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Deliverable 3.5

Synthesis of CITYOPT demonstrations

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Statement of originality

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Dissemination level

PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
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Executive summary

The objective of deliverable 3.5 is to summarize the concluded actions of CITYOPT Work Package 3 *Demonstration* of Helsinki, Nice and Vienna pilots.

Each pilot will be introduced by an overview of the entire process, followed by a description of the models and the simulations created for modelling energy systems, for Helsinki and Vienna study case, and for reducing household energy consumption during peak hours for Nice demonstration. The validation of the models has been tested on real scenarios of usage, and real potential users (professional and household end users) have been involved to test the Planning and the Operational tools, to further understand their experience of usage and collect relevant feedback to improve them in an efficient way.

The results chapters will present technical, economic and social results obtained during the simulation sessions, and during the social acceptance and usability testing sessions (contextual interviews, workshops and surveys with participants).

A final Conclusion chapter points out recommendations and defines some directions to be taken into account for further improvement, refining and application of the CITYOPT Operational and Planning tools.

The CITYOPT Planning tool has been applied in Helsinki and Vienna demonstrations.

Helsinki pilot consists of two case studies: the Östersundom case and Kalasatama case. The Östersundom case models production and storage of heat whereas the Kalasatama case models production and storage of electrical energy. The simulations and models created for simulating the energy systems, as long as the validation of such models is obtained with real measured data from Helen Ltd.'s pilot projects at the Environment Building and at the School of Sakarinmäki. The Planning Tool's optimization algorithms have been tested by potential users and a final workshop has been held to evaluate the User Experience (UET) and User Acceptance (UAT) of the tool. In Östersundom area it was suggested by the simulations that heat production would shift from conventional power generation towards distributed solar heat production assisted with heat storages. Also some of the electricity consumption could be produced with photovoltaic panels. The scenarios included also production capacity of bio-CHP plant but with the added renewable share and distributed energy system, the district could reached 30 % reduction of CO_2 emissions compared to energy production with conventional power generation and also reduce energy costs by 14-17 %.

In Kalasatama the results suggested to implement photovoltaic panels facing south direction to cover all of the utilizable rooftop area of the buildings. The self-produced energy would result into energy cost reduction of only 1,5 % and the battery energy storages wouldn't be economically feasible since no excess energy is produced. The share of solar energy would result to CO_2 emissions decrease by 4 %.

The Vienna pilot aims 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, CITYOPT Planning tool is used as "laboratory testing": the design of this district heating network has been 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, CO_2 emissions and costs.

The CITYOPT Planning tool has been tested from the point of view of User Experience (UET) and User Acceptance (UAT), during stakeholder workshops, where different stakeholders and professionals evaluated it in terms of technical usability, applicability for business purposes and exploitation of the generated results in the decision making process. The CITYOPT Planning tool allowed simulating various scenarios, calculating specific metrics (energy, environmental and economic metrics) and finding the best scenario among the scenarios simulated, through a Database Search Optimization algorithm. The tool is well appreciated by the participants, because it gives the user a visual hint about the whole system, by abstracting from the many metrics and the way they are connected together, and it helps in first step of decision making. However, the research highlighted a number of problems affecting the user experience of the CITYOPT Planning tool, which should be addressed in order to guarantee a better usability and user experience.

In REF1 and REF2, the costs are composed of the costs of the heat pumps and the costs of the gas boilers, with a similar share 80% - 20%. For the Configurations A and B, the main part of the costs is due to the gas boiler, the LTS contribute with a 7% and the heat pump around 1%. For the configurations C and D, the District heating of Vienna is responsible for most of the costs, between 67% to 75% and the gas boilers for 23% to 28% of the total costs. When the LTS is part of the network, its operation especially the operation of its coupled heat pump booster costs from 6% to 9% of the total costs.

The aim of the Nice demonstration was to demonstrate the economic and environmental benefits of the CITYOPT Operational tool designed to encourage behavioral change through demand-response solicitations. The CITYOPT Operational application forms a community of householders committed to protect the environment, avoiding overconsumption and the waste of resources. CITYOPT engages citizens through the support of local community projects. Projects address sustainability issues at the neighborhood, city scale or regional scale. As with crowdsourcing, people can support their favorite projects through the CITYOPT app: support is given by “investing” CITYOPT points in one or more projects. CITYOPT points are the “currency” used to back projects up. CITYOPT points are earned by CITYOPT members for their successful commitment during Demand-Response alerts.

In total 141 families have been selected to participate in the Nice pilot, equipped with the Linky smart meter. 9 meetings with participants were organized and conducted between September and November 2015 before the start of the Nice demonstration, where the participants were given the tablets with the application installed and get started on how to take part to the peak events. The demonstration lasted from November 2015 to May 2016, and a first round of contextual interviews was conducted on 9-11 February 2016, with a panel of participants for the CITYOPT Nice pilot demonstration. This qualitative research highlighted interesting points that has been further quantitatively analyzed with an online survey.

The Nice demonstration has shown a strong commitment of the participants to reduce their consumption during the alerts. It was observed an average load shedding, during the test period, of 300 Wh per participant between 6 and 8 pm, the average annual consumption being 3,500 kWh (90% of CITYOPT customers contracted power is less than 6 kVA). Reducing 300Wh per participant means that, if all inhabitants would participate in region PACA (Provence Alpes Côte d’Azur), 360 MWh could be saved between 6 and 8 pm which correspond to 1 hour production of a small power plant or the annual consumption of 2 elementary schools. Further detailed technical and socio-economic evaluation results will be provided in CITYOPT WP4 deliverables.

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TERMS AND ABBREVIATIONS

Term and Abbreviations	Definition
UI	User Interface
LTS	Low Thermal Storage
HTS	High Thermal Storage
RTA	Rail Tec Arsenal (Climate wind Tunnel)
UAT	User Acceptance testing
UET	User Experience testing
CHP	Combined Heat and Power
IA	Information Architecture

1. Introduction

This is a synthesis report of 3 demonstration cases in CITYOPT project: Helsinki Östersundom and Kalasatama, Nice and Vienna. The detailed results are reported in deliverable reports of WP3 Demonstration

D3.1 Helsinki demonstration

D3.2 Nice demonstration

D3.3 Vienna demonstration

2. Helsinki demonstration

Energy storage solutions in Helsinki pilot cases

The Helsinki demonstration is focused on two different cases: the Östersundom case and the Kalasatama case. The focus is on energy efficiency and different energy storage solutions as a part of smart city planning.

For the time being the electricity network is reliable in Finland but the changes in the sources of energy will alter the network's stability. The electrical energy storages have the ability to respond to the frequency fluctuations rapidly and hence they will have a stabilizing role in grid support. Heat is rarely consumed exactly at the time of production. The flexibility in demand and production is enabled with intermittent storage solutions such as water tanks. The two CITYOPT pilot cases in Helsinki focus on systems with different storage solutions.

In the Östersundom case, the CITYOPT Planning Tool has been used for designing the energy solutions for this district, that is planned to become a new residential area of Helsinki. The CITYOPT simulation tool has been developed and tested with city planners and stakeholders, in order to analyse and optimize different scales of heat energy storage solutions. The application analyses different scales of heat energy storage and shows which are the optimum sizes and setups for the district, filtering by user's priority preferences such as emissions and energy costs.

In the Kalasatama case, as the previous one, the CITYOPT application was tested and used to examine the optimal storage solution in district planning. It was also used for evaluating the business potential of electricity storages both in large- and small-scale battery energy storages. Electricity storage sizing and placement were analysed. Economic and social aspects of the implementation of different storage solutions were taken into account.

2.1. Process overview

The purpose of the CITYOPT Work Package 3 was to validate the CITYOPT Planning Tool and to improve it based on users' feedback. The application's ease of use, as well as the relevance of the results it provided, were tested during workshops with potential users of the tool, and the functionality of the application was improved based on the feedback received from the users.

The achievements of the Planning Tool application in usability and functionality were evaluated with User Experience Tests and User Acceptance Tests. Two workshops were held during the WP3 and user experiences in the usage of the CITYOPT Planning Tool were collected and analysed by researchers. The final version of the Planning Tool addresses the pain points that were elicited during the testing sessions.

Two simulation models were created in APROS and the models were run in the Planning Tool. The objective of the Helsinki demonstration was to validate the optimization results of the Planning Tool as well as the functioning of the simulation models.

One simulation model models heat storages and the other electrical energy storages. The simulation model for heat storage is created to simulate Östersundom district and to optimize the energy system on the heating point of view. The simulation model for electrical energy storage is created to simulate Kalasatama district and to optimize the energy system from the electricity point of view.

In the Östersundom case, the Planning Tool was used to optimize the energy system in a context where different scenarios for producing and storing heat were simulated. The Planning Tool's genetic algorithm was used to create best scenarios within its runtime where the optimization was based on the economic costs and on CO2 emissions of each simulated scenario. Centralized and decentralized production and storage options were also studied by varying the simulated scenarios manually by users.

