

On such basis, conservative estimates of current expectations on 2014-2029 growth rates may hover around 1%. Combined with the most recent values of 1.5 for *e* and 0.98 for *p* (from Florio and Sirtori, 2013), this gives a figure of 2.48%. Therefore, we conclude that a working assumption for Italy's present-day real SDR is 2.5%.

The JRC methodology strongly recommends that discount rates be subjected to a sensitivity analysis. Based on the above discussion, the 1%-5% range looks like an appropriate choice for it, as it runs the full gamut from a zero growth scenario to the Italian local authorities' official SDR value.

The Financial Discount Rate (FDR) (the discount rate to consider while assessing the project's viability from the point of view of a private investor), is derived from the fact that ACEA is a state-controlled enterprise with private stakeholders' participation, and that it is a listed company issuing its own debt. The FDR represents opportunity cost of capital and is valued as the loss of income from an alternative investment with a similar risk profile.

Different methods exist to estimate its value: a commonly used approach is by means of a weighted average between the cost of debt and the cost of equity (WACC), another focuses on the return lost from the best alternative investment and does not consider buying back public or private debt, but instead analyses the return on an appropriate portfolio of financial assets. Following this second approach, a study from the European Commission (2014b, p. 288) indicated 5.1% as a pertinent estimation for the nominal FDR, with a long term inflation rate of 2.2%. As will be explained in the following sections, the choice made in this analysis for the inflation rate has been 2%, which led to a correction of the FDR to the value of 5% in nominal rates (3% in real rates).

A further possible choice for the nominal FDR, which emerged from discussion with ACEA experts, is based on the cost of capital of the company, currently hovering around 6%. Yet another one is provided in Cosentino et al. (2011, p. 3), where the conducted CBA is based on a nominal rate of 5.5%, which is assumed as "a suitable trade-off between the financial and the social discount rates" (and seems to imply a nominal FDR even higher than that value). Also, in order to explore the consequences of such choices, the real Financial Discount Rate was subjected to sensitivity analysis on the rather encompassing 0%-8% range.

Be it noted that discount rates impact the NPV in a negative way. Therefore, rates of GDP growth (hence SDR) – or rates of return on invested capital – collapsing to unpredictable lows would only make any benefits flowing from present investments even more valuable at a certain future date.

Real discount rate for private investor's CBA: 3%

Real discount rate for societal CBA: 2.5%

2.2.2. Time horizon of the CBA

The choice of an appropriate time horizon significantly affects the results of any CBA, therefore it is a crucial parameter to be set. Smart Grids, like other infrastructural projects, are typically characterised by substantial initial investments, bringing benefits which are delayed in the future w.r.t. the investments themselves. Most of the times, then, appropriately setting the time horizon involves an assumption on how long the benefits flowing from the intervention will accrue in the future, an aspect clearly affected by a substantial amount of uncertainty. Potential sources of uncertainty in defining the time horizon for Smart Grid projects are e.g. the regulatory framework, project ownership, and other changes in the market setting.

The first investment figures included in our analysis date back to 2011, when ACEA started the realisation of the Malagrotta project. However, as the analysis has been carried out in 2014 after the completion of Malagrotta's infrastructural interventions, all monetary flows have been discounted back (or forward) to 2014 (i.e. the results are expressed in Euros of our reference year 2014).

For ACEA's Malagrotta project and its scalability to Rome's distribution network, several options have been considered:

- Adopting a time horizon of five years, consistent with ACEA's strategic plan 2014-2018. This solution would help shed light on the returns on the investments included in the strategic plan, considering it as a one-off outlay. It would also imply a judgment on the plan itself, identifying whether planned investments are worthwhile in the short run. However, such a choice would not take into account a rather important chunk of benefits that will be earned after 2018, due to the planned timeline of interventions. In particular, the realisation of sub-project 3 (set-up of New Management Criteria for the MV grid) is expected to yield its full benefits only from 2019 onwards. Therefore, such an evaluation would completely miss out on the effects of an important part of the SG's planned extension to the whole of Rome's network, and has therefore not been selected for this analysis.
- Adopt a time horizon of twelve years, as specified in the specific regulatory provisions concerning investments in Smart Grids, set by the Italian NRA in its integrated text concerning rules on transmission, distribution and metering of electricity (TIT 2007). In fact, the provisions set a remuneration of 2% over twelve years for Smart Grid projects, in addition to the above-mentioned baseline remuneration rate for standard electricity infrastructure. However, the TIT is subject to revision at the end of every regulatory period (in Italy four years) and this remuneration rate has been changed in order to adapt it to the changing business environment.
- Adopting a time horizon period of fifteen years from 2014 (or 19 from the very first initial investment in Malagrotta's project), up to 2029. The

concession regime on the distribution network of Rome will in fact undergo profound changes after this period, indicating the suitability of this time horizon as the one for the analysis of ACEA's investment decisions. This choice privileges a long-term horizon, which seems to be the most appropriate when dealing with regulated activities and companies. In fact, every business decision taken at ACEA today will have an effect on its future strategic/business plans, at least until ACEA is the company entitled by law to run the distribution network and upgrade it.

Of the three options considered, the one extended to the period of fifteen years, until 2029, was chosen for this analysis. As mentioned, this period seems more suitable because it covers a longer time horizon, and takes into account possible regulatory changes in the concession regime after 2029.

Time horizon of CBA: 19 years (2011 - 2029)

Reference year for discounting: 2014

2.2.3. Macroeconomic factors

Factors such as the inflation rate or the social value of avoiding the emission of a ton of CO_2 need to be taken into account in order to make estimates as accurate as possible. We will discuss here our concerning assumptions in turn.

The choice of the **carbon price** is possibly the single hardest decision in a Smart Grid CBA. Unlike other externalities (such as PM10), EU CO_2 emission permits have been traded on a dedicated market for some years now, and the social value of avoided emissions is therefore not anymore the mere object of theorising.
Unfortunately, however, this fact does not *per se* make the issue any less tricky. As for any other market price, long-run forecasting has its own difficulties; furthermore, this is an artificial market (i.e. a market for a state-made commodity such as a legal authorisation), so that the usual uncertainties connected with purely economic

factors are compounded by the ones deriving from predicting, years in advance, possible further actions taken, among others, by the European Parliament. On the other hand, monetisation of avoided emissions through carbon market prices can only document what costs must not be borne by fossil-fuel generators thanks to Smart Grids; but, what Emission Trading Schemes (ETS) are actually meant for is making polluters pay the actual social marginal cost of a certain productive activity. What should be considered for the societal assessment of a project is clearly the latter, with its possible variability in time.

Due to how Pigouvian taxes are established and maintained in the real world, however, this notional cost may or may not be exactly reflected in carbon market prices at any given point in time. In fact, a large consensus holds that the current quotation of CO_2 at ca. 6 €/ton, largely due to a recession-related allowances glut, is alarmingly low and radically disconnected from the fundamental social cost of carbon - to the point of triggering widespread commentary on the "failure" of the EU ETS. In any case, such values are very distant from what is envisaged in the European Commission's "roadmap to a competitive low-carbon economy" (EC 2011), requiring (in the baseline scenario) carbon prices of 16.5, 20 and 36 €/ton resp. by 2020, 2025 and 2030[11]. And indeed, the evident departure of the current values from the political goals of the EU has recently set off a clear shift in the policies concerned. A scheme for postponing the coming years' auctions, hence effectively curtailing supply of European Unit Allowances by 900 million units (the so-called "backloading") was approved in early 2014. Furthermore, the EC has proposed a Market Stabilisation Reserve Mechanism involving controlled injection of backloaded EUA's in order to stabilise their prices above €20-30. Such policy decisions are expected to mark a structural break in the years ahead, driving prices quite dramatically away from the current lows.

[11] Cf. EC (2011, p. 117), Annex 7.10, table 31.

In this complex situation, one may be tempted to go to extremes and conclude that carbon market prices should be simply swept aside, in favour of a conceptual framework able to assess the "real" social costs. In practice, however, such a shared conceptual framework is hardly at hand by now. For all the difficulties that we have just seen, then, carbon market prices may still be the best guide to the near future that we have got, if one is willing to concede that the political decision system may do at least a decent job in the years to come. In this report, hence, CO_2 values will still be monetised based on ETS forecasts, addressing these well-founded worries through sensitivity analysis. In such an uncertain environment, it is reassuring to find that - as will be seen below - the Net Present Value of the project at hand is largely above zero for any relevant choice of carbon dioxide's monetary value; in particular, for any choice above current ETS prices.

Focussing on backloading alone, a recent EC document (EC 2014, p. 39) lists a series of analyses: Barclays predicts an ETS price of 10 €/ton in 2020 for the 900-mln backloading scenario, while Thomson Reuters' estimate is 8 €/ton. Already at the shorter 2015 horizon, Bloomberg sees prices going up to 20 €/ton; Tschach Solutions' take is 23.5 €/ton. Further estimates are in Carraro and Favero (2009) (about 45 €/ton in 2020 in the mean scenario), Thomas (2008) (25 €/ton in 2020), Thomson Reuters (2011) (average price in 2013-2020 at 22 €/ton), Weisbach (2011) (ca. 20-22 €/ton in the 2013-2020 period), and Chen (2012) (21.7 €/ton in 2020 in the average scenario).

The Market Stabilisation Reserve mechanism would change the game quite a bit, with Thomson Reuters most recently predicting an average 2021-2030 price of 23 €/ton[12], and Energy Aspects seeing prices averaging 45 €/ton over the period 2017 to 2030 with MSR starting in 2017, and 31 €/ton if it starts in 2021[13].

[12] Hill (2014).

[13] Sikorsky (2014).

It was decided here to privilege simplicity and conservatism, employing the relatively low value of 15 €/ton as a baseline working assumption, as a rough average of the Nomisma Energia[14] and CEPS-Thomson Reuters[15] reference-scenario forecasts up to 2030. For the sensitivity analysis, values considered range from the current low of 5 €/ton to 50 €/ton, the figure generally topping the market analyses that we have just listed, as well as the EC's forecasts on ETS that were mentioned above. At any rate, let us repeat that NPVs for Rome are largely above zero for any meaningful choice of carbon prices.

