Energimyndigheten

SLUTRAPPORT BILAGA 2

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e-Flex

Digital plattform för handel och styrning av energi

Energimyndighetens titel på projektet – svenska	
Digital plattform för handel och styrning av energi Bilaga 2: Delrapport Utveckling av digital plattform	
Energimyndighetens titel på projektet – engelska	
Digital platform for energy trade and consumer flexibility Appendix 2: Interim Report Development of the digital platform	
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Preface

The Energy Agency has financially supported implementation of the project Digital Platform for trade and management of energy. The project is implemented within the framework of the Digitalization program which enables energy and climate transition. AP2 report is a part of final reports of e-Flex project which deals with development and implementing Digital Platform (DP) through proper communications between involved actors.

Project participants: Kraftringen Energi AB, Energy Opticon AB, Sustainable Business Hub Scandinavia AB, Lund University, RISE and Region Skåne.

Work Package	Title
AP0	Project management
AP1	Potential study for energy system benefit
AP2	**Development of Digital Platform (DP)**
AP3	Development of business model
AP4	Pilot
AP5	Evaluation of Pilots
AP6	Replicability and scale-up
AP7	Communication and dissemination

Abbreviations

AP	Arbetspaket
API	Application Programming Interface
COP	Coefficient Of Performance
DC	District Cooling
DH	District Heating
DH/C	District Heating & Cooling
DHW	Domestic Hot Water
DP	Digital Platform
ECO	Economic
ENTSO-E	European Network of Transmission System Operators for Electricity
EO	Energy Opticon AB
EO3	Energy Optima 3 Software
HP	Heat Pump
KPI	Key Performance Indicator
KR	Kraftringen AB
LTH	Lunds Tekniska Högskola
PE	Primary Energy
PEF	Primary Energy Factor
RF	Regionfastigheter
RS	Region Skåne
SH	Space Heating
SSRS	SQL Server Reporting Services
TDP	Transaction Digital Platform
TO	Test Object

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Summary

Work Package 2 (ArbetsPaket 2 - AP2) of the e-flex project, Digital Platform (DP), is explained in this report. The goal of AP2 is to develop a platform that generates operational plans for 5 test objects (TOs) based on dynamic price model for District Heating, Cooling (DH/C) and electricity coming from the energy company. Furthermore, this platform must provide the proper methods to secure data flows between the actors. AP2 report describes the prerequisites for the platform, how the platform works, how the data is exchanged and how the operational plans are generated. The uniqueness is that e-flex is the hub between the overall optimization system for the production facilities in the city and property owners and that the operational plans switch between different energy sources based on dynamic price models and environmental output.

The five TOs described in detail in AP1, are located in the hospital area in Lund and owned by Regionfastigheter (RF), which is owned by Region Skåne (RS), and DH/C are supplied by Kraftringen (KR).

The data flow is managed by Energy Opticon (EO), together with RS and a building optimization company, which has smart data systems to manage data and control indoor temperatures by installing temperature sensors. The optimizations, which are the core of the platform, run in EO's system Energy Optima 3 (EO3). Several optimization scenarios with different weights on economy, environment and

primary energy (PE) are implemented and analyzed within the project. One main purpose of this project is to make optimal use of the existing energy flexibility and thus provide financial savings both for the property owner, RF, and the energy company, Kraftringen (KR). Another purpose is to reduce environmental impact and therefore also provide a decrease in CO_2 and PE use.

The DP connects the energy company with the buildings in the city for co-optimization. The communication that flows through the platform is, among other things, information about production units, marginal production cost and available flexibility on the customer side. EO is responsible for the digital platform as well as the interfaces that retrieve or send data from it. The calculations are dependent on the fact that the data is flowing continuously from both sides.

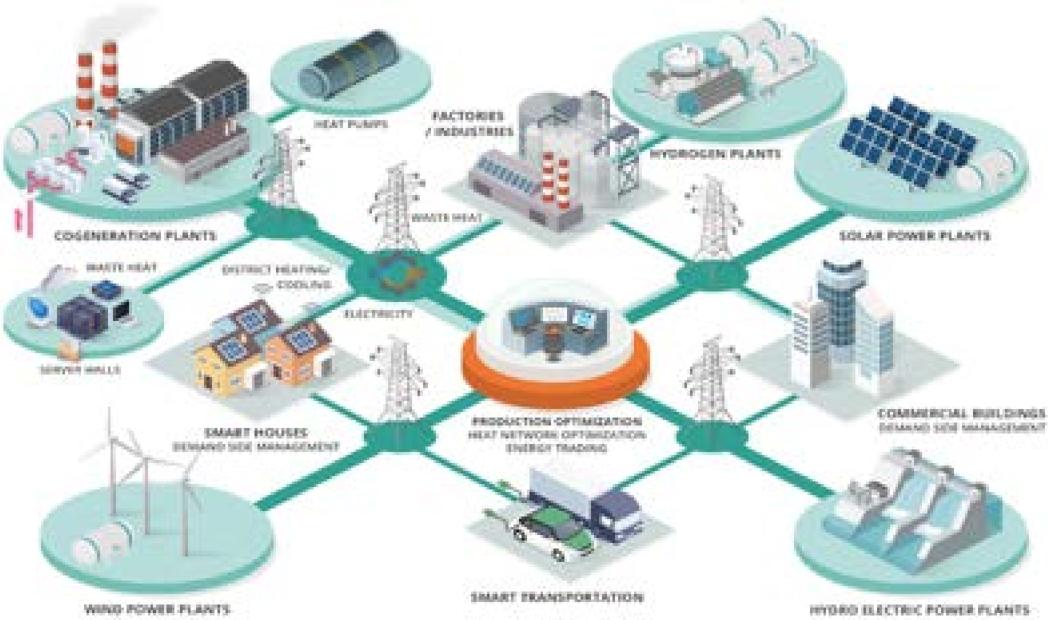
Furthermore, for the system to work in the most efficient way, some form of control of the buildings is required, together with a secure way of communicating (cyber security). This report summarizes the latest security measures that have been implemented on the e-flex cloud platform to manage known risks and strengthen IT security. The report explains the measures that have been taken to ensure a robust and sustainable security architecture that resists potential threats and ensures a high level of data protection and compliance.

The e-Flex project initiated a unique and successful collaboration between energy companies, property owners, and suppliers of energy optimization and building optimization systems. The result of this AP2 shows the possibility of creating a DP that generates specific operational plans for the TOs based on dynamic price signals for electricity, heat and cooling and this can be done in a secure way.

This collaborative project has developed an efficient, replicable and scalable solution for consumer flexibility for DH/C and electricity. It has also achieved to create a more robust and environmentally friendly energy system. The platform has been well-tested and evaluated, and more building owners are getting ready to be connected. Several energy companies across the Nordics have shown strong interest in rolling out e-Flex for their own energy systems, and it's a wide-spread consensus that these types of solutions are a part of tomorrow's smart and flexible energy systems.

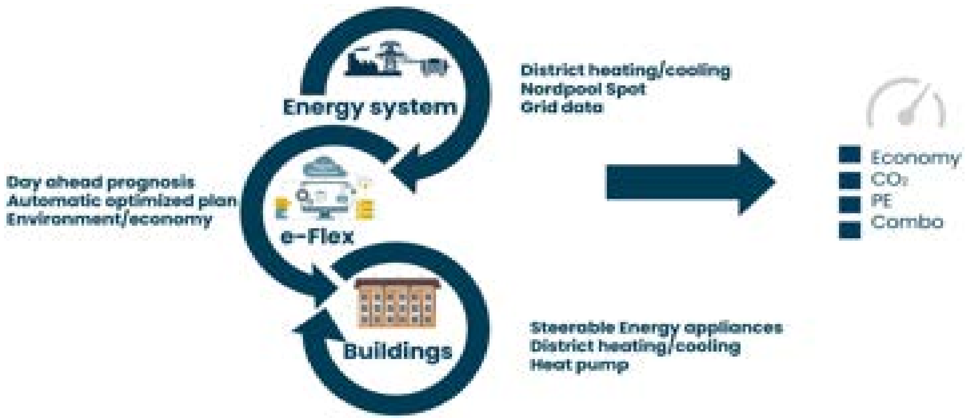
Introduction

A future integrated energy system is shown in the picture below. It emphasizes integration and co-optimization of different parts as one, flexible energy system (as in e-Flex) instead of sub-optimization of each part separately. A comprehensive optimization from production sites to customer sites would increase flexibility and create savings both in terms of cost and environmental effects. As can be seen, an energy optimization system in the middle is interacting with all connected units simultaneously and optimizing all together to achieve maximum savings.



