Upgrading the performance of district heating networks

Best practice instruments and tools for diagnosing and retrofitting of district heating networks

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The Upgrade DH project

The overall objective of the Upgrade DH project is to improve the performance of district heating (DH) networks in Europe by supporting selected demonstration cases for upgrading, which can be replicated in Europe.

The Upgrade DH project supports the upgrading and retrofitting process of DH systems in different climate regions of Europe, covering various countries: Bosnia-Herzegovina, Denmark, Croatia, Germany, Italy, Lithuania, Poland, and The Netherlands. In each of the target countries (Figure 1), the upgrading process will be initiated at concrete DH systems of the so-called Upgrade DH demonstration cases (demo cases). The gained knowledge and experiences will be further replicated to other European countries and DH systems (replication cases) in order to leverage the impact.

Core activities of the Upgrade DH project include the collection of the best upgrading measures and tools, the support of the upgrading process for selected district heating networks, the organisation of capacity building measures about DH upgrading, financing and business models, as well as the development of national and regional action plans.

In addition, an image raising campaign for modern DH networks will be carried out in the Upgrade DH project. The outcome will be the initiation of district heating upgrading process in the above-mentioned target countries and beyond.

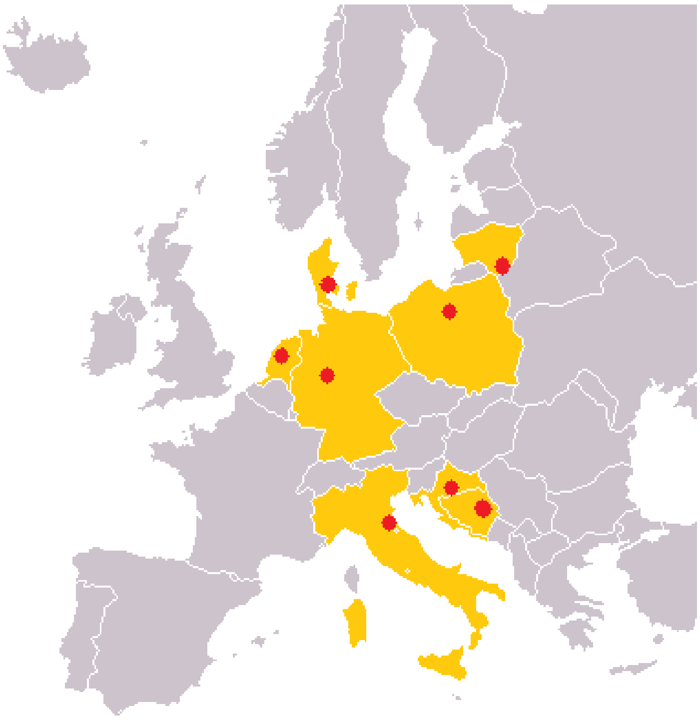

Figure 1: Upgrade DH target countries and demo cases

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Contents

1 Introduction

The objective of this catalogue is to provide an overview of the best instruments and tools for diagnosing and retrofitting of district heating networks. The key characteristics as well as means of application of the tools and instruments are described. This information shall not only help to facilitate retrofitting of DH networks for planners and stakeholders, but also to facilitate day-to-day sustainable operation decisions. Applying suitable instruments and tools to a DH network have the potential to increase the economic and environmental benefits of a DH system.

The instruments and tools presented in this report include calculation, modelling, planning, mapping and decision-making tools. Furthermore, a general description and information on the possibilities and limitations of the tools, costs, developers (research based tools, commercial tools), and requested input data are provided.

In this catalogue, the instruments and tools are sorted in software tools in Chapter 2 and rather practical instruments that are largely independent from specific software applications in Chapter 3.

The instruments and tools presented here were described by different partners of the Upgrade DH project. The authors of each instrument or tool are named in the beginning of each sub-chapter.

2 Identified best practice software tools

2.1 Economic calculation tool for small modular district heating and cooling projects

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Table 1 Economic calculation tool for small modular district heating and cooling projects

Name	Economic calculation tool for small modular district heating and cooling projects
General description	The economic calculation tool for small modular district heating and cooling projects was developed by Skupina FABRIKA, Slovenia, as a part of the CoolHeating project. It can be used to perform a feasibility analysis for implementing new district heating units/systems. The tool is a Microsoft Excel based spreadsheet and is easy to use. It uses macros and Visual Basic for Applications programming. It is intended for district heating utilities, local governments and policy makers. A guideline on how to use the tool and the tool itself can be accessed via the CoolHeating webpage (www.coolheating.eu). It is basically used for preparing full business plans for the implementation of district heating systems. The tool can be edited, i.e. it is open source and can be modified, based on the needs of the user. The idea of the tool is to be easy to use, especially for the non-professionals and non-experts in the field, since there is already a high number of professional tools in the market.
Application and required input data	The user needs to provide the input data in the form of expected investment and operation costs, financing details, potential revenues and other relevant parameters. The tool then calculates the performance of the project, giving the detailed overview of different aspects, i.e. liabilities and equity, income statements, assets and profitability indicators (internal rate of return, payback period and net present value of the project). Furthermore, it also provides a sensitivity analysis for operating costs and heat price.
Purpose	☒ calculation ☒ planning ☒ decision making
Possibilities	- Easy to use - Available in seven languages - Free
Limitations	- Can only be used for the feasibility analysis of new systems - Simple

Language	☒ EN ☒ HR ☒ RS ☒ DE ☒ MZ ☒ SI ☒ BA
User level	☒ Basic economic and technical knowledge
Required operation system	☒ laptop/pc
Provider	Skupina FABRIKA, Slovenia http://www.coolheating.eu/en/publications.html ☒ research based
Cost	☒ free

2.2 EnergyPRO software

Authors:

Anes Kazagić, JP Elektroprivreda BiH d.d.-Sarajevo, Bosnia nad Herzegovina

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Table 2 EnergyPRO

Name	EnergyPRO
General description	EnergyPRO is a commercial modelling software used primarily in relation to district heating projects. It can be used to carry out an integrated detailed technical and financial analysis of both existing and new energy projects in a very user-friendly interface providing the user with a clear overview of the project. EnergyPRO can be used in a variety of projects such as district heating cogeneration plants with gas engines combined with boilers and thermal storage, industrial cogeneration plants supplying both electricity, steam and hot water to a site, cogeneration plants with absorption chilling (trigeneration), biogas fuelled CHP plants with a biogas store, biomass cogeneration plants as well as other types of projects. The calculations are made under due consideration to any conditions specified in the project offering precise results in a printable format accepted by the World Bank and other major international investment banks. The software is based on a modular structure which allows the user to carry out different analyses. EnergyPRO can also be used for analysing hydro pumping stations, compressed air energy storage and other electricity storage projects. EnergyPRO allows the daily optimization of the operation to be made against fixed tariffs for electricity or against spot market prices. The optimization is taking into account the limited sizes of thermal and fuel storages. EnergyPRO provides the user with a detailed financial plan in a standard format, accepted by international banks and funding institutions. This includes a presentation of the operating results for the project, monthly cash flows, income statements (P&L), balance sheets and key investment figures such as NPV, IRR and payback time. The software enables the user to calculate and produce a report for the emissions (CO_2, NO_X, SO_2, etc.) by the proposed project.

