

THERMOS



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THERMOS



creara
ENERGY EXPERTS

Introducing THERMOS

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IDEA 2019, Pittsburgh - 24 June 2019



Problem

Pre-feasibility DHC studies are expensive, take time, and rely on uneven approaches, leading public authorities to face growing challenges to effectively manage their energy planning tasks.

The needs of local authorities



- Consistency in approaches
- Comparability of results
- Information about methodologies used
- Time and cost efficiencies

- **Robust methodologies and tools to rapidly identify, analyse and compare specific thermal energy system option**

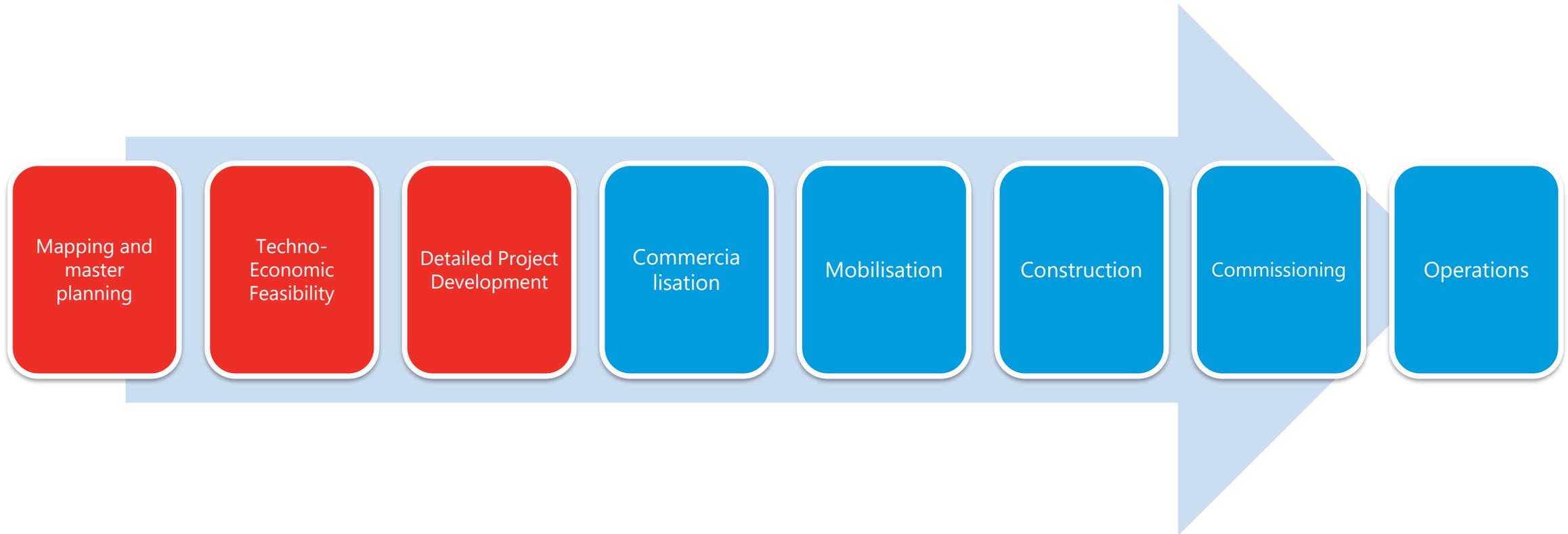
- **Building capacity in public authorities responsible for energy planning is essential to develop strategic local sustainable energy solutions.**

The THERMOS solution



- An open-source web-based software application
- A standardised approach for
 - methods
 - data
 - tools
- Developed in collaboration with the final users
- Allowing sophisticated thermal energy system planning far more **rapidly** and **cheaply** than they can today