Picture 1: Total Optimization in future energy systems

For this reason, EO's optimization software EO3, which is the core of the DP of e-Flex, interacts from the energy company KR's side with production units, marginal production costs, the overall district heating network, and Nordpool Elspot price. From the building side, it is connected to the customer sites and integrated units through RS building control system called TDP, and a building optimization system. All data flows through the DP, which is the smart engine for the creation of operational plans for the TOs.



Picture 2: The concept of e-Flex

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Several strategic security measures have been implemented on the cloud platform to manage identified risks and strengthen security at all levels. The work has mainly focused on improving authentication processes, automating security controls, strengthening monitoring functions and ensuring robust API security. For this reason, a risk analysis has been conducted.

The following items will be included in this work package:

• EO calculates the price model based on collected data, which is the basis for creating a collaborative platform and variable hourly prices for electricity and DH/C.

• Construction of model and algorithms for the customer as well as new calculation methods for the total model. The modeling has been done within DP and KR system and connections to RS.

• Development of new ways to send and receive data through secured validated API

• Development of load forecasting models within EO in DP

• Presentation methods for clarity and transparency by daily SSRS reporting system to show daily plans and results and functionality of DP

• Follow-up and evaluation methods for the results by showing comparative graphs and providing data for evaluation phase AP5

• Evaluate & analyze the data platform from a security perspective

• Develop and recommend a security architecture

• Develop a lifecycle process for security work through the risk analysis assessment

Characteristics

The main characteristics and challenges of the project are listed as below:

- A digital platform which connects cutting-edge technologies for production optimization and building optimization
- Total optimization of flexible, integrated energy systems
- Trading and energy management
- Strategies for energy transition
- Reducing consumption and improving energy efficiency to influence the environmental impact
- Smart IT solutions for real-time measurements, control and optimization
- The optimization is done via control signals based on forecasts and online measurement, based on both financial and environmental parameters.
- Forecasts of consumption and of environmental impacts
- New business models
- Confidentiality and functionality of any data concerning the hospital area must not be compromised.

Challenges

- Managing massive data in the platform to send to and receive from different locations
- Synchronizing data and preparing for an effective optimization based on different scenarios
- Adjusting and developing the modeling according to the changes
- Follow-up and coordinating tasks between different parties to proceed the project
- Protect data in terms of cybersecurity and confidentiality

Implementation

The DP needs some input to be able to calculate the operational plans. One important input is that it communicates with the optimization system on KR side. KR grid is connected to Helsingborg and Landskrona through the Evita cooperation.

EO is, with the software EO3, one of the largest suppliers of specialized software for economic total optimization of energy and hydrogen systems, accurate load and price forecasting and support for different trading markets (such as day-ahead, intraday and ancillary service). EO3 optimizes and provides decision support for the production, both daily planning and long-term investment planning, such as dimensioning of new units. EO3 also has functionality for optimization of the forward temperature in the heat networks, which is input for consumer flexibility.

EO3 is software that calculates the most optimal way to operate all the units for the three cities given technical and economic data and load and price forecasts through its unique optimization algorithms. The fact that there are many units in the Evita system makes it a complex environment to calculate the marginal cost to produce energy. The cost on the margin is dynamic in nature and is the basis for cooperation with the buildings in the city, since switching between different forms of energy can be beneficial for both parties. The marginal cost is calculated in KRs EO3 system. The system shows on an hourly basis which plant in the Evita system that is on the margin (See AP3 for more details).

AP1 is a very important input for AP2 since it showed the necessity of some form of win-win situation for both KR and RF. AP1 showed that there was potential in the test objects and there was, therefore, a reason to continue with testing if this was the case in real operation. AP3 also gave input to AP2 since this is the basis for the business models that are used for the cooperation in the DP between the property owner and the energy company.

The connection between KRs system and the DP is crucial for the co-optimization to occur with the city. The staff in the energy company are ultimately responsible for the planning of the production and sending out the correct amount of energy to the city. Therefore, they need to have a realistic picture of what the demand for different forms of energy will be. The timing of the optimizations on the DP was, therefore, important to fit both with the planning schedule of the operational staff but also with the property owners that receive the energy in the city.

However, in this project we did not optimize only toward the economy, or only toward the environment, but a platform that could create operational plans based on a combination of both environmental and economic gains was created. Therefore, there are four different optimization scenarios:

1) **ECO Optimization** to optimize costs and increase saving
2) **CO_2 Optimization** to minimize generating CO_2
3) **PE Optimization** to maximize saving in PE use
4) **Combination** of all abovementioned optimizations together

Then, all these scenarios can be compared to the actual outcome and reference case as it was before starting the project to see how much saving has been achieved and how much could be achieved potentially. Environmental data from KRs system for DH/C was used in these calculations together with a forecast for emissions for electricity that was created by LTH. The Nordpool Spotprice is also another input.

Modeling in the Digital Platform

Several offices and residential buildings in the hospital area of Lund owned by RS are selected as five different TOs in e-Flex. An off-line model of each TO is created on the DP in its own EO3 system in a graphical editor. The characteristics and input of this model is based on technical and economic data for each TO. The aim is to create a digital twin of the TOs.

They are generally identified as power reduction (implemented in 4 TOs), replacement of energy carriers or energy flexibility (in 3 TOs), and heat flexibility (in 1 TO). In all cases, energy price comes from KR system based on marginal cost. Different methods were established to calculate and then evaluate marginal production costs. It was one of the most challenging parts of the project since there are many running units in the shared network between KR and other energy companies.

Power reduction: In the first TO, only power reduction was investigated and the possibility of short electricity outage temporarily in ventilation system of a building was proven to help power grid load especially in peak loads. However, the power reduction option is implemented in other 3 TOs to be able to reduce electricity consumption which will be described later.

Energy Flexibility: Heating and cooling of the buildings in TO2, 3 and 5 were provided by cooling machine and heat pumps before commissioning e-Flex. Then, they got the possibility to have flexibility (switching) between buying electricity (HP operation for own heating or cooling production) or buying DH/C from KR. It should be mentioned that they were already connected to DH/C network before the project, but they had a static operational plan mainly using DH/C as peak load. For TO5, DH was used in summer, the rest of the months only as peak load.

The possibility of power reduction is implemented in these TOs also. The electricity price is based on spot price market plus grid tariff and taxes while DH/C price is based on KR business model and marginal cost. Finally, a total energy optimization for the whole energy system from the production to the consumption is generated by EO3 within DP. The outcome is being sent to the customer site as a daily operational plan based on requested active scenario (ECO/CO_2/PE/Combination).

Picture 3: Functionality of the TOs

Heat Flexibility: Heating in TO4 is provided by DH and the possibility to turn it off temporarily has been added to it based on the heat flexibility of the building as a deviation from standard profile in KR production. A building optimization system optimizes cost and indoor comfort in each specific building with a price signal. The idea could be to change the customers' behavior especially in peak times and thereby gain mutual benefits by deviating from the regular load profile.

After the off-line model is finished it is time to test it in real life through connecting all the dots and to test the algorithms. The models were tested together with connections and data interfaces. After passing test phases, the models were tested in live mode. Any issues within DP and the project have been fixed through appropriate and fast communication between all parties. Continuous dialogue was open between the production site and property owner to make sure that the project proceeded smoothly as planned and in fixing issues quickly. New ideas and developments were proposed, discussed and implemented if needed.

Test Objects Descriptions

TO1 – Power Reduction

The first TO includes an exhaust and supply air ventilation with heat recovery through a FTX system. FTX is a fan-controlled supply and extract air system with heat recovery to supply large quantities of ventilation air. Three FTX units are equipped with a heat exchanger, and close to each other. So, the focus is electricity reduction by turning off ventilation system when it is possible. The ventilation system works between 7:00 to 17:00 every day.

