CITYOPT - Holistic simulation and optimisation of energy systems in Smart Cities

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Replication guidelines

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Statement of originality

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Table of contents

List of tables

List of figures

Acronyms and Abbreviations

Acronyms and Abbreviations	Definition
DH	District heating
LTS	Low Thermal Storage
HTS	High Thermal Storage
RTA	Rail Tec Arsenal (Climate wind Tunnel)
DOW	Description of Work
CHP	Combined Heat and Power
UI	User Interface
KPI	Key performance indicator
BESS	Battery Energy Storage System
CTG	Combustion Turbine Generator
TSO	Transmission system operator
DSO	Distribution system operator

Table 1: Acronyms and abbreviations

1. EXECUTIVE SUMMARY

The document presents the results of the replication guidelines of the CITYOPT project. CITYOPT project has developed two applications for planning and operation of smart cities. The CITYOPT Planning Tool is an optimization tool which can used to design of energy system of the district. The CITYOPT Operational Tool is a mobile or tablet application which can be used for informing about needs of load shifting in electricity network and for motivating a community of end users to co-operate with electricity company by shifting the use of electrical appliances when a peak load is occurring.

The objective of the document is to explain how to repeat the similar experiments as in CITYOPT demonstrations using the same methods but with different subjects and stakeholders. Furthermore, the guidelines are given for better implementation of the results and utilisation of the CITYOPT tools in the similar analyses in the future. As for some of the study cases, further replication would mainly concern scaling into several similar cases or into even bigger cases by which further development of the simulation models will become inevitable.

The issues assessed in this document are related to how the CITYOPT outcomes and experiences during the study cases can be reused for similar cases in other European countries or other circumstances. In addition, the document identifies what are the criteria that determine the generalizability of the existing simulation models (planning tool) and the operational tool to different locations in Europe.

<u>Summary of results and conclusions (in replication) for Vienna Case</u>

In the Vienna study two critical factor should be consider in future project which explore to recover waste heat from industrial facilities in a district heating network. The first one is temperature ranges and production time of the recovered waste heat defining the design and dimension of the elements. The second one is the financial risk due to the large up-front investments in: the distribution network, the controls equipment and the pumps as well as the industrial companies that would not typically contribute to the investment in heating networks. Therefore, public funding support can be a key element. Additionally, indirect benefits from the development of these types of projects should also be considered into the project (e.g. security, reduction of emissions, improvement of the health quality and creation of local jobs). The strength of the CITYOPT planning tool is in possibilities to model the case, optimize the energy system typology and size dimensioning and present the performance parameters of the optimized case.

<u>Summary of results and conclusions (in replication) for Helsinki Cases Östersundom& Kalasatama.</u>

As for the Östersundom case, one of the most valuable outcomes were the processes of using the CITYOPT planning tool for urban development purposes. The process scheme could be further developed and would have a great replicability for similar purposes anywhere within the EU. The simulation model can be modified to become usable for other locations within the EU as long as local data (weather, consumption profiles etc.) are available. As for the Kalasatama case, the replication rate is high one in case the location is within the borders of Finland. This is mostly due to the market mechanisms and the local legislations are the same as in original case, which simplifies the replicability. The Kalasatama model need to be further developed in order to provide more use options for battery storage. In this way, new business models can be identified and more optimized uses for battery storages can be found.

The CITYOPT Planning Tool is replicable considering its ability to cover system settings of various sizes. Depending on the maturity of the technologies in question and the state of construction of simulated area the CITYOPT Planning Tool can result either in theoretical simulation results or more accurate ones that fit into current ecosystem, and can be validated by monitoring and measurements. The CITYOPT Planning Tool can be adjusted to different setups and hence its usability to other areas has been recognized. To deploy the results requires several stakeholders each of which provides different services and knowledge. Although city planning is a slow process and it hinders the replication of the simulation results into actual use. A risk is that the city plans change during the developing period and the guidelines from CITYOPT Planning Tool are no longer valid. In a smaller system the CITYOPT Planning Tool could be used to run for example different business cases and this would increase the Tool’s replicability to several stakeholders.

Summary of results and conclusions (in replication) for Nice Case

The Nice study has shown the implication of a community for the saving of electricity and to change the behaviour or end users in regards to electric appliances use. The transformation of savings into benefits of community project by a mechanism of crowd funding is an opportunity to take in consideration.

The replication to European countries is recommended when the electricity fare is expensive or when the flexibility of the demand response is desirable: especially for countries which have time dependent consumption peaks and lack of production at the same time.

The practical implementation requires the user side appliances (smart meter system, user devices e.g. tablet or mobile application) and information system from electricity companies giving indication of peak periods. The estimated benefits of the demonstrated approach are beneficial for all the stakeholders involved in the electricity value chain (production, transport, supply) as well as for the end users.

Overall summary of replication potential and aspects

CITYOPT project has provided tools which can be used during the life cycle of energy networks. The CITYOPT Planning tool operates in the study and design phase and is addressed to TSO (transmission system operator), DSO (distribution system operator), energy producer, energy distributor, decision maker (i.e. owner, municipality) and the CITYOPT Operational tool operates during the operational phase and can be addressed to above-mentioned stakeholders and end-users (within a community)

The complete chain of the energy is covered: from the means of production/recovery, the transport, the storage, the distribution and the use.

2. Introduction

2.1. Deliverable context and objectives

The objectives of the replication guidelines are:

- summarize the main finding from the demonstration cases evaluations and to convert them into improvement recommendations for the 3 pilots when considering a replication in a similar context;
- Point out replication conditions in a wider context in different areas.

Beyond the providing of suggestions for those planning to deploy and finance the CITYOPT tools, the replication guidelines are intended to feed the elaboration of the Exploitation plan (WP5 -Task 5.2).

According to the CITYOPT description of work (DOW), the replication guidelines considers the previous technical and socio-economic results and their business models (Task 4.1 Technical evaluation; Task 4.2 Economic evaluation; T4.3 User-acceptance evaluation) but also associated cultural and country specific aspects such regulations or incentives.

This report is part of CITYOPT (Holistic simulation and optimisation of energy systems in Smart Cities, project in EU funded 7th Framework Programme) work package 4 Evaluation, Task 4.4 Suggestions for RTD and take-up.

2.2. Adopted methodology for the guidelines elaboration

In order to provide the replication guidelines and according to the DoW provisions, two replication contexts were considered:

- Areas and contexts similar to the three project pilots;
- Significantly different areas and contexts.

The first step of the methodology has been to finely characterize the pilot contexts in order to be able to distinguish between “similar” and “significantly different” contexts. For that purpose we have taken into account three key aspects (criteria):

- National regulation, local strategic plans and incentives (what, when)
- Local urban planning, monitoring issues with regard to energy (for what purpose, where);
- Local governance, strategies, projects and know-how of the stakeholders (with whom).

Three pilot contexts were described (Section 2 hereinafter) with regard to these three aspects and analysed them in order to highlight the key characteristics that should be found in areas and contexts considered as “similar”.

The second step of our methodology was to identify what were the key implementation stages of the two CITYOPT tools (Planning and Operation tool) in the three pilots (e.g. initial activities, lab tests, users tests, ...) and, beyond the CITYOPT partners, what other local stakeholders have taken active part in the pilot deployment or having got benefits from the tools use (Section 2 hereinafter).

Per pilot, per implementation stage and on the basis of the technical and socio-economic evaluations results (Task 4.1 Technical evaluation; Task 4.2 Economic evaluation; T4.3 User-acceptance evaluation) we have performed a replication analysis (third step) aimed at identifying (Section 2) the improvement recommendations for similar contexts i.e. if the project could start again the stage, how to do better from both technical and socio-economic point of view?

In the fourth step a brainstorming within the partners involved in Task 4.4 was organised. This has led partners to:

- discuss the scalability of the project results in areas and contexts having different characteristics;
- Identify the replication guidelines in wider contexts, i.e. if we should advice future users, what technical and socio-economic aspects to put forward to overcome possible barriers and to make the implementation successful?

It has to be noticed that according to the considered implementation step and pilot maturity, the replication guidelines are intended by future users in a RTD or in a market context.

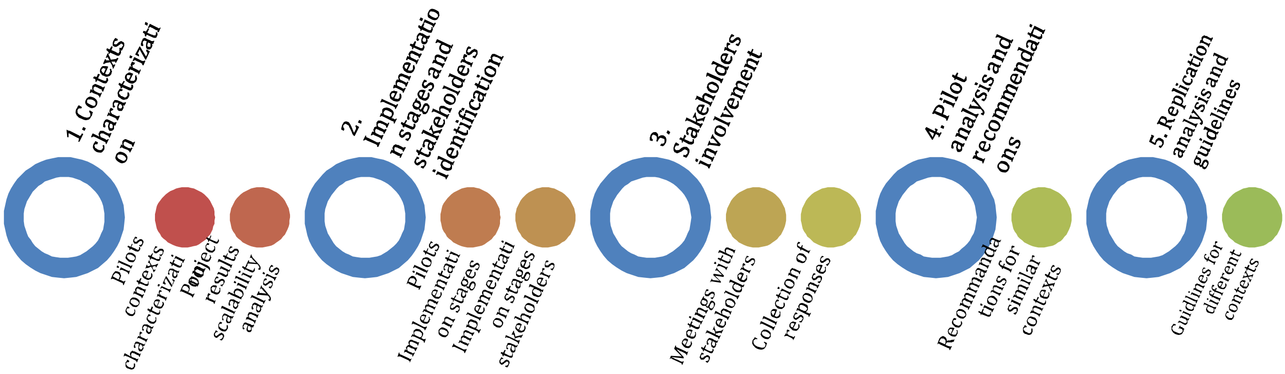


Figure 1: Summary of the adopted methodology

3. Lessons learned from pilots and recommendations

3.1. CITYOPT Planning tool

The CITYOPT planning tool supports simulating, optimizing and analysing various city planning alternatives and their impact. It offers the possibility to combine different integrated energy sources like renewables, storage facilities, energy efficient buildings assets, etc. in order to find the strategy which gives the best compromise in term of sustainability and economic benefits for the stakeholders in charge of the city planning.