A further aspect to consider is **inflation**. Investment deployment obviously involves time-varying costs in terms of operational capital and labour. A value of 2% was assumed as an estimate of the average expectation of growth rate of such costs, in line with the ECB's inflation target. This implied a slight correction of the aforementioned 5.1% nominal FDR suggested in EC (2014b), based on a 2.2% inflation forecast, due to the fact that current expectations do not suggest Italian inflation may overshoot the ECB target in the relevant horizon.

EU CO_2 Allowance price: 15 €/ton

Average inflation rate per year: 2%

2.2.4. Electricity demand

Demand for electricity depends on the development of other factors, such as population growth, domestic consumption, non-domestic consumption, electricity losses. Naturally, it is necessary to base the choice of the electricity demand or the demand growth on country-specific forecasts.

[14] Nomisma Energia – Mercato ETS (2014).

[15] Thomson Reuters Point Carbon (2014).

Electricity price developments should also be taken into account. Since electricity savings are typically one of the most significant benefits resulting from the implementation of smart meters - e.g. KEMA (2010) -, an increase in the electricity price would result in a potentially higher monetary benefit in terms of electricity savings.

In this specific context, evolution of electricity demand will significantly affect the impact of future extensions of the pilot project to the whole city grid, involving benefits stretching into the future and investments to be performed throughout 2019. Demand forecasts for Central Italy by the Italian TSO TERNA (2013) impute a 2013-2023 average expected electricity demand yearly growth rate of 1.2% for the "development" scenario, and of 0.4% for the baseline (i.e. low growth) scenario. Considering the recent brisker dynamics of Rome's GDP per capita growth w.r.t. the rest of Central Italy, judgment suggested to assume a figure somewhat above the average between the two, i.e. 1%.

Electricity demand obviously has a large impact on the outcome of the CBA. Conform to the JRC guidelines, it was therefore subject to a sensitivity analysis on the -1% to 2% range.

Yearly rate of growth of electricity demand: 1%

2.2.5. Emission factors

Smart Grid projects typically result in energy savings (e.g. due to reduction of electricity losses) or favourable changes in the generation mix thanks to increased DG hosting capacity. The context-specific coefficient that translates a unit generation decrease into the corresponding amount of avoided greenhouse gas emissions is the **emission factor** (EF). The Covenant of Mayors - an association of Europe's urban areas of which Rome has been a signatory since 2009 - provides its members with country-specific EF's for computations related to its programmes, calculated based on both the "classical" and Life-Cycle Assessment[16] methodology. It was decided to adopt Italy's LCA EF from the Covenant of Mayors[17], equal to 0.708 ton CO_2-eq/MWh_e, as the value used in this analysis. Note that this also implies the assumption that the impact of project-related increases in RES electricity generation within ACEA's jurisdiction on the country-wide energy mix is negligible. This value was subjected to sensitivity analysis on the 0.5-0.95 range.

Emission factor: 0.708 ton CO_2-eq/MWh_e

2.2.6. Dynamics and uncertainty of costs and benefits

As ACEA carried out detailed analyses in order to estimate a monetisation for the benefits, the underlying hypotheses supporting their calculation are described below.

Various damaging events affect the grid over time, implying costs as high as the impact connected to the events. In order to reduce said costs, a series of investments planned on an annual base are operated. The main goal of the methodology is to give, for any operation on the grid, the expected value of total benefits (avoided costs), comprised of the margin of error in the evaluation. Operations are characterised by a unitary cost and a benefit, defined as the reduction of the total risk connected to each intervention (avoided cost). The benefit is then replicated in the years, and actualised taking into account its degradation. The sorting of all possible interventions on each element of the grid, using their cost-benefit ratio as a

[16] The Life-Cycle Assessment (LCA) methodology takes into account all emissions caused by a technology over the whole of its life-cycle, i.e. including installation and decommissioning. By way of example, classical EF's for PV panels are very close to zero, while this does not hold for LCA EF.

[17] The Covenant of Mayors is a local authority association for the promotion of sustainable policies, of which the municipality of Rome has been a signatory since 18th June 2009.

criterion, defines the optimal plan for operations to be executed. The cumulative benefit curve connected to such order of operation allows for an informed choice of the percentage of grid to operate investments on, according to the desired percentage of total benefit to achieve.

As a consequence, the following two assumptions were considered appropriate and feasible to reflect the uncertainty of the estimates, while at the same time being sufficiently conservative:

- *Error margin*: all monetised benefits are reduced by a 3% rate to account for uncertainty in benefit monetisation due to the underlying technical metrics;
- *Benefit decrease*: an average rate of annual decrease of 5% for benefits related to physical infrastructure (e.g. reclosers) and of 1% for benefits related to software (e.g. algorithms).

As regards monetisation uncertainty, the full span from a 5% decrease to a 2% increase in benefits w.r.t. the values reported by ACEA is explored. The hypothesised technical yearly reduction rates in benefits related to physical infrastructures and software are instead subjected to test resp. in the 2%-8% and 0%-6% ranges.

Error margin in evaluating benefits: 3%

Yearly average decrease of benefits:

- ***5% for infrastructure***
- ***1% for software***

Parameter	[UNIT]	Value	Reference
Time Horizon	years	15 - 19	ACEA
Real Financial Discount Rate (FDR)	%/year	3%	EC, literature and own assessment
Real Social Discount Rate (SDR)	%/year	2.5%	EC, literature and own assessment
Inflation rate	%/year	2%	ECB inflation target
Average uncertainty in monetisation of benefits	%	3%	ACEA
Average rate of decrease of benefits related to investments in infrastructure	%/year	5%	ACEA
Average rate of decrease of benefits related to investments in software	%/year	1%	ACEA
Average rate of electricity demand increase	%/year	1%	TERNA and own assessment
Emission factor	ton CO_2-eq/MWh_e	0.708	Covenant of Mayors
1 ton CO_2-equivalent average price in EU ETS	€	15	EC, literature and own assessment

Table 3: Values of CBA parameters

2.3. CBA for Malagrotta and its extension to Rome

The JRC methodology described above has been developed to be flexible enough to be applied to any Smart Grid project. Since its publication in 2012, it has been refined and applied to several projects and EU policies, e.g.:

- the selection of Projects of Common Interest in the fields of Smart Grids, according to Regulation 347/2013 for Trans-European energy infrastructure[18];
- the assessment of national Cost Benefit Analyses for the roll-out of smart metering in EU Member States, according to the provisions of Directive 72/2009 on the functioning of the internal electricity market and of the Commission recommendation on preparations for the roll-out of smart metering systems [C/2012/1342][19].

The methodology, however, has been designed not only to support the European Commission's policy processes, but first of all to provide a flexible tool for investors, project promoters and all other stakeholders to identify the impact of specific Smart Grid projects. For this reason, one of the JRC's main research efforts is to test the methodology on real Smart Grid projects: the cooperation between ACEA and the JRC has been crucial in applying the methodology to Malagrotta and then to its scalability to the distribution network of the city of Rome.

In section 2.3.1 and following ones, we will proceed to a step-by-step description of the methodology's application to the project at hand. Next, in sections 2.3.8 and 2.3.9, we will present its key results for Malagrotta alone and for its extension to the whole city of Rome, first based on the point of view of the individual investor and then on that of society as a whole. This aims to answer the following questions:

[18] EC (2013).

[19] EC(2014).

- From the point of view of the investor, is the project financially viable (i.e. there is a business case to deploy Smart Grid projects)? This assessment is made for both Malagrotta alone and its extension to the whole of Rome's distribution network.
- What is the effect on the analysis of taking the point of view of a private investor and of society as a whole (hence, taking externalities into account)?

2.3.1. CBA Step 1 – Review and describe the technologies, elements and goals of the project

The following table provides the main feature of ACEA's project in terms of goals and engineering features.

PROJECT DESCRIPTION	
PROJECT GOAL	To demonstrate new telecommunication technologies and new criteria of electricity network management are effective under real conditions.
PROJECT SPECIFIC OBJECTIVES	1. Improving system quality and continuity of Rome's energy network through automation systems for fault detection and isolation on the MV energy network. 2. Improving the distribution network observability through monitoring and remote control of the low voltage (LV) energy flows. 3. Assessing the positive impact of automation with the new grid management criteria.
START - END DATES	CAPEX: 2011 – 2019 / Return on investment: 2015-2029
FUNDING SCHEME	AEEGSI ARG/el 39/10
LOCATION	Rome area (Italy)

Table 4: Overall description of the ACEA project in Rome

MAIN FEATURES	PROJECT SMART GRID	ROME
LV CONSUMERS INVOLVED	1.200	~ 1.600.000
MV DISTRIBUTED GENERATION	4	~ 200
NUMBER OF HV/MV PRIMARY SUBSTATIONS	2	~ 70
NUMBER OF MV/LV SECONDARY SUBSTATIONS	76	~ 13.000

Table 5: Main features of the project

2.3.2. CBA Step 2 – Map assets into functionalities

The identification of assets into functionalities is provided and quantified by ACEA, thanks to their internal expertise. ACEA provided data that have been taken as input for this analysis and are detailed in the next paragraphs.

In doing this process, ACEA developed a "Driver", i.e. a custom-made indicator that is the result of a specific model putting in relation, among other variables:

- the number of MV and LV users,
- the probability of faults
- the cost of installing the specific technical solutions tested of each sub-project, and
- the reduction in adverse events and the consequential increase in quality of electricity of supply, as measured by reductions in duration and number of

interruptions in supply[20] (i.e. Smart Grids functionalities that can be monetised, according to the current regulatory framework)

for each of the 1568 grid sections of Rome's distribution network and for each sub-project.

2.3.3. CBA Step 3 – Map functionalities onto benefits

Finally, the three "drivers" (one per each sub-project) were expressed into the expected monetary benefits of realising the project, such as the decrease in compensations owed to consumers for each interruption, the cost of interventions on the grid, the avoided investment costs otherwise necessary to comply with regulatory design (increasing quality targets for electricity supply at every regulatory period), etc. This last step constitutes the mapping of functionalities into benefits.