Application and required input data	EnergyPRO is a complete modelling software package for combined techno-economic analysis and optimisation of both cogeneration and trigeneration projects as well as other types of complex energy projects with a combined supply of electricity and thermal energy (steam, hot water or cooling) from multiple different energy producing units. EnergyPRO is typically used for techno-economic analysis of energy projects such as district heating cogeneration plants with gas engines combined with boilers and thermal storage, industrial cogeneration plants supplying both electricity, steam and hot water to a site, cogeneration plants with absorption chilling (trigeneration), biogas fuelled CHP plants with a biogas store, biomass cogeneration plants. In energyPRO, all data that correspond to the district heating case can be entered from external sources (weather conditions manually imported or online downloaded for the considered region), heating and cooling demands (depending or not depending on external conditions), specific fuels, energy conversion units (in general or described by load curves), electricity market, economic input data etc.
Purpose	☒ calculation ☒ modelling ☒ planning ☒ decision making
Possibilities	- Calculating the optimal operation of an energy plant - Making detailed investment analyses (a number of financial and technical reports available) - Modelling industrial cogeneration and trigeneration - Simulating energy plants participating on different electricity markets - Analysing the interaction between separate energy plants
Limitations	- Depending on the online data if o do not own our own measurements - The available reports are context sensitive, which primarily means that some irrelevant information is excluded.
Language	☒ EN ☒ DE ☒ DK ☒ PL
User level	☒ technical engineer
Required operation system	☒ laptop/pc

Provider	EMD International A/S Niels Jernes Vej 10 9220 Aalborg Ø Denmark Tel.: +45 9635 4444 Fax: +45 9635 4446 https://www.emd.dk/
Cost	☒ commercial Approx. price: 3,600€ for the DESIGN module which is required for all other modules. Any additional module (FINANCE, ACCOUNTS, OPERATION, REGION, INTERFACE, MARKETS, COMPARE) costs 900€.
References	EMD INTERNATIONAL A/S (2014) User's Guide - ENERGYPRO, Aalborg, Denmark

2.3 Heat Solution™ by ENFOR™

Author:

Mikkel Westenholz, ENFOR, Denmark

Table 3 Heat Solution™ by ENFOR™

Name	Heat Solution™ by ENFOR™
General description	Heat Solutions™ (formerly known as PRESS™) is an integrated portfolio of forecasting and optimization solutions for the district heating sector. The solution consists of MetFor™, which delivers locally-calibrated weather forecasts, HeatFor™ which provides heat demand forecasts and HeatTO™, which provides temperature optimization of the supply temperature. The solution can reduce heat losses and thereby reduce production costs, heat prices and CO_2 emissions while increasing security of supply. The three sub-solutions work as an integrated system. MetFor™ creates a local calibrated weather forecast. It is based on 2-3 external weather forecasts which are weighted and combined with local weather measurements. The locally calibrated weather forecast is fed into HeatFor™ and combined with historical demand data in order to deliver an accurate heat demand forecast. Based on this heat demand forecast and online measurements from the heating network (flow, supply and return temperature), HeatTO™ optimizes the supply temperature to meet demand, while minimizing supply temperature. Heat Solutions™ is based on self-learning algorithms that continuously self-calibrate and improve as they receive data from the district heating network, and thereby the system is fully automatic. Ideally the solution is integrated with local online weather measurements but can also run solely on meteorological forecasts. Heat Solutions™ is provided with a data validation module and a data interfaces which enable SCADA integration through text files, FTP, database access or web services. The data validation module ensures that data with errors is identified, corrected or replaced by other values. Heat Solutions™ can be delivered as a software package which is installed at the district heating operator or as a hosted solution at ENFOR™. In addition, the solution comes with various support and maintenance packages that can be tailor-made.
Application and required input data	The solutions leverage on the availability of historical time series of: - Meteorological data (possibly multiple sources) - Network heat demand - Supply temperature of the network. In order for the modules operations to be fully automatized, a system integration with local SCADA systems has to be set-up.
Purpose	☒ Forecasting ☒ Optimization

Possibilities	- Increase security of supply (ensuring quality of service) - Decrease heat losses and costs (limiting excess heat) - Reduce fuel consumption and CO_2 emissions
Limitations	- Requires data exchange from the district heating network
Language	☒ EN ☒ DK (other languages may be easily added)
User level	☒ end user
Required operation system	☒ server
Provider	www.enfor.dk ☒ commercial
Cost	☒ commercial, approx. price: varying with network size (Typical payback period is 1-3 years)

2.4 HOMER software tool

Authors:

Anes Kazagić, JP Elektroprivreda BiH d.d.-Sarajevo, Bosnia and Herzegovina

Ajla Merzić, JP Elektroprivreda BiH d.d.-Sarajevo, Bosnia and Herzegovina

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Table 4 HOMER software tool

Name	HOMER software tool
General description	HOMER (Hybrid Optimization of Multiple Energy Resources) is a modelling software tool mostly used for microgrid design optimization and feasibility analysis. It can be used for analysing existing, as well as options and complexities of building new cost effective and reliable microgrids that combine traditionally generated and renewable power (or are only based on renewable power), storage, and load management. These analyses are mostly performed for remote power, island utilities and microgrids. HOMER can be used in a variety of projects, both, for electricity and thermal energy production analysis, but with a more focus on the first energy form. It offers different modules and system components with appropriate features specific to that energy source or option like wind, solar, biomass, hydro, combined heat and power, hydrogen, batteries, diesel generators, etc. whereby possibilities of a simple grid connected hybrid power system can be analysed as well. The calculations are made under due consideration to any conditions specified in the project, offering precise results in a printable format, including tabular overviews and very good graphic displays. HOMER is based on a modular structure which allows the user to carry out different analyses with different system components in different working modes. For instance, it enables the user to model changes that can occur over the course of a project, e.g. PV degradation, grid price and fuel price increase, load growth, etc. The software tool offers also several dispatch strategy algorithms that decide which components (solar, battery, generators, etc.) will operate to meet the load in a particular period of time. By applying the MATLAB Link Module, HOMER allows the user to create and use her/his own dispatch strategy, giving the user total control over how the microgrid model should operate. HOMER provides the user with a detailed financial plan including operating results for the project, cash flows and key investment figures such as NPV and payback time. The software enables the user to calculate emissions or estimate their savings, as well as the achieved RES share by the proposed project.
Application and required input data	The HOMER software tool provides a variety of services to facility managers, project developers, program planners and technology developers to help them design cost-effective and sustainable power systems. It is ideally suited for screening potential microgrid projects and helps developer determine quickly whether a project is promising enough to pursue. It also helps the user in determining which renewable (solar, wind, biomass, or small hydro), storage

	technologies (e.g. lead-acid, zinc, vanadium, nickel, lithium, flywheel, hydrogen) are cost-effective, what load management, combined heat and power and other diesel optimization options make sense, and what is an optimal capacity for each of these. HOMER saves developers substantial effort and expense by narrowing these conceptual design choices at the prefeasibility stage rather than performing detailed engineering designs on suboptimal system designs. All necessary data that correspond to microgrid modelling purposes and their economic sustainability assessment can be entered for each specific case. These input data include energy potential data specific for each energy source and other external conditions like weather parameters, data related to the use of specific technology, i.e. power generating unit, demand for electric and/or thermal energy, specific fuels, grid connection selling or purchasing prices, economic input data, etc.
Purpose	☒ calculation ☒ modelling ☒ planning ☒ decision making
Possibilities	- Conceptualizing microgrid components and their optimal capacities, according to electricity and/or heat demand and resources available - Calculating optimal operation parameters for the considered system - Making investment analyses - Obtaining feasibility reports - Easily performing sensitivity analyses - Creating and applying own dispatch strategies - Analysing the interaction between separate energy plants - Obtaining parameters related to the environmental impact assessment (emissions or their savings, RES share data) - Using available data on energy resource potential from databases provided within the software tool - Useing available data on different types of technologies (system components) provided within the software tool - Adding or creating new technologies (system components) not provided within the software tool
Limitations	- It is originally developed to support design of off-grid community scale electrical energy systems, but expanded to model grid connected and thermal systems. - The DH network elaboration is not included within the software tool

