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D5.1: GENERIC MONITORING PRINCIPLE AND EQUIPMENT FOR TEMPO

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SUMMARY

The present document constitutes Deliverable D5.1 "Generic monitoring principle and equipment for TEMPO" developed within WP5 of the H2020 TEMPO project. The TEMPO – Temperature Optimisation for Low Temperature District Heating across Europe – project develops technical innovations that enable district heating networks to operate at lower temperatures. By decreasing the temperature in the systems, it reduces heat losses and allows a higher share of renewable and excess heat to be used as heat sources. The use of these heat sources will be crucial to adapt current district heating systems and create new ones suitable for a sustainable energy system. This report describes the monitoring requirements, describes the key performance indicators and their calculation, as well as a generic hydraulic diagram and monitoring concept. This will allow for an assessment of DH network performance improvements among the demo sites assessing comparable figures and additionally gain better insight into the enhancements made by the different innovations.

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GLOSSARY / LIST OF ACRONYMS

ACRONYM	DEFINITION
CHP	Combined heat and power plant
CSV	Comma-separated values
DH	District Heating
HDD	Heating degree days
KPI	Key performance indicator
SCIS	Smart City Information System
TEMPO	Temperature Optimisation for Low Temperature District Heating across Europe
WP	Work package

1 INTRODUCTION

As introduction a brief description of the TEMPO project is given, which can also be found online under https://www.tempo-dhc.eu

The TEMPO – Temperature Optimisation for Low Temperature District Heating across Europe – project develops technical innovations that enable district heating networks to operate at lower temperatures. By decreasing the temperature in the systems, it reduces heat losses and allows a higher share of renewable and excess heat to be used as heat sources. The use of these heat sources will be crucial to adapt current district heating systems and create new ones suitable for a sustainable energy system.

Six technological innovations that contribute to minimising the temperature in networks and enables a cost-efficient implementation of low temperature networks will undergo final development in TEMPO. Each of the innovations can bring value to most district heating networks individually. However, the main strength of this project lies in the combination of the individual technologies into solution packages for dedicated application areas. Three solution packages customised to three different application areas, that together covers 90% of the district heating market in Europe, will be tested in selected representative demos:

- New urban low temperature district heating networks
- New rural low temperature district heating networks
- Existing high temperature district heating networks

These three innovative demonstration sites are in the regions of Hamburg (Germany), Nuremberg (Germany) and Brescia (Italy).

Additionally, TEMPO will develop innovative approaches to consumer empowerment enabled by digital solutions. The project will also develop new business models and demonstrate their replication potential for the roll-out of sustainable and economically viable district heating networks across the EU.

TEMPO kicked off in October 2017 and will run for four years. It is funded by the European Union's Horizon 2020 Programme for Research and Innovation.

This report describes the "Definition of the monitoring concept and equipment". Appropriate demo performance quantifiers and a generic monitoring principle were chosen. This will allow for an assessment of DH network performance improvements among the demo sites assessing comparable figures and additionally gain better insight into the enhancements made by the different innovations (Tasks 5.2 and 5.3). The developed monitoring concept will allow for: a) calculation of relevant performance indicators and b) finding optimisation potential by analysis of monitoring data.

This deliverable includes the definition of the calculation methods for the chosen indicators, the definition of system boundaries, the definition of monitoring frequency, storage and transfer of the monitoring data to AIT and other partners. Considering the monitoring of the system it is envisaged that no personal data (e.g. any information that relates to an identified or identifiable living individual) will be collected. The process of evaluation of the single thermal load profiles from customers will include (if necessary) a de-identification, encryption, anonymization or pseudo-anonymization to make the personal data not identifiable and therefore they cannot be considered as personal data. In case data must be truly anonymised, the anonymization will be irreversible.

2 MONITORING REQUIREMENTS AND ALIGNED LIST OF KEY PERFORMANCE INDICATORS

The three innovative demonstration sites of TEMPO will be in the regions of Hamburg (Germany), Nuremberg (Germany) and Brescia (Italy).