It should be noted that this step of the CBA has been crucial in the development of the analysis, as usually the same DSOs may find it difficult to clearly identify the monetary outcome of investments made over their own grid. Such refined calculations not only resulted in a clear indication of monetary benefits, but also, for each of the three sub-projects, identified a specific timeline to scale up the project to Rome's network, spotlighting those grid sections that bring the most benefits in the shortest time and therefore spelling out a clear road-map to deploy the Smart Grid project effectively, whilst maximising ACEA's NPV.

2.3.4. CBA Step 4 – Establish the baseline

The project baseline defines the standard against which the condition resulting from the realisation of the Smart Grid project is compared. Typically referred to as

[20] As provided by AEEGSI, in Italy regulatory provisions on quality of electricity supply for each DSO are measured by both total duration of interruptions during 1 year (so-called D1) and number of interruptions during 1 year (so-called N1 indicator).

Business as Usual (BaU), it reflects the condition of the distribution network of reference without any Smart Grid intervention, taking only planned maintenance into account.

For the purposes of carrying out this CBA, the overall Smart Grid project was analytically divided in the three sub-projects described earlier in Section 1.2. Costs and benefits stemming from the project are then assessed comparing those associated with a BaU scenario and those that would be incurred in scenarios where ACEA implements the three sub-projects (each sub-project separately and then all the three together). The robustness of resulting figures has been scrutinised also by internal ACEA's expertise, taking into account also historical costs and benefits accrued by the company when realising other grid interventions. The involvement of DSO internal expertise is in fact crucial in such analysis, as they are the ones directly involved in realising the project.

As an additional note the way baselines and metrics are calculated in practice depends upon local conditions and current information availability, as known by the DSO. This may have significant impact on the final results and possibly on the comparability of different analyses: very unlikely the analyses (and especially mapping assets into benefits and then functionalities) performed for this project would make sense if just transposed into another Smart Grid project taking place in a different regulatory environment, with different technical challenges, etc. DSO' involvement is therefore a key asset to correctly identify the context of each project and gather the appropriate, first-hand data.

2.3.5. CBA Step 5 – Monetise the benefits and identify the beneficiaries

Projects can impact at the level of avoided costs or yield other benefits, as reduced greenhouse gases emissions, etc. The monetary values of the benefits of the project were calculated based on the assumptions on parameters presented in section 2.2 and considering foreseeable boundary conditions. The perspectives of different stakeholders (e.g. DSOs, residential consumers, society) were assessed by applying comparable sets of benefit metrics. The benefits accruing for Malagrotta and for the whole of the city of Rome from the three sub-projects were considered for the analysis. These include the intrinsic benefits of each sub-project, accruing to ACEA from a) the regulated remuneration of invested capital; b) avoided regulatory penalties, related to improvements in electricity supply (e.g. shorter interruption duration); c) avoided maintenance and intervention costs when grid faults take place. These can be broken down into benefits flowing to the DSO due to infrastructure items installed in year 1, year 2, year 3, etc., of the project deployment.

Clearly, the regulator's rationale in establishing such remuneration and penalties was to make ACEA internalise part of the customers' welfare gains and losses linked to network performance (e.g. via better or worse quality of supply). Under perfect competition (and symmetric information), such welfare gains would translate into higher perceived service quality, for which consumers may be willing to pay a bit more; price externalities would ensue, making for transitory extra-profits for the investing firm. The Regulator's aim is to mimic such market dynamics in a natural monopoly environment, as a way to incentivise the DSO towards (esp. innovative) investments.

Even if information asymmetry between regulator and DSO is disregarded, however, due to the absence of first degree price discrimination, neither price externalities nor regulated returns could ever capture the full consumer surplus gains from reduced outages. In principle, one may attempt to gauge these directly through some measure of project-related improved security of supply monetised via the relevant Value Of Lost Load (VOLL). However, the current state of research on the topic is such that esp. the latter parameter poses rather daring measurement problems. At the present stage, it seems necessary to be content with the rough guide to welfare gains represented by regulatory remuneration and avoided penalties, and it was therefore decided to include the latter in the Societal CBA, too. The approach seems particularly fit to Rome, where the vast majority of customers are residential, as for this category Italian regulators seem to have set incentive rates near the higher end of the relevant spectrum[21]: in other words, due to political priorities, Italian DSOs seem to be punished relatively harshly w.r.t. other European ones in case they fail to keep domestic lights on. It is fair to suppose, however, that the full amount of social surplus may still be underestimated by this procedure (therefore it can be concluded that NPV evaluations reported are rather prudential and the welfare gain for the society might be higher than what we estimate).

The DSO is not held legally responsible for *force majeure* events; however, such penalties are subjected to a €5.5 million cap per year, applied to the summation of avoided penalties flowing from the sub-projects impacting on reduced outages (i.e., MV Automation and LV Monitoring). This may work both as a form of public insurance for DSOs (with an excess franchise aimed at preventing moral hazard) and as a rough regulatory shortcut to mimic the slope of marginal welfare costs, which is likely to be decreasing in longer and more frequent outages[22]. In both the private-investor and societal CBA, therefore, benefits from avoided penalties are correspondingly curtailed at such cap. Since it is attempted in the following to compute IRRs and NPVs from each sub-project independently, and the size ratio (e.g. in uncapped NPV terms) of sub-projects 1 and 2 is roughly 1:2, in all further analyses fictional €1.8 and €3.7 million caps will be imposed resp. on sub-project 1 and 2. This preserves comparability between computed NPV values for the whole project and for the different sub-projects.[23]

In order to guide investment decisions, however, it is desirable that one may get a flavour of the intrinsic structural dynamics of benefits for each sub-project,

[21] Cf. Bertazzi, Fumagalli, and Lo Schiavo (2005, p. 5).

[22] Cf. *ibid.*, p. 4; also, most recently, Praktiknjo (2014) (for Germany).

[23] Indeed, the summation of avoided penalties from the sub-projects under such fictional caps is roughly the same as the one under the regulatory cap for the whole Smart Grid project.

regardless of all superimposed constraints. This can be readily obtained from Figure 7, where benefit flows for each sub-project and for the aggregate are depicted after all regulatory caps are removed. The figure clearly shows that, for Rome, interventions on LV monitoring yield much higher benefits than what is the case for the other two sub-projects. This result carries over to NPVs (also capped ones, as seen in the following, thanks to the properly adjusted fictional caps employed). Thus, investments in LV monitoring seem to feature the brightest investment outlook.