Language	☒ EN ☒ DE ☒ DK ☒ PL
User level	☒ technical engineer
Required operation system	☒ laptop/pc
Provider	HOMER Energy 1790 30th St, Suite 100 Boulder, CO 80301 USA Tel.: + 1 720 565 4046 support@homerenergy.com
Cost	☒ free (a free 21-day Trial) ☒ commercial, different prices for different licenses defined by user groups (Students, Academic and Standard license) going from approx. price of: $6/month for a Student license on a yearly basis; $21/month for an Academic license on a yearly basis; $42/month for a Standard license on a yearly basis, all for the HOMER Pro module. HOMER Pro can be supplemented with additional modules for even more powerful modelling capabilities, whereby each of these modules has its own purchasing price.
References	https://www.homerenergy.com/company/index.html A. LYDEN, R. PEPPER, P.G. TUOHY (2018) A modelling tool selection process for planning of community scale energy systems including storage and demand side management, Sustainable Cities and Society, Vol. 39, P.P. 674-688

2.5 LEANHEAT peak power optimization

Author:

Vesa Jaakkola, LEANHEAT, Finland

Table 5 LEANHEAT peak power optimization

Name	LEANHEAT peak power optimization
General description	Leanheat has developed and commercialized a solution to optimize the peak heating power utilizing sensors and artificial intelligence. It has already been done in several thousands of buildings and in 100,000 homes. As a result, around 20% of the basic heating costs have been saved without having to compromise on living comfort.
Application and required input data	Leanheat solution utilizes indoor sensor data, weather forecast and accurate thermodynamic models of buildings to optimize the heating supply to the building over time. Artificial Intelligence detects the individual consumption profile of hot water and space heating for each property, as well as potential changes of the patterns in time. The forecast model allows for pre-heating of buildings, ensuring smooth indoor conditions. Thus, the heat demands of the users are spread and discharged proactively during the peak timespan. The results in thousands of buildings show that an average decrease of about 20% heating power is achieved while keeping the indoor conditions stable.
Purpose	☒ optimization service (cloud based)
Possibilities	- Peak power reduction on average 20% - 2-4 degrees lower return temperature - More accurate forecast of demand for production optimization
Limitations	- Support mainly for central heating systems with radiators or floor heating (water circulation based systems)
Language	☒ EN
User level	☒ technical engineer
Required operation system	☒ other: Cloud based solution
Provider	Leanheat, www.leanheat.com ☒ commercial
Cost	☒ commercial Approx. price: depending the scope of deployment and size of the building

2.6 LEANHEAT demand response

Author:

Vesa Jaakkola, LEANHEAT, Finland

Table 6 2.2 LEANHEAT demand response

Name	LEANHEAT demand response
General description	Demand Response refers to the heating control mode, which aims to optimize the entire production-consumption chain. Control is not implemented at the single building, but rather at the entire district heating network and production level. Optimal implementation is different in each network and production environment, so implementation requires closer cooperation with the heat producer.
Application and required input data	The demand flexibility may be implemented, for example, through an hourly price of district heating, so that the energy company provides financial incentives for users to reduce or increase the consumption depending on the production situation. Few district heating companies have the capacity to do so, but the sector is advancing rapidly - for example, in Finland, 5,000 dwellings in Fortum's district heating network have been connected, leveraging demand response for the heat demand control in the residential buildings.
Purpose	☒ optimization service (cloud based)
Possibilities	- Control of heating demand based on district heating costs - Possibility to control heating according to several optimization parameters
Limitations	Support mainly for central heating systems with radiators or floor heating (water circulation based systems)
Language	☒ EN
User level	☒ technical engineer
Required operation system	☒other Cloud based solution
Provider	LEANHEAT, www.leanheat.com ☒ commercial
Cost	☒ commercial Price depending to the scale of deployment (number of buildings, number of apartments)

2.7 Optit's Solution for Energy Production Optimisation

Author:

Stefano Morgione, OPTIT, Italy

Table 7 Optit's Solution for Energy Production Optimisation

Name	Optit's Solution for Energy Production Optimisation
General description	Optit's solution for CHCP systems optimization (evolving to manage ever more complex energy systems) is a web-based, multi-user, multi-plant enterprise application. The main processes are: - Configuration and set-up of the systems, both to configure the operating production environment and what-if analyses (potentially supporting investment evaluation); - Annual forecast and budgeting, yielding long term optimized operation patterns that take into account and leverage upon yearly constraints (both technical and economic); - Day-by-day forecast and hourly optimized operations, allowing for an automatized process to generate optimal unit commitment patters to be fed to SCADA systems for field enforcement (as well as data and reports for operations to management reporting). It is possible to characterize the technical, operational and economic framework for the system and for each production asset. Almost every asset type is natively managed and finely configurable, so that the optimized solutions may be adherent to the real-world operational environment, including: - CHP units (endothermal engines, CCGT, ORC) - boilers (biomass or gas-fuelled or electrode boilers) - heat pumps - chilling units (absorption and compression) - storages (heat, chill, electricity) - external sources (third-party providers which supply an energy vector at a certain tariff). The system configuration is extremely detailed and easily accessible to the user (even though the initial set-up is often performed by Optit's personnel), as well as not necessarily static, meaning that several aspects of the framework may be assigned to specific timeframes (e.g. prices and tariffs). The tool consists of four main modules: - forecasting module - long-term optimization - short-term optimization - system integration and optimization

	FORECASTING MODULE The forecasting module yields the prediction of any energy demand profile (heat, chill, electricity), utilizing historical time-series and meteorological data (or any other meaningful specific driver, which may be strongly correlated to the energy demand). The forecast model leverages upon a machine-learning model, constituted by a combination of multi-linear regression and "inertial" algorithms (taking prominently into account what happened in the very near past), currently being improved by integration of neural networks models. The system is inherently self-adaptive, meaning that performances increases with the time-series depth. It is also possible to manually select anomalous instances, so that outliers (due to measurement devices malfunctions or data transmission errors) may be excluded from the learning process of the algorithms. **LONG-TERM OPTIMIZATION** The long-term optimization identifies the annual hourly production plan maximizing the overall EBITDA, based on the system configuration and the input provisional data, and, at the same time, yielding the optimal monthly allocation of the yearly constraints, so that it may be leveraged upon in a strategic manner. Providing the historical data mid-way through the year, it is possible to update the monthly target constraint values, so that re-optimization may be carried out in light of actual past production data and refined provisional data. It is possible to perform a mid-term optimization (a month), which inherits the monthly target constraints from the last year-long optimization. The application allows for numerous what-if scenario management (e.g. variation of technical and economic framework, production assets at disposal, maintenance periods, prices projection), with the capacity to consolidate the "best" scenario that will be used as a reference for short term optimization This may be done also when the production environment is set-up, creating a sort of "what-if environment" for all sorts of analyses to be carried out. **SHORT-TERM OPTIMIZATION** The short-term optimization allows for next-day analyses, also inheriting the long-term constraints allocation (eventually adjusted by the planner). The optimized production schedule is provided for the following 7 days, based on meteorological and prices forecasts, in a semi-automatized process. Extending the time horizon up to 7 days guarantees a baseline for the production plan of the following days, in case technical and field communication errors might occur, potentially compromising the validity of the following optimization. In any case, a rolling scheduled routine is predisposed, so that every day the historical data is updated, the forecasts are performed, the optimization process is run and the results are communicated to the user's SCADA system.

	SYSTEM INTEGRATION AND AUTOMATIZATION All processes regarding updating forecasts and provisional models, the reporting system and, in general, the optimization itself requires that the system is fed with past operational data, as well as actual past prices and meteorological observations. This data stream is usually set up with the user's SCADA system, which is usually the collector of all necessary data, through scheduled operations on a daily basis, feeding the system database. The main output of the solution consists in the weekly/monthly/annual production plan on an hourly basis, with regard to the various energy vectors involved, referring to the single production assets. That is accompanied with the economic balance with the same granularity. It is also possible to compare the past optimized solution with what actually happened, in terms of energy production, prices, meteorological conditions and forecasts benchmark. Still, at the moment, Optit's solution is not intended to replace real-time monitoring systems nor the user's Management Control, in terms of official budgeting and economic reporting. That said, the solution allows to visualize the results both directly on the web applicative and offline through Excel reporting, possibly for extra-system analyses, for they provide very detailed information regarding production (up to the single asset), economics (hourly margin balance, as well as the recap of the economic framework) and allocation of the yearly constraints. **UPCOMING EVOLUTION AND NEW FEATURES** The application is undergoing strong evolution and investments, to be released between 2018 and 2019. These will include: - more advanced data cleansing algorithms will improve robustness against measurement and communication errors, thus ensuring better historical data management; - further machine learning algorithms will be implemented, introducing a dynamic and self-learning management of different predictive models, choosing the optimal mix for the contingent situation, as well as considering a wider spectrum of meteorological variables. - the system will be enabled to perform multiple daily optimization runs, in order to interact dynamically with the intraday electricity market. Furthermore, in order to support the growing transition towards smart systems and different energy vectors integration (4th generation District Heating), further renewable sources and topological elements will be integrated in deeper detail. Finally, although the solution already provides a series of management reports, structured Business Intelligence tools will be integrated to facilitate data navigation and make significantly more flexible the architecture of new report templates, based on the specific user's needs.