In the Kalasatama case, the Planning Tool was used to optimize the sizing and placement of the battery energy storages considering centralized and decentralized energy systems. The algorithm optimizes costs and CO2 emissions. The simulated scenarios were selected to be distributed and centralized energy system regarding the storage capacity. In each scenario the demand was modelled with three different consumption profiles each building type having also own photovoltaic production. The Planning Tool created the most optimal scenarios within the genetic algorithm's runtime after which the best scenarios were analysed.

The optimization models were validated with real case studies in Östersundom and Kalasatama. Data from the energy efficient School of Sakarinmäki in Östersundom was collected regarding heating demand and available self-produced heat from renewables (solar thermal collectors) and oil. Kalasatama case was provided with data from the Environment Building in Viikki, Helsinki. Photovoltaic panels of 60 kW, lithium-ion battery of 45 kWh and 90 kW, and an electric vehicle charger were installed at the Environment Building and the operating data regarding consumption, production and storage was collected. Both real pilots, School of Sakarinmäki and Environment Building, represent a typical future building types of Östersundom and Kalasatama districts.

This Deliverable is only a synthesis of work done in Work Package 3 and hence considering Helsinki demonstration the full report of all actions of Helsinki pilot are in Deliverable 3.1 *Helsinki demonstration*, model validation in Deliverable 3.4 *Model validation* and simulation results and the full result analysis are in Deliverable 4.1 *Evaluation of ITC the solution*.

2.2. Models

2.2.1. Östersundom simulation model

The Östersundom model represents a large district containing 14 areas, each with different square meter amounts of multi-storey buildings, town houses, smaller residential buildings, public buildings (schools, kindergarten etc.), commercial buildings and shops. When it comes to energy solution, the whole Östersundom area contains one combined heat and power (CHP) plant. This plant is controlled according to the heat demand while producing electricity simultaneously as one-third respect to the heat production.

There is a centralized thermal storage for the whole district while thermal storage capacity can be added to each area separately. The sizes of the storages are modified through their volumes between zero to 20 000 m^3 per urban area. The Östersundom district model contains also a district heating component from which one could change the supply and return temperatures of the district heating network and lower the heating value of the fuel used in the CHP plant. It can be regarded that this district heating component is forming a unity with the CHP component. See Figure 1 for overview of the Östersundom model.

NOTE: There might be a limit for some of the user-given values. Exceeding these limits might cause problems with summations since the Östersundom model contains components with thermodynamic properties that might cause the simulation to crash once they become unstable.

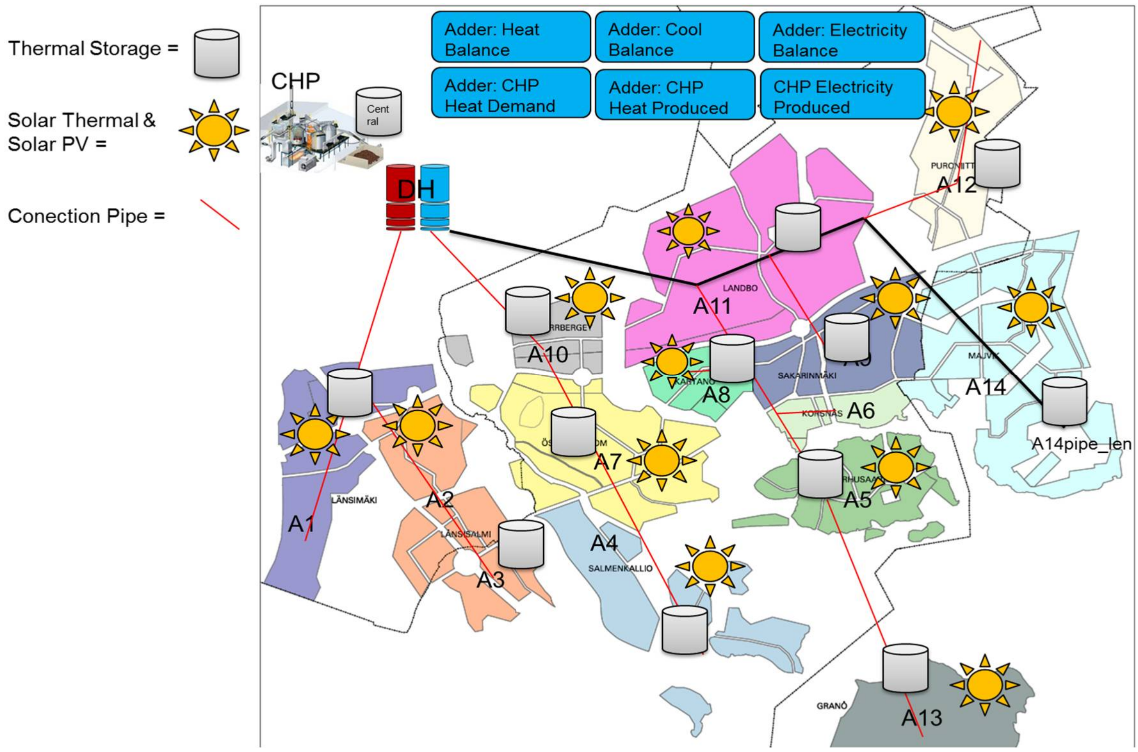


Figure 1. Layout of the Östersundom model and its components.

2.2.2. Kalasatama simulation model

The purpose of the Kalasatama model is to test different control strategies for an energy system involving solar photovoltaic panels and battery energy storage. The model consists of three different building types: residential, commercial and office (see Figure 2). Each building has same parameters in the model and differ only considering electricity consumption profile. A centralized building was also modelled in the Kalasatama model where the consumption profile is regarded as combined consumption from the three different building types. The idea is to assess the potential of either centralized or decentralized energy system for a building block in the Kalasatama central area (either common solar photovoltaic and battery energy system or separate system).

At the moment the Kalasatama model contains only a strategy of storing and selling excess solar energy and the control of the strategy follows the following order:

1. Solar electricity is deduced from the demand
    a. Excess solar electricity is stored in the battery whenever there is capacity available, there is a certain percent conversion losses whenever the battery is charged.
    b. Excess solar electricity is sold in case the battery is full.
2. Use battery in case there is capacity, there is a certain percent conversion losses whenever the battery is discharged.
3. The rest of the demand is bought from the grid.

CO2 emissions and electricity costs are calculated directly from user given data and electrical consumption profiles. The available spot-price data in the model is based on European spot market prices for electricity in year 2014. Weather data is also averaged data from the Helsinki area from year 2014. The model can be used for either finding the optimal photovoltaic panel settings, or finding the optimal battery capacity for a certain electrical consumption profile (building type) based on prices, CO2 or other environmental aspects.

NOTE: The simulation time step is 3600 seconds (one hour) which means that input data need to be given accordingly.