3.1.1. Vienna pilot

The Vienna study case is based on three office buildings located on the 21st district of Vienna named TECHbase, ENERGYbase and FUTUREbase. FUTUREbase is still under planning and therefore is not already built. They lie in close proximity to the facilities of Rail Tec Arsenal GmbH (RTA). This facility tests the operation of vehicles at low temperatures using for this purpose a climatic wind tunnel of big dimensions. During these tests a huge amount of waste heat is rejected from the chillers to the air employed to cold down the climatic wind tunnel.

The goal of the Vienna study case is to integrate the existing thermal energy supply systems with the cooling system of RTA’s climatic tunnel in a thermal network that will make use of the waste heat to cover the office buildings’ heating demand. In this study case the design of this district heating network will be set including the requirements on thermal storage to match the time dependence of waste heat production with the heat demand in terms of primary energy savings, CO2 emissions and costs. CITYOPT Planning tool will be used as “laboratory testing”. Therefore, CITYOPT Planning tool will be used to assess the optimal design of the district heating network to integrate its different elements (building, thermal storages, energy supply systems, Vienna district heating network and waste heat from RTA).

3.1.1.1. Pilot context and results

District heating market in Austria

There are two types of “district heating” in Austria: The “Fernwärme”, which is the same as the usual terminology for district heating, and the “Nahwärme”, which refers to the small, local systems, usually with a capacity between 50 kW and a few MW, and often using lower temperature water. The two main energy sources for district heat generation are natural gas and renewable sources where the use of wood waste, and is typical particularly at the small, “Nahwärme” systems. Additionally, the share of CHP in district heating production is quite high: in the last 10 years it was between 60% and 70%. District heating has a quite competitive price compared to other energy sources being in average 134€/MWh[1]. Nevertheless, the information about prices is quite heterogeneous, as there are sometimes big differences among cities/regions.

The share of households using district heating is quite high in Austria, especially in a few cities. In 2012 it was 28% in the whole country, while in Klagenfurt it was 30%, in Vienna 36% and in Linz 60%[2]. The two biggest consumers of DH are the residential sector with 41% and the services with 36%. Industry has a 14% share of total DH consumption (the remaining part accounts for losses). In 2010 a significant increase is visible in total DH consumption, from under 70 to above 80 PJ, and that latter level more or less remained the same in 2011 and 2012. In Austria majority of the regulation is managed on "länder" (federal state) level, while there is also national regulation. There are different measures in the federal state level that promote the operation and extension of district heating systems, in some cases including compulsory connections[3].

In Austria no national price regulation is in force, usually the municipalities are responsible for price setting as many of the DH companies are owned by them. Some cases DH companies set prices freely and competition authority monitors excessive profits based on competition law[4], other cases the municipality sets the prices. Prices are quite different among various parts of the country, and the price setting methodology is not always published. The most commonly used methodology is the cost-plus price regulation[5]. In Wien for example, energy prices charged for space heating are subject to official price decision, issued by the Governor of Vienna[6]. In Linz, the city with the highest share of district heating, the prices did not change from 1990 until 2004, and the little bit higher 2011 price level was the same as the one in 1983[7]. In 2011 and 2012 Linz AG raised the prices referring to increasing fuel prices and consumer price index, but still this price is the lowest across Austria.

Industrial waste heat in Vienna

The load and temperature profiles of industrial processes as well as their combination on site vary a lot between different branches and even between different plants of the same branch producing similar goods. Therefore it is necessary to analyze viability of waste heat integration on the basis of exemplary plants. This is furthermore important as the available waste heat potential, which can possibly be integrated into district heating grids. Furthermore the overall integration capacity of industrial waste heat into existing district heating networks has to be discussed in detail. Empirical load data of existing heating grids show that in summer only about 10% of the maximum power in winter is needed. In general, industrial plants do not have higher production rates in winter than in summer; this means that only a comparable small part of the power demand is accessible for industrial waste heat. Moreover the industrial waste heat then is in competition with a possible heat supply from waste incineration being constant all over the year. E.g. in the Viennese district heating

[1] Fernwärme, sicher, sauber, bequem - Eine Informationsbroschüre der österreichischen Fernwärmewirtschaft, http://www.fernwaerme.at/media/uploads/misc/fernwaerme.pdf, In the following part of this study, we will use the ex-pression district heating for both of them, because in the statistics there are rarely separate numbers for them.
[2] Source : https://www.gaswaerme.at/bfw/themen/index_html?uid=2737
[3] European Commission's Progress Report on the application of Directive 2006/32/EC on energy end-use efficiency and energy services and on the application of Directive 2004/8/EC on the promotion of cogeneration based on a useful
[4] http://www.epha.ee/File/Overview%20of%20DH%20pricing%20and%20regulation%20in%20Europe_H-P%20Korhonen.pdf
[5] IEA: Coming in from the cold - Improving District Heating Policy in Transition Economies, 2004
[6] https://www.wienenergie.at/eportal/ep/programView.do/pageTypeId/11889/programId/15491/channelId/-22264
[7] http://www.linz.at/images/LL_207_43_43_Fernwaerme.pdf

grid nearly the whole base load in summer is provided by waste incineration, leading to a very limited integration potential for industrial waste heat[8].

Figure 2 shows that the densely built-up inner districts the waste heat supply rate would be comparatively low (marked in red and orange) in Vienna. In areas in the outskirt districts near commercial/industrial sites there is sufficient waste heat available to supply new residential areas which are currently planned or under construction.

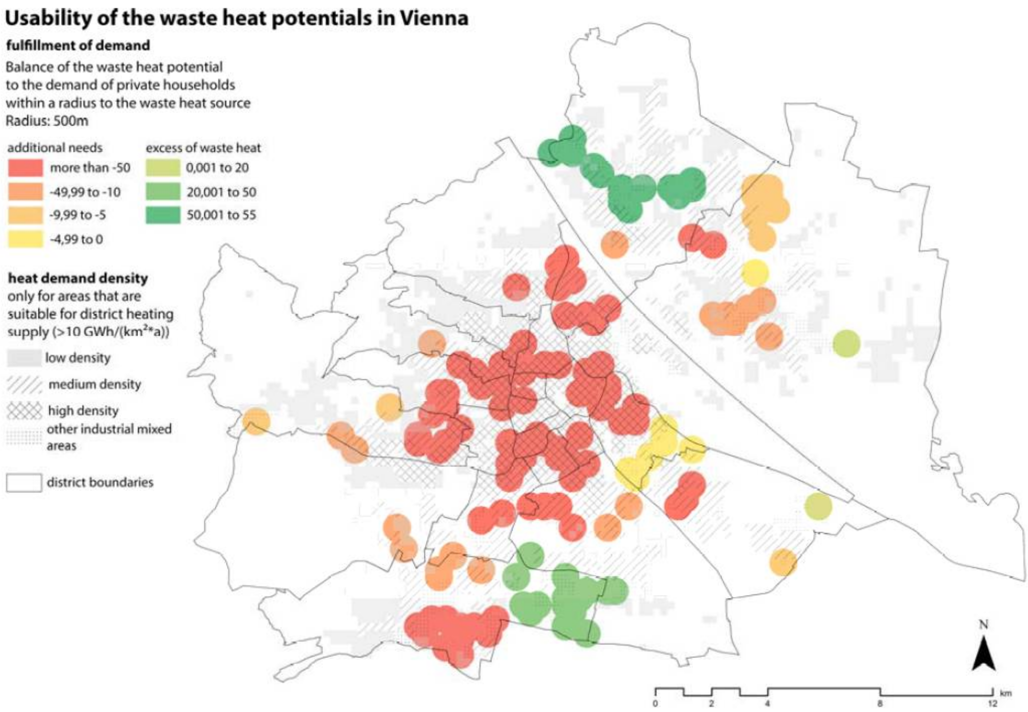


Figure 2: Residential heating demand in Vienna, to be covered by waste heat from commercial[9]

Additionally, some project of DH system utilizing waste heat has been implemented in the city of Vienna (see Table 2). Nevertheless, all of them are related with continuous process where the uncertainties concerning temperature ranges and time production of the heat are relatively low compare with use of waste heat production from RTA´s wind climate tunnel analyzed in the Vienna study case under CITYOPT project.

Industry	Company name	Use of waste heat	Available waste heat

[8] Hummel Marcus et al., Assessment of the economic viability of the integration of industrial waste heat into existing district heating grids

[9] W. Loibl et al. Waste-heat re-use from commercial sources in urban environments – identification of potentials and assessment of supply-demand matches, a Vienna case study, 2016. WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT

Production of detergents / cleaners, glue	Henkel Austria	Heat of the drying process is transferred to district heating Wien via heat exchangers	19,400 MWh per year
Storage	United ice factories	Internal consumption for building heating, large part: feed into the district heating network	13,400 MWh per year
Meat processing	Company Trünkel	Internal waste heat of the combined refrigeration system	217.7 MWh per year
Manufacture of electricity distribution and control apparatus	Heart valves	Internal use of the exhaust air of the melting furnaces, delivery of the excess heat to neighbouring production operation via local heating circuit	366.7 MWh per year
vehicle construction	MAN Commercial Vehicles	Waste heat from the exhaust fumes of the thermal afterburning of solvent vapours in paint systems or drying rooms can be fed into the firing network	2,353 MWh per year
vehicle construction	General Motors	Internal use for engine preheating	4,457.8 MWh per year
laundry	Service wash and cleaning unit (SWR) - Wiener Krankenanstaltenverbund	Waste water heat exchanger for heating the fresh water	Saving 1,700 MWh of steam per year

Table 2: Project already implemented in the city of Vienna to recover waste heat from the industrial process to be used in the district heating network

<u>Use of the CITYOPT Planning Tool in the study case</u>

The goal of the Vienna study case is to integrate the existing thermal energy supply systems with the cooling system of RTA's climatic tunnel in a thermal network that will make use of the industrial waste heat to cover the office buildings' heating demand.