Application and required input data	Depending on the nature of the project, different approaches may be considered and, consequently, different layers of input data are needed. **Pilot Projects** In pilot projects (conformed as consulting projects), the main focus is to benchmark the performance of Optit's solution with respect to the current system management, highlighting the technical and economic benefits, as well as assessing the forecasting accuracy. Firstly, the system is set-up, so that the real-world framework may be properly represented in the model. Therefore, the various technical, operational and economic parameters are needed to be configured both at a plant and a single machine level. As a non-exhaustive example list, the main information concerns: - Contractual and pricing framework, in regards of purchasing and selling energy and fuel; - Incentives structure, such as ETS; - Rated energy yields and efficiency curve for each asset; - Technical and operational constraints, such as maximum daily start-ups, minimum working and idle time and minimum/maximum load for each asset; - Ramp-up, ramp-down and transient characterization for each asset; - Maintenance costs for each asset. Then, the historical hourly time series of energy production and fuel consumption for each machine in a reference period, as well as meteorological and prices time series, are imported, so that a benchmark operational baseline may be assessed. Secondly, forecasts of energy demands are assessed and optimization runs are performed, eventually iterating with the client in order to fine-tune the configuration in light of the early results, until a shared degree of confidence in the robustness of the solution is reached. Finally, a presentation on the methodology, assumptions, and optimization results is produced. **Production Service** As the system is to be implemented in a production environment, starting from the activities above described, the system integration specifics are to be defined. In particular, the means with which Optit's solution exchanges data with the local SCADA, the reporting configuration and the timing of the operational process, all are to be defined and tuned with the end users. Furthermore, what (and through which means) sources for meteorological data and prices forecasts are to be picked and integrated, all are to be decided.

Purpose	☒ modelling ☒ planning ☒ decision making ☒ optimization
Possibilities	- Optimized and automatized operations of complex energy production systems - Management of technical, economical, operational constraints (both short and long term) - Possibility of tailor-made solutions, via customization of the state-of-the-art solution
Limitations	- Heuristic/linear model imply some level of approximation (flows and temperatures not explicitly managed dynamically) - The distribution network after the production plant is not modelled explicitly - Non-negligible quantity of quality data are needed for a correct configuration
Language	☒ EN ☒ IT
User level	☒ technical engineer (for the regular system supervision) ☒ other (the detailed output reporting is management-oriented, accordingly not only technical personnel is able to work with the Solution. Standard use of the application is accessible to general users, following adequate training, while advanced analysis may require some support from advanced analysts)
Required operation system	☒ laptop/pc ☒ server (possibly provided by Optit)
Provider	Optit srl, www.optit.net ☒ commercial
Cost	☒ commercial The price is to be decided depending on size and complexity of the system

2.8 Optit's Solution for DHC network development

Author:

Stefano Morgione, OPTIT, Italy

Table 8 Optit's Solution for DHC network development

Name	Optit's Solution for DHC network development
General description	Commercial and Strategic Network planning requires a tool to determine the optimal investment strategy for its development, for both District Heating (DH) and District Cooling (DC). The main questions to be answered are the following: - Strategic development: given two or more network expansion configurations (e.g., new backbones), and a set of potential customers (prospects), which development solution maximizes the Net Present Value (NPV)? - Commercial development: given an existing, not saturated, district heating (or cooling) network and its current users, who are the best new users to target in order to maximize the NPV of the new network investments while respecting overall thermo-hydraulic constraints? Saturated networks can also be managed, in terms of redefining the contractual power for current users who do not utilize it fully (e.g. for consumptions reduction due to habit changes or building refurbishments improving energetic performance) or in terms of peak shaving, thus creating room for new customers (e.g., instalment of thermal storage solutions, contemporaneity factor). The key point is finding the best compromise between business/economic drivers and technical constraints (i.e. proper hydronic balance and each user's heat demand supply). Opti's solution is based on integer programming modelling and metaheuristics approaches, designed in partnership with the University of Bologna and with some of the leading Italian Utilities, such as Hera and A2A Calore & Servizi (ACS), in order to support district heating system planning by identifying the most advantageous subset of new users that should be connected to an existing network. It is a Model Driven Decision Support System (DSS), since the dominant component is a quantitative model, designed as plug-in of an open source Geographical Information System (GIS) to support decision making of DH network managers and their staff in regards of the optimal network expansion plan. The problem is stated to define the district heating network expansion plan, which maximize the NPV within a given time horizon. The optimization module is modelled as a Mixed Integer Linear Program (MILP), providing as output: - The set of potential new customers that is most profitable to reach; - Consequently, the piping needed to be built and its sizing.

	Thus, the economic model embeds a thermo-hydraulic model for feasibility checks of the solutions. The economic model takes into account: - heat production cost and selling revenues; - new piping and substations size-dependent cost - amortization, taxes, budget constraints. Moreover, an acquisition curve can be applied, reflecting the possibility that new customers connection may dilute over the investment time, while the cost of laying down the pipes may have to be sustained the first year. Hence, the values of the corresponding costs and revenues are to be actualized accordingly. The thermal-hydraulic model takes into account all physical properties of the pipes (length, diameter, etc.) as well as of the injection points (generation units power, etc.), ensuring the proper operation of the extended network. Optit's solution is a desktop application, deployed as a Service (be it via consulting or remote access to the solution), bypassing the need for heavy IT integration requirements, accessible to technical and commercial users. It is designed to be a plug-in of OpenJump (an open source GIS tool), that guarantees a large set of functionalities and efficiency in the treatment of large amounts of vector data. The overall look&feel and functionalities resembles GIS tools, with the central representation of the graphs and the management of the various element layers shown on the side. The tool allows to navigate the decision-making process and show outcomes and detailed reports, in order to facilitate a comprehensive overview of the elaborated scenario in terms of: - Technical and economic configuration - Optimal solution (e.g. the new customer to connect and the new pipes to lay down) - Financial investment plan for the desired duration. The computational times are suitable for business applications: instances with hundreds of potential customers are easily dealt with, while instances above a certain size (e.g. thousands of customers) are usually tackled either by aggregating the customers with similar features into a smaller number of virtual customers, or by decomposing the instance into smaller ones, which are optimized separately, though with a level of information exchange between each other. In addition, larger instances up to full town size can be easily handled by connecting all the potential customers: not focusing on the customers leading to higher NPV, the feasibility of the solution from a thermo-hydraulic standpoint, as well as the scenario economic figures, can be assessed. Thus, all relevant solutions that could represent a benchmark can be verified and its social value can be addressed, in addition to the economics. As an example, the full city coverage cost and feasibility can be determined, supporting policy makers in realizing the marginal cost needed to guarantee the right of all citizens to be connected to the heat network, despite not being the optimal solution from a purely economic point of view.