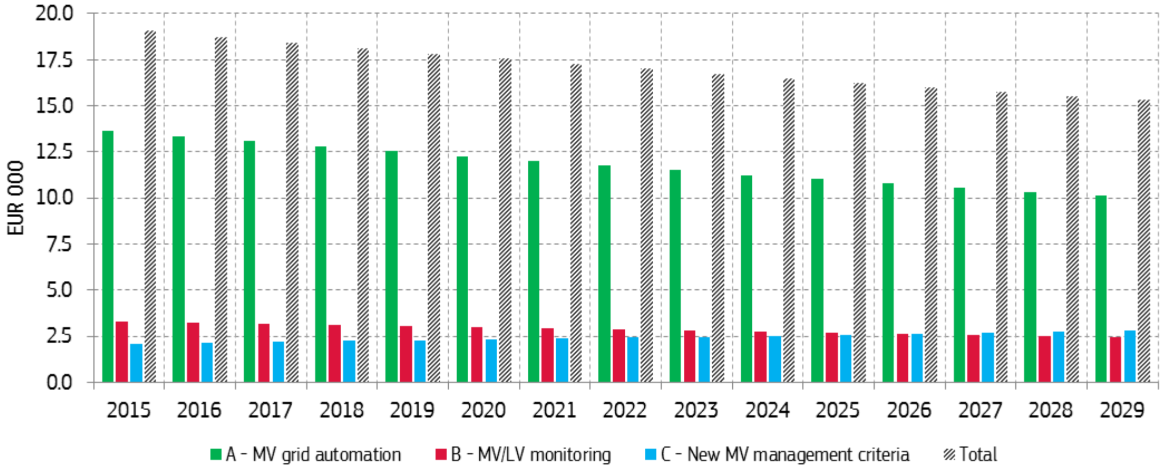


Figure 6: Benefits gained annually for the Malagrotta project

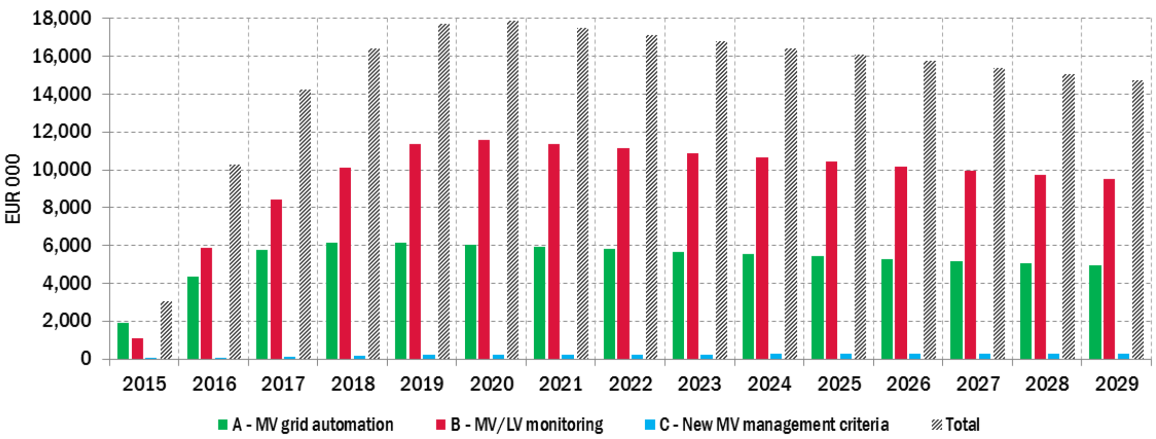
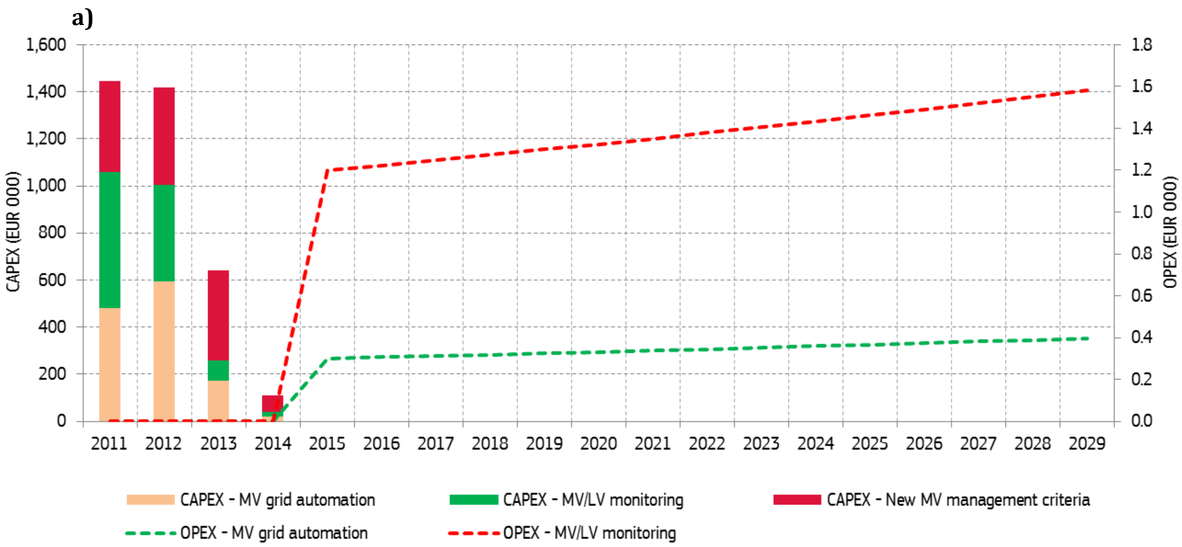


Figure 7: Benefits gained annually for the extension of the project to Rome

In addition to the above, there are further benefits deriving from avoided GHG emissions and from the regulated remuneration of invested capital in the Smart Grids projects. While the former is the main positive externality flowing from the project, and is hence specific to the societal analysis, the latter was included in both the private-investor and the societal analysis, for the theoretical reasons that were explained in this section.

2.3.6. CBA Step 6 – Financial model – costs identification and quantification

The costs for Capital Expenditures and Operating Expenditures (CAPEX and OPEX) estimated for the implementation of the three sub-projects were considered for Malagrotta and for the Rome extension in turn. As recommended in the CBA guidelines, replacement costs have been duly considered when occurring at the end of each asset's life time.



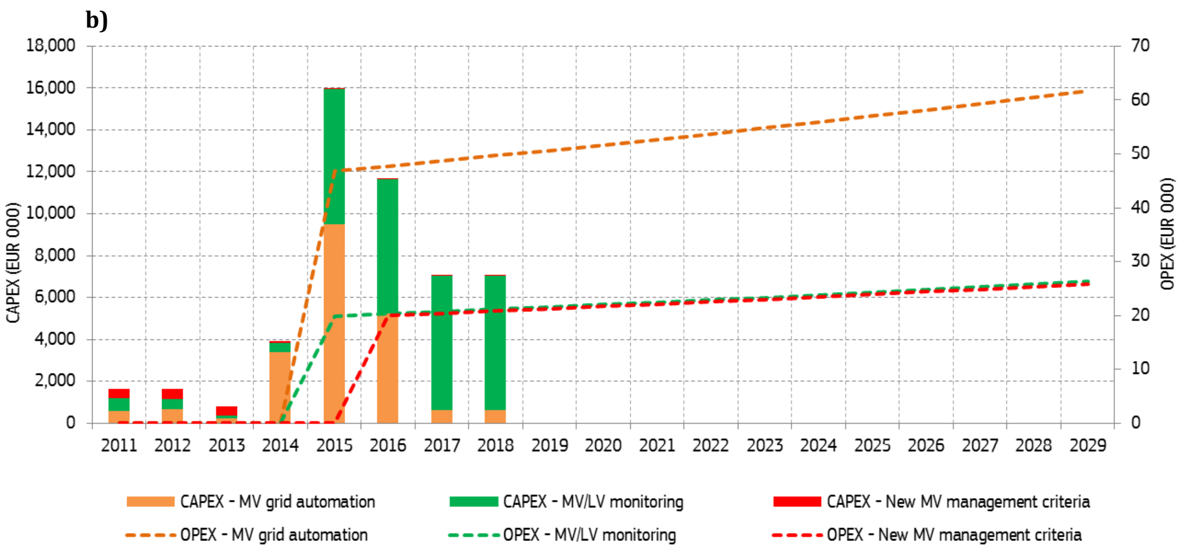


Figure 8: CAPEX and OPEX for Malagrotta project (a) and for the extension to Rome (b)

For simplicity, it has been assumed that all the assets are considered to last for the economic value of the project (fifteen years) so that there is no problem involving calculation of replacement costs and residual value of the replaced asset. In Figure 8 it is possible to observe the values hypothesised for CAPEX and OPEX throughout the years both for the Malagrotta project and for the extension to the entire city of Rome.

The capital expenditures for the sub-projects are expected to be carried out across several years, and the same holds for the related benefits. It is important to note here that the Automation and Remote Control/Monitoring sub-projects (i.e., sub-projects 1 and 2) are based on physical assets, which benefits are assumed to accrue with a 5% yearly decline rate. On the other hand, the New Grid Management Criteria sub-project is based on the improvement of software algorithms, for which the assumption of such a steep decline pace seems unwarranted. It was hence suggested that the latter's benefits would flow with a milder decreasing trend of 1% per year. As already mentioned, such values were subjected to sensitivity analysis resp. on the 2-8% and 0-6% range.

2.3.7. CBA Step 7 – Financial model – Benefits and Free Cash-Flow analysis

We now proceed to present the monetised benefits, as they are realised for the DSO as an individual investor. As earlier mentioned, the ACEA projects were initially assessed at a nominal FDR of 5% (i.e. a real FDR of 3%). Taxes have not been taken into account, as recommended by the JRC methodology.

To be noted that these expected benefits may represent both the cash flows realised by the potential investor (ACEA) and avoided costs. In the latter case, ACEA foresees to avoid costs that are currently sustained as fixed costs, due to the general maintenance of the assets. These costs are needed to ensure technological updating and efficiency of ACEA’s assets; as such, they will not produce a cash flow directly, but will instead allow reducing maintenance costs and avoiding regulatory fees and penalties for under-performance of the electricity distribution service, so to increase the availability of cash.

A further aspect of Italian regulation relevant to the present analysis is the fact that ACEA's network investments receive (via tariffs) a regulated remuneration on standard electrical infrastructure; furthermore, investments in Smart Grids earn returns which are 2% in excess of such baseline regulatory rate. Being part of ACEA's income, this should obviously be included in the private investor CBA.

Regulated returns on invested capital are calculated on the RAB (regulated asset base). This was computed based on accountancy methods for electricity utilities prescribed by the current Italian legislation, as spelled out in the relevant documents by the Authority for electricity, gas and water services (AEEGSI)[24]. Namely, net fixed assets (measured via historic CAPEX figures and netted of accumulated depreciation, based on regulatory useful lives for the relevant investment items) have been factored in after the regulatory two-year time lag has lapsed. They are then annually updated by the revalued historic cost method, i.e. expressed in current prices through a gross fixed cost investment deflator that (according to common regulatory practices) was approximated by the inflation rate. RAB is then computed from this value by addition of net working capital and subtraction of adjustments for severance indemnity (currently parametrically estimated as resp. 1% and 2.17% of revalued net fixed assets, as per the aforementioned Regulation)[25]. As said, the Malagrotta pilot project benefits from the Regulatory treatment for Smart grids granting an additional 2% for the first twelve years of the investment's useful life.

Intuitively, a financial viability analysis can consider both directly accruing benefits and avoided costs. An avoided cost can in fact be considered as additional cash

[24] The valid reference for this is AEEGSI (2012).

[25] Since balance sheet figures for OPEX are available, it was also attempted to assess net working capital from them (the accounting approach currently followed for gas utilities), with no significant divergence.

being available in the future as a consequence of the decrease of fixed or variable costs of the company. The financial model is presented below in form of cash flow analysis (CF).

As it is customary in the financial literature, the financial feasibility of the projects were assessed by calculating the Net Present Value (NPV) of the monetised benefits expected to be received as a consequence of the ACEA investments made.

The NPV was calculated as follows:

$$NPV = \sum_{t=1}^{N} \frac{CF_t}{(1+i)^t} - investment_{t=0}$$

where:

N = number of years for which the cash flow is expected to be received;

i = interest rate applied representing the opportunity cost of capital. As discussed at length above, the private investor analysis adopted an FDR appropriate to the present context;

t = number of years from the moment the investment is fully disbursed by the DSO;

Investment = the total Capital and Operational Expenditure expected to be sustained by the DSO.

The NPV is an indicator of how much value an investment or project is expected to add to a company. If the NPV is a positive value, the project generates positive cash inflow at the end of the period considered, or vice versa.

2.3.8. Private investor CBA - Results

The crucial CBA outcome for the three Smart Grid projects can be found in the overview table below, where the reader may find the Net Present Value and the

Internal Rate of Return[26] for the Private Investor CBA of the Malagrotta project and of its extension to Rome.