CITYOPT Planning tool was used as "laboratory testing" because the different configurations and scenarios cannot be implemented in a real-world demonstration case as the implementation of the district heating network will not take place during the scope of the CITYOPT project. The different elements have been modelled and integrated in APROS to create the overall template for the Vienna study case. The elements modelled by APROS where the energy system of the different buildings, three office buildings, the district heating network, two thermal storages and the control system. The model was extended including and additional building and a connection to main district heating network to generalize the model and increase the replicability and scalability.

Two reference cases REF1 and REF2 (only 3 buildings involved or 4 buildings and a connection to the main DH of Vienna) have been used to set up four configurations of the Vienna study case. Configuration 1A considers three office buildings with a water tank (High Temperature Storage, HTS) as thermal storage, Configuration 1B extends configuration A by including a ground heat storage (Low Temperature Storage, LTS), Configuration 2A extends configuration 1A with an additional office building and Configuration 2B extends configuration 2A including a ground heat storage. For each configuration, several scenarios were created to explore the use and design of a ground heat storage and/or a water tank storage including the analysis to explore the optimal solutions in terms of primary energy consumption, CO2 emissions and costs.

Point of view of stakeholders for CITYOPT planning tool

The study concerning usability of the CITYOPT planning tool was done based on interviews with AIT experts in modelling and stakeholders linked to the activities of the Vienna study case.

The AIT experts gave an overall positive feedback of the tool, thanks to the high potentiality of its application in their daily work tasks. In particular the tool is seen as a ready-to-use visual support for the first steps in decision making process, given its features of envisioning and changing variables, comparing different scenarios, and speeding up the initial evaluation process. The first usage of the tool requires preliminary preparation due to the still fragmented parts of the navigation and some misleading interpretation labels. However, efficiency is high as it is easy to perform the tasks and get the required results, once the user got familiar with the tool. Minor errors were due to repetitiveness of the tasks, but they can be easily solved by providing more intuitive UI elements and clearer information about the required data.

From the interview with the stakeholders, the general outcome was that the tool can support in making decisions and support discussions among them for the development of the projects. In this sense, one very important aspect is the capability of CITYOPT Planning tool to create metrics to evaluate the economic viability of an investment. The flexibility of the tool was also appreciated, indeed it easily allows linking any type of energy model, since it allows to use specific models to get optimal solution depending of their needs and constraints. This was specially highlighted by RTA´s wind climate tunnel, because the possibility of the CITYOPT planning tool to work with dynamic simulations is essential to treat the variability of the industrial waste heat in terms of production and temperature ranges.

Main results achieved in the study case

The analysis of the results from the simulations of the Vienna study case in CITYOPT, indicates that the best scenario, no matter the reference case chosen, is never the same if only the costs are considered or if only the Primary energy and CO2 emissions are considered. In case that only the metrics Primary energy and CO2 emissions are taken into account, then the best scenario, for each reference REF1 and REF2, is a scenario that does not imply the LTS, but only the HTS: 100 m^3 when 3 buildings are considered and 150 m^3 when 4 buildings are considered. For the point of view of the cost, this means considering only the metric Costs, then the best scenario involves a 1960 m^3 LTS and a 150 m^3 or 100 m^3 HTS. For both cases (only 3 buildings involved or 4 buildings and a connection to the main DH of Vienna), the best scenario in terms of operational costs is also the worst scenario in terms of Primary energy used and CO2 emissions.

The use of high temperature storage alone, for industrial waste heat, is not economically feasible, if its capacity is limited, because this leads to high operational costs due to the gas boilers use, making the all investment non-profitable. A low temperature storage allows using a high share of waste heat, has low operational costs but generates a non-negligible amount of CO2 due to the need of a heat pump booster to raise up the temperatures to the level required by the customers. A simple economic analysis shows that cases with a LTS and a HTS can pay off, but only on a long term period.

At first glance, the replicability of the Vienna study case can seem limited, because of the limited amount of customers and all its specificities, but considering all the different combinations possible in this case, the flexibility of the APROS models and all the challenges it addresses, such as fluctuating energy supply, low-temperatures, integration of new buildings, this Vienna study case can be scaled up and suitable for many other cases.

This section presents SWOT analysis for the design, development and test stages together with the recommendation for future developments. The table 3 presents the SWOT analysis for the Vienna study case.

SWOT Analysis of Vienna study case

Strengths	Weaknesses
▪ CITYOPT Planning tool is generic giving the possibility to link other energy modelling software a part of APROS. ▪ Possibility to use detailed models based on dynamic simulations to explore the use of industrial waste heat in the district heating networks. ▪ CITYOPT planning tool allow to analyse the use the heat rejected by RTA into a local heating district network and the use of different type of thermal storages including the design of these elements. ▪ CITYOPT planning tool is a generic numerical optimization tool which allows the use two different numerical optimization algorithms (Database search optimization and GA algorithms)	▪ The long simulation time for the district heating model of the Vienna study case prevented the use GA optimization ▪ High amount of data in terms of quantity and quality ▪ The contribution of the stakeholders was limited due to their lack of resources for contribution ▪ Low capacity of the current server to perform the simulations ▪ The first use of the CITYOPT planning tool requires preliminary preparation ▪ CITYOPT planning tool should be more transparent about the data which are used into the district heating models of the Vienna study case. ▪ Lack of interactive guidelines in the CITYOPT planning tool.

▪ CITYOPT planning tool can support the first steps during the decision making among the stakeholders for the implementation and design of a micro-district heating network which use industrial waste heat creating scenarios, metrics and visualization the results ▪ CITYOPT planning tool allows to create metrics base on the results of the simulation including the assessment of economic aspects (e.g. payback period of the investments) ▪ CITYOPT planning tool allows creating tables and charts to visualize the results easily ▪ The model allows identifying the optimal design is terms of Cost, Emission and Energy for a micro-district heating network which use industrial waste heat creating scenario ▪ CITYOPT planning tool store the results of the run scenarios to be reused	▪ The workflow to create expressions is complex (e.g. metric) and requires expertise ▪ Low functionalities to customize the charts and tables
Opportunities ▪ Support the energy companies (e.g. WienEnergy) to optimize the design of their district heating network and to explore the inclusion of the industrial waste heat as heating sources. ▪ Support the energy companies and other stakeholders to develop new business models (e.g. Wirtschaftsagentur Wien, WienEnergy…). ▪ Support to the Wirtschaftsagentur Wien in the decision making process for new investments in building to adopt new energy solution in their buildings (e.g. heap pumps together with thermal solar panels) ▪ Support to the Wirtschaftsagentur Wien to optimize new innovative buildings (e.g. Asper IQ) which are not economically profitable in terms of technology innovation to reduce the subsidies.	Threats ▪ Energy simulation software with already implemented optimization algorithm specific for their algorithm ▪ CITYOPT planning tool could be too technical for specific stakeholders producing a loss of attractiveness. ▪ The high effort to develop and calibrate a dynamic district heating model from scratch could be a high constraint for the commercial success.

▪ Possible project to use CITYOPT planning tool to optimize the design and operation for RTA´s Climate tunnel ▪ The development of additional communication surfaces with other energy modelling software (e.g. TRNSYS) ▪ Flexibility of the CITYOPT tool to connect other urban simulation engines (e.g. TRNSYS). ▪ Provide consulting services to similar study cases were industrial heat waste production has a high variability in terms of temperature range and production. ▪ Improve the performance of speed of the CITYOPT Planning tool by changing the server with higher capacity. ▪ using CITYOPT Planning Tools is business opportunity for energy consult	

Table 4: CITYOPT Planning Tools SWOT for the Vienna study Case

The next table shows the recommendation for the user experiences, stakeholder and AIT technician involved in the project.

	Recommendations for the replication of the Vienna study Case
Socio-Technical Aspects	Early engagement of the stakeholders, especially in the design phase, to identify their needs and vision of the project. This allows creating a common understanding and use CITYOPT planning tool to support in their decision making process in a more efficient way. The energy model software, degree of detail of the model, data quantity and quality, optimization methods, tested scenarios and metrics has to be discussed and agreed with the stakeholders to avoid future problems in the subsequence stages of the project.
Technical aspects	The User Interface should be improved to be more intuitive to increase the attractiveness of the stakeholders. In this sense the improvement of the workflows for setting parameters, scenarios, expression in metrics and transparency of the data used for the design of the district heating model should be improved.

	The User Interface should include additional functionalities to customize tables and charts. These improvements will allow communicating in a more effective way the results to the stakeholders giving support in the decision making process. The balance between quality of the results and time consuming has to be consider in the selection of the energy modelling software to be used into the project. In the Vienna study case, APROS was the proper tool to capture the dynamics of the elements of the district heating network but with high increase of the simulation time of the scenarios. The use of different simulation vendors in different granularities is very important to cover more potential customers and domains in terms of modelling. This is because the exploitation and commercial success if CITYOPT planning tool highly depends on the effort to develop and calibrate the simulation models, which represent the heart of each study case. The training and interactive tutorial for the users about the CITYOPT planning tool and study cases should be provided.

Table 5: CITYOPT Planning tools recommendations for the Vienna study case replication.