	Finally, also the environmental impact in terms of carbon dioxide emissions can be quantified, given the generation units and their energy conversion performance. In fact, different energy mixes can be utilized to provide the heat required by customers, whose carbon footprint can be assessed. Finally, the main key success factors of Optit's tool are: - Quick generation of results, allowing for agile what-if analyses activities and the decision process itself; - Integrating the different perspectives of commercial staff and technicians, each one provided with results compliant with the others' goals/constraints; - High number of decision variables within the model, allowing decision makers to perform many kinds of what-if analyses
Application and required input data	The following data is necessary for the set-up of the system: a) Geographic Data: - geographic coordinates and peak power of production plants and users (existing and potential), as well as cartographic information regarding the existing piping - road network shape, as for a reference background (if available) Depending of available data, some address matching activities or manual input of data in the system may be possible. b) Economic Data: - piping and substations capital costs (including both the elements themselves and the installation work) - average heat production costs in €/MWh (considering fuel costs, losses and auxiliary costs) - estimated operating costs for each year of the simulation scenario - heat sales revenue drivers (tariffs: one or possibly multiple) - taxation rate, WACC rate and time horizon for the evaluation of the investment with the NPV method - amortization time for the network and the substations c) Technical Data: - supply & return line design network temperatures - maximum pressure of the supply line, minimum pressure of the return line, minimum pressure drop (supply/return) at the most disadvantaged user - users' Coincidence Factor and yearly equivalent hours count (if not available, then some aggregated data of billed heat consumption) - piping dimensioning criteria (maximum flow speed, maximum head loss)

	If the information above (regarding the economic and technical data) is not fully available, it may be integrated leveraging on the Optit's expertise for educated guesses.
Purpose	☒ modelling ☒ planning ☒ decision making ☒ optimization
Possibilities	- Generate reliable and complex investment plans that take into account optimization criteria - Thermohydraulic validation of the solutions - What-if analyses potential
Limitations	- Need of precise cartographic data and pipping/users characterization - Very large instances are complex to manage all at once, (may require some "districtualization" analysis - Initial setup requires expert advice
Language	☒ EN ☒ IT
User level	☒ technical engineer ☒ other (after a first configuration with commercial and technical personnel, the tool may be utilized in production environment without specific deep know-how)
Required operation system	☒ laptop/pc ☒ server (possibly provided by Optit)
Provider	Optit srl, www.optit.net ☒ commercial
Cost	☒ commercial, approx. price: 25-50,000 € for license, TBC for spot consulting that leverages on the methodology.

2.9 TELEPERM XP (code name SPPA-T2000)

Authors:

Anes Kazagić, JP Elektroprivreda BiH d.d.-Sarajevo, Bosnia and Herzegovina

Ajla Merzić, JP Elektroprivreda BiH d.d.-Sarajevo, Bosnia and Herzegovina

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Jasenko Fazlić, JP Elektroprivreda BiH d.d.-Sarajevo, Bosnia and Herzegovina

Table 9 TELEPERM XP

Name	TELEPERM XP (code name SPPA-T2000)
General description	The TELEPERM XP (TXP) process control system provides all instrumentation and control (I&C) facilities that are necessary for automating, handling, monitoring, and archiving processes (such as the operational instrumentation and control systems of power plants). It is a distributed control system for all requirements, consisting of different subsystems: - an operation and monitoring system (OM) which includes process control and information system for operator-process communication and visualization; - an engineering system that can be used for engineering, configuration, commissioning and maintenance purposes; - a diagnostic system used for I&C; - a network communication system; - an automation system used for process automation. It can be used for facilities like small boilers up to large power stations through: - high degree of modularity; - step by step automation; - performance up to one man control room. It can provide an open communication and world wide access to TXP applications via intranet, internet utilizing a standard web browser and extranet on Windows-PC´s. It is characterized by an easy integration in the existing plant infrastructure and operates using standards, including ISO/OSI communication and has an integrated configurable redundancy. One of its main features are powerful subsystems which are characterized by: - high processing density; - penetration of the I&C system into the field level and intelligent field devices; - decentralized processing; - integrated forward documentation and automatic code generation of user programs; - integrated diagnostics system (as optional).
Application and required input data	TELEPERM XP is a power network solution that can be used for the engineering of large plants. It is applied for process operation, process information and process management purposes. It provides a variety of services, whereby early diagnostics for faster error

	localization and preventive detection of failures and cost savings for running systems by increasing availability can be pointed out. All necessary data that correspond to each specific facility type can be entered, like facility parameters, operational parameters and dynamic characteristics, including case specific allowed limit values, etc. Thereby necessary information and results are displayed for the user in form of pictograms, diagrams, analogue and/or binary values.
Purpose	☒ other: operation, control and monitoring
Possibilities	- High availability thanks to system-wide configurable redundancy - High customer benefit during operation through powerful diagnostics, service functions by using intelligent field devices and fast fault analysis through a common alarm concept - High accuracy with time resolution of 1 ms and system wide time accuracy of 10 ms - Easy supervision and navigation during normal plant operation
Limitations	- It is developed to support technical engineers - The setting up of the system can take a while
Language	☒ EN ☒ DE
User level	☒ technical engineer
Required operation system	☒ laptop/pc ☒ server
Provider	Siemens AG Freyeslebenstrasse 1 91058 Erlangen Germany Email: support.energy@siemens.com
Cost	☒commercial (price is system needs dependent)
References	https://www.energy.siemens.com/hq/en/automation/power-generation/sppa-t2000.htm SIEMENS (2004) TELEPERM XP, Technical Data SIEMENS, TXP Training Course, TXP Training for Sahand Power Plant SIEMENS, ANDREAS LANG (2007) SPPA-T2000, Instrumentation & Controls

2.10 TERMIS Software

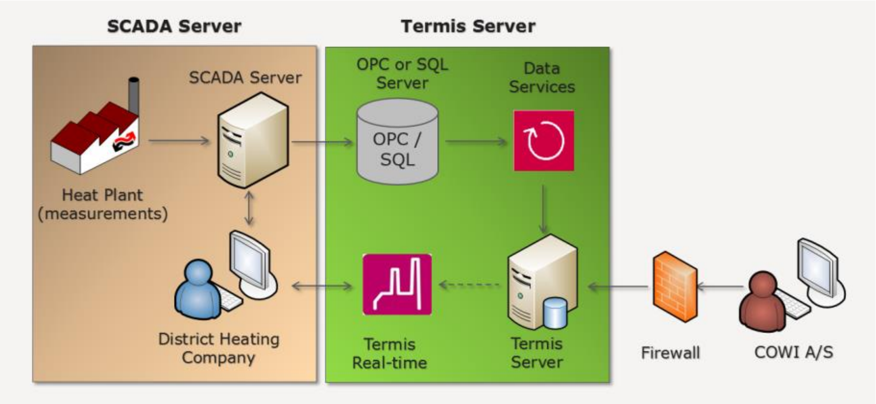
Author:

Thomas Andreas Østergaard, COWI A/S, Denmark

Table 10 TERMIS Software

Name	Termis
General description	Termis is a hydraulic modelling tool used for District Heating, which simulates flow, pressure and thermal behavior in the distribution network. Termis conducts hydraulic simulations that can be used to optimize the District Heating supply and utility production within your energy system. The hydraulic analysis is based on real time data from the SCADA system that allows the District Heating companies to obtain more information about their entire network and operation. This allow them to make smarter and better decision making leading to optimizing cost-effectiveness and overall efficiency. The Termis software is a very intuitive and user friendly interface because it can be manually customized to suit the users demand. Termis is used for designing District Heating Networks, to meet future demands, avoid bottlenecks and comply regulations. Termis enables a close collaboration between staff, such as COWI A/S, who are a certified system integrator, and costumers providing instant answers to enquiries occurring. The Termis software includes a modular structure that enables the users to conduct a variety of analyses e.g. master planning, feasibility studies and also chilled water distribution. It can be used for calculating flows, temperatures, pressures, pumping head, load on pipes, pressure loss gradients, temperature losses, pressure losses, costs, renovation plans etc. Termis allows the costumer to look at the network on a broad and detailed level. Interventions such as supply changes, opening or closing of valves, turning pumps and plants on and off, and assessing the impact on consumer supply are easily simulated and illustrated on the display. Termis is used on a daily basis by more than 500 cities worldwide and secures energy to more than 100 millions of homes. Termis is a well-known and tested software with more than 30 years of experience within the field.