Private investor CBA ***Smart Grid project***	**MALAGROTTA** ***(Pilot)***	**ROMA** ***(Scale-up)***
NPV (Net Present Value year 2014)	- K€ 1,262	K€ 35,972
IRR (Internal Rate of Return)	1.23%	16.60%

Table 6: Outcomes of the CBA for the Malagrotta project and its extension to the Rome area – Private investor approach (values in K€, base year 2014)

From the table above, it is immediate to glean what can be deemed the central result of the whole JRC analysis: the Malagrotta project would not be financially viable as a stand-alone investment plan, but it plays a key trailblazer role for the Smart infrastructuring of the whole electricity network of the city of Rome – which is, after all, exactly what a pilot project is meant to do. This fact turns out very clearly already for the Private investor CBA, and will be - predictably - further reinforced by the Societal CBA, as will be seen presently. Moreover, let it be remarked already here that the sensitivity analysis will comfortably confirm this result for all relevant parameter ranges.

We can add further detail by briefly presenting the disaggregated results for the three sub-projects:

Private investor CBA ***Automation***	**MALAGROTTA** ***(Pilot)***	**ROMA** ***(Scale-up)***
NPV (Net Present Value year 2014)	-K€ 374	K€ 10,026
IRR (Internal Rate of Return)	1.86%	12.55%

Private investor CBA ***MV/LV monitoring***	**MALAGROTTA** ***(Pilot)***	**ROMA** ***(Scale-up)***
NPV (Net Present Value year 2014)	-K€ 456	K€ 24,608
IRR (Internal Rate of Return)	0.61%	21.17%

[26] The Internal Rate of Return for societal analyses was computed on the whole of cash flow representing monetised benefits accruing to society, hence *including* monetised avoided GHG emissions.

Private investor CBA *New Management Criteria*	MALAGROTTA *(Pilot)*	ROMA *(Scale-up)*
NPV (Net Present Value year 2014)	-K€ 432	K€ 1,406
IRR (Internal Rate of Return)	1.13%	12.28%

Table 7 Outcomes of the CBA for disaggregated sub-projects – Private investor approach (values in K€, base year 2014)

A monetary appraisal of costs and benefits on behalf of society with a related impact analysis was therefore estimated, taking into account the plausible social impacts derived from the ACEA projects.

The most likely positive social impacts were identified in the reduction of air pollution derived from a more efficient distribution of electricity, which implies a decreased electricity generation. In order to translate this likelihood of positive impacts into monetary values that may be considered as financial values, three key elements of relatively easy estimation are considered.

The assumption is that the measures implemented by the projects will impact society positively in form of avoided carbon emissions and pollution. These societal benefits (SB) are calculated through the multiplication of the following factors:

- MWh of saved generation[27]
- Avoided tons of CO_2-equivalent per saved MWh
- Average EUR value of a ton of CO_2-eq saved.

Hence, benefit monetisation is based on the availability of meaningful and reliable information substantiating them. By way of example, preliminary evidence based on experiments carried out by ACEA on the Malagrotta network[28] suggests that the New Grid Management Criteria (NGMC) allow for a decrease in network losses from 4.33%

[27] Saved electricity generation is assumed as a consequence of the improvements in the electricity distribution due to the investment.

[28] ACEA (2013, p. 46).

to 3.20%-3.10%. Furthermore, ACEA carried out estimates of the future NGMC-related annual saved generation for each primary substation on which their adoption is planned. Such values were updated yearly based on the expected increase in the city's electricity demand, specified in section 2.2.4, to get an overall assessment of energy savings in Rome. These are then converted in tons of CO_2-eq, and monetised based on the assumptions on carbon prices and emission factors that were detailed in sections 2.2.3 and 2.2.5 above:

$$SB_t = \Delta CO_{2t} \cdot EF \cdot P_{CO_2}$$

where:

SB = societal benefits coming NGMC-related from avoided emissions

ΔCO_2 = decreased CO_2 emissions thanks to the project (in tons)

EF = LCA emission factors

P_{CO_2} = estimated monetary social value of one ton of avoided emissions

The benefits calculated according to the above formula were added into the financial model and discounted in the same way:

$$NPV_{SB} = \sum_{t=1}^{N} \frac{SB_t}{(1+SDR)^t}$$

where SDR stands for the Social Discount Rate discussed in section 2.2.1 above. As already mentioned, this rate is subjected to sensitivity analysis, so that the related elements of uncertainty are taken into account.

Societal benefits are a result of all the efforts taken in all the sub-projects supporting a Smart Grid. It is for this reason that this analysis focused on the benefit of all sub-projects as a whole, instead of specifically assigning these benefits to one or another sub-project[29]. For the sake of simplicity, this analysis assigns the societal benefits as if

[29] Project 3 could not be operational without the measures taken in projects 1 and 2. Projects 1 and 2 are undertaken as their output allows project 3 to be realised.

derived only by sub-project 3, which is supposed to implement the Smart Grids and the related network automation (new grid management criteria).

The monetised benefits from a DSO perspective are integrated with the monetised societal benefits in the tables below. The two previous assumptions adopted for the financial model (error margin in the monetisation of benefits and average rate of benefit decrease linked to the investments made) were kept unchanged in the societal model[30].

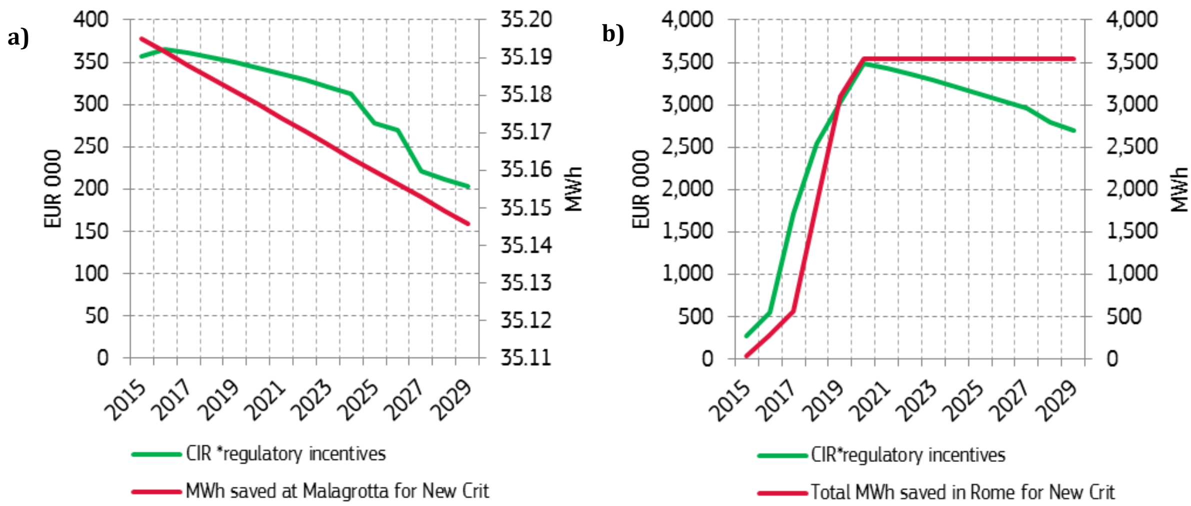


Figure 9: Incentives and saved MWh for Malagrotta project (a) and Rome (b)

[30] Taxes have not been taken into account as recommended by the JRC methodology.

2.3.9. Societal CBA - Results

The following table shows the results in terms of NPV and Internal Rate of Return of the Societal Cost Benefit Analysis applied to the three projects in Malagrotta and in the whole of the city of Rome.

Societal CBA *Project Smart Grid*	MALAGROTTA *(Pilot)*	ROMA *(Scale-up)*
NPV (Net Present Value year 2014)	-K€ 1,104	K€ 39,119
IRR (Internal Rate of Return)	1.25%	16.67%

Table 8: Outcomes of the CBA for the Malagrotta project and its extension to the Rome area – Societal approach (values in K€, base year 2014)

It can be seen that, as anticipated, the fundamental result presented above for the Private investor CBA carries over to the Societal CBA. Furthermore, let it be noted that both NPVs increase by a remarkable amount. As will also emerge from the Sensitivity Analysis here below, this is due in larger measure (and is hence much more sensitive) to the lower value of SDR w.r.t. FDR, than to the monetisation of externalities such as avoided GHG emissions.

As above, we can implement these results by disaggregating the values for each sub-project, as shown in Table 9:

Societal CBA *Automation*	MALAGROTTA *(Pilot)*	ROMA *(Scale-up)*
NPV (Net Present Value year 2014)	-K€ 362	K€ 11,033
IRR (Internal Rate of Return)	1.55%	12.55%

Societal CBA *MV/LV monitoring*	MALAGROTTA *(Pilot)*	ROMA *(Scale-up)*
NPV (Net Present Value year 2014)	-K€ 410	K€ 26,274
IRR (Internal Rate of Return)	0.61%	21.17%

Societal CBA *New Management Criteria*	MALAGROTTA *(Pilot)*	ROMA *(Scale-up)*
NPV (Net Present Value year 2014)	-K€ 376	K€ 1,688
IRR (Internal Rate of Return)	1.18%	12.74%

Table 9: Sum up of outcomes of the CBA for the Malagrotta sub-projects and their extension to the Rome area – Societal approach

2.4. *Sensitivity analysis*

The sensitivity analysis is a necessary component of a CBA, as it shows the impact of uncertainty/variations of key variables on the results of the analysis. The parameters that have been considered for the sensitivity analysis are detailed in the following table.

Parameters for Sensitivity Analysis	Unit	Baseline Model Value	Values' Range
Real Financial Discount Rate (FDR)	%/year	3%	0% ± 8%
Real Social Discount Rate (SDR)	%/year	2.5%	0% ± 5%
Average uncertainty in monetisation of benefits	%	3%	-2% ±17%
Average rate of decrease of benefits related to investments in infrastructure	%/year	5%	2% ±11%
Average rate of decrease of benefits related to investments in software	%/year	1%	0% ± 8%
Average Rate of increase OPEX	%/year	0%	0% ± 6%
Average Rate of increase CAPEX	%/year	0%	0% ± 16%
Emission Factor	ton CO_2-eq/MWh_e	0.708	0.50 ± 0.95
1 ton CO_2-eq average price in EU ETS	€	15	0 ± 50

Table 10: Sensitivity analysis – input parameters for the financial models

The results for the private-investor and societal sensitivity analyses are presented in the next paragraphs:

i. first for each of the pilot's three sub-projects separately (MV grid automation, LV monitoring and New Grid Management Criteria);
ii. then for the aggregate Malagrotta project;
iii. finally, for the scale-up to Rome's distribution network.

