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# OPTIMAL DESIGN OF FLEXIBLE HEAT NETWORKS

*A Data Management Plan created using DMPonline.be*

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**Template:** FWO DMP (Flemish Standard DMP)

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**Project abstract:**

In Belgium, heating accounts for 50 % of the final energy consumption, and heat generation is still dominated by burning fossil fuels. The heat sector will have to change significantly to make decarbonization possible. In this context, heat networks are considered one of the core technologies enabling renewable heating. In particular so-called 4th generation heat networks (4GDH) that operate at low temperatures between 50-60°C, with multiple heat sources and heat storages. These networks allow to re-utilize residual heat and include renewable-based heat sources like geothermal and solar thermal energy, or heat generated by heat pumps. However, these networks require elaborate design optimization to reach cost- and energy efficiency and to meet all technical constraints. Current research on the design optimization of 4GDH networks either lacks a sufficient level of detail in the used models, provides no scalable solution, or is based on physically inaccurate linearized assumptions. The scientific goal of this PhD project is to derive a scalable mathematical optimization framework for the optimal design of 4GDH networks, including renewable heat sources and storages while accounting for future uncertainties (robust optimization). The network physics will be represented via an accurate non-linear physics-based model.

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## FWO DMP (Flemish Standard DMP)

### 1. Research Data Summary

List and describe all datasets or research materials that you plan to generate/collect or reuse during your research project. For each dataset or data type (observational, experimental etc.), provide a short name & description (sufficient for yourself to know what data it is about), indicate whether the data are newly generated/collected or reused, digital or physical, also indicate the type of the data (the kind of content), its technical format (file extension), and an estimate of the upper limit of the volume of the data.

				Only for digital data	Only for digital data	Only for digital data	Only for physical data
Dataset Name	Description	New or reused	Digital or Physical	Digital Data Type	Digital Data format	Digital data volume (MB/GB/TB)	Physical volume
		<i>Please choose from the following options:</i> <ul style="list-style-type: none"> <li>• Generate new data</li> <li>• Reuse existing data</li> </ul>	<i>Please choose from the following options:</i> <ul style="list-style-type: none"> <li>• Digital</li> <li>• Physical</li> </ul>	<i>Please choose from the following options:</i> <ul style="list-style-type: none"> <li>• Observational</li> <li>• Experimental</li> <li>• Compiled/aggregated data</li> <li>• Simulation data</li> <li>• Software</li> <li>• Other</li> <li>• NA</li> </ul>	<i>Please choose from the following options:</i> <ul style="list-style-type: none"> <li>• .por, .xml, .tab, .csv, .pdf, .txt, .rtf, .dwg, .gml, ...</li> <li>• NA</li> </ul>	<i>Please choose from the following options:</i> <ul style="list-style-type: none"> <li>• &lt;100MB</li> <li>• &lt;1GB</li> <li>• &lt;100GB</li> <li>• &lt;1TB</li> <li>• &lt;5TB</li> <li>• &lt;10TB</li> <li>• &lt;50TB</li> <li>• &gt;50TB</li> <li>• NA</li> </ul>	
Case input data	Input data to generate a new district heating network (DHN) case. It consists of: <ul style="list-style-type: none"> <li>• GIS data on the street grid and the building demands,</li> <li>• and of measurement data on environmental conditions such as outside temperature and solar irradiance.</li> </ul>	Generate new data	Digital	<ul style="list-style-type: none"> <li>• "Other" for the environmental data. It is originally measurement data but I am not conducting the measurements myself but retrieve that data from the web.</li> <li>• "Software data" for the GIS data. It is generated via a software (QGIS) and the relevant information is then exported as files.</li> <li>• "Compiled/aggregated" for the .mat input file after the pre-processing</li> </ul>	<ul style="list-style-type: none"> <li>• .shp, .qgz, and .kml files for the GIS data</li> <li>• .csv files for the environmental data</li> <li>• .mat files once the case input data is compiled (pre-processed)</li> </ul>	<1GB	