- The region of Hamburg (Germany): A new network will supply heat and cold to a neighborhood of new low-energy buildings, heated by geothermal heat and residual heat of a CHP. Solution package 1 will be demonstrated to reduce temperatures and therefore enable integration of a geothermal energy source and cooling.
- The region of Nuremberg (Germany): A new network will supply heat to a less dense area of new buildings, heated by residual heat of a biogas plant and biogas CHPs. Solution package 2 will be demonstrated at this demo site to reduce temperatures and so open up the possibility to integrate a renewable energy source at a later stage.
- Brescia (Italy): The A2A pilot project involves part of the Brescia district heating network in a low building density area consisting mainly of terraced houses and some apartment blocks. The existing network is heated by a waste-to-energy plant (~50% coverage), residual heat from industry and CHP, and peak-load gas boilers. The A2A network in Brescia started operating in the '70s, and currently operates at temperature levels of 120/60°C.

Monitoring and calculation of key performance indicators will allow for assessment of DH network performance improvements among the demo sites assessing comparable figures and additionally gain better insight into the enhancements made by the different innovations. The WP5 "Evaluation and Knowhow Transfer" and specifically the key performance indicators are built upon results from the Smart City Information System project (SCIS is a project funded by the European Union, https://smartcities-infosystem.eu) as well as of other projects carried out by the TEMPO project partners. SCIS gives guidelines, which come as a result of synthetized analysis of different projects related to the Smart Cities data evaluation, and they are organized into a series of documents provided on the following link: https://smartcities-infosystem.eu/library/resources/scis-essential-monitoring-guides/

The first document to assist, entitled "SCSI Technical Monitoring Guide" [1], sets a base for a standardized methodology of the evaluation and assessment related to different actions within the scope of TEMPO. It elaborates (but is not restricted to) the requirements for the monitoring data with respect to the data quality, time frame, identification and sensors on the one hand, and on the other hand it explains the specifications of the monitoring plan, the characterization of the data to be provided, and their collection. Based on the information from this document, within the TEMPO framework following requirements have been defined: indicative time resolution of the data logging has to be 5 minutes (or below). The logged data must be stored locally for at least half a year (indicative period) and the data must be automatically transferred at least once per day to an ftp server at AIT (csv-file) or directly into an AIT database in an encrypted (or adequately considered) format if any personal data are included.

Another document referred to in this calculation, entitled "SCSI Key Performance Indicator Guide" [2], defines relevant key performance indicators (KPIs), together with the data requirements for their calculation. To that purpose, the questions of the data comparability and characteristic data sets (design, monitoring, baseline) are discussed, together with other relevant issues. The main part of this document, however, is the definition of individual KPIs.

The following table shows the aligned list of indicators for the comparison of the TEMPO demo cases. Additional KPIs for the individual demo cases, which are not applicable to all demo cases are not part of the generic monitoring concept and not reported in Table 1, but will be reported in the deliverables D5.2 and D5.3 The description and the calculation methods of the indicators can be found in the Description of the key performance indicators. Apart from the indicators themselves, the list contains information about the units of calculation and it provides information on the calculation standards used.

Table 1: List of key performance indicators

Key performance indicators	Units	Chapter
Primary energy demand savings, [2]	kWh/year, %	4.1
Greenhouse gas emission savings, [2]	t/year	0
Reduced heat distribution losses	kWh/year, %	4.3
Share from residual or renewable energy sources	%	4.4
Heating degree days, [2]	Kd/year	4.5
Return temperature reduction	K	4.6

3 GENERIC HYDRAULIC DIAGRAM AND MONITORING CONCEPT

To measure and calculate the key performance indicators, a generic hydraulic diagram, in principle applicable to all demo cases, and a monitoring concept were developed, see Figure 1. The heat production (gas boiler, heat pump, etc.) and the exemplary heating network (consumers Cons1 to ConsN) are connected via a thermal storage system. System boundaries can be drawn through each of the flow, heat, or electricity meters. With this concept, many interesting values can be calculated, for example the efficiency of the heat generators, and the heat losses of the storage tank or the network. As can be seen, the outermost system boundaries include the fuel consumption and the electricity consumption of the heat generators (CHP, heat pump, gas boiler), respectively, as well as the consumption of each consumer and the electricity output of the CHP. This general monitoring concept must be individually adapted to each demo case to fulfill the needs of TEMPO.