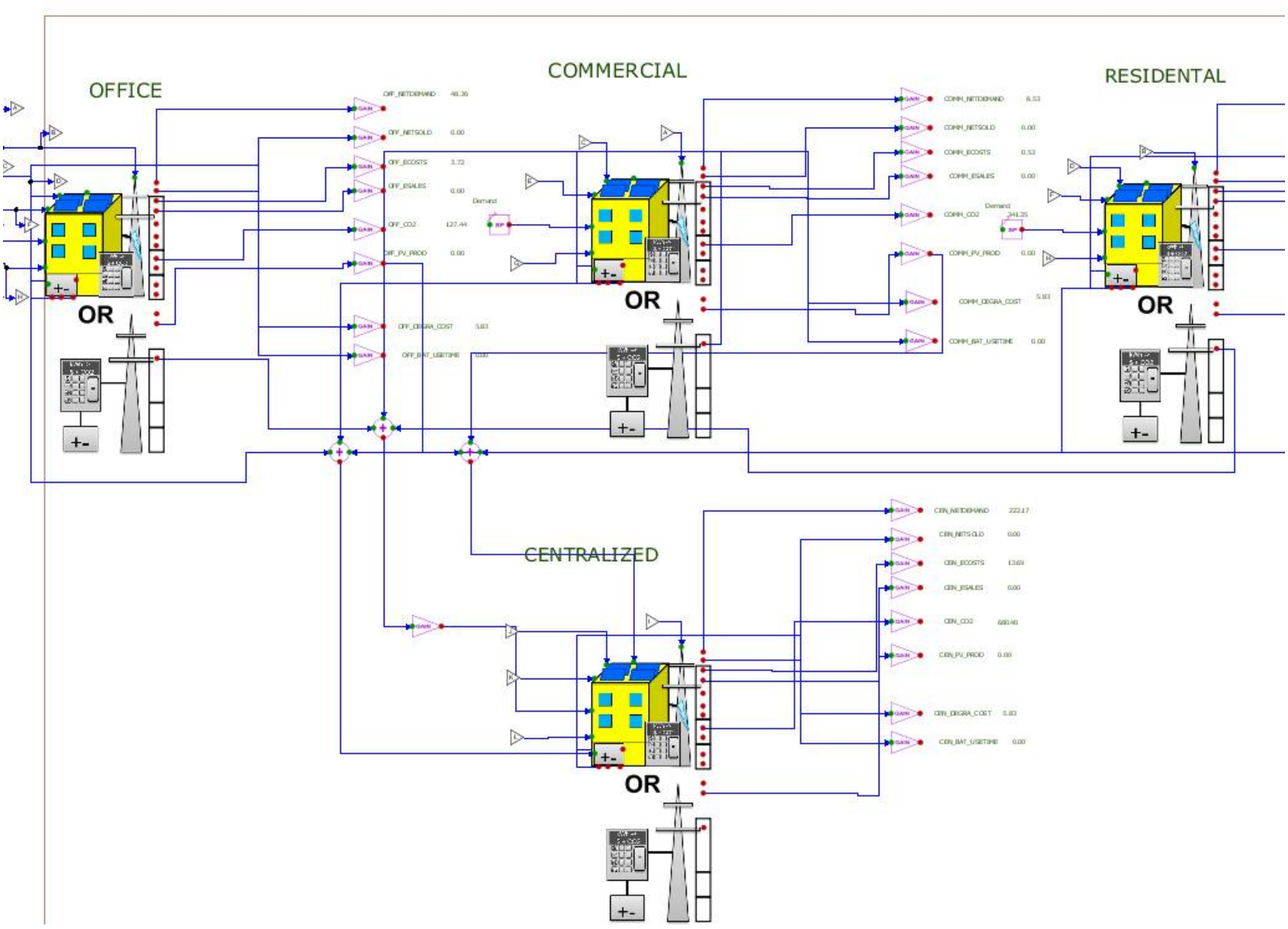


Figure 2. Kalasatama simulation model components.

2.3. Simulations

2.3.1. Case Östersundom – simulated scenarios

Planning Tool simulations were based on the Östersundom simulation model made in APROS (www.apros.fi). The model parameters were set according to the planned area in terms of floor areas and estimated district heating pipe properties. The Östersundom simulations were done in collaboration with the attendants during the user acceptance workshop in 2016. The participants created all in all 6 different scenarios that were later simulated and evaluated in terms of energy costs and CO2-emissions. The simulated energy systems were compared to basic scenario (CHP plant producing heat and electricity to the district).

The Planning Tool's genetic optimization algorithm was used to create scenarios with optimal configurations of photovoltaic production, solar thermal production and thermal storages with respect to energy costs and CO2 emissions. In GA-optimisation the main task for the user is to define boundaries for the parameters within which the GA-optimisation is allowed to vary the parameter values. The simulated scenarios were as follows

User-determined scenarios

The user-determined scenarios were:

- A centralized 27 MW photovoltaic plant with total panel area of 146 000 m^2 and no storage.
- A centralized solar heat plant with total panel area of 146 000 m^2 and storage capacity of volume 3 000 m^3.
- A centralized solar heat plant with total panel area of 146 000 m^2 and storage capacity of volume 10 000 m^3.
- A centralized solar heat plant with total panel area of 146 000 m^2 and storage capacity of volume 75 000 m^3.
- Distributed solar heat production with panel area of 5 %/2.5 % of available floor area in the district's different urban areas and no storage.
- Distributed solar heat production with panel area and storage capacity of 5 %/2.5 % of available floor area in the district's different urban areas.

Genetic optimization

The scenarios resulted from genetic optimization were:

- Distributed electricity and heat production with total panel area of 215 369 m^2 and distributed energy storage 219 990 m^3.
- Distributed electricity and heat production with total panel area of 224 122 m^2 and distributed energy storage 215 761 m^3.
- Distributed electricity and heat production with total panel area of 237 758 m^2 and distributed energy storage 204 704 m^3.
- Distributed electricity and heat production with total panel area of 215 328 m^2 and distributed energy storage 213 164 m^3.
- Distributed electricity and heat production with total panel area of 204 784 m^2 and distributed energy storage 218 632 m^3.
- Distributed electricity and heat production with total panel area of 205 308 m^2 and distributed energy storage 205 448 m^3.
- Distributed electricity and heat production with total panel area of 202 390 m^2 and distributed energy storage 198 512 m^3.
- Distributed electricity and heat production with total panel area of 185 501 m^2 and distributed energy storage 210 563 m^3.
- Distributed electricity and heat production with total panel area of 232 129 m^2 and distributed energy storage 182 564 m^3.
- Distributed electricity and heat production with total panel area of 219 715 m^2 and distributed energy storage 203 023 m^3.
- Distributed electricity and heat production with total panel area of 246 388 m^2 and distributed energy storage 201 999 m^3.
- Distributed electricity and heat production with total panel area of 169 835 m^2 and distributed energy storage 191 768 m^3.

The simulation results are given in section 2.4. The result section describes the achievable outcomes with above listed scenarios in terms of technical, economic and social aspects. It is also discussed what would be optimal system configuration based on the simulation results.

2.3.2. Case Kalasatama – simulated scenarios

With the validated simulation model two scenarios were run with the Planning Tool's genetic optimization algorithm. The best solutions were selected regarding optimal placement and sizing of battery energy storages and photovoltaic production capacity and the optimization based on energy costs and CO2 emissions.

The optimisations of the block in Kalasatama were done in several separate genetic algorithm (GA) optimisation runs in order to examine the difference between centralized and decentralized solutions. In the centralized case all buildings had a common energy system and the system was optimized as one "block" while in the decentralized case each building was separately optimized.

The combined building offering private homes, office premises and shops was modelled to have own photovoltaic production paired with electrical energy storage. The battery energy storage was modelled to do local optimization to smoothen the production and allow flexible use of electricity with different consumption needs.

The other scenario modelled distributed production and storage integrated into different building types separately built. Simulation model models the differences between the buildings in their need of storage capacity coupled with production.

The simulation model describes the utilization rate of the battery in each scenario and allows to study the feasibility and business potential of centralized and decentralized energy systems. The energy systems are integrated to the consumption within the building to avoid the current non-profitable markets in electrical energy storage. The simulation model takes into account the current electricity market position where the purchaser pays taxes and transfer among the electricity when energy is transferred in the electricity grid.

The simulation results for Case Kalasatama are also given in section 2.4. Similar discussion as for Case Östersundom considering technical, economic and social aspects is carried out.

2.4. Results

2.4.1. Technical results

Case Östersundom

The Planning Tool simulations revealed that the genetic optimization algorithm is more powerful in finding optimal energy system settings than experts. A common conclusion is that the solar collectors and heat storages are to be distributed. With the distributed energy system, the production and storage capacities vary with respect to the size of the certain area in the district.

From the GA-optimization results it can be seen that all of the feasible solutions contain heat storage capacities close to the upper boundaries given for each area. In addition, both heat and electricity are produced partly by solar energy and the CHP capacity was lower than in that of the basic scenario. When comparing the expert panel (user-determined) to that of those of the genetic algorithm (Figure 3), it is clear that better results could be achieved with genetic algorithms. The results from simulated scenarios are further reported in detail in Deliverables 3.1 *Helsinki demonstration* and 4.1 *Evaluation of the ICT solution*.

Figure 3. Results from scenarios generated by the genetic algorithm, user-determined scenarios are within the encircled area.

Case Kalasatama

The Planning Tool simulations resulted to energy system where the battery energy storage was regarded as redundant since the suggested storage capacity was zero kilowatt-hours. The photovoltaic production was maximized when the panels were facing south direction. In all of the cases, as in centralized combined building and separate distributed buildings, the outcome was similar and suggested to utilize maximum available roof-top area to produce solar energy. In conclusion the electrical energy storage did not have additional value to the energy system regarding the control logic of the simulation model. The results from simulated scenarios are reported in Deliverables 3.1 *Helsinki demonstration* and 4.1 *Evaluation of the ITC solution* in more detail.

2.4.2. Economic results

Case Östersundom

From the economical point of view the CITYOPT Planning Tool optimization algorithm proved to be capable of minimizing yearly energy costs within defined boundaries of simulation model. With well optimized energy system settings as in sizing and placement the CITYOPT Planning Tool found out viable configurations. The distributed energy systems were found to be more economically efficient than centralized energy systems and also the benefit compared to basic scenario with only conventional power generation was the highest. The yearly savings in energy costs considering the whole Östersundom district would be 3,7 M€ if the convention power generation were to be replaced by distributed renewable energy production and heat storage. The results reflect the current market prices and the evolution of energy prices will also affect the simulation results and the configuration of the optimal scenario. Also the economical results are reported in Deliverables 3.1 and 4.1.