Code	The optimization framework I am developing during my PhD is mainly written in MATLAB though some pre- and post-processing scripts are written in Python.	Generate new data & reuse existing data	Digital	Software	.m and .py code scripts	<1GB	
Result files	Files containing the results of a conducted optimization such as the network topology, the operation of the network and the physical state of the network.	Generate new data	Digital	Simulation data	.mat and .csv files	<1GB	
Complete case data	Folder containing the input and result files of the case/of that study and a copy of the code version which was used to conduct the optimization.	Generate new data & reuse existing data	Digital	Compiled/aggregated data (aggregation of all the above mentioned data)	.shp, .qgz, .kml, .csv, .mat, .m, .py, .csv	<100GB	

**If you reuse existing data, please specify the source, preferably by using a persistent identifier (e.g. DOI, Handle, URL etc.) per dataset or data type:**

- Temperature data is retrieved from the Royal Meteorological Institute of Belgium <https://opendata.meteo.be/downloadPage.php>
- Solar irradiance data is retrieved from European Commission - EU Science Hub, Sarah-2: [https://joint-research-centre.ec.europa.eu/photovoltaic-geographical-information-system-pvgis/pvgis-data-download/sarah-2-solar-radiation-data\\_en](https://joint-research-centre.ec.europa.eu/photovoltaic-geographical-information-system-pvgis/pvgis-data-download/sarah-2-solar-radiation-data_en)
- Heat demand data retrieved from the Warmtekaart vlaanderen: <https://www.vlaanderen.be/bouwen-wonen-en-energie/groene-energie/warmtekaart>
- The code which we are continuously developing is tracked in KUL's Gitlab: <https://gitlab.kuleuven.be/ideal>

**Are there any ethical issues concerning the creation and/or use of the data (e.g. experiments on humans or animals, dual use)? Describe these issues in the comment section. Please refer to specific datasets or data types when appropriate.**

- No

**Will you process personal data? If so, briefly describe the kind of personal data you will use in the comment section. Please refer to specific datasets or data types when appropriate.**

- No

**Does your work have potential for commercial valorization (e.g. tech transfer, for example spin-offs, commercial**

**exploitation, ...)? If so, please comment per dataset or data type where appropriate.**

- Yes

We are currently exploring valorization opportunities of the optimization framework we are developing for the optimal design of heating networks. The valorization potential is not so much in the data that we currently have but in the optimization as a service. The data we would then forward to e.g. planners of heating networks would be mainly the data on the network design and operation so the result data ("Result files"). However, the used input data (such as heat demands) would probably also be of interest for the companies ("Case input data").

**Do existing 3rd party agreements restrict exploitation or dissemination of the data you (re)use (e.g. Material/Data transfer agreements/ research collaboration agreements)? If so, please explain in the comment section to what data they relate and what restrictions are in place.**

- No

**Are there any other legal issues, such as intellectual property rights and ownership, to be managed related to the data you (re)use? If so, please explain in the comment section to what data they relate and which restrictions will be asserted.**

- No

## **2. Documentation and Metadata**

**Clearly describe what approach will be followed to capture the accompanying information necessary to keep data understandable and usable, for yourself and others, now and in the future (e.g., in terms of documentation levels and types required, procedures used, Electronic Lab Notebooks, README.txt files, Codebook.tsv etc. where this information is recorded).**

- The code that we are developing is well documented as it is tracked in GitLab and we are developing based on "best practices" for Git meaning to have small and frequent commits with clear commit messages. We also comment the code properly.
- We provide readme's and manual's in Git next to the code to explain new users clearly and step by step how the code can be used and where required input data is stored.
- For data related to publications we upload the required data to reproduce the results on RDR which is KU Leuven's institutional research data repository for the publication of research data that allows to upload, describe, and share research data based on the FAIR principle.

**Will a metadata standard be used to make it easier to find and reuse the data? If so, please specify (where appropriate per dataset or data type) which metadata standard will be used. If not, please specify (where appropriate per dataset or data type) which metadata will be created to make the data easier to find and reuse.**

- Yes

We will use the RDR of KU Leuven to store the data and we will follow the metadata standards recommended by "Research data management" of KU Leuven.

## **3. Data storage & back-up during the research project**

#### **Where will the data be stored?**

- During the research, the data is stored within the OneDrive environment of KU Leuven.
- The software (code) development is done using GitLab (on KU Leuven's servers).
- After the research, all data needed to reproduce the published research results will be securely kept in the Research Data Repository (RDR) of KU Leuven.