THERMOS addresses early stages of DHC

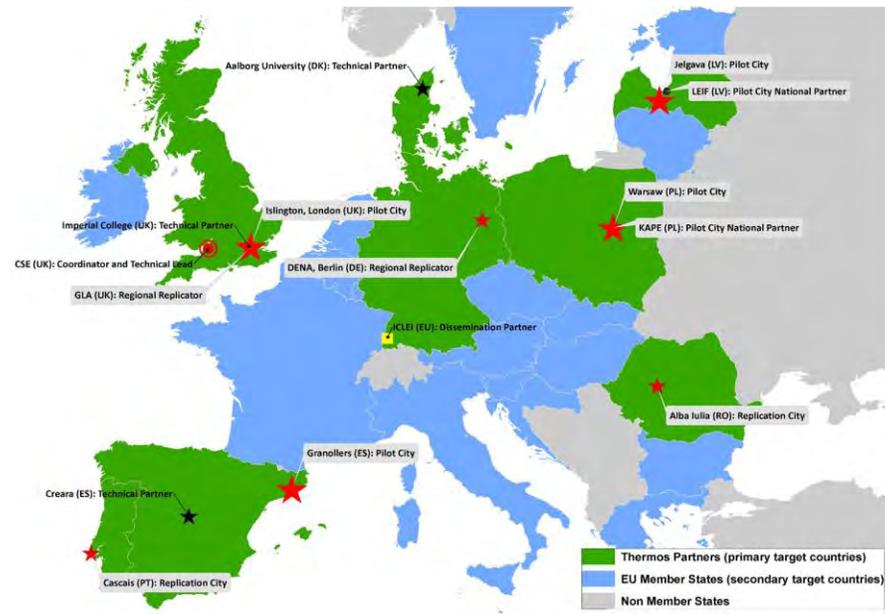


The Horizon 2020 Programme



- 80 billion Euros for Research and Innovation in Europe over 2014-2020
 - 6 billions for (non-nuclear) energy
- Collaborative – no profit projects bringing together organisations from at least 3 European countries
- Open to international partners as well