In this TO, only power reduction was investigated. The possibility of short electricity outage temporarily in ventilation system of a building was proven to help power grid load especially in peak loads. The purpose is to lower electricity demand during peak hours. The electricity is supplied by the grid. The operational order is on/off in a binary mode by either running continuously ventilation system as usual (most of the year - 0) or working at half speed to reduce electricity consumption (flexible mode - 1) to get benefit from buying less electricity from the grid, only in a short time since turning off the ventilation more than 1 hour is problematic. The criteria to apply this flexibility and activate the order are:

1) Max 1 hour activation of down-regulating of electricity since longer time causes issues in building envelope
2) At least 3 hours between down-regulations
3) To get paid for helping the grid during peak loads when compensation is allowed

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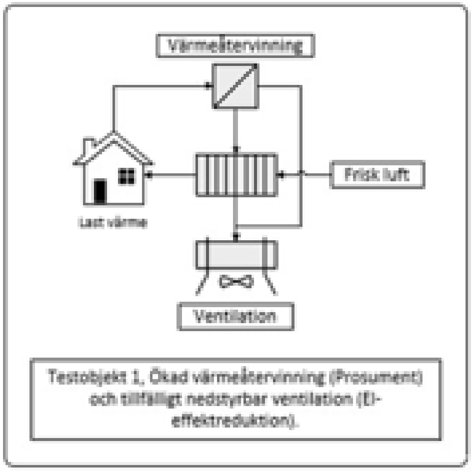


Picture 4: TO1

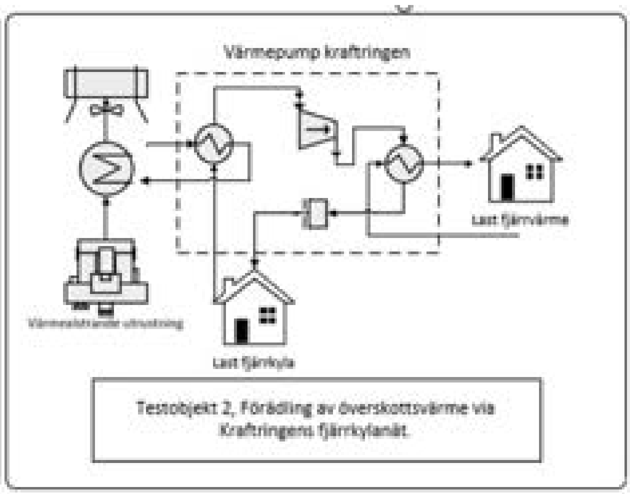
Down-regulating of electricity (Effektersättning) is compensation paid when lowering electricity consumption in peak hours. It should be used only when really needed, which could happen on a few occasions per year.

TO 2 – Flexibility between DC/El. (Cooling Machine)

The initial purpose of this site was recovering surplus heat from a heat-generator unit and export to district heating network of Kraftringen, but it turned out to only have a regular cooling machine. That means that low grade/waste heat was excluded from e-Flex altogether. So, this unit is only comparing operational cost and environmental factors of electricity with DC from Kraftringen.

The operational order is switching between only buy DC (1) or running cooling machine as well as buying supplementary DC (0). The DC price is according to the confidential business model based on hourly marginal cost.

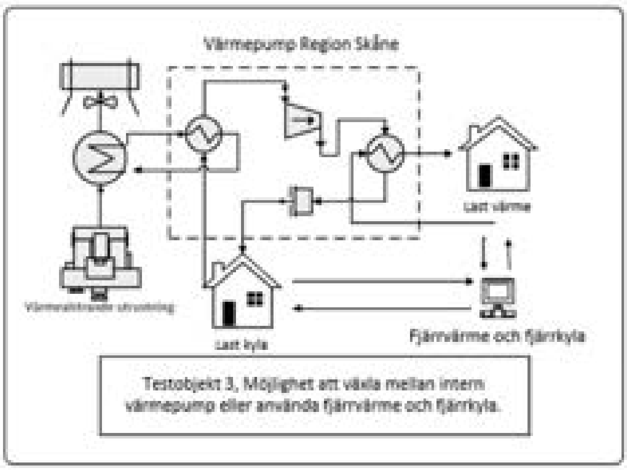
In addition, compensation in peak hours would only be paid if it deviates from the original optimized plan. For example, if the cooling machine is supposed to be operating based on less expensive electricity and on the other hand, it is requested to avoid using it to help the power grid, a compensation fee will be paid. COP of the cooling machine is considered as 3.03.



Picture 5: TO2

TO 3 – Energy Flexibility: DH&C ± El. (HP)

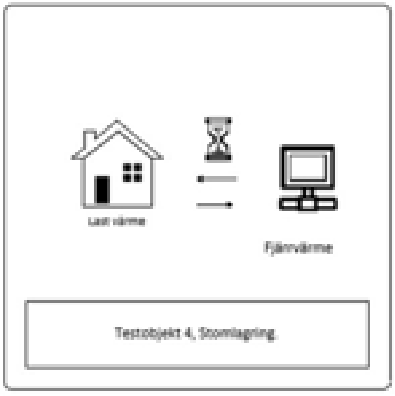
The aim of this site is finding the best economic/environmental benefits in switching between own cooling and heat production by HP together with buying supplementary DH/C (0) or only buying DH/C from KR (1) except in peak hours. In addition, electricity compensation is paid if it switches to buy DC in peak hours and deviates from original plan. In this cogeneration HP system, cooling is the main output, and heat recovery is considered as a bonus. COP of HP for cooling and heating part is considered 3.56 and 4.56, respectively.



Picture 6: TO3

TO4 – Dynamic Price Model

This site is designed to optimize energy flows in an office building equipped with a smart control system and temperature sensors. It enables storing heat in the building frame to buy less DH as well as shifting the consumption time. The purpose is evaluation of how this technology can be combined with a variable hourly-based DH price from KR and how the heat outtake changes depending on the dynamic price model. The model is only aimed to generate the active value (1) which is then sent in the operational plan as an activation of TO4 and business as usual.



Picture 7: DSM in TO4

Test Object 5 - Energy Flexibility: DH ± El. (HP)

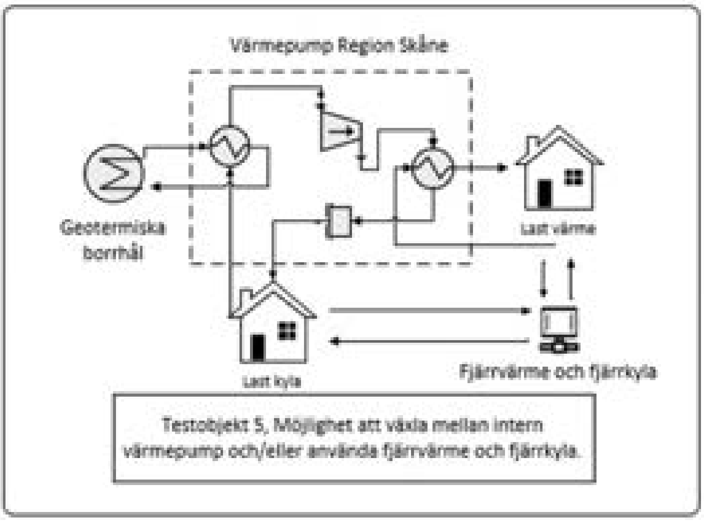
The aim of this site is switching between either own heating production by HP plus supplementary DH from KR (0) or only buying DH from KR (1). HP system is compromising three borehole-fed HPs. Domestic Hot Water (DHW) is always supplied by DH to ensure sufficiently higher temperatures. Space Heating (SH) is supplied with HP and DH helps out in peak hours. In summer, HP is used to being off in favor of DH. During the project, this operational strategy is abandoned, instead the energy source that currently has the lowest operating cost and/or environmental impact is used as much as possible. As a result, energy solutions with the lowest energy price/environmental impact must always be in operation with the exception during critical hours in the electricity grid.