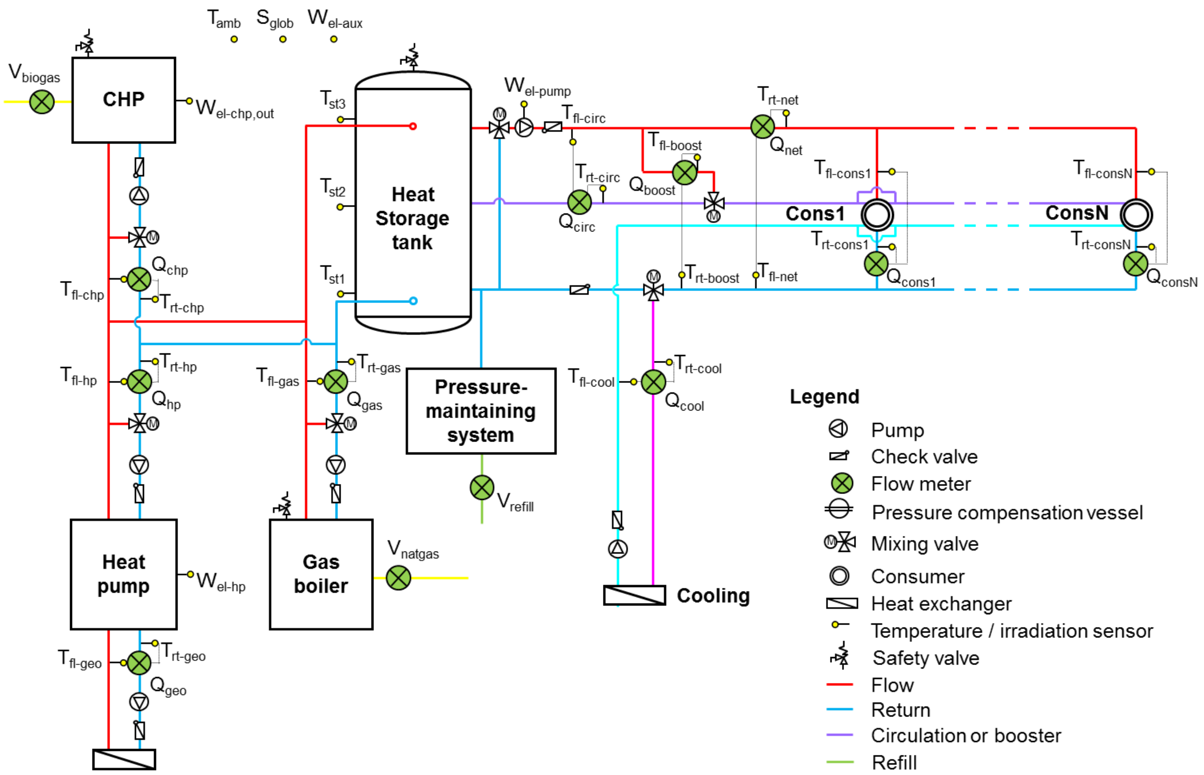

Figure 1: Generic hydraulic diagram and monitoring concept (green: flow meters; yellow: temperature and irradiation sensors, electricity meters)

The sensors nomenclature is clustered into four main categories (weather data, heat production, storage tank and heat consumption) and summarized below.