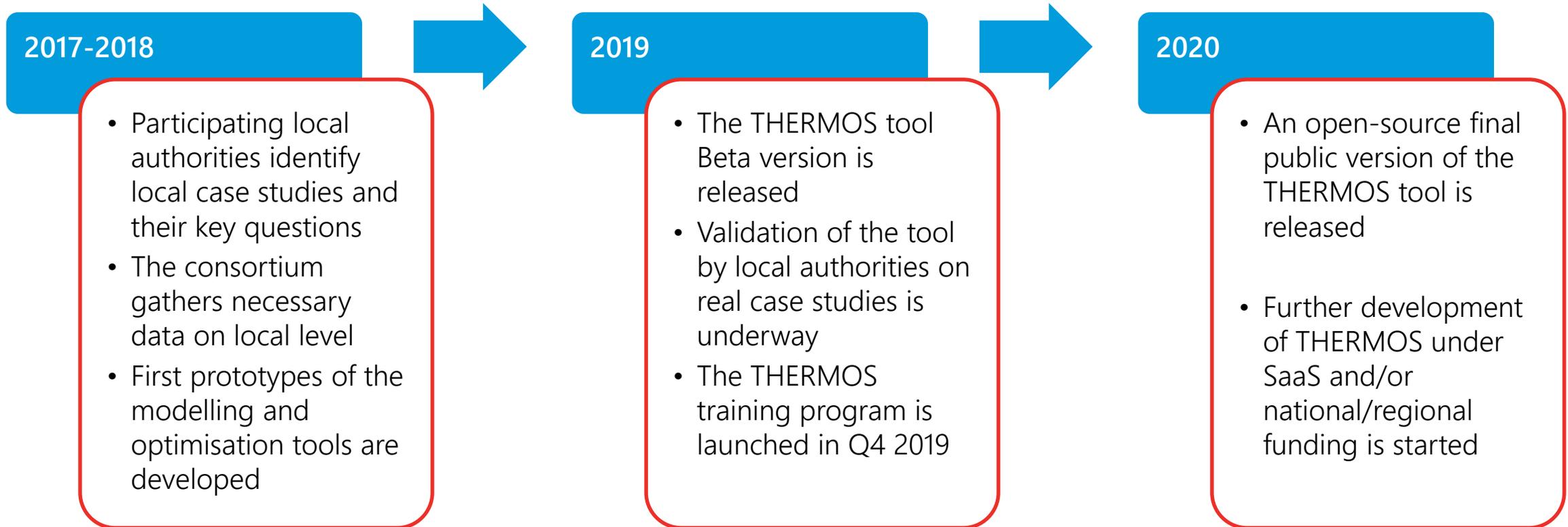
THERMOS consortium



- Brings together research, consulting and multiplier organisations with local, regional and national authorities - the final users
- Provides for development, validation and exploitation



THERMOS timeline and milestones



Thank you!

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THERMOS



The THERMOS application

Joshua Thumim, Centre for Sustainable Energy, Bristol, UK

IDEA 2019, Pittsburgh, 24 June 2019



Aims of this presentation

- Share our excitement about THERMOS!
- Offer you an insight into the problems we have solved, and how the solutions may be valuable to you in your work
- Hopefully build on this to develop connections with potential users

Structure

- 1. What is THERMOS?**
 - A THERMOS solution
 - A THERMOS problem
 - Making maps
- 2. Technical details**
 - What is being optimised?
 - What is represented in the model?
 - How do we estimate building demands?
- 3. Features in the pipeline**
- 4. How can THERMOS add value?**

What is THERMOS?

- “Thermal Energy Resource Modelling and Optimisation System”
- Web-based software for detailed pre-feasibility analysis of heating and cooling network options
- Designed to support project development from area-wide mapping and masterplanning, through to detailed consideration of optimal network layouts

How does it work?

- I'll show you this backwards:
 1. What does a solution look like?
 2. How do we frame a problem?
 3. How can we use THERMOS to create a new building demand and network routing map (required for the previous steps)?

A THERMOS solution

- Is a geographic and topological description of a heat distribution network (cooling is coming later this year):
 - Supply sites and sizes
 - Pipe sizes, routes and connectivity
 - Connected demands, sizes and peaks
 - Revenues, Costs -> NPV
- The solution maximises NPV given the inputs
- Other objectives and constraints are in the pipeline



252 candidates selected

- 18 Wharton Street x
- 8 Merriman Way x
- 2 Franklin Court x
- 2 South 16th Street x

Length	2.157 km
Base cost	873.678 k€
Demand	3.094 GWh/yr
Peak	3.305 MWp
In solution	252 yes x
Coincidence	85.192 %
Capacity	2.049 MW
Diameter	113.317 mm
Principal	2.149 M€
Revenue	278.476 k€/yr
Losses	381.576 MWh/yr, NaNW/m

Name	Wh/yr	Wp	Type	Class	In?
			path	Connector	✓
	46.282 M	44.81 k	building	Commercial	✓

- None
- Maps
- Satellite
- Candidates
- Heatmap
- Labels

Allowed, but not in solution

Required, and in solution

Allowed, and in solution

Not allowed

Not reachable



Framing a THERMOS problem

- Given a map of:
 - Buildings and their demands
 - Potential supply sites
 - Potential network routes
- A problem is a user-defined subset of the above, whose members either *can* or *must* be in the solution
- THERMOS finds the solution with the highest NPV given these inputs
- This cannot be done by hand or eye, because of the number of possible networks -> $(2^n - 1)$ ignoring routing permutations, where n is the number of connection candidates
- 2 -> 3, 10 -> 1023, 100 ~> 10^{30} , 500 ~> 10^{150}