Application and required input data	Termis is a unique modelling tool that uses external data (real time data) from the SCADA system and converts it into a Termis model. This enables Termis to go beyond being just a static planning tool and into a more dynamic decision making tool that is integrated into the daily operation with many benefits and economic advantages for the costumers. Termis can combine the real time data with weather forecasts data from the DMI server, enabling the costumer to predict future consumption. Termis also communicates together with the COWI surveillance system to assist with any given problem.
Purpose	☒ calculation ☒ modelling ☒ planning ☒ mapping ☒ decision making
Possibilities	- Hydraulic simulation and modelling of District Heating Systems - Design of new District Heating Networks - Perform hydraulic analyses and various calculations (real time capabilities) - Optimization of District Heating supply, utility and pump systems
Limitations	- Dependent on available data from the District Heating Networks and SCADA system - Dependent on the online data to construct prognoses
Language	☒ EN ☒ DK ☒ DE ☒ FR ☒ CH ☒ RUS ☒ and more
User level	☒ software engineer ☒ technical engineer ☒ end user

Required operation system	☒ laptop/pc ☒ server
Provider	Schneider Electric District Energy Management 26561 Rancho Pkwy South, Lake Forest, CA 92610 Tel.: +1 (949)-727-3200 Fax: + (949(-727-3200 www.software.schneider-electric.com/products/termis
Cost	☒ commercial, Price depending on license capabilities **Contact COWI for enquiries.** COWI COWI A/S Jens Chr. Skous Vej 9 8000 Aarhus C Denmark Email:TermisSupport@COWI.COM
Image	 **Figure 2 TERMIS information exchange**
References	SCHNEIDER ELECTRIC (2016) Termis District Energy Management, Unleash the potential of every employee in the utility to serve your customers, Rancho Pkwy Sourth, Lake Forest, California https://www.schneider-electric.dk/da/product-range-presentation/61613-termis-engineering/ COWI A/S (2016) TERMIS and Thermographic Analysis, Aarhus, Denmark COWI A/S (2017) Saving Potential from FTO and RTO, Business models, Aarhus, Denmark COWI A/S (2018) Strategy for lowering of Flow and Return Temperatures, using TERMIS, Aarhus, Denmark COWI (2018) Thermographic Inspection – Hvalsø combined heat and power plant, Aarhus, Denmark

2.11 TERMIS - Flow Temperature Optimization software (FTO)

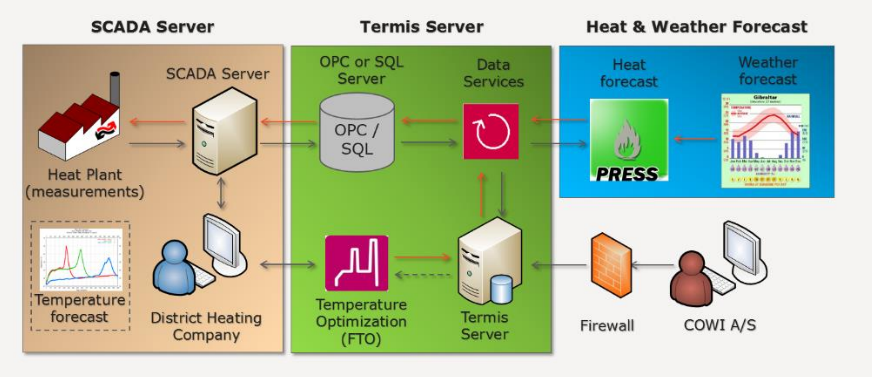
Author:

Thomas Andreas Østergaard, COWI A/S, Denmark

Table 11 Termis Flow Temperature Optimization (FTO)

Name	Termis – Flow Temperature Optimization software (FTO)
General description	Termis Flow Temperature Optimization (FTO) is a software that optimizes the supply temperature at the heat plants. Termis FTO uses real time hydraulic networks that ensures the costumer correct time delays, heat accumulation to cover morning peak loads, correct heat loss and optimization of multiple heat sources. The Termis FTO model provides the costumer with a detailed model of the minimum supply temperature at the consumers which is based on the outdoor temperature, maximum and minimum inlet temperature at plants, maximum rate of change of inlet temperature at plants and maximum flow capacity at heat plants and pumps in the network. Termis FTO can be used to analyse a more dynamic optimization of the District Heating Network. Termis FTO minimizes the operation costs within the network by automatically adjusting set points for inlet temperatures at the heat plants, while ensuring that all consumers have at least their minimum supply temperature secured. The accumulated energy in the network, change in consumption and weather conditions together with pumping- and production costs are all considered in the modular structure. Termis FTO differs from a traditional approach that sends a constant inlet temperature through the network, independent of the different consumer's minimum heat demand, to providing an inlet temperature that varies dependent on the consumers minimum heat demand in the network and the weather conditions. This low temperature District Heating Network results in minimizing heat loss from the network enabling the costumers to save energy. Termis FTO is a very user friendly software since it is an extension module to Termis that gives the costumer a full overview of the network and tools to calculate further savings on both operating costs and capital investments. COWI A/S functions as support service to FTO and are in close contact with the costumer and Schneider Electric/Aveva.

Application and required input data	Termis FTO is an extension module to Termis and is based on external data from the SCADA server involving Heat Plant measurements, and weather forecasts data from DMI to predict the temperature forecast. The external data are sent into the Termis server to be processed. The Termis server involves a SQL server, Data services, and Temperature Optimization software (FTO). Termis FTO also includes data from Heat forecasts using PRESS which is a prognosis software using load prognoses time series that are included into the Termis model.
Purpose	☒ calculation
Possibilities	- Calculating the optimal supply temperature while securing the consumers heat demand - Calculating the optimal operation of the energy plants at minimum costs - Simulates the District Heating Network as close to reality as possible
Limitations	- Dependent on available data from the district heating networks and SCADA system - Dependent on the online data to construct prognoses for the temperature optimization
Language	☒ EN ☒ DK ☒ many other …
User level	☒ software engineer ☒ technical engineer ☒ end user ☒ other …
Required operation system	☒ laptop/pc ☒ server

Provider	Schneider Electric/AVEVA District Energy Management 26561 Rancho Pkwy South, Lake Forest, CA 92610 Tel.: +1 (949)-727-3200 Fax: + (949(-727-3200 www.software.schneider-electric.com/products/termis **Contact COWI for enquiries.** COWI COWI A/S Jens Chr. Skous Vej 9 8000 Aarhus C Denmark Email:TermisSupport@COWI.COM
Cost	☒ commercial, Price depending on size of DH system
Image	 **Figure 3 TERMIS information exchange**
References	SCHNEIDER ELECTRIC (2016) Termis District Energy Management, Unleash the potential of every employee in the utility to serve your customers, Rancho Pkwy Sourth, Lake Forest, California https://www.schneider-electric.dk/da/product-range-presentation/61613-termis-engineering/ COWI A/S (2016) TERMIS and Thermographic Analysis, Aarhus, Denmark COWI A/S (2017) Saving Potential from FTO and RTO, Business models, Aarhus, Denmark COWI A/S (2018) Strategy for lowering of Flow and Return Temperatures, using TERMIS, Aarhus, Denmark COWI (2018) Thermographic Inspection – Hvalsø combined heat and power plant, Aarhus, Denmark