Case Kalasatama

The Kalasatama simulations resulted in minor savings in yearly energy costs when the generated scenarios were compared to basic scenario with conventional power generation. The economical savings were due to minimizing grid purchases considering electricity and hence the savings were seen as reduced cost of purchased energy and reduced amount of paid taxes. The locally produced solar electricity resulted in yearly monetary compensations from 129 € to 799 € depending on the building type. The battery energy storage was not seen as economically viable investment with simulated utilization and hence the economic results encourage only to invest on optimized design of photovoltaic production. Economic results considering Kalasatama case are comprehensively reported in Deliverables 3.1 *Helsinki demonstration* and 4.1 *Evaluation of ITC solutions*.

2.4.3. Social results

The user acceptance testing of CITYOPT Planning Tool with potential users was based on a qualitative methodology, in a workshop format, and involved three participants, representative of three different user groups:

- Energy providers (a representative of Helen Ltd.)
- External consultants (an external freelance consultant)

- City planners (a representative of the City of Helsinki Planning Department)

Participants planned three different scenarios and simulated them using the CITYOPT tool. In general, the tool seems useful and the results on the optimised scenarios are easy to interpret. However, the initial set-up (creation of models) can require considerable efforts and participants suggested that might not be worth for small projects to use the CITYOPT tool for running simulations.

Learnability, efficiency, errors and satisfaction

The learnability of the tool seems to be quite high, but this is compensated by a high efficiency (i.e. once got used with the tool it's easy to run simulations). No major errors have been observed during the usage of the tool. Minor ones were due to repetitiveness of the tasks (e.g. edit long lists of parameters), while others can be easily solved (e.g. not understanding if data has been saved) by providing clearer UI elements.

In fact the emerging themes mainly concern:

- IA (information architecture) issues, such as missing direct links between textual and visual data,
- UI, layout display and interactive element sizing,
- Vocabulary, participants found verbal labelling too cryptic sometimes,
- Level of complexity is not always appropriate to the user, for example City planners need a less complex flow of navigation and elements to manage

2.5. Conclusions

In conclusion of Helsinki case studies the CITYOPT Planning Tool can be considered as powerful design and optimization tool when there are huge amount of possible outcomes. As a result when comparing Östersundom and Kalasatama simulations the tool is better suited to simulate and optimize smaller areas with well-defined boundaries and system properties. Hence the Planning Tool would be more useful in cases such as Kalasatama. Larger districts as Östersundom with complex configuration and lot of uncertainty in future development the optimization results might provide misleading results due to uncertain assumptions.

3. Nice demonstration

The aim of the Nice demonstration was to demonstrate the economic and environmental benefits of the CITYOPT Operational tool designed to encourage behavioral change through demand-response solicitations.

Case description

Provence-Alpes-Côte d'Azur is one of France's most fragile regions for electricity supply, since it is connected to the main electricity plants by just one network. Particularly in winter, when electrical heating means electricity use rises, locals experience frequent blackouts, as the local energy provider, EDF, struggles to manage the supply. Additional energy production resources, mostly carbon powered and polluting, are activated to meet temporary energy demand increases, and to avoid bottlenecks in energy demand, as well as eventual black-outs.

This is why Nice Côte d'Azur has been selected as a pilot city for the CITYOPT project. The Nice pilot looks at the residential level, and explores how people's everyday behaviors can be nudged to better support the energy use of the entire region. To help people change the way they consume electricity, the pilot provides selected locals with the CITYOPT mobile app (a.k.a. the CITYOPT Operational tool).

The app alerts participants the day before each energy consumption peak. Participants are invited to join the CITYOPT mission and devise their own household strategy to reduce their electricity consumption. Energy savings, which are calculated from the household's daily consumption detected by a pre-installed "Linky" smart-meter, are then rewarded with points. Participants can donate their points to support a community project of their choice. The project with the most points will be funded and put into action. Actual consumption data was also measured through pre-installed smart-meters, and used to evaluate the effectiveness of the CITYOPT system.

3.1. Process overview

The CITYOPT Operational application forms a community of householders committed to protect the environment, avoiding overconsumption and the waste of resources (see user tutorial in Figure 4).

CITYOPT engages citizens through the support of local community projects (5-A). Projects address sustainability issues at the neighborhood, city scale or regional scale: for instance a community project could support local schools of the city to buy pedagogical material.

As with crowdsourcing, people can support their favorite projects through the CITYOPT app. Support is given "investing" CITYOPT points in one or more projects. CITYOPT points are the "currency" used to back projects up. CITYOPT points are earned by CITYOPT members for their successful commitment during Demand-Response alerts. Based on the aggregated savings from all participants, the energy supplier is then converting the accumulated points into a financial support to the community project(s).

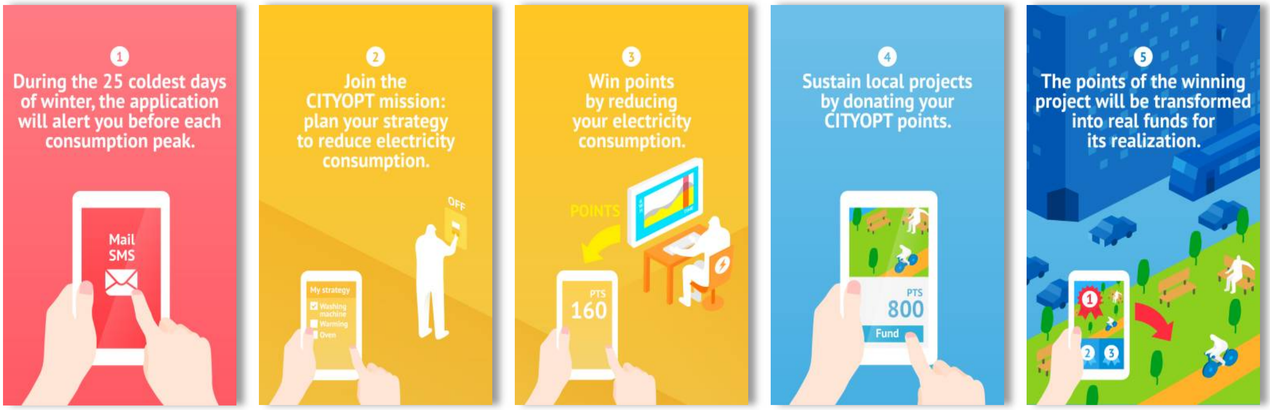
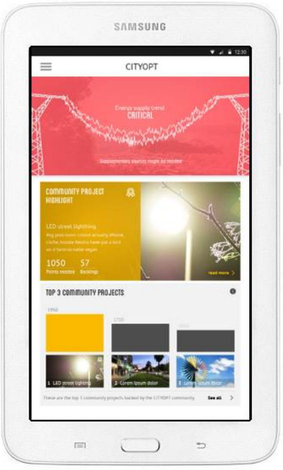
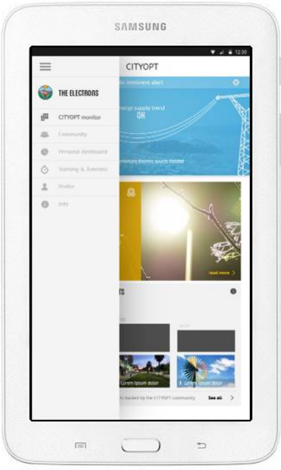


Figure 4. User tutorial of the CITYOPT application.

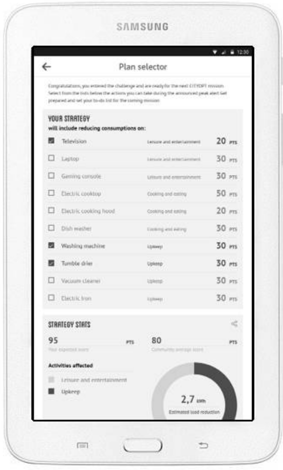


(A) Landing page showing the energy network status (during an alert = red); Top 3 community projects which can be supported by the participants

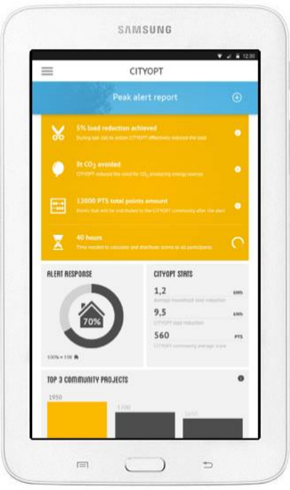


(B) Landing page showing the energy network status (no alert = blue) with left sliding menu bar

(C) Demand-response notification page where the participant can define a strategy for the alert or skip it.