Electricity reduction depends on availability of the overlying energy system. During peak hours, electricity reduction compensation is paid, which means that the operating strategy can be deviated from as long as the replacement level for power reduction is greater than the possible cost/environmental savings that HP in relation to DH would have entailed.

TO5 is comprising three sets of HP plus DH and electricity which are being measured as below:

Picture 8: HPs and DH metering in TO5

Using the measurement values and then adding together heat production from HP plus heat from DH gives us the total heat demand in kW for this TO.



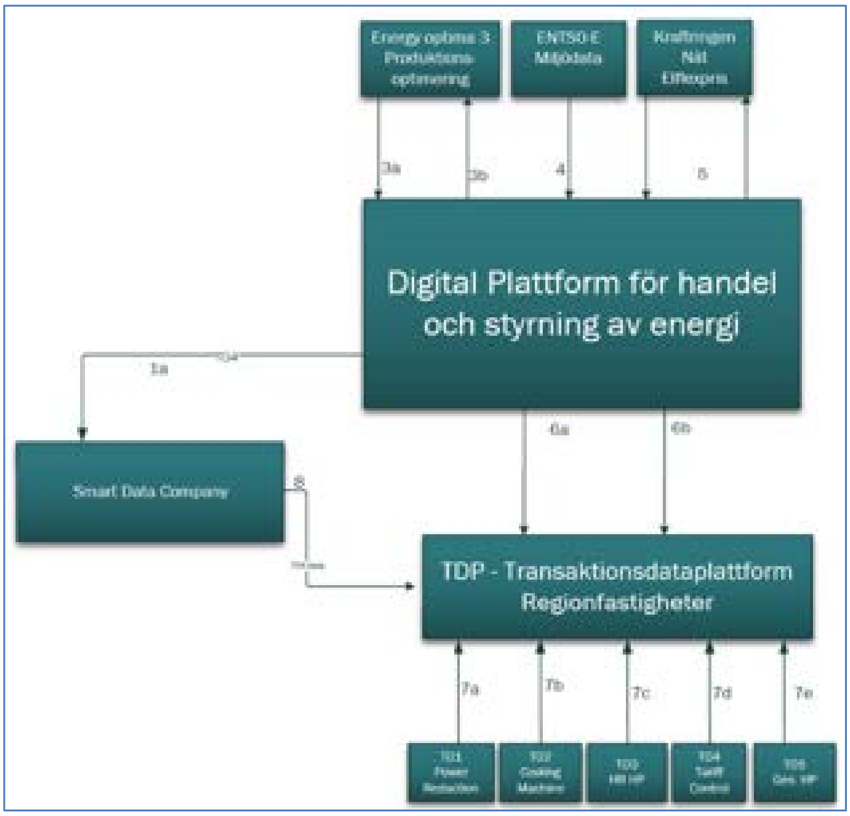
Picture 9: TO5

Integration

One interface is created between KRs EO3 system and the EO3 system on the DP. Another interface is created between RS data system and the DP. The traffic between the network and the connection to the database is in hourly time horizon and secure and encrypted. Necessary and enough information was delivered to KR staff to know how to deal with newly implemented data on their system.

The integration between DP, optimization system in energy company site, and TOs in customer side are described here as the core of DP task. As it can be seen, DP is connected to the functioning EO3 in Kraftringen site to get production optimization plan, production units' data, marginal price costs, and environmental factors of DH/C in an hourly resolution. Furthermore, electricity price (elspot) comes from Nordpool. There is another interface to get electricity production data in Sweden from ENTSO-E to calculate environmental factors for electricity. Another connection with the KR network is established for flexible electricity price and down-regulating (effektersättning) if needed in peak hours.

On the other hand, DP is interacted with Transaction Digital Platform (TDP) which is a local data lake in RS system. TOs data except TO4 including measurements, availability and functionality is transferred through it as well as automatic steering through daily operational plan (körplan). In addition, a part of the data of TO4 is handled through an implemented API of the smart data company between EO and RS. Once the operational plan is sent to RF it is automatically accepted in their control system unless there is some form of problem on their side. Data is then sent back to the DP in form of measurements that the operational plan was executed.

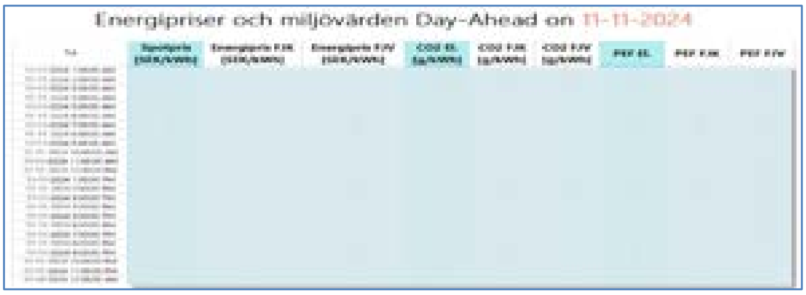


Picture 10: Overview of data connections between different parts

Operational Plan

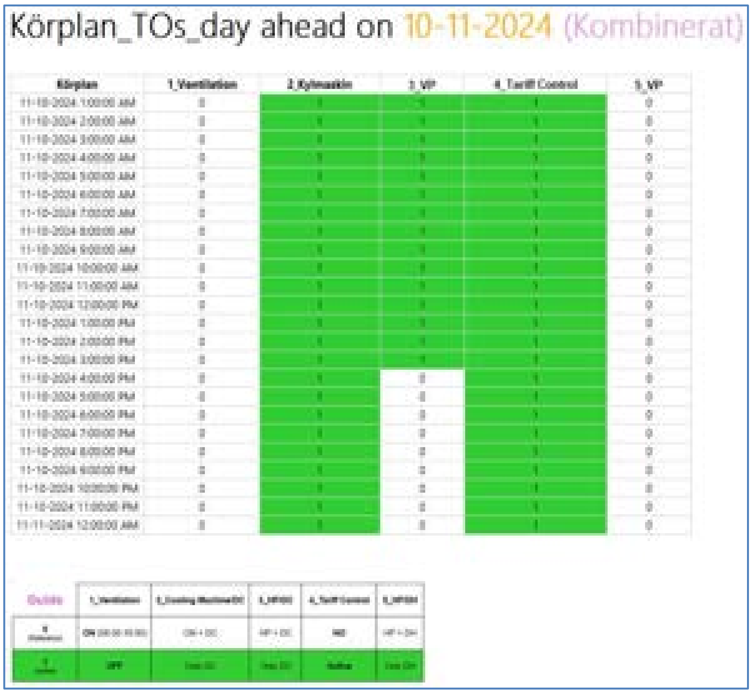
By gathering all necessary data like energy prices and environmental parameters from different parts (KR, RS, ENTSO-E and smart building company) in DP, optimizations are done towards economy, environmental and combination automatically. For this reason, all data tags are identified and documented in a protocol data sheet including name, unit, type, interval limit and short description. If data is out of determined range or there is an interruption in the communication and/or the data is not flowing correctly, the last existing validated data will be used.

Amongst different optimization scenarios, the customer's requested one as the daily optimized operational plan (körplan) based on TOs availability for the day-ahead is sent to each TO, separately. Also, all measurements are stored for follow-up calculations and comparison of the results between different scenarios, and finally evaluation phase.



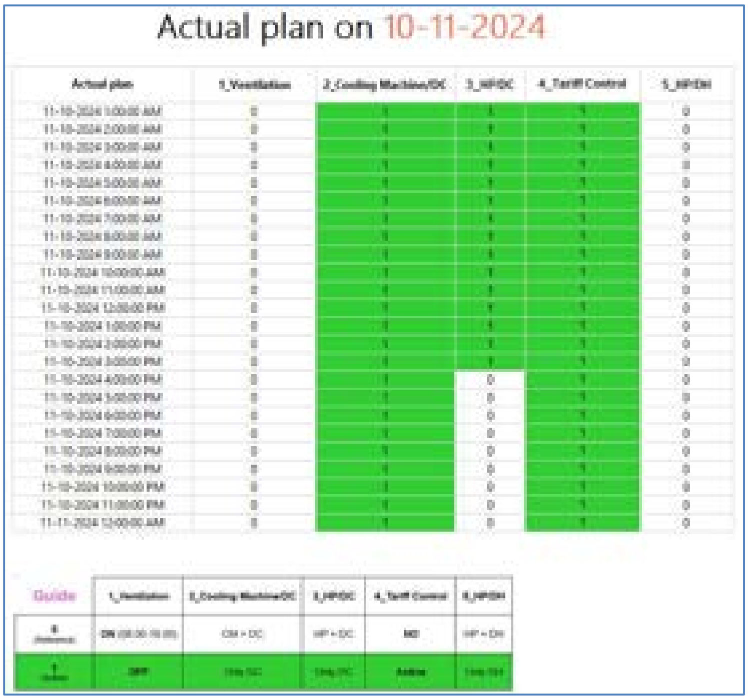
Picture 11: A sample of most important data gathered in DP

Day-ahead plan in binary mode is being sent every afternoon in an hourly resolution for all TOs based on their availability. Value (0) means no deviation to the reference case, and it acts as before the project while value (1) asks TO to be active and works in new operational mode.