3.1.2. Helsinki study cases

Two cases were included for the part of Helsinki; the Östersundom case and the Kalasatama case. The focus of these were on energy efficiency and different energy storage solutions as a part of smart city planning. In both cases, the possibilities and benefits of using storage solution in combination with renewable energy production were examined. Furthermore, the suitability of the CITYOPT planning tool for supporting urban planning was also investigated through the Östersundom case.

3.1.2.1. Pilot context and results

Both Helsinki pilot cases were useful for testing the usability of the CITYOPT planning tool from two aspects: optimizing energy system of a larger area and optimizing a more specified energy system for a building block. The main difference between the cases was the detail level of simulation and analysis.

The Östersundom demo considered the overall urban and energy system planning for a future district that will be realized part by part over a total timespan of decades (e.g. 20-50 years). Since the intention was to create an area where renewable energy would have a central role, the complexity of this case came from the numerous combinations of different energy production and heat storage solutions. There would be in total 14 areas, each with their own capacity (according to demand, available resources and land) of renewable energy production and storage. By adding prices and CO_2-emission data to the simulation models thousands of scenarios generated by the planning tool could be compared to each other. From the results it was concluded that the value of optimizing was not in finding one “best” scenario for the Östersundom area. Instead, several good scenarios from which good practice and strategic information can be found to assist urban planning and energy system design.

The CITYOPT planning tool has a good potential as a support tool for urban planning and energy system design. Finnish environmental policy has contributed to goals regarding energy use and production. This has led to incentives and regulations that affects both the building and energy industry. By using the CITYOPT planning tool, stakeholders related to urban planning, local decision making, energy industry, building industry and others could together specify the conditions for the new area according their regulations and interests. A great challenge is, however, to facilitate this kind of process since there are usually stakeholders who are experts in different fields. For instance, an urban planner would not necessarily understand issues related to energy production while an engineer might not know the principles of designing functional areas for living. It became clear during the CITYOPT project that a facilitator would be needed. The facilitator would use the CITYOPT planning tool as a platform through which the stakeholders can interact and communicate. This however requires the facilitator to have some knowledge about the most important elements of urban design and energy system design.

The process of facilitating stakeholders would have a high potential for replication. However, the key elements for successful urban design and development involving stakeholders with different field of expertize and roles need first to be identified. The main processes identified during the CITYOPT project are shown in Figure 3.. These will most likely be further developed and their underlying elements better identified once the use of CITYOPT planning tool is being replicated in other urban development project.

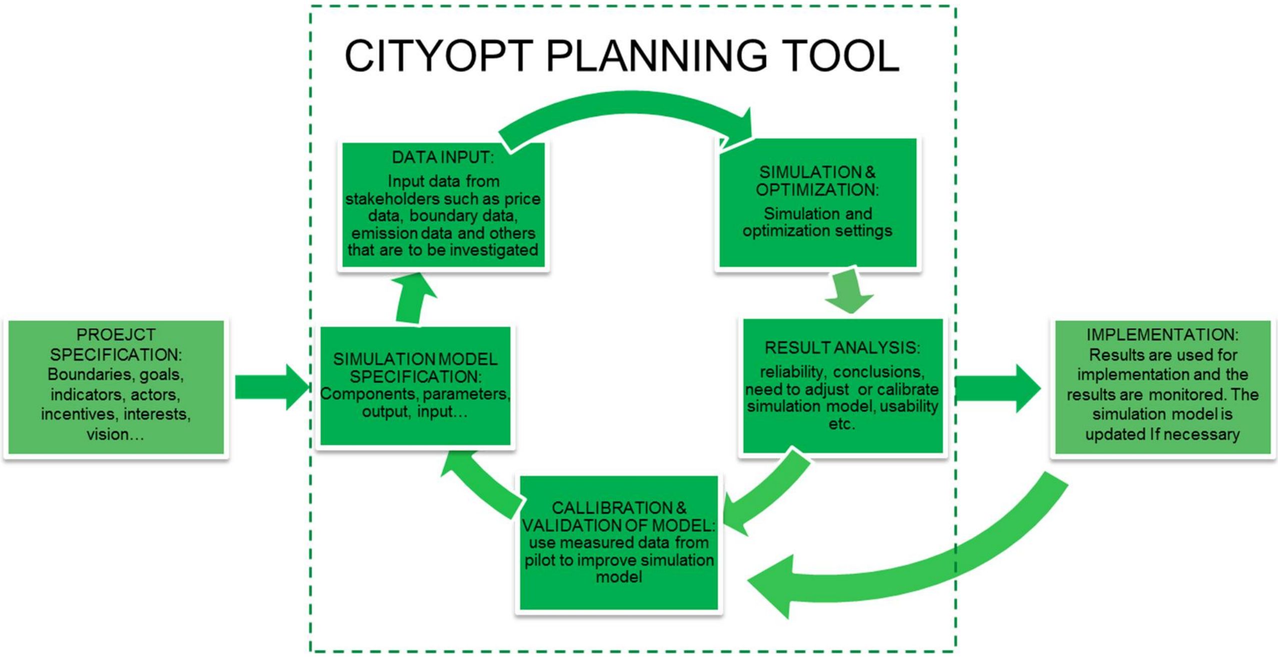


Figure 3: Process diagram for urban development involving CITOPT planning tool

As a pilot, the Östersundom case was mostly useful for collecting information and explore the potential of the CITYOPT planning tool to support urban planning in an energy system design context. The School of Sakarinmäki was available for calibrating the model of the storage component and examining the energy profile of such building type. Since the area is not yet completed and no larger energy system installations exist, it was not possible to properly calibrate the simulation model from real measurements. The optimisation results were therefore useful for determining the potential of renewable energy production and storage on a more theoretical level.

For the further development and construction of the Östersundom area, we suggest the following practices are recommendations (see Table 4). The CITYOPT planning tool is first used for a smaller area to verify simulation models and optimal setting. The calibrated model is then used for simulating and optimizing larger areas with the addition of further energy systems and infrastructure. Since the Östersundom area is to be built in several steps, the CITYOPT planning tool is to be used for simulating the area for each advancement. In this way, things that might affect the outcomes, such as prices, regulations, political decisions, new technologies, public opinion etc., can be better regarded.

In other words, the results from the planning tool should not be used to decide the plans for such a large area several decades in beforehand. Optimisation results from each smaller step would contribute with information for future development of the area while better strategies can be made through risk and sensitivity analyses. This would however add another dimension to the optimisation, and the number of generated scenarios needed might grow exponentially and the result analysis might therefore become more challenging.

SWOT Analysis of Helsinki Östersundom study case	
Strengths ▪ CITYOPT planning tool provides a platform through which stakeholders can interact with each other and produce a common plan. ▪ Time and resources can be reduced by simulation and optimisation ▪ The planning tool provides sufficient data for scenario comparison and risk analysis. ▪ Simulation model can be improved and extended if necessary making it formidable for future uses or to be used in other cases. ▪ The simulation model enables quick scenario generation for optimisation purposes. ▪ CITYOPT Planning Tool will be open access code	Weaknesses ▪ Area is still under planning phase and many of simulation parameters and inputs are inaccurate or assumptions ▪ Area will be built in steps over period of decades leaving the plans exposed to changes in the underlying factors (price, incentives, resources etc.) ▪ Iterative progress between planning, implementation and calibration of model, that could be time and resource consuming ▪ A facilitator is needed for guiding stake-holder interactions and use of the planning tool ▪ Cost of simulation model is difficult to estimate in beforehand
Opportunities	Threats

▪ Generate strategic numbers and performance indicators that would support both planning and implementation of urban areas. ▪ Help stakeholders to join visions and goals ▪ Help stakeholders to form regulation improved business opportunities that would ultimately lead to better and safer services. ▪ Model or some of its components can be replicated and used as a standard procedure in urban development projects. ▪ The parameters and inputs can be updated after the better data is available during the progress of the area planning and construction.	▪ CITYOPT planning tool could be too technical for specific stakeholders producing a loss of attractiveness ▪ The high effort to develop and calibrate a dynamic district heating model from scratch could be a high constrain for the commercial success. ▪ No appointed entity responsible for overseeing, developing and the maintaining the tool.

Table 6: CITYOPT planning tool SWOT for the Helsinki Östersundom study case.

	Recommendations for the Helsinki Östersundom study case replication
Technical aspects	The recommended case study steps: • Simulations and optimisation to find key numbers for development and risk assessment. • Implement the strategy for a smaller area. • Calibrate simulation model with measured data and update user-input-data. • Reassess the risks and performance indicators with improved simulation model and adjust the strategy thereby.
Socio-economic aspects	The recommended case study steps: • Gather the interest of different actors that would have interest in providing services or products for the area. • Assess how different strategies or solutions would create better opportunities for these actors to be able to provide their products/services with less trade-off on quality and safety. For instance, low temperature district heating could enable more alternatives of thermal storages and heat production technologies.

	Other aspects needed to account for is the local and national strategy concerning living and energy production. Incentives/support coming from these are to be taken into account in order to better estimate the advantage of certain solution or technologies. For example, tax reduction or investment support for the procurement of certain renewable energy production capacity. These aspects might make the whole equation of finding optimal solution even more complex. However, potential investors and solution-providers can be attracted to the area by looking up what incentives are available and plan the area to better enhance the effect of these.

Table 7: CITYOPT planning tool recommendations for the Helsinki Östersundom study case replication.

The Kalasatama became more detailed than the Östersundom model in terms of energy system design. The intention was to make use of the Suvilahti battery storage as a demo case but the Environmental building in Viikki was used instead due to installation delays in Suvilahti. Both the Suvilahti and the Environmental building systems had proper measurement equipment installed and measured data is therefore available for future analyses. It could be concluded from the results that the battery solution would not be profitable only for storing excess solar electricity and business models concerning further utilization options for the battery is recommended. Current regulation also makes the co-ownership of battery storages less profitable due to the grid transfer cost and tax-treatment. More business opportunities would be available for both battery owners and storage services in case regulations would change to the benefit of battery technologies or new market places would be created to give credit to the special characteristics of electrical energy storages such as fast and accurate response and regulation.