Framing a THERMOS problem

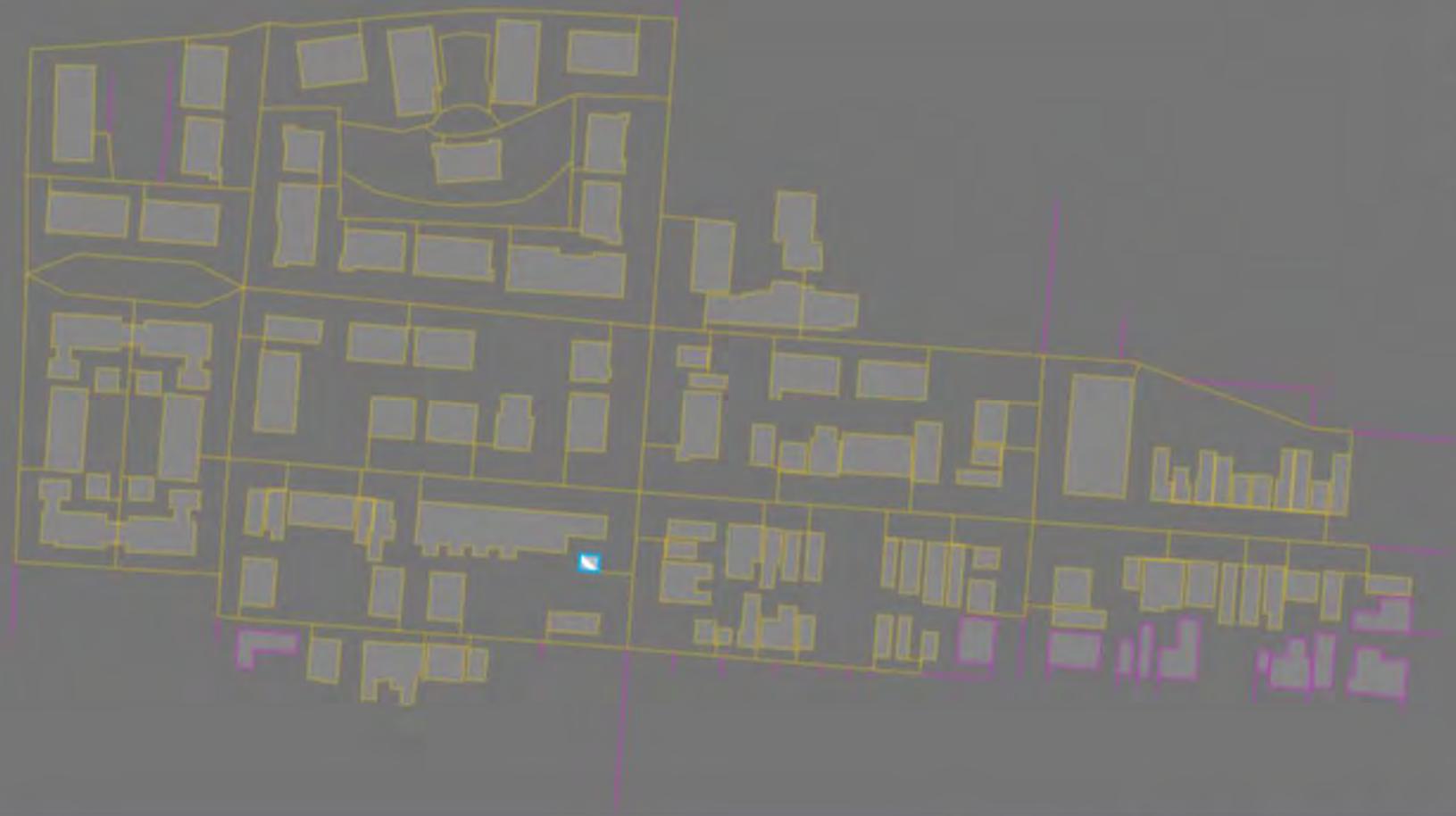
- The user-interface provides the tools required to define a problem



Search...