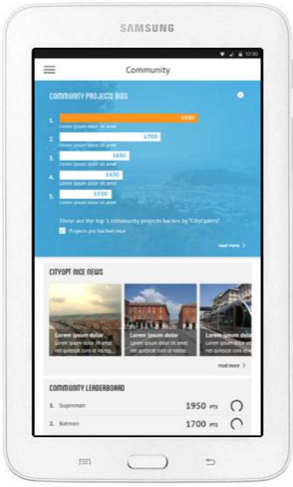


(D) Plan selection page where users define their strategy: selection of the appliances they want to switch off, lower, shift, & corresponding estimation of points

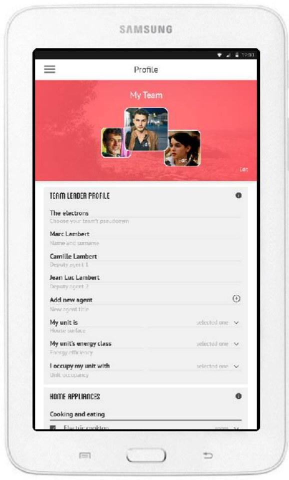


(E) Post alert report presenting actual savings and actual earned number of points after analysis of the load curve from the smart meter

(F) Personal dashboard allowing the participant to follow its scores and progress



(G) Community page allowing to see participant ranking within the community, to share achievements on social networks, etc.



(H) Profile page where the participant can configure their profile, household details and available home appliances.

Figure 5 – Mock-up of the existing CITYOPT Operational application translated in English

CITYOPT participants receive email and text messages on their mobile phones before every

Demand-Response notification[1]: when they are available and decide to participate, users must define their strategy through the application. Choosing which domestic appliance will be turned off, decreased of shifted during an alert allowing them to gain points to be later invested in the community projects (Figure 5-D).

CITYOPT participants engage with each-other: they receive after each demand-response notification a report on the actual impact of their behavioral change with indicators illustrating savings at the individual scale and at the community scale (Figure 5-E). These indicators, as well as the number of allocated CITYOPT points, are calculated from an analysis of their load curve provided by their smart meter: statistical models and algorithms using the half-hourly data from the smart meters are implemented. Participants can tap into social networks to show their commitment and get others to join for a more sustainable environment (Figure 5-G).

The implementation process of the Nice demonstration included the following activities:

- Recruitment of households:
    - More than 5000 mails sent for recruiting 140 participants
    - Agreement established with the French DSO (ENEDIS) to synchronise the CITYOPT recruitment with the deployment of the French Smart meter Linky
    - Elaboration of a participant contract
    - Declaration to French data protection authority
- Delivery of the tablets, continuous participants coaching and training:
    - 9 meetings with the participants for delivering the tablets and initial tutorial
    - 1 permanent email hotline and call center available to support the recruitment and answer Q&A from the participants during the pilot
    - 2 plenary meetings and 1 final event
- Actual demonstration phase : Demand-Response notifications, monitoring and evaluation of the pilot phase
    - 25 peak alerts from November 2015 to June 2016
    - More than 588.000 points allocated by the participants thanks to their energy conservation efforts to the 3 community projects, corresponding to 1.400€.
    - Qualitative analysis through contextual interview with a panel of participants
    - Quantitative analysis through an online participants survey

Further details are available in Deliverable D3.2 – *Nice Demonstration*.

3.2. Models

The CITYOPT Operational application exploits half-hourly data from the smart meters (Linky) in order to analyse the impact of the customer behavioural change on its load curve and the overall impact on the energy network. To this end a statistical model has been developed by EDF originally in the Nice Grid project, and then further refined in CITYOPT.

[1] The customer participant contract set a maximum number of 25 notifications allowed during the 12 months CITYOPT pilot experiment.

In France, Linky[2] is the smart meter being rolled out to 35 million French customers. An agreement was established with the French DSO ENEDIS (formerly ERDF) in order to access the smart meters load curves from CITYOPT pilot's participants. An appropriate declaration was submitted to the French CNIL (Commission Nationale Informatique et Libertés) in order to address privacy issues related to the handling of these data throughout the French demonstration.

Baseline estimations to assess the impact of different energy efficiency interventions and experiments are notoriously difficult to obtain. A meter only measures energy consumption and it is not possible to measure what a participant has not consumed. To overcome this problem EDF's research and technical development teams have developed a statistical method (based on LASSO regression) to calculate the amount of power saved by people taking part in an energy efficiency intervention as a result of changes in their energy use. Essentially EDF has developed methods of estimating a reference curve for a group of research participants. This curve (called baseline) corresponds to the load curve of the participants if they had not reduced their power consumption. The depth of the power suppression consists in the difference between the baseline and the actual load curve of the participant (See Figure 6).

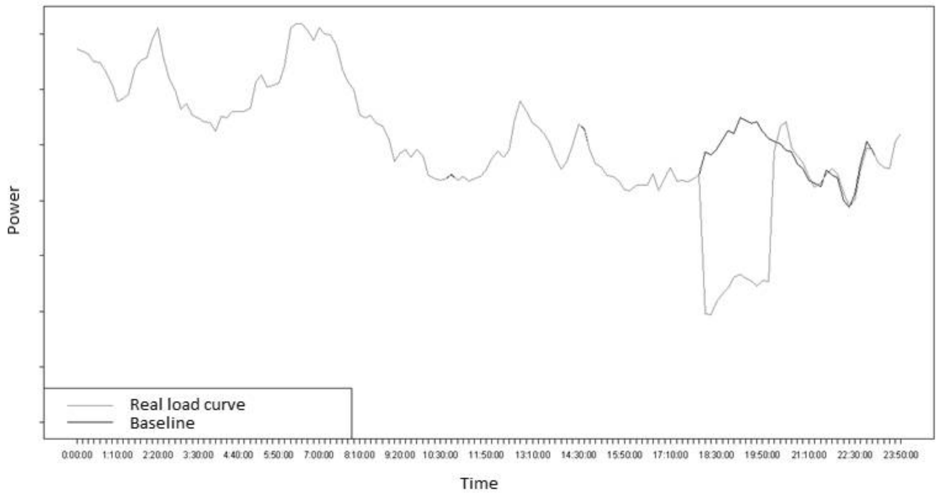


Figure 6 - Peak load energy demand average reduction on a winter day – Source: EDF

To estimate the power of the baseline at a time slot t; the explanatory variables are the non-biased load curve part of the participant group and the power of a control group at the same time slot t. Each member of the control group are carefully selected from a panel of household load curves so that they have the same observable characteristics as the research participants (type of house, square-meters etc.). However there can still be a bias between the load curve of the control group and the curve of the research participant group. This is because those participating in energy research are often more environmentally aware and sensitive to their energy use and carbon foot print etc. than the general population. To address this issue the approach developed by EDF

[2] Linky smart meter technical specifications : http://www.erdf.fr/sites/default/files/documentation/ERDF-CPT-Linky-SPEC-FONC-CPL_Specifications_fonctionnelles_du_profil_CPL_Linky.pdf

reweights individuals from the control group to decrease the bias between the load curve of control group and the load curve of the research participant group. The method gives weight to each individual member of the control group depending on the distance between their load curve and that of the research participant group. This statistical method is patented by EDF: (V/Réf.: B2433, N/Réf.: VDB/SG – FR 13 54694, Published: November 28, 2014: Reference FR 3006075 - “Estimation non consommation après effacement”).

3.3. Simulations

The hypothesis used for the CITYOPT project results was established based on the outcomes of the GRID4EU / NICE GRID[3] experiment:

In NICE GRID, 70% of customers had a contracted power of 9kVa with an annual average of 8000 kWh consumption. In the CITYOPT project only 12% of customers have a contracted power of 9 kVa or more (most of them have a 6kVa contract) and the annual consumption is about 3500 kWh. This means that the consumption reduction between 6 and 8 pm should be less than 350kW. But the collective incentive and the application should improve the result.