Stabilizing the grid becomes more important with growing renewable capacity in Finland. A good way to do this is by using battery storages. With storage the stability of the grid can be maintained for example by shaving the production peaks and time shifting the production. Different business models and operation logics need to be tested for this meanwhile the regulations are to be adjusted for the benefit of utilizing energy storages. The recommendations for the CITYOPT Planning Tool implementation in case of Kalasatama are given in Table 6.

When it comes to the Kalasatama model, the current simulation model is replicable in most cases in Finland where the same components (buildings, battery, solar PV etc.) are included. However, this model needs to be further developed to give any further value in the future. It needs to contain a battery optimisation model as a sub-component in order to better correspond to the real system. There is nevertheless the risk of the model becoming too complicated for the CITYOPT planning tool in case further control logic and business model optimizations will be added to this. The use would then require deep knowledge about the simulation model and how to set control strategies. This would narrow down the user group to only a few experts and eventually also limit its level of replication.

Regarding the pilot, the area for simulated set-up does not represent most optimal scenario since it is common knowledge that the grid is stable and strong in city centres. In addition densely built district as Kalasatama provides relatively small percentage of usable area for photovoltaic panels and due to this excess energy is not a problem within the buildings. However the model is well suited to estimate the preferred configurations of photovoltaic panels to add renewable energy share of consumed energy by the buildings.

Weather there is need for a storage can arise also if the area has other problems than excess solar energy production. The battery energy storage can bring value to the owner if the area suffers from reactive power fees, blackouts or sudden short term peak loads. The battery energy storage is capable of providing all of these services simultaneously with or without functionality of smoothening renewable production. These additional needs for storage are area specific and need to be considered in the simulation model with respect to the studied case. This evolution to the simulation model is likely to be done in near future. It is also inevitable since the short-term storage needs and sudden production peaks are increasing in the grid due to renewable uptake. This on its behalf has an influence on storage options to emerge for self-produced energy and hence several other functionalities need to be considered to add the value of battery energy storage invested to smoothen renewable production.

Main results achieved in the study case

In Kalasatama study case the main outcome was considering the optimal photovoltaic panel setup. It was found out that all of the utilizable rooftop area is feasible and profitable to be used. Also to face all of the panels towards south would result in best production rates. It was also studied whether it is more profitable to have supporting storage solutions installed separately in each building or to have it installed in common space. It turned out that no excess solar electricity was produced and hence the storage was not seen as key component in such energy system.

The solar energy production would decrease CO2 emissions approximately by 4 % compared to conventional power generation. Monetary savings were marginal since only few hundreds of euros could be saved from electricity procurement and transfer costs. This, however, excluded the investments of the system.

The completed KPIs that were used to analyse the Kalasatama pilot case are listed in Appendix 1. The SWOT-analysis of the Kalasatama model is presented in Table 8.

SWOT Analysis of Helsinki-Kalasatama study case	
Strengths ▪ CITYOPT planning tool provides a platform through which stakeholder can interact with each other and produce a common plan. ▪ Time and resources can be reduced by simulation and optimisation	Weaknesses ▪ Simulation model needs to become more advanced in order to bring further value. This would require resources and make optimisation more complex to set up and results harder to analyse.

▪ The planning tool provides sufficient data for scenario comparison and risk analysis. ▪ Simulation model can be improved and extended if necessary making it formidable for future uses or to be used in other cases. ▪ The simulation model enables quick scenario generation for optimisation purposes. ▪ CITYOPT Planning Tool will be open access code	▪ Small time-step between data sampling leading to massive data and thereby computer hard drive capacity. ▪ The grid behaviour is hard to predict in order to estimate a proper control logic. ▪ The markets and the business models are not yet well defined and the transformation is slow hence the model cannot predict the future.
Opportunities ▪ Working control models could contribute to better grid security and opportunities for smart grid solutions. ▪ An extended simulation model could take further power production and storage options into consideration. ▪ A quick way to examine how different regulations and price variation regarding power systems and grids would affect the profitability of different storage and power production options. ▪ The parameters and inputs can be updated after the better data is available during the progress of the area planning and construction. ▪ Market and business models are possible to simulate and optimise	Threats ▪ No appointed entity responsible for overseeing, developing and the maintaining the tool. ▪ Optimisation model becomes complex and expensive thus reducing the value gained from using the tool.

Table 9: CITYOPT Planning tool SWOT of the Helsinki-Kalasatama study case.

	Recommendations for the replication of the Helsinki-Kalasatama study case
Technical aspects	Either further development of business models and creation of new market places are need by the players of energy sector or the simulation model needs to be adjusted to many different plausible scenarios to give insight to feasible market development. By further calibrating and improving simulation models, the risk for investments and business models can better be identified and lowered.

Socio-economic aspects	The attractiveness to the customers of energy system configured from PV panels and storage needs to be surveyed. Is the model feasible and what are competitive solutions? Incentives and financial support to the investment will speed up the uptake and also alter the markets.

Table 10: CITYOPT planning tool recommendations for the Helsinki Kalasatama study case replication.

3.2. CITYOPT Operational tool

CITYOPT Operational Tool is an online application (Internet based) aiming to encourage energy savings behaviour in a community of citizens. The application involves the community by load shedding's solicitations. Savings realized by conscientious end users solicited are reallocated for the funding of energy efficiency projects.

3.2.1. Nice pilot

The region of Nice, is one of France's most fragile regions for electricity supply. Particularly in winter, when heating sees electricity rise, the locals experience frequent blackouts, as the local energy provider, EDF, tries to manage the supply. This is why CITYOPT project has chosen the Nice pilot to develop and test the Operational Tool to deal with energy consumption, and to involve local citizens.

3.2.1.1. Pilot context and results

The Nice study case takes place in a context of limitation of energy use at certain times due to the limitation of electricity transport and distribution infrastructures. Indeed, Nice depends on a single high voltage transport line which delivers the south east of France (5 Million inhabitants), in particular an urbanized coast from Marseille to Menton.

Due to the tourism attractiveness of the region, the population can double in certain towns during summer holidays.

In France, RTE is the unique player that carries electricity to high and very high voltage, from its production sites (for example, an EDF plant) to the sites or industrial customers that are directly connected to the network or through distribution networks that make the link with consumers including individuals. The network of electricity transmission stops where the distribution begins, the change in voltage is performed in an electrical transformer station.

There are 32 distributors of electricity including Enedis (ex ERDF) and autonomous distribution authorities who manage the medium and low voltage power lines. RTE is a stand-alone subsidiary of EDF. EDF is one of the suppliers of electricity (and also a producer) in France. There are other providers such as Engie, Direct Energie, Ekwateur, Enercoop etc.

The strategy of suppliers is to reduce the consumption peaks which can happen in average (depending of the period) once a month maximum by a demand-response policy.

As an answer to the recurrent problem of electricity load and supply balancing, energy suppliers use local electric power plants which cost a lot in term of maintenance and result in significant CO_2 emissions.

Short description of the Operational tool and of how it has been used in Nice

Nice study case has enrolled participants that have been equipped with smart electric meters (LINKY smart meters) during an intensive deployment of smart electricity meters in Nice by ENEDIS started in 2014.

CITYOPT Operational Tool has provided a system to encourage energy savings behaviour in a community of citizens. The main objective was to involve the population through load shedding's solicitations associated to an innovative incentives mechanism.

In order to involve the final customer to accept the demand-response policy, CITYOPT has developed an energy community network. The main principle of the energy community network is to reward best practices in response to load shedding solicitations: when a user has committed to the demand from EDF and has reduced its electric energy consumption during a peak, the value of the savings (load shedding) is reallocated to a project supported by the community under the form of points. Thus, the community is rewarded for its energetic consciousness.

3 main objectives were expected from the study case:

1) Change the current (daily) behaviour of end-users regarding electricity use.
2) Crowd fund local[10] and collective actions[11] thanks to the savings realized.
3) Create the energy capacity which is enabled by the participation of the community involved in CITYOPT operational tool. Of course, CITYOPT project aimed to evaluate the approach and the decisions proposed in the study case.

What has been deployed in the Nice pilot?

137 participants (dwellers) have been involved within a single community in Nice. Each of the dwellings received a tablet pc to access to the CITYOPT online application (front-end http://www.cityopt-nice.fr/ui/).

EDF was responsible to schedule peak date while NCA has identified 3 projects that were eligible to the crowd funding of the CITYOPT community.

In case of peak, scheduled 24 hours before, the CITYOPT Operational Tool front-end server was broadcasting an invitation to participate (by email and SMS) to every participant.

The dwellers had to decide either to participate or not. If they accepted, they had to choose which equipment they planned to switch off and/or decrease (e.g. lowering the heating set point) during the peak.

Then, after calculation by the EDF back-end server, the participants were receiving[12] an estimation of the potential points gained (in a delay of 24 hours after the peak).

Finally, in a delay of 72 hours after the peak, dwellers were receiving[3] the real number of won points, thanks to the calculation (disaggregation of consumption data) realized by the EDF back-end server from the load curves provided by the LINKY smart meters and delivered by ENEDIS.

[10] at urban or district scale or building scale.
[11] that are representative of a respectful use of the electricity.
[12] By email and also with an update on the front-end application interface.

Implemented stages and associated stakeholders

For each identified stakeholder are pointed out the views caught during the project.

