

# Heat Roadmap Europe

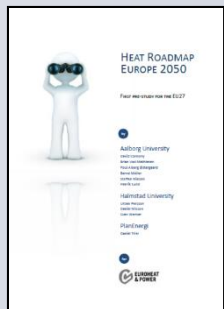
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[www.heatroadmap.eu](http://www.heatroadmap.eu)

[www.dconnolly.net](http://www.dconnolly.net)

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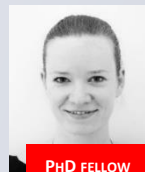
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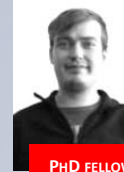
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# What do we do...?

**Energy Planning** (Theories, Methodologies, Tools, Analyses, Case studies and Proposals)

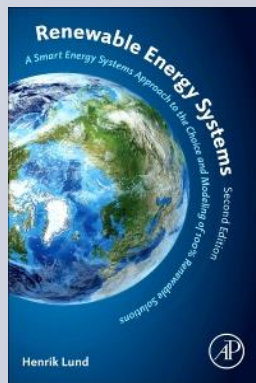
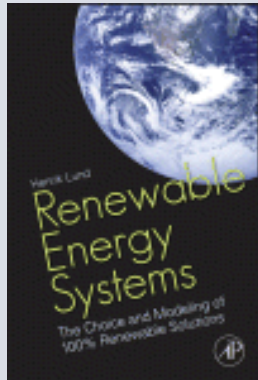
- Energy System Analysis (incl. GIS)
- Feasibility Studies
- Public Regulation



# Smart Energy System

➔ [www.SmartEnergySystem.eu](http://www.SmartEnergySystem.eu)

➔ [www.EnergyPLAN.eu](http://www.EnergyPLAN.eu)



Energy 42 (2012) 96–102

Contents lists available at SciVerse ScienceDirect

**Energy**

journal homepage: [www.elsevier.com/locate/energy](http://www.elsevier.com/locate/energy)

Review

From electricity smart grids to smart energy systems – A market operation based approach and understanding

Henrik Lund <sup>a,\*</sup>, Anders N. Andersen <sup>b</sup>, Poul Alberg Østergaard <sup>a</sup>, Brian Vad Mathiesen <sup>c</sup>, David Connolly <sup>c</sup>

<sup>a</sup> Department of Development and Planning, Aalborg University, Vestre Havnemønstre 9, DK-9000 Aalborg, Denmark  
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**EnergyPLAN** Advanced energy system analysis computer model

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Get Started Training Forum Models Smart Energy Systems Other Tools

### Smart Energy Systems

One of the key objectives with the EnergyPLAN tool is to aid in the design of 100% renewable energy systems. Since the development of EnergyPLAN began back in the year 2000, the concept of a 100% renewable energy system has evolved significantly. We ...

### Benefits

- Access to a network of global users
- User-friendly and very fast for a normal PC (seconds)
- Detailed hourly analyses of a complete energy system
- Access to library of hourly data
- Long list of case studies from various countries
- Free of charge
- Free online training, guides, workshops, and documentation
- Facilitates third-party developments by allowing add-on help tools

[Download Model](#)