3.4. Results

3.4.1. Technical results

Technical results of the Nice Demonstration can be summarized as follows:

- 140 participants
- 25 alerts from November 2015 to May 2016
- 26% of electricity consumption reduction from 6 to 8pm
- 300 Wh/participant of energy savings from 6 to 8pm
- 360 MWh of energy savings between 6 and 8pm if all inhabitants in the PACA region were to participate
    - → this corresponds to the annual consumption of 2 elementary schools

Those figures are further developed in WP4 *Evaluation* deliverable D4.1 *Evaluation of the ICT solution.*

Also a number of KPIs were established to monitor the implementation of the Nice demonstration. They are summarized in the table below:

Indicators	Targeted Value at m29 (June 2016 - end of the NCA experimentation)	Actual value at the end of the demonstration (m29)
Number of information sessions to update the	3	9

[3] GRID4EU / Nice Grid experiment : http://www.grid4eu.eu/ & http://www.nicegrid.fr/

participants of the progress		
Average percentage of participants attending the information sessions	75%	85%
Percentage of participants leaving the experiment before the end of their contract	5%	3%
Number of technical bugs found during the test phase	10	8
Number of alerts sent	25	25
Average percentage of participants who connected to the app for a given alert	80%	76%
Average percentage of unregistered strategy due to technical bugs in the application	5%	2%

Table 1. List of Key Performance Indicators applied in the Nice demonstration

3.4.2. Economic results

Based on the demonstration outcomes, it is conservatively estimated that each CITYOPT participant (end-user of the application) generates at least an average 3-5€ yearly savings through demand response and shifting their peak demand enabling increased efficiency of the utilization asset, eased capacity issues on distribution networks and a reduction in generator margins and the costs of calling on traditional spinning reserve. These savings are likely to grow in the coming years reaching at least an average of 10€ for each participant by 2030[4]. These savings are shared between different types of energy companies (Energy supplier, DSO, etc.) depending on national utilities industry structures, regulations and the different mechanisms of national electricity markets. The 10€ yearly saving / participant is the estimated saving from the energy companies point of view: it could be given back to the customers, or as it is currently in the CITYOPT operational tool model, used to crowdfund community projects.

[4] Again this is a conservative estimate based on the experience of EDF acquired through CITYOPT and on previous related experiments; it is easily within the estimates of leading industry research which estimates global residential Demand Response revenue will grow from $332.4 million in 2014 to $2.3 billion in 2023 (Navigant Research 2016).

In addition to the savings from shifting peak demand most participants are likely to become more aware of their energy use and as such reduce their consumption as a ‘knock on effect’ of participation in shifting their peak demand. These additional savings go directly to participants in the form of reduced energy bills. They are likely to be small at the level of the individual, a conservative estimate being an average of 1%, but this is significant (250 GWh/year) when we think about the possibilities provided by just 10% of the millions of residential customers of the EDF group worldwide.

3.4.3. Social results

Results of the pilot are a combination of both qualitative and quantitative data, driven from:

- 6 Contextual interviews with participants
- Online survey with all (or most of) the 140 volunteer households
- Measured data from the CityOpt app and the Linky smart meter

Main drivers to participation

Some of the most triggering factors to people involvement and engagement were related to different values and goals:

1. Educational: willingness about learning and understanding better about energy consumption, which is related to more individualistic values
2. Environmental concern: people already interested and engaged with environmental issues are actually easy to involve, and it is in between self-interest, civic norms and altruism
3. Community: people feel engaged when they can make comparison with neighbours and friends
4. Local stewardship and Crowdfunding: knowing their engagement and effort would turn into pragmatic effects on the neighbourhood makes people more interested and attached to their role and the mission they are taking

Most of the participant stayed engaged for the whole duration of the demonstration (only 6% of reduced participation rate).
Only 7% of the respondents consider the participation to the project a cause of discomfort, and the main reason was that they should avoid cooking electrically during the peaks, that means to change food habits. 20% of the respondents, those with a high commitment, have no problems in changing food habits. Energy intensive appliances are considered the easiest to include in the strategy by the 85-90% of the participants, partly because by not using these appliances people would gain more points.
80% consider funding community projects an incentive to participate: they appreciate the opportunity to choose a project for the wealth of their community, but also they would like even more to suggest community projects themselves.

Comprehensive social results of the CITYOPT demonstration are presented in scientific paper:
“GOOD CAUSES” CROWDFUNDING AS A DRIVER FOR BEHAVIOURAL CHANGE IN DEMAND RESPONSE SCENARIOS” – Behave 2016 – 4th European Conference on Behaviour and Energy Efficiency, Coimbra, 8-9 September 2016 – Gabriele Santinelli, Veronique Beillan, Ilaria Monteverdi, Isabelle Jalmain, Régis Decorme, Marie Tatibouet.

3.5. Conclusions

A number of positive conclusions are drawn from the Nice experiment:

- A successful recruitment campaign with a better success rate than previous similar experiments involving EDF
- An overall positive appreciation of the concept and of the operational application by the participants.
  - The user research highlighted 8 general areas of improvement that could lead to enhanced user engagement with the CITYOPT app, and that can be generalised for similar demand response applications.
  - For instance people don't spend a lot of time using the CITYOPT app, but they need to access it at any time and from any place, whenever a peak notification requires their response: device preferences for the app were equally distributed among tablets (35%), smartphones (32%) and PCs/laptops (28%), suggesting that a cross-platform and cross-device application, capable of running on mobile devices as well as desktop PCs, is critical.
- The Nice pilot has resulted in a very large number of articles in national and local press media and the Operational application obtained 2 awards: the 2016 "Trophée du Cadre de Vie – FIMBACTE", the 2017 "Observeur du Design label" and the special award "Etoile du Design" with distinction for sustainable development.

With regards to economic results and the potential for replication of the Nice experiment after the end of the project, a number of possible drivers have been identified. These drivers should facilitate CITYOPT large scale deployment and replication on the medium-long term:

- Giving more value to « flexibility »: this should happen through the Capacity market
  - *"The Capacity Market is designed to ensure sufficient reliable capacity is available by providing payments to encourage investment in new capacity or for existing capacity to remain open"*
- Increasing CO2 taxes
- Including « flexibility » as a requirement in the RT2012 (French thermal regulation)
- Creating more dynamic « peak electricity tariffs » to give more value to flexibility

4. Vienna demonstration

4.1. Process overview

The goal of the Vienna study case is to integrate the existing thermal energy supply and storage 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. CITYOPT Planning tool will be 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 building (gas boilers, heat pumps, solar panels, ground heat exchanger), the building (ENERGYbase, TECHBase and FUTUREbase), the district heating network including pipes, water pumps and heat-exchangers, the 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.

Four configurations have been set to study the Vienna study case. Configuration A which study the connection of the buildings, the energy system already placed in the buildings (thermal solar panels, heat pumps and gas boiler), RTA´s climate wind tunnel and a water tank as thermal storage, Configuration B which is as Configuration A but extended including a ground heat storage, Configuration C, which is as Configuration A but connected to the district heating network with an additional office building and Configuration D which is as configuration C including a ground heat storage. Two reference scenarios, where the buildings are working autonomously together with 24 alternative scenarios are set to explore different sizes for the thermal storages. The results from the scenarios and the subsequence analysis were done to explore the optimal solutions in terms of primary energy consumption, CO2 emissions and costs.

Finally, several workshops were set with the stakeholders to evaluate CITYOPT Planning tool from technical point of view, the usability and replicability of the results from the Vienna study case and the use of the tool in other study cases. The results from these workshops summarize presented in this document.

4.2. Models

The overall APROS model of the Vienna case is presented in Error! Reference source not found.. It concerns only the highest structure of the model and each component model consists of several substructures depending on its complexity. The network is designed in a way that the three main buildings (TECHBase, FUTUREBase, ENERGYBase) and the High Temperature Storage (HTS) are always included in the network and all the flow circulating in the pipes has to go through the HTS. A ground heat pump is connected to the boreholes and used to heat up the boreholes output temperatures (20-35°C) to the appropriate temperature levels of the (HTS) (35-100°C) which is also the temperature circulating in the whole network. At each time step, the APROS model tries to satisfy the buildings heating needs using the cheapest heat supply option available (gas boilers, solar panels and a heat pump, High Temperature Storage (HTS) or the Low Temperature Storage (LTS) or the Vienna District heating network).