Implementation stage	Stakeholder or representative of Stakeholder involved	View
1. Design and support of the application	EDF, Nice Côte d'Azur (NCA), CSTB, Experientia (EXP)	EDF: global design of the application and technical design of the back-end server. Business model validation & interviews with participants CSTB: design and implementation of the front end server and application. NCA: business model. EXP: design of user interface.
2. Involvement of participants and the business value creation.	EDF, Nice Côte d'Azur, CSTB, Experientia	EDF: recruitment, training of participants & interviews (before, during and after) NCA: recruitment, training of participants, support. CSTB: training of participants. EXP: Interview of participants.
3. Selection and animation of the crowd funding projects.	Nice Côte d'Azur	NCA: finding of projects.

Table 11: Implementation stages of CITYOPT Operational Tool.

Main results achieved in the study case.

The KPIs definition is presented in Appendix 1.

Potential[13] future reduction of CTG Investment per dwelling	6,45 €
Total of reduction costs of the combustion of fuel per dwelling (for the 6 months period)	0,3 €
Total of CO2 saved per dwelling (for the 6 months period)	164,4 g CO2
Total of KWH saved per dwelling (for the 6 months period)	4,1 KWh

Table 12: KPIs results of the CITYOPT Operational Tool.

These figures are important since the savings come mainly from dwellers that didn't use electric heating systems. So, we can see that the impact on the change of behaviour regarding other home appliances such as dryer, cooktop, dishing machine, washing machine etc. is after all significant (see Appendix 2: Consumption in W of main domestic appliances).

3.2.1.2. Improvement issues

 SWOT of the Design and support of the application stage	
Strengths Web application is reliable. User interface is ergonomic.	Weaknesses There is an important gap between estimated / actual number of points. The app works only with 7inch tablets. Estimation of points is based on EDF statistical data – Actual points allocation is based on EDF patented analysis method and also estimation of the "normal" consumption (baseline consumption). The real activity (like presence) of the dweller(s) is not managed.
Opportunities	Threats

[13] Projected future (at 2030) Economic Valuation according to specific hypothesis detailed in the deliverable CityOPT evaluation 4.1. Valuation in the current context has not been realized, but without investment in CTG, capacity values of flexibility could be divised per 4 (capacity price observed for January 2017 in France is around 10€/kW against our hypothesis of 40€/kW).

CITYOPT Operational tool can be supported and deployed by EDF existing portal and application: E.quilibre & EDF&moi app. The CITYOPT operational tool is a prototype which is operational. The technical specification should benefit from the current version. Cross-platform app: Several areas of improvements have been identified through the user research phase conducted by EXP and are summarized in D3.5. In particular, an explicit requirement was expressed to have the same application compatible with householders' own existing devices (e.g. computers, tablets, smart phones). In addition to enhancing the user experience and engagement, this would also improve the business model of the app (no need to provide/buy a specific / device tablet for the app).	

Table 13: CITYOPT Operational tool SWOT for the design and support of the application stage.

	Recommendations for the Design and support of the application stage
Technical aspects	Develop IOS/Androïd Applications and/or cross-platform version working on multiple mobile devices in order to spread extensively the tool. Improve reliability of the calculation/statistical methods in order to provide more coherencies with the real behaviours of the participants and to improve the reliability of the delivery of points. • Use personal data instead of generic statistical data • Use disaggregation of load curve • Use additional sensors/actuators: for example exploit explicit partnerships with NETATMO (external partner) and SOWEE (EDF subsidiary), • Reduce the duration to get load curve from the DSO for the calculation of points in order to be more reactive in the game.
Socio-economic aspects	Thanks to the current running version of the application, the costs and the delays of development should be reduced for the development of a commercial version.

Table 14: CITYOPT Operational tool recommendation for the design and support of the application stage.

SWOT of the Involvement of participants and the business value creation stage

Strengths	Weaknesses
The tool represents an interactive and convenient way to involve dwellers when a load peak is forecasted. It represents an application which can be replicated in all European countries where the Demand Response market is growing. It presents an interest for the territory (Nice Côte d'Azur) in terms of promotion of innovative approaches for sustainable development.	The involvement of TSO (RTE) and DSO (ENEDIS).is missing if we want to cover the Demand Response strategy and decision. Feedback to the community regarding the project founded is missing.
Opportunities	**Threats**
Replication (in France) is easier if the projects are attractive for the local community enabling a better appropriation It is an opportunity for DSO, TSO and Electricity Producer to combine Demand Response and Energy Efficiency. As soon as the cost of electricity is expensive, the use of operational tool becomes interesting.	Uncertainty in the electric capacity represented by the community : it needs to involve a greater number of participants, and to extend the offer to non-residential participants There is a low redistribution of savings due to uncertainty in the electric capacity of shedding which can be guaranteed by the community. (Indeed, the value of compensation fare is very low because of the uncertainty). Inconsistency for the energy producer in the electric capacity represented by the community.

Table 15: CITYOPT Operational tool SWOT for the involvement of participants and the business value creation stage.

And following each implementation stage analysis, list the improvements recommendations e.g. under a sheet form

Recommendations for the involvement of participants and the business value creation

Technical aspects	Develop and encourage IoT deployment (EDF partnerships) to control electric appliances when a "load shedding contract" exists in order to consolidate the

	degree of confidence in the energy capacity that can be potentially provided by the communities.
Socio-economic aspects	Promote special fares (contract) to encourage the load shedding and to consolidate the confidence in the electric capacity provided by the community. Provide additional / sustainable feedback to the participants on the realisation of the community projects thanks to their support Involve Transport and Distribution actors (RTE and ENEDIS) in the funding compensations : link to the INTERFLEX project which is going to further investigate this aspect Need to find additional funding : this could come from the participants as well, from the local authorities, etc.

Table 16: CITYOPT Operational tool recommendations for the involvement of participants and the business value creation

 SWOT of the selection and the animation of the crowd funding projects stage	
Strengths The tool represents a real strength to promote innovative projects in the domain of energy savings and CO_2 emission reduction and/or extend to other domains ; potentially also national charity, etc.	Weaknesses The finding of project is managed by a single (only one) stakeholder. The duration to collect money from the savings could be too long for specific types of community projects. Possibility to have several community projects funded is missing. This is important to keep customer engagement...
Opportunities Crowd funding is an opportunity for business incubators or for any representative national agency that support innovative projects: e.g. support of national charity. Crowd funding is another approach for collective decision at urban, district, building. It represents a new way to involve citizen in the public decisions (participative politic).	Threats The budget is too low: need for a greater volume of participants (in France).

Possibility to extend the target of projects to other society stakes like human rights, social policy etc. Opportunity for participants to give additional money (on their own) to support community projects.	

Table 17: CITYOPT Operational tool SWOT for the selection and the animation of the crowd funding projects.

And following each implementation stage analysis, list the improvements recommendations e.g. under a sheet form

	Recommendations for the selection and the animation the of the crowd funding projects
Technical aspects	Develop a portal for project applications (projects that support energy efficiency or CO2 emission reduction or other society stakes).
Socio-economic aspects	Involve project/company incubators or energy agency Other electricity stakeholders (like RTE, ENEDIS etc.) should encourage the use of CITYOPT operational tool. Involve the politics decision maker in the selection of projects

Table 18: CITYOPT Operational tool recommendations for the selection and the animation of the crowd funding projects stage

4. Replication

4.1. Planning Tool

4.1.1. Characterization of other possible replication contexts

The CITYOPT Planning Tool is flexible tool to be used in analyses of different type of systems, which can be modelled with system simulation tools. This gives freedom to use optimisation tool in many areas of interests. The CITYOPT planning tool supports simulating, optimizing and analysing various city planning alternatives and their impact. The current models for Vienna, Östersundom and Kalatasama study cases offer the possibility to combine different integrated energy sources (conventional, renewables, district heating...), energy storages storage (thermal and electric), energy efficient buildings assets, etc. in order to find the strategy which gives the best compromise in term of sustainability and economic benefits for the stakeholders in charge of city planning.

4.1.2. Replication guidelines

In this section the replication guidelines extracted from the Vienna, Östersundom and Kalatasama study cases are presented. These guidelines point out the different aspects which should be considered for future developments, which want to replicate these study cases or to approach similar developments.

4.1.2.1. Vienna study case

Table 19 shows the main issue which should be considered in the design of the micro district heating network when the waste heat from a facility is recovered to be used as a heat source.

	Guidelines for the replication of Vienna model
Technical aspects	▪ Temperature ranges and production time of the recovered waste heat of the industrial facility will define the design and dimension of the elements linked to the district heating network, together with the feasibility of the project. ▪ Data quality and quantity are essential for thermal profiles with a wide range of temperature ranges and production periods. ▪ The economic viability of district heat is affected by the overall heat demand, which should be sufficient to justify the investment. Buildings with very low energy demand, may affect to the success of the project. ▪ Ground thermal storage is useful with low temperature ranges, allow higher decoupling between heat production and conduction but the stored heat must be upgraded through a heat pump. Water tank is useful for high temperature ranges; it can be used directly to cover the heat demand but makes necessary a high regular waste heat generation due to its low decoupling. ▪ The use of local energy sources already installed into the building contributes to reduce new investment for the backup system but could produce an underuse of this overcapacity. The connection to other local district heating increase the security supply and at the same time additional business opportunities in a wider market. ▪ During the design of the district heating network the losses of the network must be considered as they increase the energy of demand of the overall system and maybe reduce the cost and environmental benefits. ▪ Financial risk could be high due to it is required large up-front investments in the distribution network, control equipment and pumps and the

	industrial companies would not typically contribute to the investment in heating networks. Therefore, public funding support can be a key element.
Socio-economic aspects	▪ Less energy intensive and non-energy intensive industrial enterprises can be reluctant as they consider it risky to the core business. This makes necessary the creation of a long term framework among local authorities, network operators and companies which secure aligned incentives, share risks and benefits, and governmental support throughout the process of development of the clusters and its common infrastructures. ▪ The indirect benefits from the development of the project recover the heat industry should also be considered into the project. This benefits are in term of increase of energy security, reduction of emissions, improvement of the health quality and creation of local jobs.