Picture 12: Day-ahead plan for all TOs

If any of TOs is not available like in maintenance period or due to technical issues in coming hours/days, the optimizations automatically go back to the reference case and then no active plan (0) will be sent to it in the corresponding period. This unavailability is always visible in DP within the specific data tag which is being continuously updated hourly. As shown, the active optimization scenario to generate this plan is a combination of financial and environmental optimization in this specific day based on RS' request. Then, the actual outcome plan can be compared with the requested day-ahead plan. As can be seen, there is no deviation from the requested plan in this case compared to the previous picture.



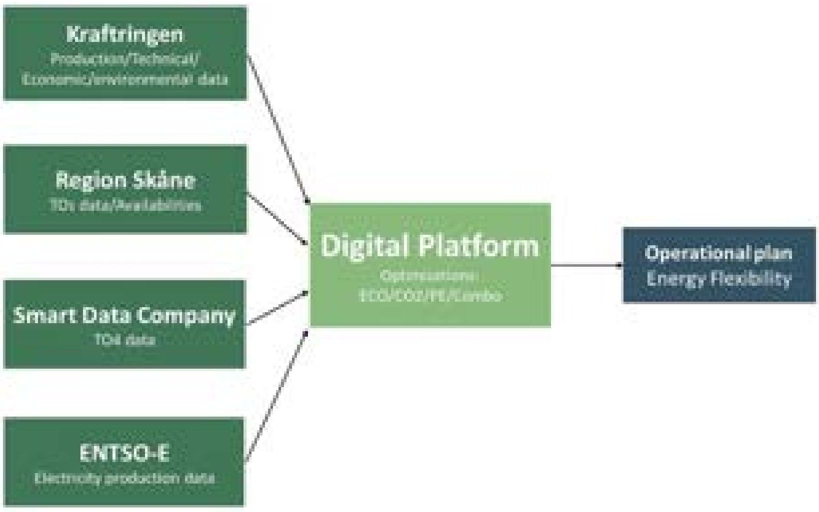
Actual plan on 10-11-2024

Actual plan	1_Ventilation	2_Cooling Machine/DC	3_HP/DC	4_Tariff Control	5_HP/DH
11-10-2024 1:00:00 AM	0	1	1	1	0
11-10-2024 2:00:00 AM	0	1	1	1	0
11-10-2024 3:00:00 AM	0	1	1	1	0
11-10-2024 4:00:00 AM	0	1	1	1	0
11-10-2024 5:00:00 AM	0	1	1	1	0
11-10-2024 6:00:00 AM	0	1	1	1	0
11-10-2024 7:00:00 AM	0	1	1	1	0
11-10-2024 8:00:00 AM	0	1	1	1	0
11-10-2024 9:00:00 AM	0	1	1	1	0
11-10-2024 10:00:00 AM	0	1	1	1	0
11-10-2024 11:00:00 AM	0	1	1	1	0
11-10-2024 12:00:00 PM	0	1	1	1	0
11-10-2024 1:00:00 PM	0	1	1	1	0
11-10-2024 2:00:00 PM	0	1	1	1	0
11-10-2024 3:00:00 PM	0	1	1	1	0
11-10-2024 4:00:00 PM	0	1	0	1	0
11-10-2024 5:00:00 PM	0	1	0	1	0
11-10-2024 6:00:00 PM	0	1	0	1	0
11-10-2024 7:00:00 PM	0	1	0	1	0
11-10-2024 8:00:00 PM	0	1	0	1	0
11-10-2024 9:00:00 PM	0	1	0	1	0
11-10-2024 10:00:00 PM	0	1	0	1	0
11-10-2024 11:00:00 PM	0	1	0	1	0
11-11-2024 12:00:00 AM	0	1	0	1	0

Guide	1_Ventilation	2_Cooling Machine/DC	3_HP/DC	4_Tariff Control	5_HP/DH
0 (Reference)	ON (08:00-16:00)	CM + DC	HP + DC	NO	HP + DH
1 (Active)	OFF	Only DC	Only DC	Active	Only DH

Picture 13: Actual happened plan

An overview of data collection and plan generation in DP is shown in picture below. Necessary data is collected from different locations and combined in DP as inputs. Then operational plan will be generated accordingly based on the inputs.



Picture 14: Actual happened plan

Environmental optimization

Environmental factors and their effect on climate change are becoming more and more the center of attention. Many countries are regulating environmental parameters, mainly CO_2 which are being produced by different sectors. Industries and energy companies are playing an important role in producing and controlling emissions. So, environmental optimization has become more important and has been requested by utilities and municipalities as well as economic optimization.

The ability to optimize the energy system based on environmental parameters is a novelty in this project. It can be performed separately or along with conventional financial optimization. So, environmental optimization including CO_2 and PE was implemented as a new and very important scenario. It would enable decision makers to follow corresponding policies.

Environmental parameters i.e. CO_2 intensity and PEF should be calculated hourly for both sections separately: 1) Power grid based on ENTSO-E prognosis, and 2) DH/C based on KR production data. So, there would be six calculations for CO_2 & PE of each Power grid, DH & DC systems.

Power grid

Environmental forecast relies on prognosis of electricity generated by each section like hydropower, nuclear, wind farms, solar cells etc. This data can be obtained by weather and energy data providers in the big picture and not only focusing on local and regional data of located site. For example, it is possible to use ENTSO-E prognosis data of whole Sweden for any site located in Sweden and then send it to the energy company system connected to DH/C and HP for calculations.

DH/C

Environmental factor for heating & cooling comes from production site of energy company. Live calculations as an average environmental impact by fixed numbers multiplying in each production unit, and then combine load divided by total production.

Finally, different optimization scenarios have been established to optimize the system according to CO_2 generation and PE saving as well as usual cost optimization. As mentioned, it is also possible to follow a combination optimization of all abovementioned scenarios.

Risk Analysis and Assessment

The risks and the relevant threats to the cloud platform and its security are discussed in this section. The focus is on identifying the areas where vulnerabilities can arise, as well as what consequences these can have for the business. In addition, a penetration test has been conducted to check the security of the system against unauthorized access and it was passed successfully. Specific measures to reduce risks and ensure a high level of security in the platform is implemented through this analysis:

Security Controls Automation

To reduce the risk of misconfigurations and ensure that all resources on the cloud platform comply with security policies, automated security controls have been put in place. These controls have been implemented using tools such as:

- Energy Opticon Policy: These services continuously monitor and evaluate configurations in the cloud environment, identify misconfigurations, and ensure that resources comply with defined security policies.
- Infrastructure as Code (IaC) with security policies: Automated tests are run on each change to the infrastructure to validate that the changes comply with security requirements before they are implemented.

Enhanced Authentication and Access Control

To reduce the risk of unauthorized access, the security of the authentication process has been strengthened through the following most central solutions:

- Mandatory two-factor authentication (MFA): Two-factor authentication has now been introduced for all users on the platform, requiring both a password and a one-time code generated by an authenticator app or sent via SMS.
- Strengthened password policy: Password policies have been updated to require strong, high-complexity passwords and regular changes. Reusing old passwords is no longer allowed.
- Role-based access control (RBAC): User roles and their permissions have been updated to ensure that each user has access to only the resources that are necessary for their job duties.