<u>Weather data</u>

S_{Global}	Irradiation (W/m²)
T_{amb}	Ambient temperature (°C)

<u>Heat production</u>

Q_{gas}	Heat meter gas boiler (kWh)
T_{fl-gas}	Flow temperature gas boiler (°C)

$T_{rt\text{-}gas}$	Return temperature gas boiler (°C)
V_{natgas}	Flow meter input gas boiler (m³)
Q_{hp}	Heat meter heat pump output (kWh)
$T_{fl\text{-}hp}$	Flow temperature heat pump output (°C)
$T_{rt\text{-}hp}$	Return temperature heat pump output (°C)
$W_{el\text{-}hp}$	Electricity meter heat pump (kWh)
Q_{geo}	Heat meter geothermal (kWh)
$T_{fl\text{-}geo}$	Flow temperature geothermal (°C)
$T_{rt\text{-}geo}$	Return temperature geothermal (°C)
Q_{chp}	Heat meter CHP (kWh)
$T_{fl\text{-}chp}$	Flow temperature CHP (°C)
$T_{rt\text{-}chp}$	Return temperature CHP (°C)
V_{biogas}	Flow meter input CHP (m³)
$W_{el\text{-}chp,out}$	Electricity meter output CHP (kWh)
$W_{el\text{-}pump}$	Electricity meter network pump (kWh)
$W_{el\text{-}aux}$	Electricity meter auxiliary components (circulation pumps, valves, controls) (kWh)

<u>Storage tank</u>

T_{st1}, T_{st2}, T_{st3}	Temperature in different heights of the storage (°C)
V_{refill}	Volume meter refill water (m³)

<u>Heat consumption</u>

Q_{net}	Heat meter consumption network (kWh)
$T_{fl\text{-}net}$	Flow temperature network (°C)
$T_{rt\text{-}net}$	Return temperature network (°C)
Q_{circ}	Heat meter circulation (kWh)
$T_{fl\text{-}circ}$	Flow temperature circulation (°C)
$T_{rt\text{-}circ}$	Return temperature circulation (°C)
Q_{cons1}, …, Q_{consN}	Heat meter consumer 1 to N (kWh)
$T_{fl\text{-}cons1}$, …, $T_{fl\text{-}consN}$	Flow temperature consumer 1 to N (°C)
$T_{rt\text{-}cons1}$, …, $T_{rt\text{-}consN}$	Return temperature consumer 1 to N (°C)

4 DESCRIPTION OF THE KEY PERFORMANCE INDICATORS

4.1 PRIMARY ENERGY DEMAND SAVINGS, [2]

Definition	The primary energy demand/consumption savings of a system encompasses all the naturally available energy that is consumed in the supply chains of the used energy carriers. To enable the comparability between systems, the total primary energy demand/consumption can be related to the size of the system (e.g. conditioned area) and the considered time interval (e.g. month, year). Additionally the energy efficiency gains for the different innovations proposed in the project will be calculated based on the percentage difference of primary energy savings between the improved solutions and the baseline scenario.
Calculation	$$PE_{d,baseline} = TE_{d,baseline} \cdot PEF_T + EE_{d,baseline} \cdot PEF_E$$ $$PE_{d,improved} = TE_{d,improved} \cdot PEF_{T,improved} + EE_{d,improved} \cdot PEF_{E,improved}$$ $$PE_{savings} = PE_{d,baseline} - PE_{d,improved}$$ $PE_{savings}$ Primary energy demand savings (kWh/year) $PE_{d,baseline}$ Primary energy demand of the baseline scenario (kWh/year) $TE_{d,baseline}$ Thermal energy demand of the baseline scenario (kWh/year) $EE_{d,baseline}$ Electrical energy demand of the baseline scenario (kWh/year) $PE_{d,improved}$ Primary energy demand of the improved scenario, e.g. applying the innovations (kWh/year) $TE_{d,improved}$ Thermal energy demand of the improved scenario, e.g. applying the innovations (kWh/year) $EE_{d,improved}$ Electrical energy demand of the improved scenario, e.g. applying the innovations (kWh/year) $PEF_{T,baseline}$ Primary energy factor for thermal energy of the baseline scenario (weighted average based on source/fuel mix in production) $PEF_{T,improved}$ Primary energy factor for thermal energy of the improved scenario, e.g. applying the innovations (weighted average based on source/fuel mix in production) $PEF_{E.baseline}$ Primary energy factor for electrical energy of the baseline scenario (weighted average based on source/fuel mix in production)