0 candidates selected

- None
- Maps
- Satellite
- Candidates
- Heatmap
- Labels



Leaflet

<input type="checkbox"/>	Name	Wh/yr	Wp	<input type="checkbox"/>	Type	Class	In?
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<input type="checkbox"/>		7.901 M	25.761 k	0	building		
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Filter:

- No
- Yes

1 filter applied, showing 1 of 390 candidates.

Effect of varying the sale price of heat



Search...

0 candidates selected

- None
- Maps
- Satellite
- Candidates
- Heatmap
- Labels

Price (c/kWh) 9.0
 Connections 68
 NPV (\$) 2,009,000
 Runtime (s) 68



Leaflet

<input type="checkbox"/>	Name	Wh/yr	Wp	<input type="checkbox"/>	Type	Class	In?
<input type="checkbox"/>				1.293 k	path	Connector	✓
<input type="checkbox"/>		46.282 M	44.81 k	0	building	Commercial	✓

1 filter applied, showing 223 of 390 candidates.

CLEAR FILTERS

Forcing a connection



Search...

0 candidates selected

- None
- Maps
- Satellite
- Candidates
- Heatmap
- Labels



Leaflet

<input type="checkbox"/>	Name	Wh/yr	Wp	<input type="checkbox"/>	Type	Class	In?
<input type="checkbox"/>				1.293 k	path	Connector	✓
<input type="checkbox"/>		46.282 M	44.81 k	0	building	Commercial	✓

1 filter applied, showing 230 of 396 candidates.

CLEAR FILTERS

Adding a new route segment



Search...

0 candidates selected

- None
- Maps
- Satellite
- Candidates
- Heatmap
- Labels



Leaflet

<input type="checkbox"/>	Name	Wh/yr	Wp	<input type="checkbox"/>	Type	Class	In?
<input type="checkbox"/>				1.293 k	path	Connector	✓
<input type="checkbox"/>		46.282 M	44.81 k	0	building	Commercial	✓

1 filter applied, showing 226 of 398 candidates.

CLEAR FILTERS

Forcing another connection



1 candidate selected

Type

Classification

Constraint

Name

Base cost 1.241 k[€]

Demand 6.025 MWh/yr

Peak 24.83 kWp

In solution

Principal 1.241 k[€]

Revenue 542.212 [€]/yr

<input type="checkbox"/>	Name	Wh/yr	Wp	€	Type	Class	In?
<input type="checkbox"/>				1.293 k	path	Connector	✓
<input type="checkbox"/>		46.282 M	44.81 k	0	building	Commercial	✓

Export solution to GIS / CAD etc.



Enter postc...

Browser

- ★ Favorites
- ▶ Project Home
- ▶ Home
- ▶ /
- ▶ GeoPackage
- ▶ SpatiaLite
 - ▶ aalborg.sqlite
 - ▶ PostGIS
 - ▶ MSSQL
 - ▶ DB2
- ▶ WMS/WMTS
- ▶ XYZ Tiles
- ▶ WCS
- ▶ WFS
- ▶ OWS
- ▶ ArcCisMapServer