Continuous Monitoring

To ensure that potential threats are detected in real-time, a comprehensive monitoring solution has been implemented:

- Security Information and Event Management (SIEM): A SIEM system has been implemented to collect, analyze, and correlate log data from across the cloud platform. This system continuously monitors the platform to detect unusual activities or intrusion attempts.
- Real-time alarms: The monitoring system has been configured to generate real-time alerts in the event of suspicious activity, giving the security team the ability to react quickly and prevent potential security incidents before they develop.

API Security

To minimize the risks associated with external API calls, API security has been improved by implementing the following measures:

- Strong authentication: All API calls require authentication using OAuth 2.0 or similar protocols to ensure that only authorized users and systems can access the services.

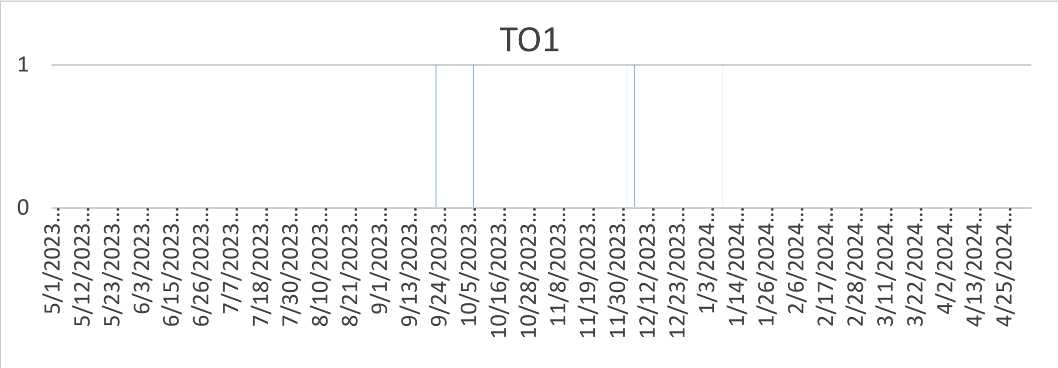
- Encrypted communication: All API calls are encrypted using Transport Layer Security (TLS) to protect data in transit and prevent man-in-the-middle attacks.
- API gateway with access control: An API gateway uses to manage authentication and authorization of all API calls. This gateway also monitors traffic patterns and can block suspicious calls.

Results

The e-Flex showed that it is possible to model and connect the energy company with the energy consumers on the DP to create a win-win situation in which the property owner changes its behavior and cost, CO_2 and primary energy are reduced. Furthermore, it is possible to do this in a safe IT environment with Cyber security.

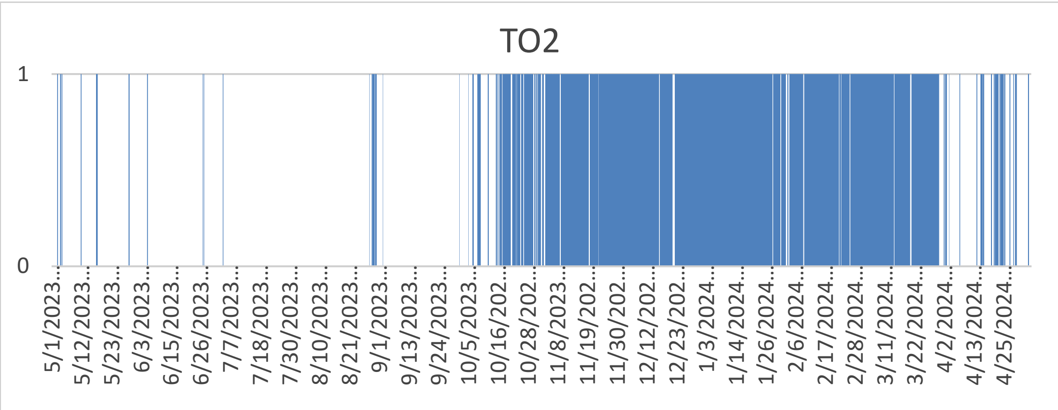
As explained in the previous chapter, new ideas were applied to selected TOs mainly by energy flexibility through connecting customer sites to DH/C network to be able to choose between electricity and DH/C in a more efficient way according to defined strategies. Heat flexibility is another remarkable feature of the project to release load on DH network.

Changing in the customer behavior by deviation from reference case is shown in the pictures below as blue bars. TO1 was active on a few occasions since it is mostly about checking the possibility of using power reduction and it worked as planned.



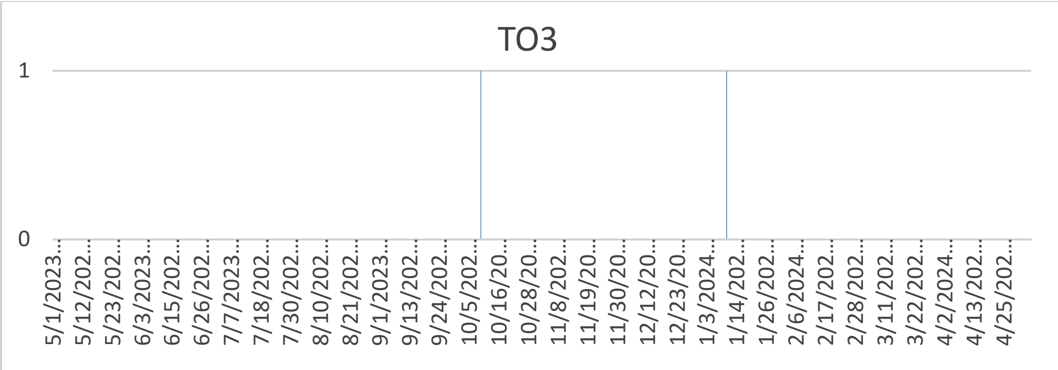
Picture 15: Testing electricity reduction

TO2 was mostly active during winter by running only in DC mode rather than buying electricity to run cooling machine.



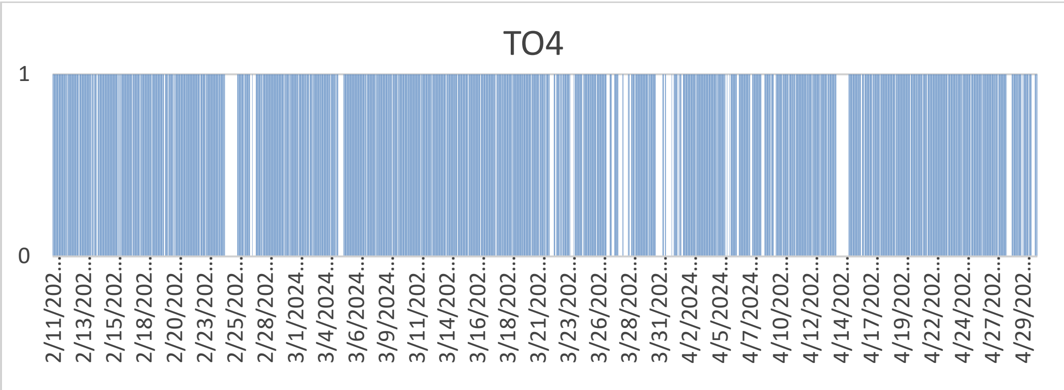
Picture 16: Either running in-site cooling machine (0) or DC (1)

TO3 was activated a few times since it preferred to run HP as well to have surplus heat as the bonus.



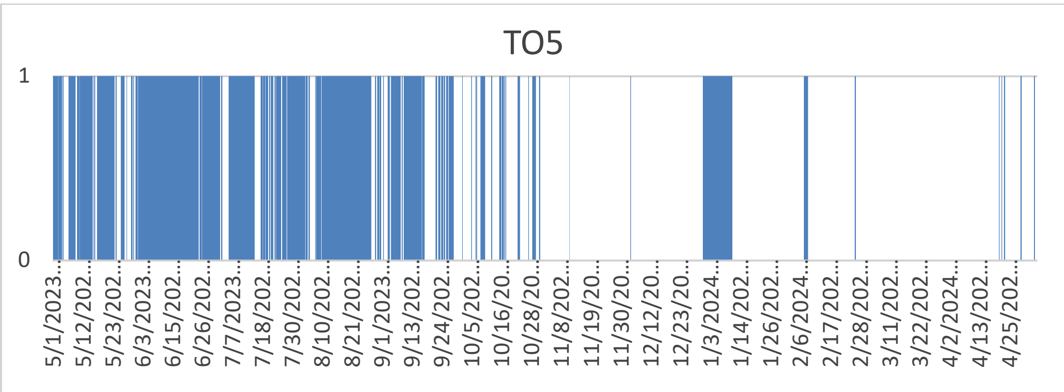
Picture 17: Participate in-site heat pump to help existing DC (0) or only DC (1)

TO4 was almost continuously active to use heat flexibility.