In this way, we can easily compare how variations in each parameter's value might yield significant or negligible impacts, depending on the scale of the intervention (pilot's sub-project, pilot as a whole or entire distribution network).

It should be noted that the impact of potential OPEX and CAPEX yearly cost increases over and above the baseline yearly inflation rate. This test was only performed on the whole of Rome, as the Malagrotta project is included in it and most of the CAPEX and OPEX expenses yet to be incurred obviously regard the Smart Grid scale-up to Rome's network, as historical values have been taken into account when calculating the NPVs for both Malagrotta and the three sub-projects.

The aim is to capture the possible effects of a sharp increase of imported inflation on the cost of physical capital. As seen, such effects are assumed to concentrate on CAPEX, where capital intensity is likely higher, and reach rather aggressive values (up to 16% yearly increase), as a conservative measure to cover the possibility of spiralling inflation. As will be seen presently, not even rather dramatic scenarios such as these can drive the project's NPVs for Rome below zero.

2.4.1. *Sensitivity analysis sub-project 1: MV Automation*

Table 11 reports the results of sensitivity analysis of selected parameters on the NPV for project 1 (Automation of Medium Voltage grid), where the red areas show lower NPV values. Cells in yellow show NPVs calculated according to baseline parameters, as reported in Table 3, whereas the figures in the green or red areas represent variations in NPV as parameter values change.

While the CBA outcomes may change significantly depending on the variation of key variables considered, under no circumstances are the signs of the NPV values overturned, confirming JRC's CBA methodology as an appropriate tool for investment decisions.

Financial discount rate	0.0%	1.0%	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%
Rome	17,007	14,412	12,097	10,026	8,171	6,505	5,006	3,655	2,434
Malagrotta	-8	-139	-261	-374	-481	-582	-678	-769	-856

Pct of uncertainty of benefits monetisation	-2.0%	0.0%	2.0%	4.0%	6.0%	8.0%	10.0%	12.0%	14.0%	16.0%	17.0%
Rome	10,026	10,026	10,026	10,026	10,026	10,026	10,017	9,979	9,941	9,903	9,884
Malagrotta	-368	-370	-373	-376	-378	-381	-383	-386	-388	-391	-392

Yearly decrease rate of benefits from infrastructure	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%	9.0%	10.0%	11.0%
Rome	10,026	10,026	10,026	10,026	10,026	10,026	10,026	10,026	10,026	9,952
Malagrotta	-349	-358	-367	-374	-381	-388	-394	-400	-405	-410

Pct of electricity demand increase per year	-1.0%	-0.5%	0.0%	0.5%	1.0%	1.5%
Rome	10,026	10,026	10,026	10,026	10,026	10,026
Malagrotta	-387	-384	-381	-378	-374	-371

Yearly increase in CAPEX costs	0.0%	2.0%	4.0%	6.0%	8.0%	10.0%	12.0%	14.0%	16.0%
Rome	10,026	9,834	9,638	9,438	9,235	9,028	8,817	8,603	8,385

Yearly increase in OPEX costs	0.0%	2.0%	4.0%	6.0%
Rome	10,026	9,950	9,859	9,751

Table 11: Sensitivity analysis of private investor's CBA for sub-project 1 – MV Automation (values in K€, base year 2014).

It can be noticed that Malagrotta and Rome display a different behaviour in the sensitivity analysis for variations of the percentage of electricity demand increase per year: this is a consequence of the introduction of the cap on benefits from avoided penalties which was discussed in section 2.3.5. As soon as these exceed €5.5 mln, the value factored in the computation of NPVs will remain constant. This fact becomes even more apparent in the case of yearly decrease of infrastructure-related benefits, where NPVs only start dwindling after such decline in benefits is rapid enough to reduce their overall amount below the defined cap.

Social discount rate	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%	5.0%
Rome	17,007	15,672	14,412	13,222	12,097	11,033	10,026	9,074	8,171	7,316	6,505
Malagrotta	-51	-118	-182	-244	-304	-362	-418	-473	-526	-577	-627

Table 12: Sensitivity analysis of societal CBA for sub-project 1 – MV Automation (values in K€, base year 2014)

As for the Societal CBA, Table 12 shows the impact of changing values of SDR, i.e. the only parameter driving the difference between societal and private investor CBA for this sub-project: despite the huge variation in NPVs, the CBA outcome stays very positive throughout.

2.4.2. Sensitivity analysis sub-project 2: LV Monitoring and Remote Control

Table 13 and Table 14 report the results of the sensitivity analysis for sub-project 2 (LV Monitoring and Remote Control) for the private-investor and the societal CBAs.

Financial discount rate	0.0%	1.0%	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%
Rome	36,241	31,897	28,039	24,608	21,550	18,819	16,376	14,188	12,224
Malagrotta	-153	-260	-361	-456	-546	-632	-713	-791	-866

Pct of uncertainty of benefits monetisation	-2.0%	0.0%	2.0%	4.0%	6.0%	8.0%	10.0%	12.0%	14.0%	16.0%	17.0%
Rome	24,662	24,640	24,619	24,597	24,576	24,554	24,532	24,511	24,489	24,468	24,457
Malagrotta	-455	-455	-456	-457	-457	-458	-459	-459	-460	-460	-461

Yearly decrease rate of benefits from infrastructure	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%	9.0%	10.0%	11.0%
Rome	24,608	24,608	24,608	24,608	24,608	24,608	24,608	24,608	24,608	24,558
Malagrotta	-450	-452	-454	-456	-458	-460	-461	-463	-464	-465

Pct of electricity demand increase per year	-1.0%	-0.5%	0.0%	0.5%	1.0%	1.5%
Rome	24,608	24,608	24,608	24,608	24,608	24,608
Malagrotta	-459	-459	-458	-457	-456	-455

Yearly increase in CAPEX costs	0.0%	2.0%	4.0%	6.0%	8.0%	10.0%	12.0%	14.0%	16.0%
Rome	24,608	24,078	23,527	22,954	22,357	21,737	21,093	20,424	19,730

Yearly increase in OPEX costs	0.0%	2.0%	4.0%	6.0%
Rome	24,608	24,575	24,537	24,491

Table 13: Sensitivity analysis of private investor's CBA for sub-project 2 – LV Monitoring and Remote Control (values in K€, base year 2014)

Although the NPV for this sub-project is expected to remain positive, it is interesting to note that uncertainty over benefits monetisation, yearly rate of benefit decline, percentage of electricity demand increase per year and yearly increase in OPEX costs do not make any significant difference on the sub-project's outcome, pointing to the FDR as only source of variation of NPV across the time-horizon considered.

The divergence in the dynamics of Malagrotta's and Rome's sensitivity analyses has the same explanation as for sub-project 1, with the only difference that (as already seen in Figure 7 of Section 2.3.5) sub-project 2 results in higher benefits. Again, this is particularly evident for the same two parameters. Resulting NPVs remain constant as demand increases and benefits decline: indeed, total benefits for this sub-project exceed the €5.5 mln cap for all values of these parameters that were considered.

Table 14 reports the Societal CBA's sensitivity analysis for sub-project 2, once again for SDR only. A wider range of variation w.r.t. sub-project 1 can be noted; however, even for extreme SDR values, the CBA proves to have significantly positive economic effects from a societal standpoint.

Social discount rate	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%	5.0%
Rome	36,241	34,004	31,897	29,911	28,039	26,274	24,608	23,035	21,550	20,146	18,819
Malagrotta	-153	-207	-260	-312	-361	-410	-456	-502	-546	-589	-632

Table 14: Sensitivity analysis of Societal CBA for sub-project 2 – LV Monitoring and Remote Control (values in K€, base year 2014)

2.4.3. Sensitivity analysis sub-project 3: New Grid Management Criteria

Table 15 and Table 16 report the results of the sensitivity analysis for both the private investor's and societal CBA for of sub-project 3 (New grid management criteria) for Malagrotta and the whole city of Rome.

Once again, it can be readily seen that neither for Malagrotta nor for Rome does any parameter value in the ranges considered revert the signs of NPVs. It is remarkable, however, that the margin keeping the values of this sub-project above (or below) zero is significantly smaller than for the previous two. Extreme FDR values, in particular manage to drive its figures relatively close to this limit.

Financial discount rate	0.0%	1.0%	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%
Rome	2,320	1,984	1,681	1,406	1,155	926	716	522	344
Malagrotta	-98	-217	-328	-432	-529	-620	-706	-788	-866

Pct of uncertainty of benefits monetisation	-2.0%	0.0%	2.0%	4.0%	6.0%	8.0%	10.0%	12.0%	14.0%	16.0%	17.0%
Rome	1,506	1,466	1,426	1,386	1,346	1,306	1,266	1,227	1,187	1,147	1,127
Malagrotta	-430	-431	-431	-432	-432	-433	-433	-434	-434	-435	-435

Yearly decrease rate of benefits from software	0.0%	1.0%	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%
Rome	1,517	1,406	1,303	1,206	1,117	1,033	955	882	814
Malagrotta	-430	-432	-433	-435	-436	-437	-438	-439	-440

Pct of electricity demand increase per year	-1.0%	-0.5%	0.0%	0.5%	1.0%	1.5%
Rome	1,210	1,257	1,305	1,354	1,406	1,459
Malagrotta	-435	-434	-433	-432	-432	-431

Yearly increase in CAPEX costs	0.0%	2.0%	4.0%	6.0%	8.0%	10.0%	12.0%	14.0%	16.0%
Rome	1,406	1,403	1,399	1,395	1,392	1,387	1,383	1,379	1,374

Yearly increase in OPEX costs	0.0%	2.0%	4.0%	6.0%
Rome	1,406	1,403	1,400	1,396

Table 15: Sensitivity analysis Private investor's CBA for sub-project 3 - New Grid Management Criteria (values in K€, base year 2014)

Analogously to the previous two sub-projects, Table 16 shows the results of the sensitivity analysis on the relevant parameters for the New Management Criteria sub-project from a societal standpoint. Once again, for all the relevant changes in parameters values, resulting NPVs can be considered rather stable for Malagrotta and Rome alike.