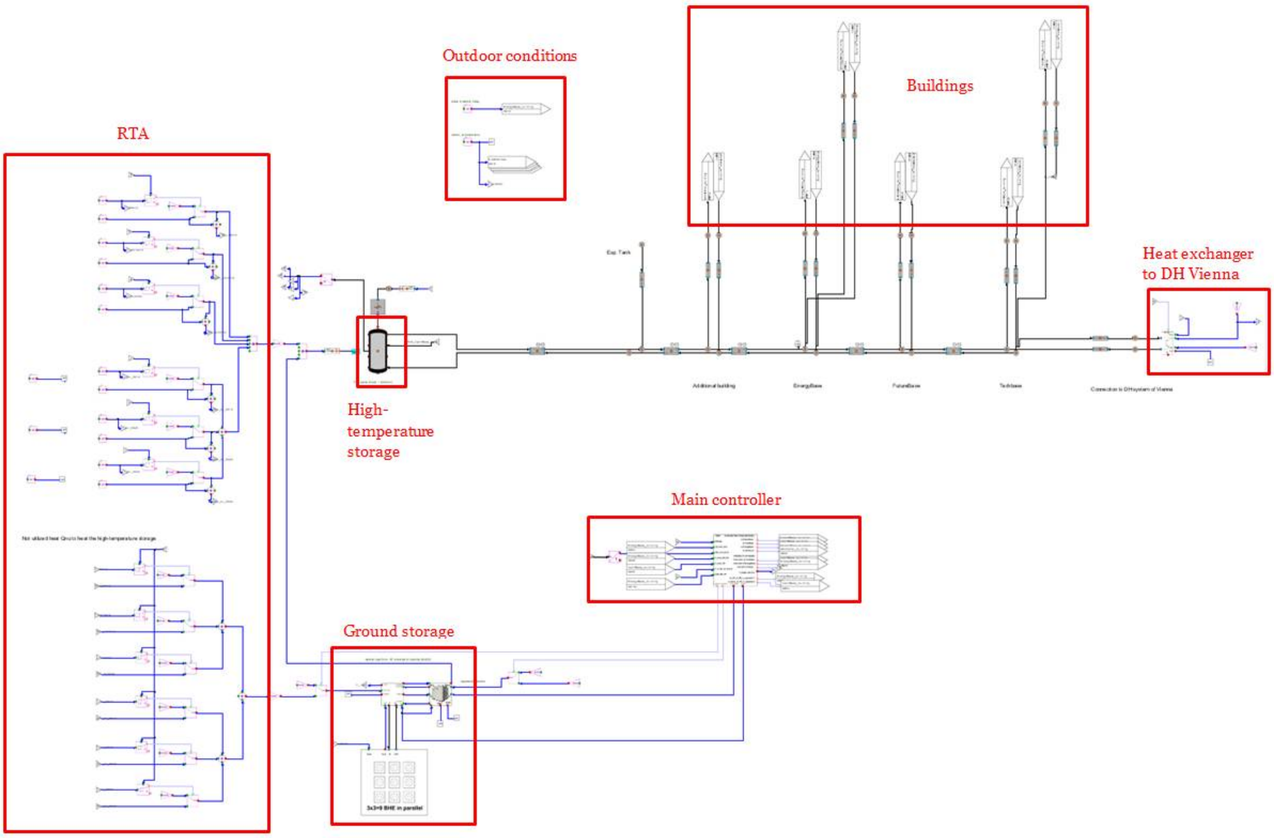


Figure 7. Overall Vienna case study modelled in APROS

In the APROS model each single component, except from the HTS (which takes the RTA waste heat available as input), can be connected or disconnected from the micro-dh network, which makes the overall model very flexible. Indeed, it is possible to model and simulate many different configurations, 85308 combinations in total, of networks including or not including renewable heat sources, fossil sources, industrial waste heat, different types of storages and one or several buildings.

4.3. Simulations

For the Vienna case study it was decided to run, within the CITYOPT planning tool, scenarios which differ in terms of configuration of the network and values of very specific parameters. Besides, considering the computing time required to complete a single simulation of one year (7 hours), the Vienna case study is analysed based on 12 simulation runs of variant scenarios from 2 different reference scenarios, for a total of 26 scenarios. The limitation of the in the number of scenarios is constrained by the timing of the simulation which is around 7 hours per scenario. For this reason, in the design of this study case Database Search Optimization has been used instead of the genetic algorithm.

These scenarios are chosen, taking into account the fixed components of the case study, which cannot be changed (all the energy systems related to the buildings and the industrial waste heat) and the components which are not existing yet and can be sized to optimized the network performances (high-temperature and low-temperature storages). Four different configurations (A, B, C and D) and two reference configurations (REF1 and REF2) represent the different connections that can be set between all the components.

In the REF 1 the three buildings are working autonomously with independent heating systems. In the Configuration A only consider TechBase, Energybase and FutureBase and the waste heat produced by RTA goes first through high temperature storage (HTS) for temperatures from 35°C to 100°C and is then distributed to the buildings according to their needs. In the Configuration B, a ground storage is added to the Configuration A, it allows storing heat to temperatures levels below 35°C via boreholes heat exchangers (LTH). In the REF 1 the three buildings are working autonomously with independent heating systems as REF1 but an additional building is added. This office building is driven by a heat pump as ENERGYbase. Configuration C is the same than the configuration A but adding an additional building and connecting to the micro-DH to evaluate back-up possibilities. Finally, in the Configuration D a ground storage is added to the Configuration C.

For each configuration, the size of the storages (when included in the configuration) takes three different values. The considered sizes were for the high-temperature storage 50 m^3, 100 m^3 and 150 m^3 and for the low-temperature storage 1960 m^3, 2352 m^3 and 2744 m^3.

Three metrics were created to assess the micro-network performances: CO2 emissions (tons/MWh), Primary Energy consumption (GWh) and costs (€). The storages sizes are related to these metrics, in the sense that a good sizing allows using a maximum waste heat and so reduces the CO2 emissions, primary energy consumption and costs (associated to gas and electricity use). As one single simulation is very demanding in terms of computational resources (time and memory space), it was decided to use the Data Base Optimization.

4.4. Results

4.4.1. Technical results

When comparing the scenarios for the Configurations A and B with the REF 1, some general tendencies can be noticed. In general the boiler production is more important than in the scenario REF1, due to the fact that in these scenarios, the boilers supply heat to TECHBase and to the network. The heat pump production and the solar production is quite stable, because they are used in priority to satisfy ENERGYBase needs. When involved in the network, the LTS contribution is steady. Most of the CO2 emissions are due to the gas boilers production and approximately 30% of the CO2 emissions are due to the operation of the LTS. The CO2 emissions due to the heat pump in the scenario REF1, 67t are drastically cut down to around 12t in the other scenarios, but replaced by the CO2 emissions from the operation of the LTS. Finally, the scenario with a 100m^3 HTS and no LTS is the less primary energy demanding scenario, but also the scenario responsible for the least CO2 emissions.

Scenario	HTS	LTS	Solar Panels	Heat pump	Gas Boiler	Network	District heating
REF1	0	0	75.4	390.4	651.7	0	0
SC1	158.3	0	149.4	105.4	747.3	356.4	0
SC2	167.8	0	145.3	105	743.2	363.2	0
SC3	175.4	0	142.3	103.6	741.6	369.5	0
SC4	4	292.6	115.6	102.5	665.6	406.9	0
SC5	4.3	303.2	115.1	101.8	657.8	410.9	0
SC6	4.5	311.7	114.1	100.6	651.4	415.2	0
SC7	7.3	300.1	110.8	102.2	661.8	413.1	0
SC8	7.3	309.4	111.6	101.2	654.7	416.3	0
SC9	7.5	317.9	110.8	100.7	647.5	419.6	0
SC10	5.7	407.2	102.2	95.7	583.3	450.7	0
SC11	9.5	316.1	111.0	101.2	650.3	421.6	0
SC12	10.1	323.8	111.1	100.5	643.8	424.1	0
REF2	0	0	75.4	623.2	651.7	0	0
SC13	177.1	0	108.5	5.9	260.7	142	842.7
SC14	185.7	0	105.5	5.9	241.3	143.8	858.6
SC15	193	0	103.8	5.9	234	146	863.3
SC16	2.4	1330.1	88.4	5.9	210.7	1025.1	745.6
SC17	2.5	1330.8	86.7	5.9	205.2	1033.0	742.0
SC18	2.9	1330.1	85.9	6.0	201.0	1037.1	735.2
SC19	3.0	465.6	77.2	6.0	138.6	1105.3	718.9
SC20	4.0	363.4	84.3	6.0	195.8	1045.7	751.4
SC21	4	363.4	83.0	6.0	193.3	1048.0	743.8
SC22	4.2	355.8	84.4	6.0	195.0	1044.8	760.1
SC23	4.6	370.0	82.6	5.9	192.2	1047.6	750.7
SC24	4.8	370.0	81.1	6.0	189.9	1049.7	743.5

Table 2: Energy supplied (MWh) by each source for all the scenarios.

Similarly, when it is compared the scenarios for the Configurations C and D with the REF 2, general conclusions can be underlined. The heat pump production has high reduction compared to the scenario REF2. The boilers and solar production is quite stable among all the scenarios. The contribution from the main DH of Vienna is slightly varying around 743MWh, except for the scenarios with the additional building and LTS are considered. When the LTS is added the HTS is almost not used anymore. The results show that for REF2 62% of the CO2 emissions are due to the boilers of TB and 38%due to the heat pump of the ENERGYBase, FUTUREBase and the additional building. In configuration C only the boilers cause the CO2 emissions but for Configuration D the CO2 emissions are essentially due to the operation of the LTS up to 64% and the gas boilers up to 36%. Finally, the Scenario with HTS of 100 m^3 and no LTS is the least demanding in terms of primary energy and CO2 emissions.