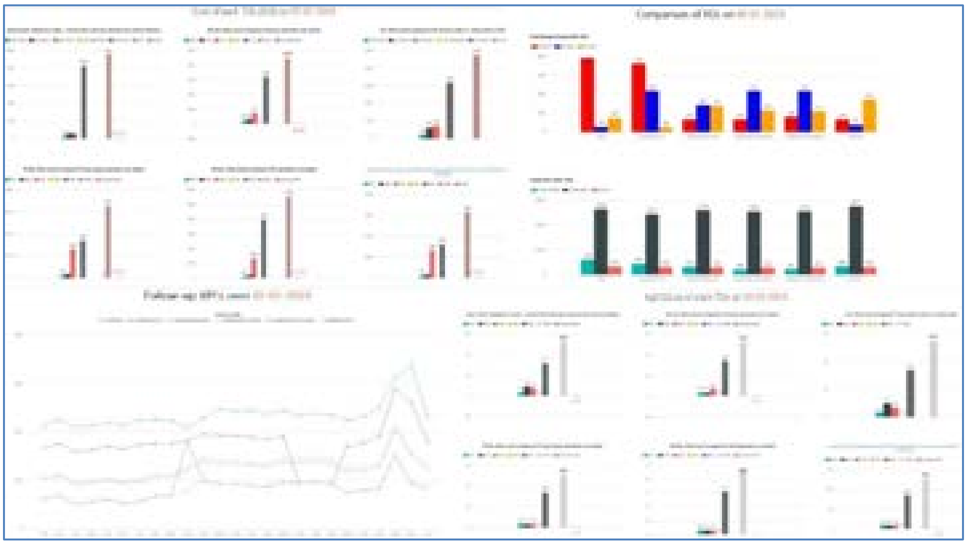
Picture 18: Heat flexibility

TO5 was mostly active during spring and summer and a part of autumn by running in full DH mode rather than buying electricity to run HP partly.



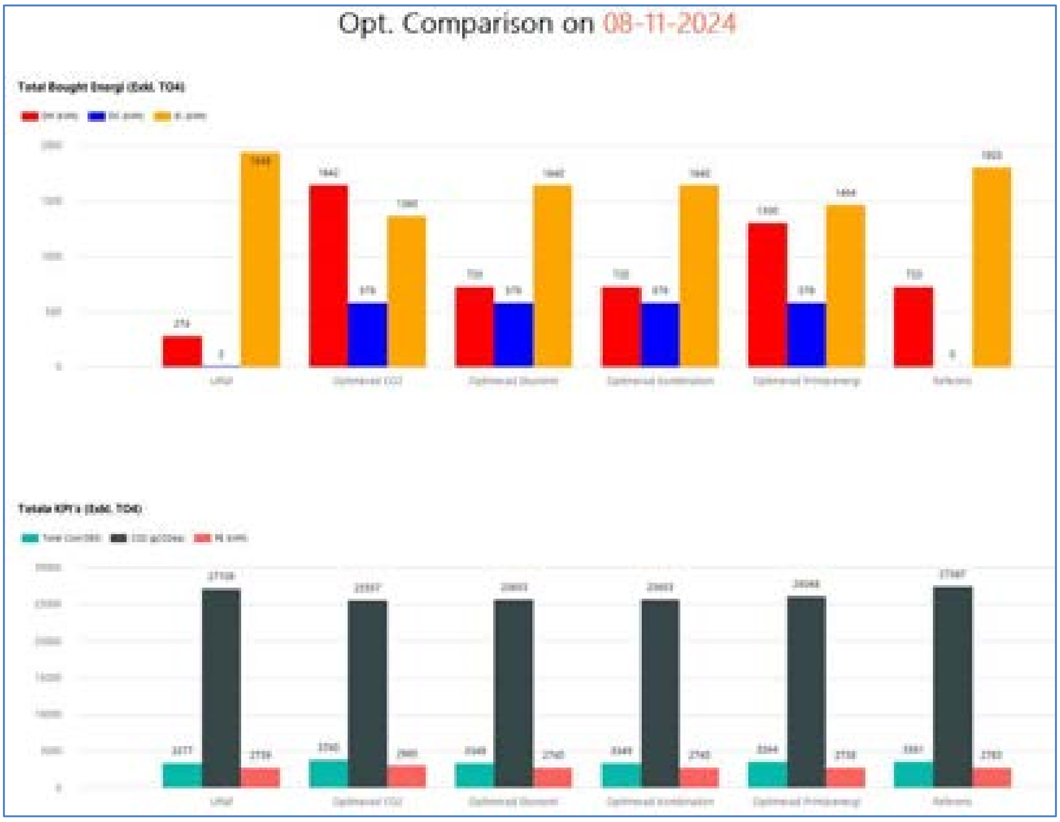
Picture 19: Participation of on-site heat pump to help existing DH (0) or only DH (1)

It should be mentioned that daily automatic SSRS reports are also generated and sent to the involved parties to show the status of different sites and performance of the optimizations as well as follow-up and evaluation.



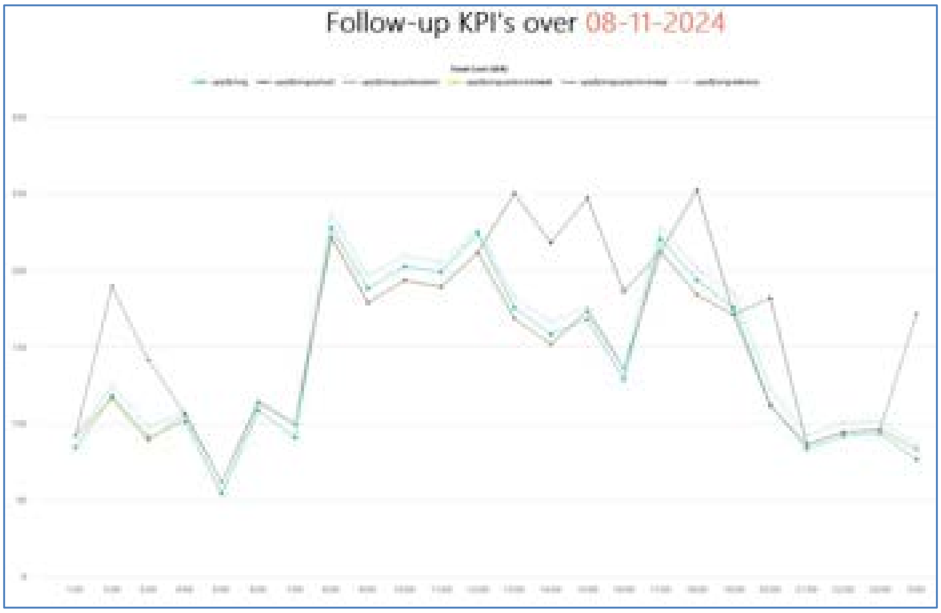
Picture 20: A sample of daily reporting

A daily comparison is done to compare between different optimization scenarios, reference case, and outcome. This comparison shows what would happen if other scenarios were active in terms of costs, environmental parameters and energy consumption.