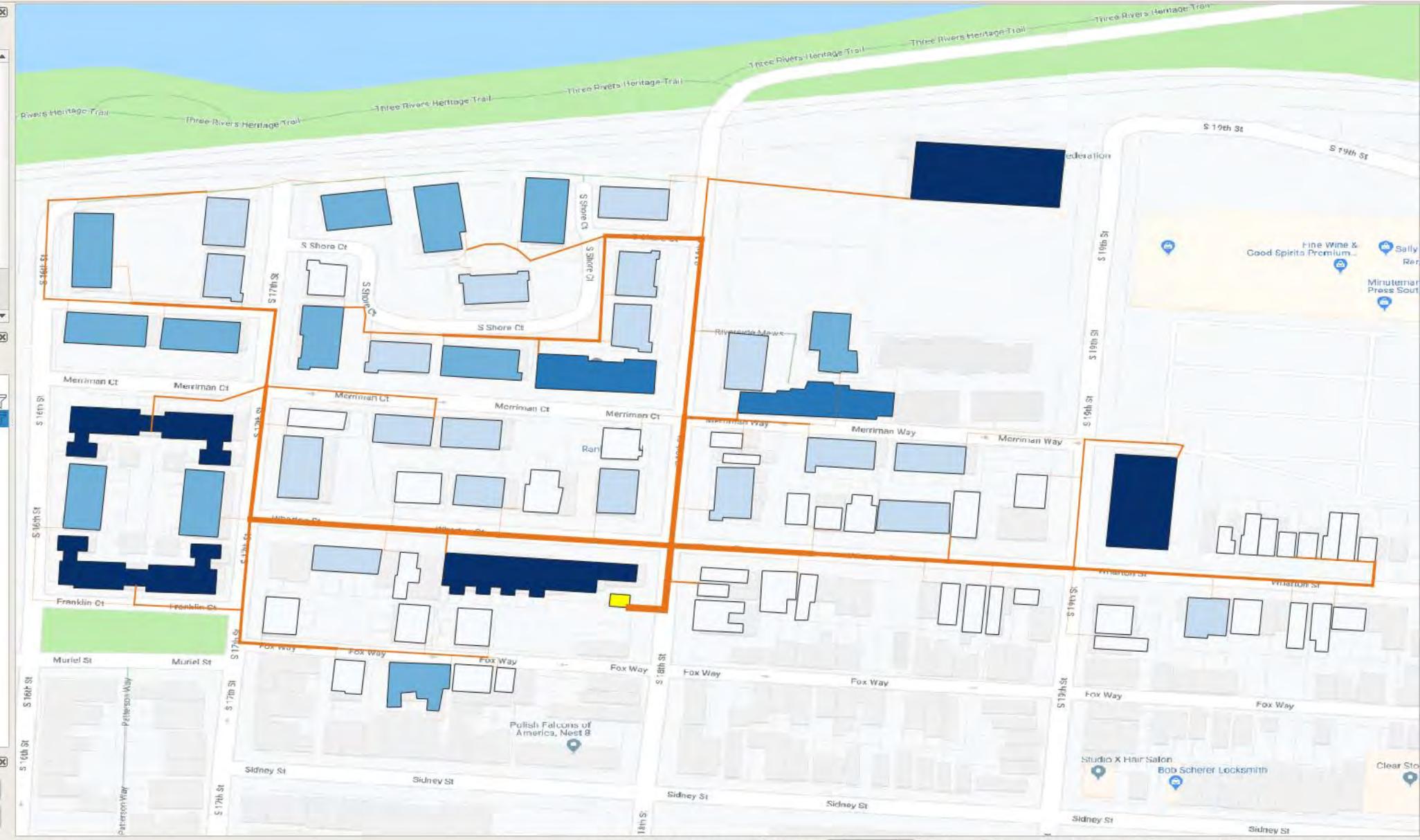
Layers

- ▶ Downtown Network Problem
- ▶ ways
- ▶ sites
- ▶ Google Maps

Zoom to Lat Lon

Enter 'Latitude, Longitude'

Type to locate (Ctrl+K)