	$PEF_{E.improved}$ Primary energy factor for electrical energy of the improved scenario, e.g. applying the innovations (weighted average based on source/fuel mix in production) $Eff_{gain} = \left(\frac{PE_{savings}}{PE_{d,baseline}}\right)$ x 100 Eff_{gain} Efficiency gain
Unit	$PE_{savings}$ in kWh/year Eff_{gain} in %

4.2 GREENHOUSE GAS EMISSION SAVINGS, [2]

Definition	The greenhouse gas emission savings, particulate matter, NO_x and SO_2 emissions of a system, correspond to the emissions that are caused by different areas of application. In different variants of this indicator the emissions caused by the production of the system components are included or excluded. In TEMPO the emissions for the production of the system components are excluded (no life cycle assessment). To enable the comparability between systems, the emissions can be related to the size of the system (e.g. gross floor area or net floor area, heated floor area) and the considered interval of time (e.g. month, year). The greenhouse gases are considered as unit of mass (tons, kg) of CO_2 or CO_2 equivalents.
Calculation	$$GGE_{baseline} = TE_{c,baseline} \cdot GEF_{T,baseline} + EE_{c,baseline} \cdot GEF_{E,baseline}$$ $$GGE_{improved} = TE_{c,improved} \cdot GEF_{T,improved} + EE_{c,improved} \cdot GEF_{E,improved}$$ $$GGE_{savings} = GGE_{baseline} - GGE_{improved}$$ $GGE_{savings}$ Greenhouse gas emission savings (t/a) $GGE_{baseline}$ Greenhouse gas emissions of the baseline scenario (t/a) $GGE_{improved}$ Greenhouse gas emissions of the improved scenario, e.g. applying the innovations (t/a) $TE_{c,baseline}$ Thermal energy consumption of the baseline scenario (kWh/a) $TE_{c,improved}$ Thermal energy consumption of the improved scenario, e.g. applying the innovations (kWh/a) $EE_{c,baseline}$ Electrical energy consumption of the baseline scenario (kWh/a) $EE_{c,improved}$ Electrical energy consumption of the improved scenario, e.g. applying the innovations (kWh/a) $GEF_{T,baseline}$ Greenhouse gas emission factor for thermal energy of the baseline scenario (weighted average based on thermal energy production source/fuel mix) (kg/kWh) $GEF_{T,improved}$ Greenhouse gas emission factor for thermal energy of the improved scenario, e.g. applying the innovations (weighted average based on thermal energy production source/fuel mix) (kg/kWh) $GEF_{E,baseline}$ Greenhouse gas emission factor for electrical energy of the baseline scenario (weighted average based on electricity production source/fuel mix) (kg/kWh) $GEF_{E,improved}$ Greenhouse gas emission factor for electrical energy of the improved scenario, e.g. applying the innovations (weighted average based on electricity production source/fuel mix) (kg/kWh)
Unit	t/year

4.3 REDUCED HEAT DISTRIBUTION LOSSES

Definition	The energy losses (heat, electricity) are the difference of the energy input and the energy output. The boundaries can be selected individually, e. g. around the storage tank, around one or more heat or electricity generators, around the consumers, or around the pipelines of the heating grid. For comparable figures, energy losses can be divided by the energy input. Additionally the energy efficiency gains for the different innovations proposed in the project will be calculated based on the percentage difference of heat distribution losses between the improved solutions and the baseline scenario.
Calculation	$$Q_{losses,reduction} = (Q_{in,baseline} - Q_{out,baseline}) - (Q_{in,improved} - Q_{out,improved})$$ $Q_{losses,reduction}$ Reduction of energy losses (kWh/a) $Q_{in,baseline}$ Energy (heat, electricity) into system boundaries of the baseline scenario (kWh/a) $Q_{out,baseline}$ Energy (heat, electricity) out of system boundaries of the baseline scenario (kWh/a) $Q_{in,improved}$ Energy (heat, electricity) into system boundaries of the improved scenario, e.g. applying the innovations (kWh/a) $Q_{out,improved}$ Energy (heat, electricity) out of system boundaries of the improved scenario, e.g. applying the innovations (kWh/a) $$Eff_{gain} = \left(\frac{Q_{losses,reduction}}{Q_{in,baseline} - Q_{out,baseline}}\right) \text{ x } 100$$ Eff_{gain} Efficiency gain
Unit	$Q_{losses,reduction}$ in kWh/year Eff_{gain} in %