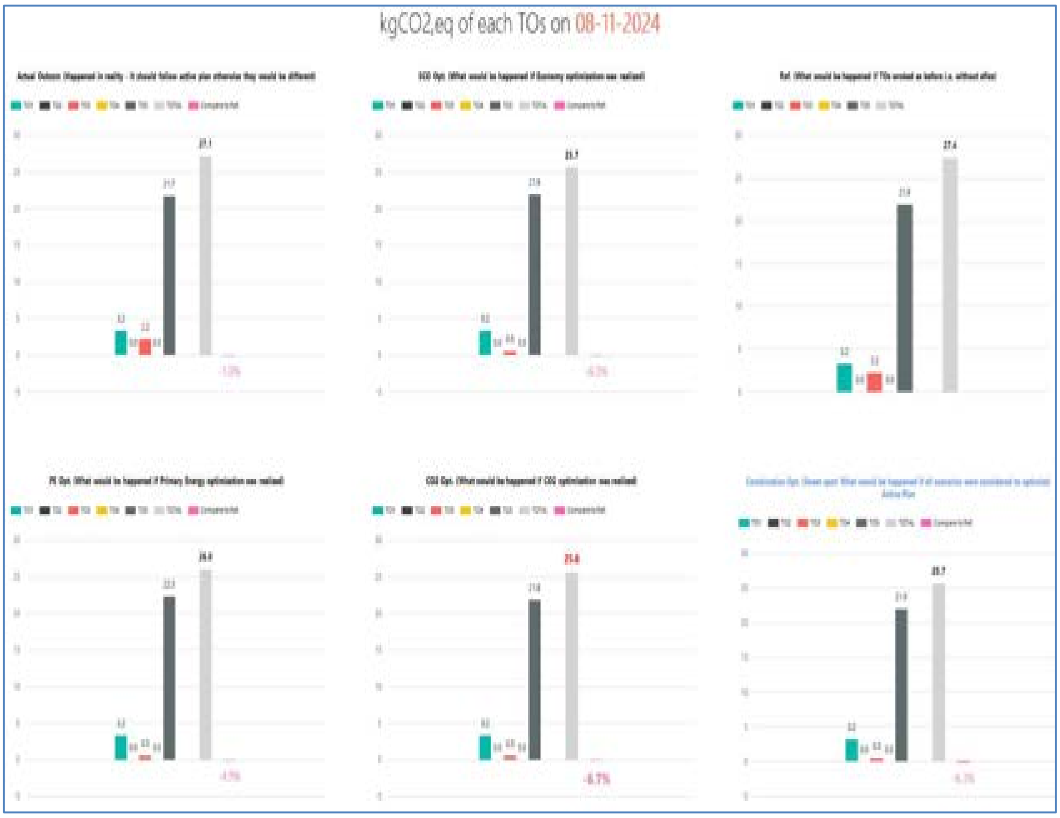
Picture 21: Comparison of different scenarios

It is also possible to follow up KPI's i.e. costs and environmental parameters of each scenario for every single hour.



Picture 22: Tracking cost of each optimization in an hourly basis of each day

In addition, a daily comparison between different TOs and scenarios for KPI's is presented to show the functionality of the optimizations compared to the reference case.



Picture 23: Comparison of CO_2 generation between different optimizations and TO's compared to the reference case

The security measures implemented provide the cloud platform with strong overall security and resiliency to potential threats and security breaches. By automating security checks, improving authentication methods, implementing continuous monitoring, and strengthening API security, the platform has strong protection against both internal and external threats. Going forward, these measures will be managed through procedures and policies from Energy Opticon, and they will undergo annual reviews and updates to ensure that they remain current and effective, as new security threats arise, and the platform's infrastructure continues to evolve. The implementation of the SIEM system improves the ability to detect and respond to security incidents at an early stage. This leads to a significant reduction in the risk of data breaches and unauthorized activity on the platform.

Discussion

As explained and shown in above pictures, the project could affect customer behavior significantly in a win-win situation by switching between operation modes based on the requested optimization plan. The customer's behavior can be changed remarkably by giving energy flexibility options to them through switching between electricity and DH/C continuously. The idea could be to change the customer behavior and thereby gain mutual benefits by deviation from the regular load profile.

The customer behavior in TO2, 4 and 5 deviated a lot from the reference case, and they shifted towards an optimized plan based on their priority i.e. financial and environmental factors. TO4 was active almost all year as it was supposed. TO2 was mostly active in winter and TO5 in spring and summer.

TO1 was not active since it was more a test scenario to check the possibility of electricity reduction and lifting load from the power grid in the future, which was successful. Only TO3 did not change the customer behavior so much because it was already an efficient system by taking advantage of recovering surplus heat from cooling part of installed HP.

All these prepared great benefits for both energy company and customer can be summarized as below:

Picture 24: Benefits with e-Flex for property owners and energy companies

The benefit for EO comprises selling e-flex as a new product, strengthening relationships with the customers, having a more environmentally friendly society, and to be known as a leading energy flexibility provider in the market.

The automation of security controls reduces the risk of human error and ensures that security policies are continuously followed without the need for manual inspection. Misconfigurations that could lead to data breaches or exposed resources are now immediately detected and corrected in real time. These enhancements provide strengthened protection of accounts, resulting in more secure and controlled access to sensitive data and services. Besides that, API security is strong, which provides improved protection and ensures that only authorized actors have access, which contributes to a safe and efficient use of the API.

In addition, daily generated reports help the involved actors to understand the system better, react on time, and make decisions and financial and environmental strategies in the long term. It can be very useful for monitoring the project and follow-up of the results.

Like many other practical projects, the e-flex project and its TO's were changed from the initial proposed idea as presented in the beginning. These changes comprising both IT, and technical matters for data connection, data transfer, physical installations and modeling within DP. The project is designed to be very dynamic and to adapt to these changes. Technical limitations and failures were obstacles which could affect the project. They should be considered immediately to being fixed or considered for updating the model and for evaluation. A secure and stable connection to transfer massive data amounts correctly between different parties was another challenge. This was examined extensively, and a lot of IT and cybersecurity efforts were made to manage this properly.

It should also be mentioned that KR staff had sufficient knowledge to use EO3 in their system. It makes it easier and faster to communicate and describe modeling and operation. It would have taken more time to share information and run all the features of the project if this was not the case. Furthermore, the results might involve staff in the control room and the production site and their work. This group of staff should also be involved in explanations about what is going to happen and how it would affect the system. By knowing the comments and feedback of the operational staff in the energy company, it will be more convenient and efficient for implementation and any adjustments in a system like this.

Conclusion

Optimization in an energy system from the production to the end-users should be done centrally to avoid sub-optimization even though it brings more complexity. A sub-optimization can occur due to simultaneous down/up regulation like when many customers react to a significant change in the energy price at the same time. This should be avoidable as the total optimization takes place continuously.

Optimization of costs and environmental parameters and using energy flexibility in test buildings in a secure data transfer way within DP is described. This entails proper communication between parties and secure data transfer within DP. Significant financial savings and mitigation of environmental impacts can be achieved by running e-flex consistently. To achieve this optimal energy flexibility and accompanying savings, the following factors are important:

- The use of a smart and reliable optimization system that can handle all the calculations required.
- A smooth and secure data collection and transfer between the production optimization system and the building optimization system
- Good and continuous communication between the energy company and the property owner

All the initial goals of AP2 are achieved regarding the mentioned characteristics, and the platform is actually running properly. In addition, the related challenges of today's energy matrix were taken into account and suitable solutions have been proposed and implemented. Whenever it was needed, new methods were implemented like establishing different methods for marginal cost calculation.

The security of the cloud platform is strong through the implementation of the high security measures, which has increased its resilience and security in several key areas:

- Reduced misconfigurations: The automation of security controls has minimized the risk of human error leading to vulnerabilities in the system.
- Improved identity management and authentication: Two-factor authentication and improved password policies have increased the security of user accounts, drastically reducing the risk of account hijacking.
- Faster detection and response to threats: Through SIEM system and the introduction of continuous monitoring and real-time alerts, the security team has been able to respond quickly to potential security incidents, leading to fewer breaches and reduced consequences in the event of threats.
- More secure API calls: With enhanced authentication requirements and encrypted communication for API calls, the security of system integrations has been enhanced, protecting against unauthorized access and data exposure.

Finally, more customers connected to DP, the higher capacity in the energy flexibility. Subsequently, it causes higher benefits for all parties to reduce costs, shaving peak loads easier, less use of heat plants running on expensive and fossil fuels, and improve environmental outcomes.