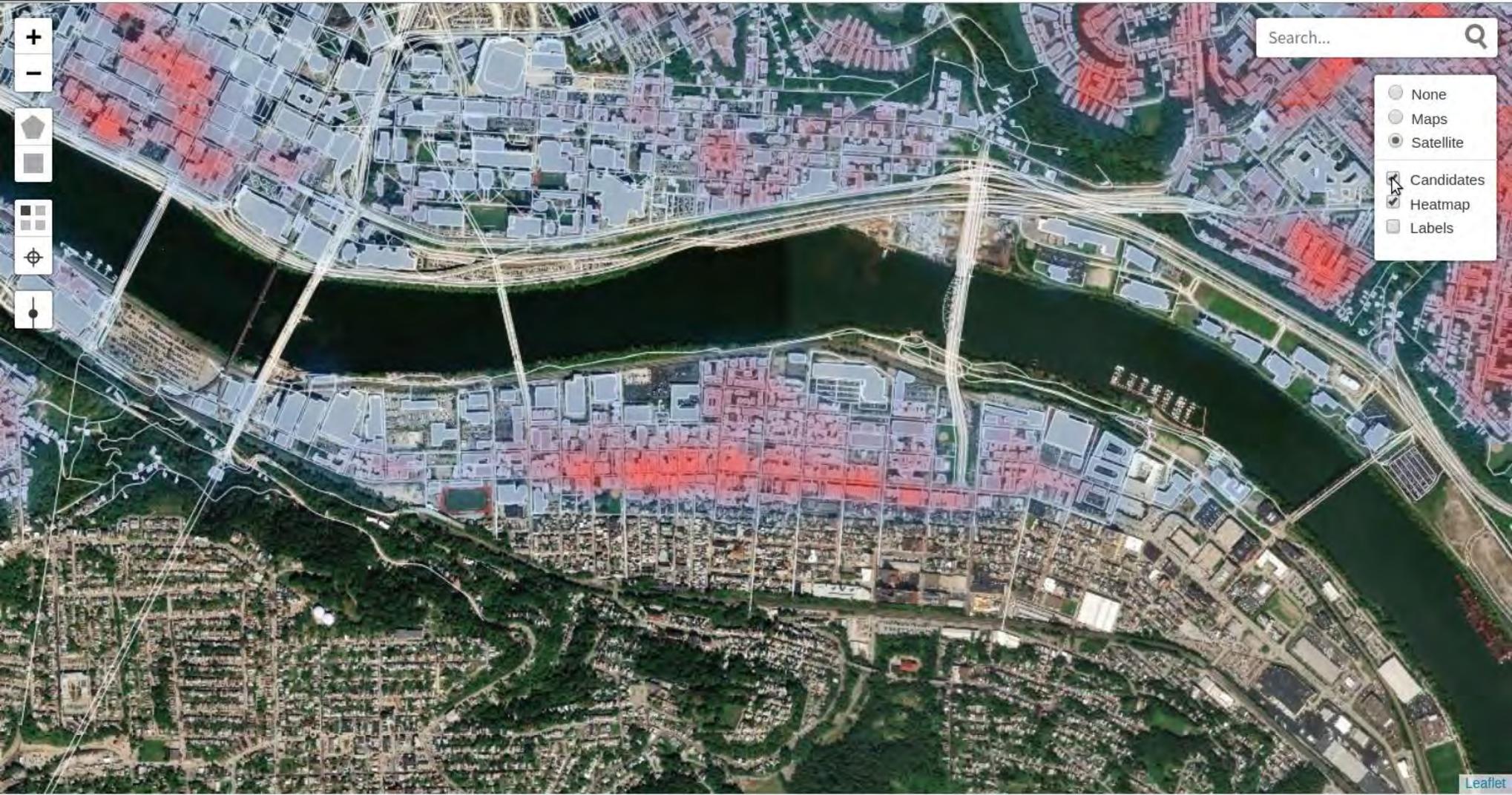


1 feature(s) selected on layer sites.

Making the maps

- THERMOS includes features to enable you to create a map for the area you are interested in
- You need to do this before you can define and solve problems
- Maps can be created either automatically from OpenStreetMap, or from your own shapefiles
- Demand estimates can be calculated automatically based on 3D building geometries (assuming LIDAR is available), or you can provide your own values in the shapefiles

Using OpenStreetMap



Search... 🔍

- None
- Maps
- Satellite
- Candidates
- Heatmap
- Labels

0 candidates selected

▼ Name	▼ Wh/yr	▼ Wp	▼ □	▼ Type	▼ Class
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Leaflet

Using your own data

- Many options; you can:
 - Upload the buildings geometry and/or the ways geometry
 - Use OSM for one, and your own data for the other
 - Upload additional tables containing attributes for joining to geometries