Table 19: Guideline for the replication of Vienna model

4.1.2.2. Helsinki study cases

Some replication issues regarding the Helsinki cases were already mentioned in the last chapter. The most valuable ways of replicating the Östersundom case would be through further use and development of the stakeholder and CITYOPT planning tool processes. This would ensure a better praxis for better communication more efficient planning and clear vision of the simulation model. Furthermore, there available simulation model can be further calibrated and improved to be used along with further construction and development of the Östersundom area. The same simulation model could also be used for similar urban development projects in Finland while the optimization objectives and input data could be adapted with less effort. The following guidelines for the replication of the Östersundom case are given in the following table.

	Guidelines for the replication of Östersundom model
Technical aspects	• Simulation model is to be calibrated and developed to become reliable when used in more general cases. • Means should be found to express soft values into numbers that later can be used as optimisation variables. • Facilitation processes, tool-use processes and stake holder processes are to be made more clear and intuitive in order to ensure better collaboration and interaction of participants. • Ensure that the simulation model is detailed enough to cover for the interests of the stake holders but simple enough so that the key stakeholder can understand and manage them

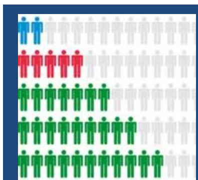
	• Prepare list of data input needed and ensure that these are obtainable (and accurate)
Socio-economic aspects	• Reuse and modify as much as possible of existing models to save resources • Involve stakeholders from different sectors so that a more holistic approach is possible. • Involve business opportunities aspect as much as possible Involve also habitant groups to receive a broader spectrum of what are the needs and the desires (what brings value) of the end customer.

Table 20: Guideline for the replication of Östersundom model

The replication of the Kalasatama case would involve the same issues as the Östersundom case. All processes involving the planning tool and stakeholders should be refined to achieve quicker results and better model design. However, the calibration and further expanding of the current simulation model would be necessary for it to become versatile and therefore better suited for replication. This means that more underlying components need to be added to give extension to the current model. Some suggestions for this would be optimisation algorithm for battery control, smart grid control logic and other renewable energy production technologies than solar photovoltaics. This would make the model more in line with new and upcoming "smart" district pilots around Finland. The same simulation model could eventually be used in other Nordic or European countries also if suitable data would be available.

When it comes to socioeconomic aspects, the replication of the Kalasatama model would contribute to the further development of smart cities and urban living. This would eventually result in improvements in life quality, new and better services and reduced environmental effects from living. Smart technology could also increase the safety of energy applications and ensure better stability and availability of electrical grids and district heating.

The following guidelines are to ensure the improved replication of the Kalasatama model.

	Guidelines for the replication of Kalasatama model
Technical aspects	• Adding underlying components of the simulation model • Calibrating components • Investigate into possible business models for storage, renewable energy, storage solutions and consumer services. • List possible regulation and incentives for energy services and involve these into the simulations to be able to assess their effect on different business opportunities and sustainability.

Socio-economic aspects	• Involve further actors in the energy industry for more inputs and added service models. • Integrate the current model with other services related to smart technologies to examine the synergies that these would provide. • Involve also end customer into replication projects in order to understand their needs and what solutions would bring added value.

Table 21: Guideline for the replication of Kalasatama model

As for the planning tool and the case of Finland, VTT is currently investigating possibilities to use the tool in projects involving massive computations in product development. The optimization functionality would fit well the cases where an optimal parameter set for a designed artefact, or an optimal design in general, needs to be generated. Based on our discussion with industrial companies there seems to be clear need for this kind of tool both in process industry as well as in manufacturing industry. The present planning tool would form a good base for the application to a completely different domain. Some of the components and other data would be useful for this kind of extension of utilization for the planning tool.

4.2. Operational Tool

4.2.1. Characterization of other possible replication contexts

Replication of the tool is possible for other region or countries of Europe. Indeed, the approach is potentially applicable to other areas where the demand has to be balanced with the offer in a collective approach.

The replication guidelines present the recommendation for the application (use) of CITYOPT Operational Tool in a different country than France.

4.2.2. Replication guidelines

4.2.2.1. Nice study case

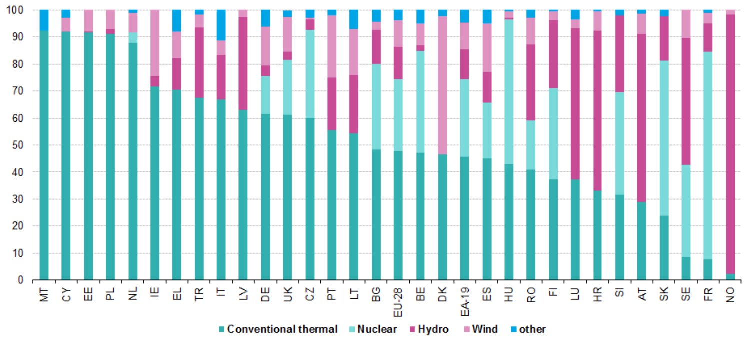
	Guidelines for the replication of Nice application
Technical aspects	1) The share of electricity in the total energy bill should be important if we want to recommend the use of the application in the region or the country targeted. On the following breakdown of electricity production by source, we see that many countries in Europe use conventional thermal and France has the most important nuclear production. For example Hungary and Slovakia are potentially eligible to the Operational Tool.

(cf. http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Breakdown_of_electricity_production_by_source,_2015_(in_%25)_update.png)

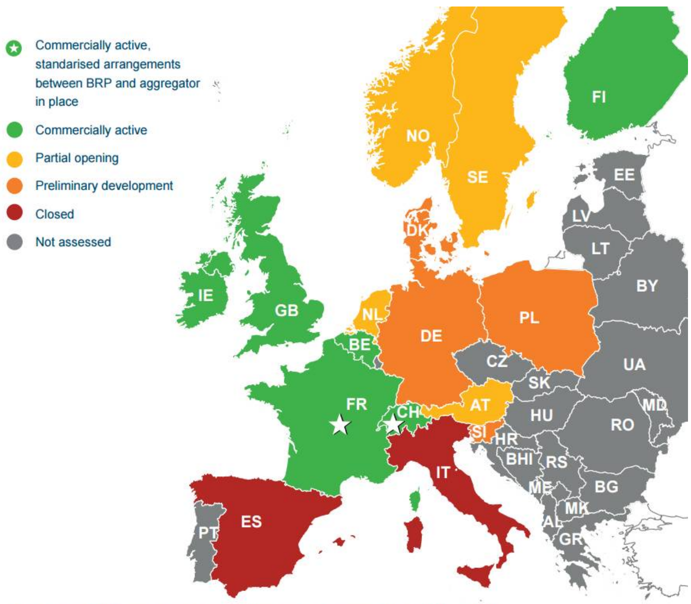
UK, Nederland's etc. are mainly user of conventional thermal.

As for example in UK (cf. https://www.ukpower.co.uk/home_energy/average-energy-bill), the part of gas usage for times more than electricity usage.

(1) Small House / Flat - gas usage of 8,000kWh and an electricity usage of 2,000kWh
(2) Medium House - gas usage of 12,500kWh and an electricity usage of 3,100kWh
(3) Large House - gas usage of 18,000kWh and an electricity usage of 4,600kWh



2) The availability of smart electric meters is mandatory for the deployment of the application. Also the maturity of the country to develop a demand response strategy is a key element.



Map of explicit demand response development in Europe Today (SEDC, 2015).

In the following study (cf. http://www.smartenergydemand.eu/wp-content/uploads/2015/10/Mapping-Demand-Response-in-Europe-Today-2015.pdf) we see the state of the art of the maturity in Europe of the demand response.

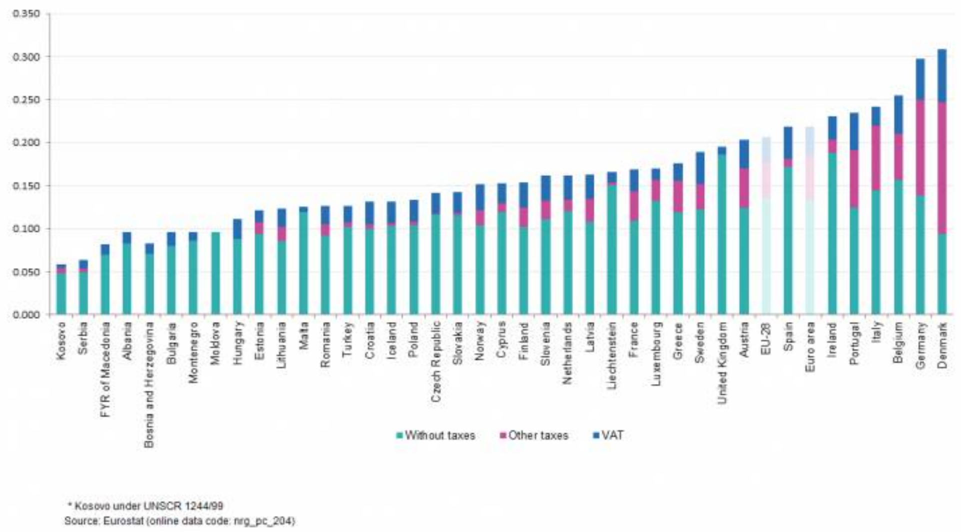
<table>
<tr>
<td>Socio-economic aspects</td>
<td>When the cost of electricity is expensive, the use of operational tool is interesting as for example in Italy, Belgium, Germany, Denmark etc. (cf. http://ec.europa.eu/e<urostat/statistics-explained/index.php/Electricity_price_statistics)

</td>
</tr>
</table>

Table 22: Guideline for the replication of Nice application

5. Conclusion

The CITYOPT Planning tool proved that the Vienna study case is useful to assess the recovering of waste heat from the industrial facilities for small district heating. In the Vienna study two critical factors should be considered in future replications. The first one is temperature ranges and production time of the recovered waste heat defining the design and dimension of the elements. The second one is the financial risk due to the large up-front investments in: the distribution network, the controls equipment and the pumps as well as the industrial companies that would not typically contribute to the investment in heating networks. Therefore, public funding support can be a key element. Additionally, indirect benefits from the development of these types of projects should also be considered into the project (e.g. security, reduction of emissions, improvement of the health quality and creation of local jobs). The strength of the CITYOPT planning tool is in possibilities to model the case, optimize the energy system typology and size dimensioning and present the performance parameters of the optimized case.