Social discount rate	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%	5.0%		
Rome	2,514	2,331	2,158	1,994	1,837	1,688	1,546	1,411	1,282	1,158	1,040		
Malagrotta	-93	-154	-212	-269	-323	-376	-427	-477	-525	-571	-616		
Price of ton of CO_2-eq	0	5	10	15	20	25	30	35	40	45	50		
Rome	1,342	1,457	1,573	1,688	1,804	1,920	2,035	2,151	2,266	2,382	2,497		
Malagrotta	-381	-379	-378	-376	-375	-373	-372	-370	-368	-367	-365		
Emission factor	0.56	0.59	0.62	0.65	0.68	0.71	0.74	0.77	0.80	0.83	0.86	0.89	0.92
Rome	1,587	1,601	1,616	1,631	1,645	1,660	1,675	1,689	1,704	1,719	1,733	1,748	1,763
Malagrotta	-378	-377	-377	-377	-377	-377	-376	-376	-376	-376	-376	-375	-375

Table 16: Sensitivity analysis of Societal CBA for sub-project 3 - New Grid Management Criteria (values in K€, base year 2014)

2.4.4. Sensitivity analysis of aggregate Smart Grids project (all three sub-projects together)

Finally, Table 17 and Table 18 present the results of the sensitivity analysis for the overall Smart Grid project (MV automation, LV monitoring and remote control and new grid management criteria).

Expectedly, the sensitivity analysis confirms the negative NPV of the Malagrotta project from both the private investor's and the societal point of view (although with much less negative values in the latter case). As explained, such results are quite expected when dealing with a pilot project; however, no scale-up of Smart Grid solutions would have been possible without the realisation of the pilot, and no real data to carry out a reliable CBA would have been available.

Financial discount rate	0.0%	1.0%	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%
Rome	55,449	48,194	41,735	35,972	30,821	26,206	22,065	18,341	14,987
Malagrotta	-259	-617	-950	-1,262	-1,556	-1,834	-2,097	-2,348	-2,588

Pct of uncertainty of benefits monetisation	-2.0%	0.0%	2.0%	4.0%	6.0%	8.0%	10.0%	12.0%	14.0%	16.0%	17.0%
Rome	36,220	36,121	36,022	35,922	35,823	35,724	35,624	35,525	35,426	35,327	35,277
Malagrotta	-1,253	-1,257	-1,260	-1,264	-1,268	-1,272	-1,275	-1,279	-1,283	-1,286	-1,288

Yearly decrease rate of benefits from infrastructure	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%	9.0%	10.0%	11.0%
Rome	35,972	35,972	35,972	35,972	35,972	35,972	35,972	35,972	35,972	35,849
Malagrotta	-1,231	-1,242	-1,253	-1,262	-1,271	-1,279	-1,287	-1,294	-1,300	-1,306

Yearly decrease rate of benefits from software	0.0%	1.0%	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%
Rome	36,083	35,972	35,869	35,772	35,683	35,599	35,521	35,448	35,380
Malagrotta	-1,261	-1,262	-1,264	-1,265	-1,267	-1,268	-1,269	-1,270	-1,271

Pct of electricity demand increase per year	-1.0%	-0.5%	0.0%	0.5%	1.0%	1.5%
Rome	35,776	35,823	35,871	35,920	35,972	36,025
Malagrotta	-1,281	-1,277	-1,272	-1,267	-1,262	-1,257

Yearly increase in CAPEX costs	0.0%	2.0%	4.0%	6.0%	8.0%	10.0%	12.0%	14.0%	16.0%
Rome	35,972	35,246	34,496	33,719	32,915	32,084	31,225	30,337	29,420

Yearly increase in OPEX costs	0.0%	2.0%	4.0%	6.0%
Rome	35,972	35,835	35,673	35,482

Table 17: Sensitivity analysis of Private investor CBA for ACEA's Smart Grids project (values in K€, base year 2014)

In conclusion, let us see the results for the societal CBA concerning the parameters which are specific to it (the results for all other variables are essentially the same as for the private-investor CBA). As can be seen, under no considered scenario does the picture undergo any fundamental changes.

Social discount rate	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%	5.0%
Rome	55,887	52,133	48,592	45,252	42,098	39,119	36,303	33,642	31,124	28,741	26,484
Malagrotta	-254	-436	-612	-781	-945	-1,104	-1,258	-1,407	-1,552	-1,693	-1,830

Price of ton of CO_2-eq	0	5	10	15	20	25	30	35	40	45	50
Rome	38,772	38,887	39,003	39,119	39,234	39,350	39,465	39,581	39,696	39,812	39,928
Malagrotta	-1,109	-1,107	-1,106	-1,104	-1,103	-1,101	-1,099	-1,098	-1,096	-1,095	-1,093

Emission factor	0.56	0.59	0.62	0.65	0.68	0.71	0.74	0.77	0.80	0.83	0.86	0.89	0.92
Rome	39,046	39,061	39,076	39,090	39,105	39,120	39,134	39,149	39,164	39,178	39,193	39,208	39,222
Malagrotta	-1,105	-1,105	-1,105	-1,104	-1,104	-1,104	-1,104	-1,104	-1,103	-1,103	-1,103	-1,103	-1,103

Table 18: Sensitivity analysis of Societal CBA for ACEA's Smart Grids project (values in K€, base year 2014)

3. Conclusions

As seen in the preceding section, the positive overall effect of ACEA's Smart Grid project stands out from the analysis amidst the numerous sources of uncertainty that were taken into consideration. Given the figures above, the case for smartening the grid of the city of Rome seems to be undeniably there. Clearly, this is much reinforced by the singularly low values of Social Discount Factor of present-day Italy, which are arguably tied to specific macroeconomic circumstances and would obviously apply to any given investment project. However, it does not fade away even under the fairly high Financial Discount Factors that were explored during the sensitivity analysis. Similarly, even accounting for substantial amounts of uncertainty in benefits monetisation (17% of reduction) does not overturn Rome's positive NPV estimates, both in the societal and private-investor CBAs. In this context, as already noted, the Malagrotta pilot project seems to be playing very well its pioneering role towards the extension of the infrastructure to the whole of the city.

It seems wise that an exercise of this sort be concluded by a word of caution. No Cost Benefit Analysis of such a complex and strategic commodity as electricity can aim at anything nearing exactness. Indeed, beside the above-discussed uncertainties associated with the monetisation attempts that were carried out, further aspects and channels of impact of Smart Grids were considered for monetisation, and eventually discarded.

Possibly the most relevant is the one regarding other polluting substances released in the course of power generation, such as NOx, SOx, PM10 and PM2.5. The literature on social cost monetisation of these substances (whose main impact is on health rather than climate) still has to reach an agreement even on several methodological issues. This is further compounded by the fact that, unlike CO_2, all the above are local pollutants, whose dispersion in the wider atmosphere is oftentimes a rather slow phenomenon. Hence, their effect strongly depends on the previous concentration in the area of emission, so that a Pigouvian tax aiming to capture their Social Marginal Costs should be varying across space and time. Clearly, in the face of such complexities, an attempt at monetisation at this stage would run a substantial risk of being little more than a finger in the air.

It is essential that any further work aiming at quantifying real economic impacts of Smart Grid project infrastructure bases its analyses on reliable and first-hand data. Therefore, the key for this work has been the dedicated cooperation of ACEA's personnel, who together with the JRC have developed from scratch complex metrics to capture the potential monetary effects of improvements in the quality of electricity supply (duration and number of interruptions mostly) that Smart Grid solution can determine. These metrics constitute the key step of JRC's CBA methodology, i.e. mapping assets into functionalities and then benefits.

Additionally, it is worth noting how active end-consumers are expected to be central for the large-scale roll-out of Smart Grids. This reminds one of the fact that the impact of each Smart Grid project can go beyond what can be captured in monetary terms; therefore, in order to obtain a more complete picture of the Smart Grid scalability challenges, the financial/economic CBA should be complemented with targeted studies on the end-consumer role and non-monetary appraisals of non-quantifiable impacts and externalities (e.g. social/health impacts, contribution to policy goals).

It can be concluded that ACEA's Malagrotta project clearly constitutes an extremely positive experience, one that bodes well for the deployment of Smart Grid infrastructure across EU countries and beyond, as well as for the general effort towards a more sustainable electricity system in Europe. The JRC will continue monitoring the progress of this and other projects by working with relevant Smart

Grid stakeholders in order to shed light on whether and how Smart Grids present a viable business case for investors and society as a whole.

4. Bibliography

ACEA (2013), "V Relazione Semestrale Smart Grid: Progetto pilota Smart Grid ACEA Distribuzione (delibera AEEGSI n. 39/10)", ACEA Distribuzione S.p.A., Rome 2013 http://www.autorita.energia.it/allegati/operatori/elettricita/smartgrid/V%20Rel%20smart%20ACEA%20D.pdf

AEEGSI (2007), "Testo Integrato delle disposizioni dell'autorita per l'energia elettrica e il gas per l'erogazione dei servizi di trasmissione, distribuzione e misura dell'energia elettrica - Periodo di regolazione 2008-2011. Allegato A.i.G.e.i.S.I.", Autorità per l'Energia Elettrica e il Gas. Delibera 348/07.

AEEGSI (2011a), "Deliberation of the Autorità per l'Energia Elettrica e il Gas n. 12/ 2011" , Autorità per l'Energia Elettrica e il Gas.