Using your own data

- For buildings, THERMOS will:
 1. Use your demand values, if you provided them; or
 2. Use your benchmarks, if you provided them; or
 3. Estimate building heights from LIDAR, if it is available; and
 4. Estimate the demands from 3D building attributes, if height is available; or
 5. Estimate the demands from 2D building attributes, if height is not available.
- For ways, you can supply the constant terms for the pipe civil cost model so they vary e.g. per road category etc.
- All these attributes can be edited in the UI for individual elements, or groups of elements, or categories of element

Recap

- THERMOS computes optimal layouts for heat networks
- You specify which buildings and routes are either *allowed* or *required* to be in the solution, and the location(s) at which heat supply can be provided
- Solution times vary with complexity, but problems comprising hundreds of buildings can be solved in seconds or minutes (remember that for 100 buildings there are approximately 10^{30} distinct sets, so this cannot be done by hand)
- THERMOS can be applied anywhere there is appropriate mapping data available – either provided by the user, or imported directly from OSM
- The system incorporates a demand-estimation method based on building geometries. This requires LIDAR coverage for 3D features.

Detail: what is being optimised?

- THERMOS optimises a model of a heat network, maximising NPV by deciding:
 - For each place where a pipe could go, whether a pipe should be there
 - For each place with demand, whether to meet the demand
 - For each place where a supply could go, whether to put a supply there
- Given these choices, it then decides:
 - For each pipe, how large the pipe has to be
 - For each supply, what the supply capacity has to be
- From this the costs and revenues are calculated

Detail: what is being modelled?

- The network model accounts for:
 - Annual and peak demands on buildings
 - Pipe capacity @ $\Delta T \Rightarrow$ Pipe diameter \Rightarrow Installed pipe cost
 - Heat losses from the network
 - Pumping costs in the network
 - Load diversity in the network
 - Heat supply cost
 - Heat sale price
 - Amount and value of emissions associated with supply
 - Amount and value of counterfactual emissions

Detail: where are the demand values from?

- Users can upload their own buildings with annual and peak demand values
- Alternatively THERMOS can estimate these using models developed in the project
 - Annual demand is estimated using predictive models trained on building geometry, using known values from Copenhagen
 - Climate differences are accounted for using Heating-Degree-Days
 - Peak demand is derived from annual demand using a model trained on a large UK halfhourly gas demand dataset

Features in the pipeline

- Supply optimiser
- Cooling network model
- More objectives and constraints
- UI enhancements
- Counterfactual comparisons

Where does THERMOS create value?

1. Better network design at the prefeasibility stage – current practice does not identify optimal solutions
2. Significantly faster assessment of options, so many more options are considered, at greatly reduced cost
3. Enables analysis of the sensitivity of the optimal network design to a range of assumptions (supply cost, heat sale price, cost of finance, etc.)
4. All of this means reduced risk of wasted time at detailed design stages
5. Automation of mapping processes eliminates time and cost to get started – anywhere in the world
6. Browser based application – no local deployment, easy
7. Our goal: accelerated rollout of the right thermal networks in the right places, leading to carbon emissions reductions.

Where does THERMOS create value?

- Quantitatively:
 - Building a citywide building-level heatmap is approximately 6-12 person-months work
 - A relatively simple network study, with three detailed options, is 12-18 person-months work
 - We believe that using THERMOS, the person-effort associated with these tasks can be cut *drastically*, while improving the quality of the results.
 - We are currently doing some work to estimate the financial value of these savings in more detail

Try THERMOS for yourself...

- Read more about the project at www.thermos-project.eu
- Read the user manual (not yet complete) at <https://v5.thermos-project.eu/help/index.html>
- in particular look at the quick start guide at <https://v5.thermos-project.eu/help/quick-start.html>
- And finally, test the application for free by visiting <https://v5.thermos-project.eu> and creating an account

Thanks for listening!

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