2.12 TERMIS - Return Temperature Optimization software (RTO)

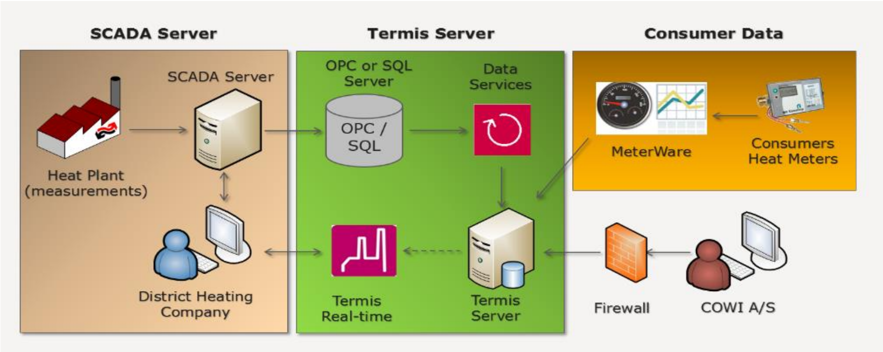
Author:

Thomas Andreas Østergaard, COWI A/S, Denmark

Table 12 Termis - Return Temperature Optimization software (RTO)

Name	TERMIS - Return Temperature Optimization software (RTO)
General description	The Return Temperature Optimization (RTO) software is a unique tool that targets the costumers to reduce the return temperature in the network. The product is a service output consisting of gathering data with MeterWare, configuration of Termis and MeterWare and processing data to document energy savings together with consultation as regards the practical part of RTO. Termis RTO is developed by COWI A/S in cooperation with utility companies and Schneider Electrics. Termis RTO is a method used for reducing the return temperature in District Heating Networks by integrating Big Data from remotely monitoring Smart Meters with real time data from the SCADA system in Termis. The remotely operated meters sends data to a database operated by MeterWare which distributes the information into Termis. The data is then plotted in Termis Operation giving the costumer a detailed plan over which consumers that have insufficient cooling of the return water. These consumers can then be identified and notified about optimization initiatives. A high return temperature in the District Heating system results in a high heat loss and inefficient energy system. Lowering the return temperature a few degrees involves high energy savings that can be gained in the networks. Another way to utilize the data is to have information on where to reduce the flow, smaller velocities, smaller gradients, less resistance, lower power expenditures and no new pumps etc. Termis can calculate the obtained energy savings, operational savings and documentation savings that benefits the economy of the District Heating companies and is in correlation with the goals of the Danish Energy Agency. The Termis RTO software is very user friendly which is illustrated through the usage of a display with smiley's to indicate each consumer's ability to cool the return temperature, which makes it easy to identify where to invest resources to optimize the District Heating Network to find the optimal focus areas. Termis RTO involves close collaboration with COWI consultancy, since we work as system integrator, and will be at instant assistance if any enquires occur to help the costumers find a good solution.

Application and required input data	Traditionally, RTO is based on the same setup as for the supply temperature optimization, but without the prognosis tool. Termis RTO uses external data (real time data) from the SCADA system and converts it into a Termis model. Termis RTO can combine the real time data with weather forecasts data from the DMI server, enabling the costumer to predict future consumption. The RTO software also integrates online heat metering data from costumers that is gathered in MeterWare and then the data is processed and distributed into Termis Real Time Model, which enable Termis RTO to model the consumers cooling of the return temperature. The RTO module is utilized through Termis as an extension to its existing installation. For Termis RTO to work properly, it is dependent on the SCADA server, Termis server and Consumer data considering Smart Meters installed in every household in the District Heating Network.
Purpose	☒ calculation
Possibilities	- Localization of consumers with an insufficient cooling of the water will be visible and can be notified about requirements in terms of installations. - Improving production of heat and electricity - Reducing heat loss and pumping costs - Increasing capacity in the District Heating network which enable more costumers to be connected. - High potential for energy savings
Limitations	- Dependent on initiatives such as tariffs, regulation, labour and District Heating systems, since none are identical. - Difficult and substantial method involving change in the District Heating setup in terms of mind-set and operation. - Requires a new mindset for the DH Company to interact more with the customers than before
Language	☒ EN ☒ DK ☒ many others
User level	☒ software engineer ☒ technical engineer ☒ end user
Required operation system	☒ laptop/pc ☒ server

Provider	Schneider Electric in collaboration with COWI A/S District Energy Management 26561 Rancho Pkwy South, Lake Forest, CA 92610 Tel.: +1 (949)-727-3200 Fax: + (949(-727-3200 www.software.schneider-electric.com/products/termis **Contact COWI for enquiries.** COWI A/S Jens Chr. Skous Vej 9 8000 Aarhus C Denmark Email:TermisSupport@COWI.COM
Cost	☒ commercial, Price depending on size of DH system
Image	 **Figure 4 TERMIS information exchange**
References	SCHNEIDER ELECTRIC (2016) Termis District Energy Management, Unleash the potential of every employee in the utility to serve your customers, Rancho Pkwy Sourth, Lake Forest, California https://www.schneider-electric.dk/da/product-range-presentation/61613-termis-engineering/ COWI A/S (2016) TERMIS and Thermographic Analysis, Aarhus, Denmark COWI A/S (2017) Saving Potential from FTO and RTO, Business models, Aarhus, Denmark COWI A/S (2018) Strategy for lowering of Flow and Return Temperatures, using TERMIS, Aarhus, Denmark COWI (2018) Thermographic Inspection – Hvalsø combined heat and power plant, Aarhus, Denmark

3 Identified best practice instruments

3.1 Areal Thermographic Surveying software

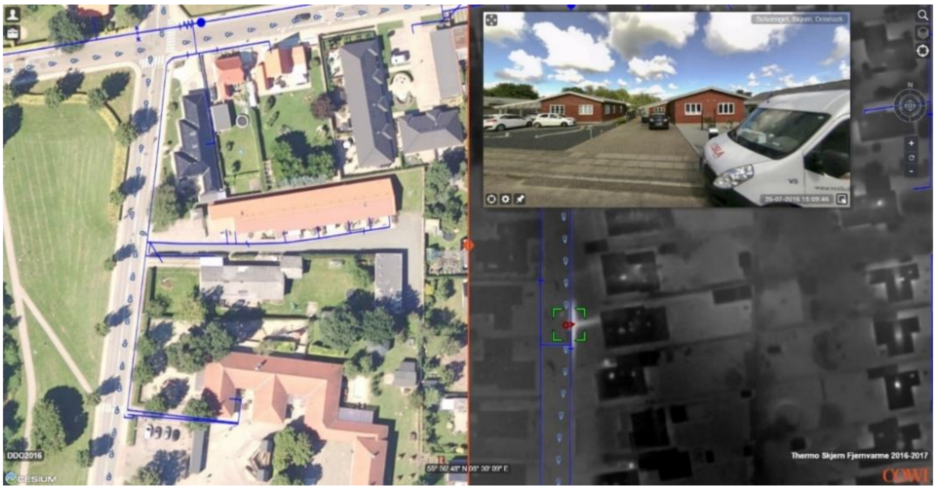
Author:

Thomas Andreas Østergaard, COWI A/S, Denmark

Table 13 Areal Thermographic Surveying software

Name	Areal Thermographic Surveying software
General description	Areal Thermographic Surveying is a mapping tool for district heating networks using thermographic images. It enables to detect heat radiation from surfaces. Thermographic surveying is based on the fact that all surfaces emit electromagnetic radiation, depending on the surface temperature. With the thermographic camera the variation of temperatures can be detected on a clear scale. Thermographic survey can be used for planning renovation and maintenance of District Heating Networks. The thermographic surveying is conducted through drones or airplanes which are equipped with thermographic cameras. It is possible to detect leakages, (even small leaks), heat leaks due to bad insulation, mislaid pipes and errors in pipe drawings, etc. The Areal Thermography of District Heating Systems is used for ensuring the security of supply, preserve the assets of value of the district heating network, minimize heating distribution costs, prioritization of renovation effort from where it provides the best value and reducing water and heat loss etc. COWI are one of the first companies who have received permit to use Areal Thermography Surveying. COWI has developed their own drones and sensors that are used for precisely identifying leakage in District Heating pipes. During the flight the area is scanned with a thermographic sensitive camera, hereafter the registered costumer pipeline network is placed in addition to the thermography, enables an identification of abnormalities. The end result is an array of areas on the map with an increased heat radiation. The mapping of leakages or possible leakages in the pipelines can be used to reduce the expenditures for renovation and maintenance of the pipelines due to it enabling the District Heating companies to prevent and react fast resulting in saving money. The mapping process is done with drones or planes that are flying over the area, in above 100 meters height, show the pipelines condition. The technology is specially designed by COWI to register heat and cold radiation to map the pipelines exact location and leakages.