AEEGSI (2011a), "Testo Integrato delle disposizioni dell'autorità per l'energia elettrica e il gas per l'erogazione dei servizi di trasmissione e distribuzione dell'energia elettrica - Periodo di regolazione 2012-2015. Allegato A. Versione modificata dalle deliberazioni: 157/2012/R/EEL, 288/2012/R/EEL, 343/2012/R/EFR, 576/2012/R/EEL, 581/2012/R/COM, 40/2013/R/EEL, 304/2013/R/EEL, 467/2013/R/COM e 607/2013/R/EEL, 152/2014/R/EEL", Autorità per l'Energia Elettrica e il Gas.

AEEGSI (2012), "Relazione A. I. R.: Disposizione dell' Autorità per l'Energia Elettrica e il Gas per l'erogazione dei servizi di trasmissione, distribuzione e misura dell'energia elettrica per il periodo di regolazione 2012-2015 e disposizioni in materia di condizioni economiche per l'erogazione del servizio di connessione (deliberazione 29 dicembre 2011, ARG/elt 199/11 e deliberazione 26 aprile 2012, 157/2012/R/EEL)", Autorità per l'Energia Elettrica e il Gas.

AEEGSI (2013), "Deliberazione 19 Dicembre 2013, 607/2013/R/EEL", Autorità per l'Energia Elettrica e il Gas.

Bertazzi, A., Fumagalli, E., and Lo Schiavo, L. (2005), "The use of customer outage cost surveys in policy decision-making: the Italian experience in regulating quality of electricity supply", CIRED Paper, presented at the 18th International Conference on Electricity Distribution, Turin, 6th-9th June 2005.

Carraro, C., and Favero, A. (2009), "The economic and financial determinants of carbon prices", *Finance a úvěr - Czech Journal of Economics and Finance*, 59, 2009, no. 5, pp. 396-409.

Chen, C. Y., "The Outlook of Carbon Prices Price Range Forecast for European Union Allowances in European Union Emission Trading Scheme Phase III", Master Programme Energy and Environmental Sciences, University of Groningen, EES 2012-143 T http://ivem.eldoc.ub.rug.nl/FILES/ivempubs/dvrapp/EES-2012/EES-2012-143T/EES-2012-143T_ConnieYunyiChen.pdf

Conferenza dei presidenti delle regioni e delle province autonome (2001), "Studi di fattibilità delle opere pubbliche - Guida per la certificazione da parte dei Nuclei regionali di valutazione e verifica degli investimenti pubblici (NUVV)" (aggiornato nel 2003)
https://www.regione.sardegna.it/documenti/1_13_20050420105857.pdf

Cosentino, V., Favuzza, S., Graditi, G., Ippolito, M. G., Massaro, F., Riva Sanseverino, E., Zizzo, G., "From fuel based generation to smart renewable generation: preliminary design for an islanded system: Part II: selection of future scenario and economical issues", CIRED Paper n. 1076, presented at the 21st International Conference on Electricity Distribution Frankfurt, 6th-9th June 2011
http://www.cired.net/publications/cired2011/part1/papers/CIRED2011_1076_final.pdf

Covenant of Mayors (2010), "Technical annex to the SEAP template instructions document: The emission factors", www.eumayors.eu/IMG/pdf/technical_annex_en.pdf

EC (2002), “Guide to cost-benefit analysis of investment: Structural Fund-ERDF, Cohesion Fund and ISPA”, Brussels. http://ec.europa.eu/regional_policy/sources/docgener/guides/cost/guide02_en.pdf

EC (2006), “Guidance on the methology for carrying out a cost benefit analysis of investment projects”, Brussels. http://ec.europa.eu/regional_policy/sources/docoffic/2007/working/wd4_cost_en.pdf

EC (2008), “Guide to cost-benefit analysis of investment: Structural Funds, Cohesion Fund and Instrument for Pre-Accession”, Brussels. http://ec.europa.eu/regional_policy/sources/docgener/guides/cost/guide2008_en.pdf

EC (2011), “Commission Staff Working Document: Impact Assessment, accompanying document to the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions: A Roadmap for moving to a competitive low carbon economy in 2050”, {SEC(2011) 288 final}, Brussels, 8.3.2011. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2011:0288:FIN:EN:PDF

EC (2013), "Evaluation of Smart Grid projects within the Smart Grid Task Force Expert Group 4 (EG4)" http://ses.jrc.ec.europa.eu/node/284

EC (2014a), “Commission Staff Working Document: Impact Assessment, Accompanying the document Commission Regulation (EU) No 176/2014, amending Regulation (EU) No 1031/2010 in particular to determine the volumes of greenhouse gas emission allowances to be auctioned in 2013-2020”, SWD(2014) 50 final, Brussels, 25.2.2014. http://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2014/swd_2014_0050_en.pdf

EC (2014b), “Guide to Cost-benefit Analysis of Investment Projects Economic appraisal tool for Cohesion Policy 2014-2020”, Luxembourg: Publications Office of

the European Union, 2014.
http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf

EC (2014c) " Benchmarking smart metering deployment in the EU-27 with a focus on electricity" (COM/2014/0356) and accompanying Staff Working Documents: Country fiches for electricity smart metering (SWD/2014/0188 final) and Cost-benefit analyses & state of play of smart metering deployment in the EU-27 (SWD/2014/0189).
http://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters

Evans, D. J., (2006), "Social Discount Rates for the European Union", Working Paper No. 2006–20, Fifth Milan European Economy Workshop, Università degli Studi di Milano, Italy. http://wp.demm.unimi.it/tl_files/wp/2006/DEMM-2006_020wp.pdf

Feldstein, M. S. (1965), "Opportunity cost calculations in cost-benefit analysis", *Kyklos*, 18, pp. 277-287.

Thomson Reuters Point Carbon (2014): Ferdinand, M., "The MSR: Impact on balance and prices", Thomson Reuters Point Carbon
www.ceps.eu/system/files/u153872/Ferdinand.pdf

Hill, J. (2014), "European carbon price set to rise to €23/t between 2021 and 2030", Cleantechnica http://cleantechnica.com/2014/09/02/european-carbon-price-set-rise-e23t-2021-2030/

HM Treasury (1997), "Appraisal and Evaluation in Central Government (The Green Book)", HMSO, London 1997.

IMF (2014), "World Economic Outlook: Recovery Strengthens, Remains Uneven", Washington, April 2014
http://www.imf.org/external/Pubs/ft/weo/2014/01/pdf/text.pdf

Jackson, J. (2011), "The Utility Smart Grid Business Case: Problems, Pitfalls and Ten Real-World Recommendations". Prepared for the 2nd Annual Evaluating the Business Case for Smart Grids Investments, 20th-21st October 2011, Orlando, US. http://www.smartgridnews.com/artman/uploads/1/utility_smart_grid_business_case.pfd

JRC (2014): Covrig C. F., Vasiljevska J., Mengolini A., Fulli G., Amoiralis E. (2014), "Smart Grids projects Outlook 2014", European Commission, Joint Research Centre http://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/publications/ld-na-26609-en-n_smart_grid_projects_outlook_2014_-_online.pdf

JRC (2012): Giordano, V. I. O., and Fulli, G. (2012), "Guidelines for conducting a cost-benefit analysis of Smart Grid projects", European Commission, Joint Research Centre http://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/publications/guidelines_for_conducting_a_cost-benefit_analysis_of_smart_grid_projects.pdf

KEMA Inc. (2010), "Research Evaluation of Wind and Solar Generation, Storage Impact, and Demand Response on the California Grid", prepared for the California Energy Commission. CEC-500- 2010-010 http://www.energy.ca.gov/2010publications/CEC-500-2010-010/CEC-500-2010-010.PDF

OECD (2014), "Economic Outlook", Volume 2014/1 http://www.oecd.org/eco/outlook/Long-term-growth-prospects-and-fiscal-requirements.pdf

Percoco (2008), "A social discount rate for Italy", *Applied Economics Letters*, 2008, 15, 73–77.

Point Carbon (2011), "Average Phase 3 EUA price of €22/t" http://www.commodities-now.com/news/environmental-markets/6934-average-phase-3-eua-price-of-22t.html

Regione Toscana (2013), “Studi di fattibilità” http://www.regione.toscana.it/studi-di-fattibilita

Terna (2013), ”Previsioni della domanda elettrica in Italia e del fabbisogno di potenza necessario anno 2013-2023” http://www.terna.it/LinkClick.aspx?fileticket=uyq0AOycl18%3d&tabid=375&mid=434

Europe Direct is a service to help you find answers to your questions about the European Union
Freephone number (*): 00 800 6 7 8 9 10 11
(*) Certain mobile telephone operators do not allow access to 00 800 numbers or these calls may be billed.

A great deal of additional information on the European Union is available on the Internet.
It can be accessed through the Europa server http://europa.eu.

How to obtain EU publications

Our publications are available from EU Bookshop (http://publications.europa.eu/howto/index_en.htm),
where you can place an order with the sales agent of your choice.

The Publications Office has a worldwide network of sales agents.
You can obtain their contact details by sending a fax to (352) 29 29-42758.

European Commission
EUR 27158 EN– Joint Research Centre – Institute for Energy and Transport

Title: A Smart Grid for the city of Rome: A Cost Benefit Analysis

Authors: Silvia Vitiello, Gianluca Flego, Alessandro Setti, Gianluca Fulli (JRC), Stefano Liotta, Silvio Alessandroni,
Luana Esposito (ACEA), Davide Parisse (External consultant)

Luxembourg: Publications Office of the European Union

2015 – 56 – 21.0 x 29.7 cm

EUR – Scientific and Technical Research series – ISSN 1831-9424 (online), ISSN 1018-5593 (print)

ISBN 978-92-79-46858-2 (PDF)
ISBN 978-92-79-46857-5 (print)

doi:10.2790/50100 (online)

LD-NA-27158-EN-2

JRC Mission

As the Commission's in-house science service, the Joint Research Centre's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle.

Working in close cooperation with policy Directorates-General, the JRC addresses key societal challenges while stimulating innovation through developing new methods, tools and standards, and sharing its know-how with the Member States, the scientific community and international partners.

Serving society
Stimulating innovation
Supporting legislation

doi:10.2790/50100

ISBN 978-92-79-46858-2

Publications Office