The replication of the Planning Tool in Kalasatama case needs further instructions and service models from the targeted user group which are the energy retailer as well as the transmission and distribution system operators of the electricity grid. To replicate the model of Östersundom case, a suggestion would be to use ready-made model components and integrate them into the Planning Tool. Also to further increase and broaden the user group of the tool the business potential of the different solutions suggested by the Planning Tool should have more weigh in the model. Depending on the maturity of the modelled technologies and the state of construction of simulated area the Planning Tool can result either in theoretical simulation results or more accurate ones that fit into current ecosystem. The Planning Tool can be adjusted to different setups and hence its usability to other areas has been recognized.

The use for the planning tool could have further possibilities than to be used for replicating the study cases within the CITYOPT project. Namely, it could be used more as a platform for optimisation purposes and assess the results from these. The main topic could be anything else than energy or urban planning as long as there is a calculating component (simulation tool). This exposes the tool for a broader group of potential users, which eventually could contribute to the further development and extended popularity of the tool.

The replication of the Operational tool could provide complementary flexibilities in many countries of Europe where the fare of electricity is expansive and when there is a possibility to reduce the investment on the electric network and the CTG. Operational tool could offer a new mean to control the demand response strategy by the involvement of communities of end-users.

Even if smart meters provide a better knowledge of the real consumption during a peak, it could be possible to use the tool without using the load curve but only by a simple calculation with the strategy planed by the dwellers.

We encourage the replication of the operational tool to check our first conclusions and to share better practices regarding electricity use in Europe.

6. Appendix 1: Project KPIs

Hereunder are listed the KPIs tables for each pilot.

6.1. Vienna Study case

KPI for energy	Information and explanation for the calculation
Energy supplied by source (MWh)	Energy supplied by source is the integral of the energy supplied by each source along the year (HTS, LTS, Solar panels, Heat pumps, Gas boiler, District heating).
Total primary energy consumption (MWh)	Total primary energy consumption is the integral of the energy demand by each building together with the heat losses in the district heating system along the year.
KPI for CO2 emission	
CO2 emissions by source (CO2 Tons/a)	The CO2 emissions by sources are calculated multiplying the energy consumption by source by their emission factor. The CO2 emissions are only calculated for three components, the gas boilers of TB, the heat pump of EB and the LTS (which actually represents the CO2 emissions due to the electric heat pump associated to the LTS to boost the temperatures to the required level of the buildings). The other components are assumed to be CO2 neutral
total CO2 emissions per energy demand (CO2tons/MWh demand)	Total CO2 emissions per energy demand is calculated summing CO2 emissions by source and divided by the total energy demand. The total energy demand is the integral of the energy demand of the along the year.
Economic metrics	
Operational costs by source (€)	Operational costs by sources are calculated multiplying the energy consumption by source by their cost factor. The operational costs are only calculated for four components, the DH of Vienna (actually the price of the heat sold by the DH of Vienna operators), the gas boilers of TB, the heat pump of EB and the LTS (which actually represents the operational costs due to

KPI for energy	Information and explanation for the calculation
Energy supplied by source (MWh)	Energy supplied by source is the integral of the energy supplied by each source along the year (HTS, LTS, Solar panels, Heat pumps, Gas boiler, District heating).
Total primary energy consumption (MWh)	Total primary energy consumption is the integral of the energy demand by each building together with the heat losses in the district heating system along the year.
	the electric heat pump associated to the LTS to boost the temperatures to the required level of the buildings). The other components are assumed to have no operational costs.
Total operational costs per energy demand (€/MWh Demand)	Total operational costs per energy demand is calculated summing operational cost by source and divided by the total energy demand. The total energy demand is the integral of the energy demand of the building along the year.

6.2. Östersundom Study Case

KPI for energy	Information and explanation for the calculation
Optimal capacity thermal storage (m^3)	Optimal capacity of thermal storage is related to the solar thermal production and it is an output parameter from the Planning Tool. The optimal storage capacity is given as a total capacity combined from all of the 14 urban areas in Östersundom district.
Location of optimal thermal storage (coordinates on the case area)	The district is divided into 14 urban areas each of which have different amounts of floor area and hence different energy demand. The optimal location of the thermal storage is determined from the thermal energy production capacity of the area and the consumption demand.
Savings in primary energy from thermal storage capacity compared to case where no capacity is being applied (%)	The thermal storage capacity adds the usability of the thermal energy source. The savings in conventional power generation due to added solar thermal production and storage are calculated by comparing optimized scenarios to basic scenario.
KPI for CO2 emission	Information and explanation for the calculation
CO2 reduction (kilotons/a)	The impact of solar thermal production and storage possibility to CO2 emissions is calculated by comparing simulated scenarios to basic scenario with only conventional power generation in CHP power plant.
Economic metrics	Information and explanation for the calculation
Monetary compensation (€)	The effect on yearly energy costs is calculated by comparing energy costs of conventional power generation to energy costs of power generation by renewable energy sources.

6.3. Kalasatama Study Case

KPI for energy	Information and explanation for the calculation

Usability of the BESS	The usability of the BESS is calculated as an activation time in each simulated scenario. The usability gives information about other possible functionalities that could be added to give more value to the purchase.
Conventional reserve power reduction (%)	This is a measure describing how much self-produced energy can be consumed instead of purchasing energy that is produced in conventional power plant. This describes the same as solar factor.
Degradation of capacity (%/a)	The battery's available capacity decreases with increasing number of charge-discharge cycles. The degradation of capacity describes how fast and how much the capacity degrades.
KPI for CO2 emission	Information and explanation for the calculation
CO2 reduction (tonne/a)	Increasing the factor of solar produced energy reduces CO2 emissions. This KPI describes the value of photovoltaic panels and battery energy storage in decreasing emissions.
Economic metrics	Information and explanation for the calculation
Monetary compensation (€/a)	Monetary compensation is achieved by avoiding the tax treatment of electricity transferred in the grid. Additional monetary compensation can be achieved by participating to different ancillary markets provided by TSO as well as by selling self-produced solar energy from PV panels and battery. The compensation depends on the available capacity and time to offer services with the battery.
Cost structure	Based on the cost structure it is possible to determine pay-back time and overall viability of energy system with battery energy storage. The cost structure of the energy system consists of energy costs, panel purchase costs and battery purchase costs.

6.4. Nice Study Case

Economic metrics	Information and explanation for the calculation

Reduction of use costs of CTG per dweller per cold period (Fall-Winter).	This calculation is based on the estimation of the reduction costs of the combustion of fuel for the community during 6 months (15 peak alerts = 30 hours).
KPI for energy	Information and explanation for the calculation
Reduction in energy consumption per dwelling (kWh/dwelling p.a.).	The average quantity of Kwh saved per dwelling is calculated from the difference between the real consumption curves of the participants involved in the load shedding solicitation and the current estimated consumption which is currently planned in advance by EDF for each day.
KPI for CO2 emission	Information and explanation for the calculation
CO2 avoided emissions (kgCO2 p.a)	The average quantity of CO2 saved is calculated from the Kwh saved per dwelling with the conversion equivalence of CO2 per KWH which is 40 g CO2/Kwh.
KPI for user Acceptance	Information and explanation for the calculation
Average participation rate	The average number of households that accepted to participate to the peak alerts missions during the pilot.
Average successful participation rate	The average number of households that accepted to participate to the peak alerts missions during the pilot and successfully reduced their consumption compared to their estimated business-as-usual average in the same time interval.
Average unsuccessful participation rate	The average number of households that accepted to participate to the peak alerts missions during the pilot but didn’t reduce their consumption compared to their estimated business-as-usual average in the same time interval.
Long-term participation rate	Difference of average participation rate between the begging of the pilot to the end of it.
Quit rate before 30% of pilot progress	The percentage of households that quit the project before 30% of the alerts has been issued.

Quit rate before 50% of pilot progress	The percentage of households that quit the project before 50% of the alerts has been issued.
Quit rate before 70% of pilot progress	The percentage of households that quit the project before 70% of the alerts has been issued.
Households with high commitment	The percentage of households with a participation rate higher than 50%.
Households with very high commitment	The percentage of households with a participation rate higher than 70%.
High perceived discomfort	The percentage of participants who reported a high level of discomfort by participating to the peak alert missions.

7. Appendix 2: Consumption in W of main domestic appliances.

Appliances	Average consumption W
Dryer	4000,00
Cook top	1300,00
Dishing machine	1000,00
Electric heater	801,00
Washing machine	801,00
Ironing	500,00
TV and computer	460,00
Oven	420,00
Game console	385,00
Desktop pc	260,00
TV	200,00
Hair dryer	169,00
Vacuum	146,00
Lighting	80,00

Appliances	Average consumption W
Laptop	54,00
Microwave	45,00
Phone charger	20,00