Application and required input data	The Thermographic Surveying is based on data from a thermographic camera which is mounted in an airplane or a drone. Data is saved as digital information and later processed to form a map. This map is called a thermographic mosaic. The data that represents possible leakages is divided into 4 classifications from 0-3 showing ID number, category, description of abnormalities and coordinates. It is requested to investigate all areas with a classification of 3. The orientation of the classification are very user friendly because it is displayed through an ID number and colour system, making it easy for the costumer to orientate themselves in the data. The located abnormalities have received a number that are illustrated in an Excel format and the coordinates are delivered by the Thermo Mosaic digitally and the geo-referred ortho-photo is delivered in the desired projection, i.e. UTM zone 32 ETRS89
Purpose	☒ mapping ☒ decision making
Possibilities	- Planning renovation and maintenance of District Heating Networks - Precise illustration of the pipelines conditions - Fast and proactive way to identify enquires in the District Heating Network - Enabling new ways of screening areas which were not possible before - Many different ways to utilize the mapping of Areal Thermographic Surveying - Very short payback time
Limitations	- To map the pipeline network precisely the weather conditions has to be optimal - Noise disturbances and time consuming process - Errors can occur due to the heat registration with the thermographic camera.
Language	☒ EN
User level	☒ technical engineer ☒Asset Manager
Required operation system	☒ laptop/pc

Provider	**<u>Contact COWI for enquiries.</u>** COWI COWI A/S Jens Chr. Skous Vej 9 8000 Aarhus C Denmark Email:TermisSupport@COWI.COM
Cost	☒ commercial, Price depending size of area to be scanned
Images	 **Figure 5 Thermo Mosaic Purmerend, the Netherlands**  **Figure 6 COWI Multiviewer – Ortho photo, COWI Street photo and Thermo Mosaic – in one view**

3.2 Crawler Eye

Author:

Tobias Roth, AGFW, Germany

Table 14 Crawler Eye

Name	Crawler Eye
General description	Some district heating pipe lines are placed in hooded channels. Most of them are made of concrete. Over the years the hooded channels suffer under the impacts of weather conditions, vegetation and heat load. This instrument allows an optical appraisal of this district heating hooded channels. Therefore, the “Crawler-Eye” is placed directly on the pipe line (see picture 1). It is moving forward on chains, one chain placed on the supply pipe line and one on the returning pipe line. The “Crawler-Eye” is equipped with an articulated arm and a turntable camera at its end. This combination allows a nearly 360° appraisal of the hooded channel. The “Crawler-Eye” is controlled by a control-unite from the inside of a van which is next to the channel-access. A small monitor represents the interface between the camera of the instrument and the user, and enables to direct the crawler. The film is recorded in order to evaluate the results on spot as well as after the use of the “Crawler-Eye”.
Application and required input data	With the results of the appraisal, first statements about the structural condition of the hooded channels can be made. Furthermore the pipes and its insulation can be examined as well. Another application is to check the state of the pipeline’s (slide-) bearings. This state-check can only be made with optical method.
Purpose	☒ detection
Possibilities	- Optical appraisal nearly 360° - Recording for later evaluation - Good documentation of Technical boundary conditions
Limitations	- Requirement for an economical use of the tool is an access to the channel - The maximum range of the crawler is about 100m (theoretical) and 75m (already reached ranged) - Inspection of steam pipes is not possible, caused by the different diameters of supply and return pipe
Language	☒ DE
User level	☒ technical engineer
Required operation system	A laptop or equal device is necessary to watch the recorded video, but other equipment is not needed

Provider	IAB – Institut für Angewandte Bauforschung Weimar gGmbH, GIB – Gesellschaft für Innovation im Bauwesen mbH ☒ commercial
Cost	☒ commercial Price: depending on the individual effort
Images	 **Figure 7 Photos of an inspection by the “Crawler-Eye” of a district heating system in Frankfurt, Germany. On the left picture is the “Crawler-Eye” and on the right picture is the monitor of the camera.**
Reference	http://www.iab-weimar.de/wp-content/uploads/2018/03/Inspektion-von-nicht-begehbaren-FW-Kan%C3%A4len-technische-Randbedingungen_GIB.pdf

3.3 Mass flow adjustment to the actual needs/demands, to save pumping energy and to achieve low return temperatures

Author:

Daniel Heiler, AGFW, Germany

Table 15 Mass flow adjustment

Name	Mass flow adjustment to the actual needs/demands, to save pumping energy and to achieve low return temperatures
General description	The adjustment should begin in each house substation. Following steps are advised: 1. Calculation of actual (heat) demand of every individual house substation (if the heat demand is known, it needs to be checked, if the demand has changed, e.g. due to insolation) 2. Thinking about a coincidence factor of the heat demand (could be between 70% - 100%, depending on type of house) 3. Adjustment of the mass flow in the flow limiter of the house substation, according to (re) calculation of heat demand and subsequent lead sealing. If the return temperature of the secondary side (customers side) is higher than it should be (depending on the lay out temperatures of the radiators), the secondary mass flow should be reduced to that point, that the pre- calculated return temperatures are achieved. There is also an option, to do the flow limitation electronically, depending on the regulation system. If such a regulator is connected to a central SCADA system of the DH company this could be done out of the SCADA system.
Application and required input data	Information on the actual heat demand of every individual connected house is necessary. According to this heat demand, the responding mass flow should be regulated. The mass flow of the network results as a sum of every individual connected house. If the mass flow of the individual house substations is already too high, the network mass flow will be much too high and requires higher pumping energy. A good figure to evaluate the energy demand for the network pumps is following: electricity consumption of all network pumps in one year in [kWh] divided by the heat sold in [MWh] of the same year. Factor = kWh_{el} / MWh_{th} The factor should be between 10 (very good) and 15 (still good). A higher factor means a high saving energy potential.

Purpose	☒ calculation ☒ modelling ☒ planning
Possibilities	- Lower return temperatures at house substations and network - Less pumping energy for network pumps necessary - Higher possibilities to connect more customers to the same pipe
Limitations	- The mass flow of the customer`s side has also to be checked, which is normally not in the field of responsibility of the dh company - Heat demand of houses is not always available; re-calculation or estimation necessary
User level	☒ technical engineer ☒ end user
Cost	To lower costs, students can be engaged e.g. for calculation of heat demands

3.4 Thermal imaging via air plane

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Table 16 Thermal imaging via air plane

Name	Thermal imaging via air plane
General description	For thermal imaging, it is important to use a plane that flies some 1,000 m high and not a drone. The plane is equipped with special thermal cameras, which allow a close overview over the whole district heating network. A side effect of this method is a GIS implementation, incl. mobile GIS, at the same time. The thermal imaging via air plane serves as a good basis for: 1. Very precise detection of leakages and heat losses (anomalies) 2. Basis for maintenance planning of the network The detected anomalies were classified into several steps (immediate action necessary, action necessary in near future, and so on) 3. GIS mapping of the whole district heating network possible, if not already existing
Application and required input data	If a digital map of the district heating system is existing, it can be used for the flight planning. In case the digital map is not yet existing, this could be an outcome of the flight, but in this case, the flight planning is more complicated.
Purpose	☒ detection ☒ planning ☒ mapping
Possibilities	- Detection of leakages and heat losses - Basis for maintenance planning - Overview over the whole DH system
Limitations	- A flight should only be conducted at night in wintertime, to have the temperature difference between the ground and the air at its maximum - relative high price
User level	No special knowledge necessary
Cost	☒ Commercial, approx. price: Price is depending on size of the DH system

Image	 **Figure 8 Image taken from a plane** **Source: SCANDAT GmbH**