Scenario	HTS	LTS	Solar Panels	Heat pump	Gas Boiler	District heating
REF1	0	0	0	68.6	179.9	0
SC1	0	0	0	12.1	206.3	0
SC2	0	0	0	13.7	189.9	0
SC3	0	0	0	14.4	194.5	0
SC4	0	74.2	0	11.9	170.3	0
SC5	0	76.7	0	12.7	169.4	0
SC6	0	79.1	0	12.8	169.1	0
SC7	0	76.1	0	11.9	181.6	0
SC8	0	77.9	0	14.6	170.2	0
SC9	0	79.9	0	12.8	169.5	0
SC10	0	103.7	0	11.2	161.1	0
SC11	0	79.4	0	14.6	174.5	0
SC12	0	80.6	0	15.9	173.9	0
REF2	0	0	0	109.5	179.9	0
SC13	0	0	0	0.7	72	5.6
SC14	0	0	0	0.7	66.6	5.7
SC15	0	0	0	0.7	64.6	5.7
SC16	0	86.1	0	0.7	56.7	5
SC17	0	89.5	0	0.7	55.6	4.9
SC18	0	92.7	0	0.7	54.9	4.9
SC19	0	119.4	0	0.7	56.7	4.7
SC20	0	91.7	0	0.7	55.6	5
SC21	0	95	0	0.7	54.9	4.9
SC22	0	89.6	0	0.7	53.9	5
SC23	0	93	0	0.7	53.1	5
SC24	0	96.8	0	0.7	52.4	4.9

Table 3: CO2 emissions (tons) of each source for all the scenarios.

4.4.2. Economic results

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 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.

In REF1 and REF2, the costs are composed of the costs of the heat pumps and the costs of the gas boilers, with a similar share 80% - 20%. For the Configurations A and B, the main part of the costs is due to the gas boiler, the LTS contribute with a 7% and the heat pump around 1%. For the configurations C and D, the District heating of Vienna is responsible for most of the costs, between 67% to 75% and the gas boilers for 23% to 28% of the total costs. When the LTS is part of the network, its operation especially the operation of its coupled heat pump booster costs from 6% to 9% of the total costs.

Reference scenario REF 1 represents 55€/MWh and 49€/MWh respectively, meanwhile the scenario with 150 m³ HTS and 1960 m³ LTS is the least cost scenario for Configuration A and Configuration B with 46€/MWh and the scenario 100 m³ HTS and 1960 m³LTS is the least cost scenario for Configuration C and Configuration D with 45€/MWh.

Scenario	HTS	LTS	Solar Panels	Heat pump	Gas Boiler	District heating
REF1	0	0	0	9'760.6	48'878.0	0
SC1	0	0	0	575.3	56'047.8	0
SC2	0	0	0	649.3	51'591.5	0
SC3	0	0	0	684.1	52'833.8	0
SC4	0	3'520.7	0	563.2	46'259.1	0
SC5	0	3'635.5	0	602.9	46'023.8	0
SC6	0	3'749.0	0	609.3	45'929.9	0
SC7	0	3'610.2	0	562.4	49'333.0	0
SC8	0	3'693.1	0	690.2	46'229.5	0
SC9	0	3'788.0	0	606	46'028.0	0
SC10	0	4'920.1	0	530.5	43'747.0	0
SC11	0	3'764.2	0	692.8	47'400.7	0
SC12	0	3'824.1	0	753.6	47'227.5	0
REF2	0	0	0	15'580.1	48'878.0	0
SC13	0	0	0	31.8	19'552.5	50'559.8
SC14	0	0	0	32.5	18'097.5	51'518.5
SC15	0	0	0	32.2	17'550.0	51'798.9
SC16	0	4'082.3	0	32	15'400.1	45'307.1
SC17	0	4'245.9	0	32.2	15'112.5	44'821.3
SC18	0	4'396.5	0	32.4	14'918.9	44'341.1
SC19	0	5'662.6	0	32.8	15'400.1	43'136.4
SC20	0	4'348.0	0	32.6	15'112.5	45'083.8
SC21	0	4'505.9	0	32.6	14'918.9	44'628.8
SC22	0	4'249.5	0	32.4	14'628.2	45'558.8
SC23	0	4'408.7	0	32.2	14'418.2	45'036.1
SC24	0	4'591.6	0	32.4	14'242.2	44'609.0

Table 4: Operational costs (€) of each source for all the scenarios.

4.4.3. Social results

4.4.3.1. Interview with AIT Engineers

The participants were to execute certain usability tasks with the tool, give feedback and reply to specific questions asked by the facilitators (Experientia and AIT). The interview followed a qualitative approach in order to go deeper inside the emerging themes of the user experience. The main purposes were the inquiry of the expected potential of the tool according to the different participant's roles, of the expected information and if the tool provided the required ones, the existence of any usability issues or other usage barriers, and people's satisfaction level, doubts, concerns and expectations for the future release of the tool.

The participants 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.

Learnability, efficiency, errors and satisfaction

The first usage of the tool is not straightforward and requires preliminary preparation (i.e. read instructions and follow example tutorials), due to the still fragmented parts of the navigation and some misleading interpretation labels. However, with a clearer and refined UI adjustment the first usage interaction would be simplified. Moreover, efficiency is high as it is easy to perform the tasks and get the required results, once the user got familiar with the tool. No major errors have been observed during the usability sessions. Minor ones 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. The participants were overall satisfied by the experience, they found that the tool could be applied 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 in energy modelling, given its features of envisioning and changing variables, comparing different scenarios, and speeding up the initial evaluation process.

4.4.3.2. Interview with the Stakeholders

The general outcome of the interviews is that the tool can support to the stakeholder in making decisions and support the discussion among the different stakeholders. In this sense, it was very important the capability of CITYOPT Planning tool to create metrics to evaluate the economic viability of an investment

Participants appreciated the flexibility of the tool in easily linking any type of energy model, since it allows to use specific models to get optimal solution depending of their needs and constrains.

4.5. Conclusions

The CITYOPT Planning tool allowed simulating various scenarios, calculating specific metrics (energy, environmental and economic metrics) and finding the best scenario among the scenarios simulated, through a Database Search Algorithm. The Vienna study case was evaluated through the CITYOPT Planning tool. The results can help decision makers to get a better understanding of the situation and some key metrics together with the optimization results can be useful to make a decision according to specific criteria.

The analysis of the results from the simulations of the Vienna study case in CITYOPT, indicate 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.

At the 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.

5. General conclusions

In conclusion the Planning Tool can be considered as powerful design and optimization tool, concerning urban districts, when there are huge amount of possible outcomes.
In fact, in the Helsinki demonstration, when comparing Östersundom and Kalasatama simulations the tool is better suited to simulate and optimize smaller areas with well-defined boundaries and system properties. Hence the Planning Tool would be more useful in cases such as Kalasatama, since that in larger districts as Östersundom, characterized with complex configuration and lot of uncertainty in future development, the optimization results might provide misleading data.

For what concerns energy systems planning and design within a network of buildings, as in the Vienna case, 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. Low temperature storage allows using a high share of waste heat has low operational costs but generates non-negligible CO2 due to the need of a heat pump booster to rise 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.
In this context, the best scenarios of usage, where only the metrics Primary energy and CO2 emissions are considered as best options, are those without LTS. In particular, for the situation when 3 buildings are connected to the district heating network is HTS 100m3 and for 4 buildings is 150 m^3. When the metrics Cost is the main driver of the optimization the best scenarios for both situations involves a 1960 m^3 LTS and a 150 m^3 or 100 m^3 HTS for 3 and 4 connected buildings respectively. Additionally, the best scenario in terms of operational costs is also the worst scenario in terms of Primary energy used and CO2 emissions.
At first glance, the replicability of the Vienna study case can seem limited but considering all the different combinations possible in this case allows to analyze and address the problem including the challenges in the modeling issues as fluctuating energy supply, low-temperatures, integration of new buildings, this Vienna study case can be scaled up and suitable for many other cases.

The tool is well appreciated by the participants, because it gives the user a visual hint about the whole system, by abstracting from the many metrics and the way they are connected together, and it helps in first step of decision making. However, the research highlighted a number of problems affecting the user experience of the CITYOPT Planning tool, which should be addressed in order to guarantee a better usability and user experience.

Concerning the Operational tool, participants appreciated the idea of having an application that enables them to better understand their household consumption and to learn how to optimize it, and they appreciated also the concept of crowdfunding embedded in the experimentation.
It was well appreciated by the participants both for its concept and of the operational application by the participants.

A successful recruitment campaign (with a better success rate than previous similar experiments involving EDF), together with the gamification dynamics (due to the point-system) and the crowdfunding component is what caught and maintained people's engagement in the experimentation. There are usability aspects of the app that still need to be improved, as emerged from the user research. In addition, another point of interest that should be further developed, refers to deepen the participation within the families, and trigger the social-networking dimension in order to engage younger generations. The demonstration should be replicate in different countries with different climates, energy costs and “heating culture”, to obtain more relevant results.

6. References

D3.1 Helsinki demostration

D3.2 Nice demonstration

D3.3 Vienna demonstration

D4.1 Evaluation of ITC solutions

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7. List of figures

8. List of tables