#### **How will the data be backed up?**

Automatically by the ICTS of KU Leuven for the mentioned storage locations.

**Is there currently sufficient storage & backup capacity during the project? If yes, specify concisely.  
If no or insufficient storage or backup capacities are available, then explain how this will be taken care of.**

- Yes

All the mentioned storage solutions are cloud storages and KU Leuven guarantees sufficient storage space for its researchers. The funding for our storage needs is also ensured by our department and our research group. Solely for the research on heating networks we have currently 1 TB of storage space available which we can further increase if needed.

#### **How will you ensure that the data are securely stored and not accessed or modified by unauthorized persons?**

For all the mentioned storage locations we work with strict access rights/roles. Only the head of the research group (prof. Maarten Blommaert) and I have owner and maintainer rights, respectively, while other collaborators, such as master thesis students, create their own forks of our code base and do not get rights to make any changes in the main code/data base.

#### **What are the expected costs for data storage and backup during the research project? How will these costs be covered?**

The costs for data storage are internally accounted for at departmental level. Our research group carries a proportional part of the departmental IT costs.

#### **4. Data preservation after the end of the research project**

**Which data will be retained for at least five years (or longer, in agreement with other retention policies that are applicable) after the end of the project? In case some data cannot be preserved, clearly state the reasons for this (e.g. legal or contractual restrictions, storage/budget issues, institutional policies...).**

- Fully developed versions/features of the optimization framework/code with exemplary input and output data sets.
- For each publication, all the data required for the reproduction of the results (input data, copy of the used code version, and result data).

#### **Where will these data be archived (stored and curated for the long-term)?**

RDR KU Leuven

**What are the expected costs for data preservation during the expected retention period? How will these costs be covered?**

The costs for data storage are internally accounted for at departmental level. Our research group carries a proportional part of the departmental IT costs.

## **5. Data sharing and reuse**

**Will the data (or part of the data) be made available for reuse after/during the project? In the comment section please explain per dataset or data type which data will be made available.**

- Yes, in a restricted access repository (after approval, institutional access only, ...)

We will publish our research in international journals, after careful consideration of valorization and patentability potential, during and/or after the project. In those cases where we have to publish in journals that are behind a paywall (e.g., Applied Energy which has a very high journal index), we will always make a digital copy of the accepted paper available through an online repository, such as Lirias, and we will make pre-prints available on arXiv. We will ensure that every publication gets a Digital Object Identifier (DOI) and that we use our ORCID on every publication, so that the identification of the authors is unambiguous.

Data related to published results will be made available through RDR KU Leuven and zenodo.org.

The complete code base will not be made openly accessible (access only after approval).

**If access is restricted, please specify who will be able to access the data and under what conditions.**

The head of the research group, prof. Maarten Blommaert, will always have full access to all the data. Other members of the research group can access the data as well if they need it for their research.

**Are there any factors that restrict or prevent the sharing of (some of) the data (e.g. as defined in an agreement with a 3rd party, legal restrictions)? Please explain in the comment section per dataset or data type where appropriate.**

- No

**Where will the data be made available? If already known, please provide a repository per dataset or data type.**

Data related to published results will be made available through RDR KU Leuven and zenodo.org.

**When will the data be made available?**

Upon publication of research results.

**Which data usage licenses are you going to provide? If none, please explain why.**

To be determined later as we are currently assessing different valorization possibilities of research.

**Do you intend to add a PID/DOI/accession number to your dataset(s)? If already available, you have the option to provide it in the comment section.**

- Yes

**What are the expected costs for data sharing? How will these costs be covered?**

The costs for data storage are internally accounted for at departmental level. Our research group carries a proportional part of the departmental IT costs.

**6. Responsibilities**

**Who will manage data documentation and metadata during the research project?**

Martin Sollich (researcher) + Maarten Blommaert (supervisor and head of research group)

**Who will manage data storage and backup during the research project?**

Martin Sollich (researcher) + Maarten Blommaert (supervisor and head of research group) + ICTS of KU Leuven

**Who will manage data preservation and sharing?**

Martin Sollich (researcher) + Maarten Blommaert (supervisor and head of research group) + ICTS of KU Leuven

**Who will update and implement this DMP?**

Martin Sollich (researcher) + Maarten Blommaert (supervisor and head of research group)