4.4 SHARE FROM RESIDUAL OR RENEWABLE ENERGY SOURCES

Definition	The share of renewable energy sources shows, how much energy of the whole generation (e.g. over a year) is generated by the renewable sources (geothermal, biogas, see Figure 1).
Calculation	$$f_{ren} = \frac{TE_{g,ren} + EE_{g,ren}}{TE_g + EE_g} * 100$$ f_{ren} Share of renewable energy sources in overall generation (%) TE_g Overall thermal energy generation (kWh/a) $TE_{g,ren}$ Renewable thermal energy generation (kWh/a) EE_g Overall electrical energy generation (kWh/a) $EE_{g,ren}$ Renewable electrical energy generation (kWh/a) PEF_T Primary energy factor for thermal energy (weighted average based on source/fuel mix in production) PEF_E Primary energy factor for electrical energy (weighted average based on source/fuel mix in production)
Unit	%

4.5 HEATING DEGREE DAYS, [2]

<table>
<tr><td>Definition</td><td>For normalizing heating energy consumption in different climate conditions the so called "heating degree days" (HDD) are used and well established. However, their definition differs and two main algorithms are known: one implementing the building's threshold heating temperature alone, the other one implementing the targeted set temperature of the building additionally. Both methods calculate the sum of a temperature difference on all days, when the heating has to be turned on (heating day). On non-heating days the temperature difference is not included into the sum.

When looking at European countries you will find different application of the methodology and with both different threshold and different set temperatures. That hampers a unified calculation. In 1996 the European Commission asked for an assessment of climatic correction methods applied in various member states. Eurostat presented the findings to the Energy Statistics Committee and the Member States in principle approved a common method for heating-temperature correction. It employs the first described formula and defines 15°C as the heating threshold temperature and 18°C as the heating set temperature. The average daily temperature is defined as the arithmetic mean of the minimum and maximum air temperature of that specific day.</td></tr>
<tr><td>Calculation</td><td>$$HDD_{18/15} = \sum_{1}^{z}(18°C - t_a) \qquad with \quad t_a = \frac{t_{min} + t_{max}}{2}$$
$$Q_{normalised} = \left(\frac{HDD_{reference}}{HDD_{actual}}\right) \cdot Q_{actual}$$</td></tr>
<tr><td>Unit</td><td>

Name	**Symbol**	**Unit**
Number of heating days in the period	z	-
Daily average ambient air temperature	t_a	°C
Heating energy demand before correction	Q_{actual}	kWh/a
Heating energy demand after correction	$Q_{normalised}$	kWh/a
HDD for a reference climate	$HDD_{reference}$	Kd/a
HDD for the actual climate	HDD_{actual}	Kd/a

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

4.6 RETURN TEMPERATURE REDUCTION

Definition	The reduction of the heat load weighted average return temperature of the heating grid is the difference of the heat load weighted average return temperature with and without the TEMPO innovations in comparable situations or periods. For comparable figures, variables like flow temperature, transferred amount of heat, ambient temperature and global radiation should be almost identical in the two periods.
Calculation	$$\Delta T_{rt} = T_{rt,baseline} - T_{rt,improved}$$ ΔT_{rt} Reduction of the heat load weighted average return temperature due to TEMPO (K) $T_{rt,baseline}$ Heat load weighted average return temperature of the baseline scenario (°C) $T_{rt,improved}$ Heat load weighted average return temperature of the improved scenario, e.g. applying the innovations (°C)
Unit	K

5 REFERENCES

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2. Garrido-Marijuan, A., Etminan, G., Möller, S., Hristova, I.: SMART CITIES INFORMATION SYSTEM - Key Performance Indicator Guide. https://smartcities-infosystem.eu/sites/www.smartcities-infosystem.eu/files/document/scis_kpi-guide_171018.pdf (2017). Accessed 27 March 2018