Download the latest version now and get started right away

### Book

**Renewable Energy Systems**  
Professor Henrik Lund  
2nd Edition Out Now

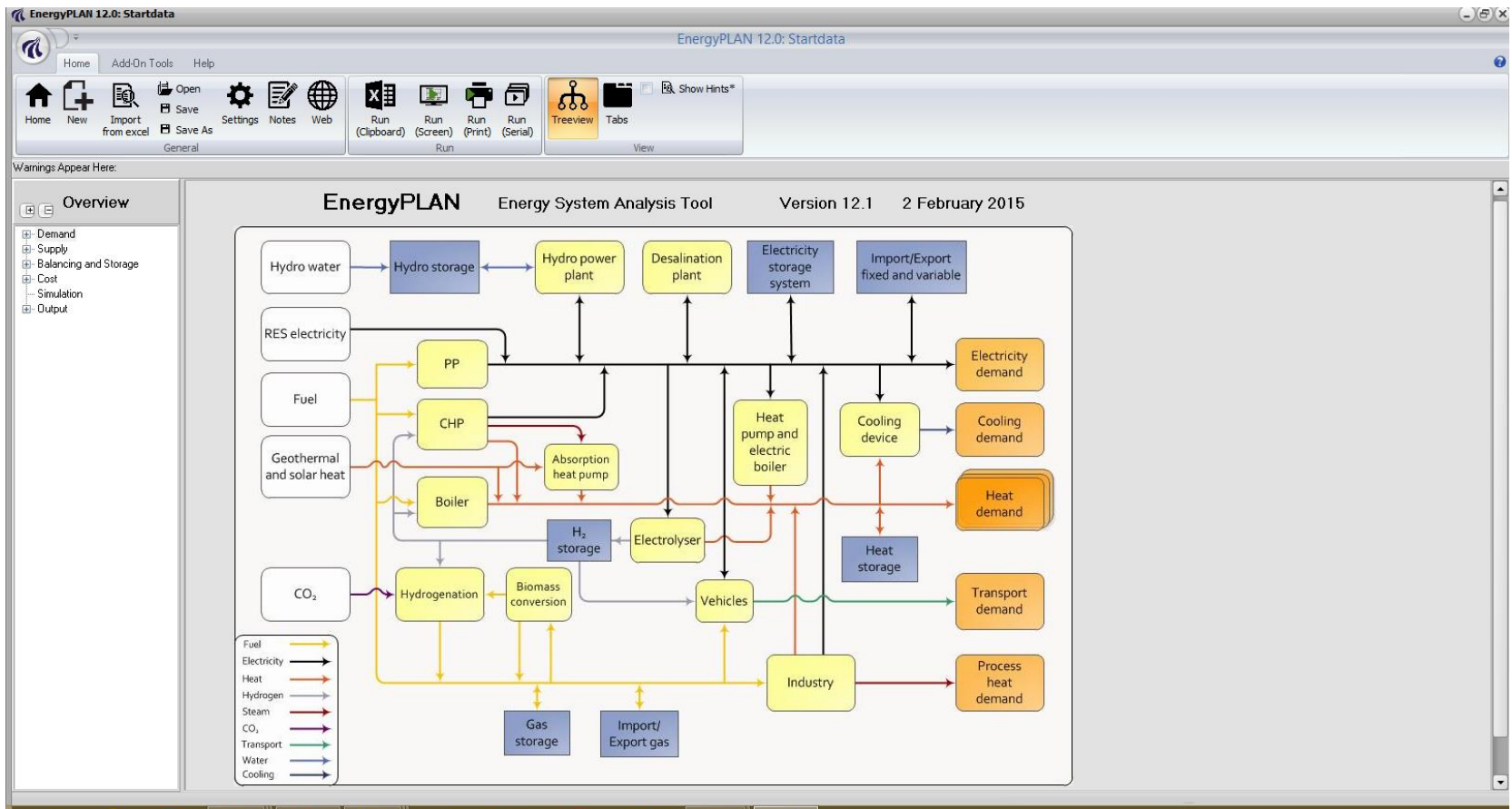
### Latest News

- Nov 2014: Sign up for the **Online Workshop**
- Aug 2014: Free **Reference Models** Now Available
- June 2014: New **Book** launched
- May 2014: New Description of **Smart Energy Systems**
- May 2014: EnergyPLAN Version 11.4 available for **Download**



# EnergyPLAN: Version 12 ([www.EnergyPLAN.eu](http://www.EnergyPLAN.eu))

*Hourly Modelling of Electricity, Heating, Cooling, Industry, and Transport*





# 600 Registered Users since 1<sup>st</sup> Feb!

[www.EnergyPLAN.eu](http://www.EnergyPLAN.eu): 2000 visitors/month

## Members Map

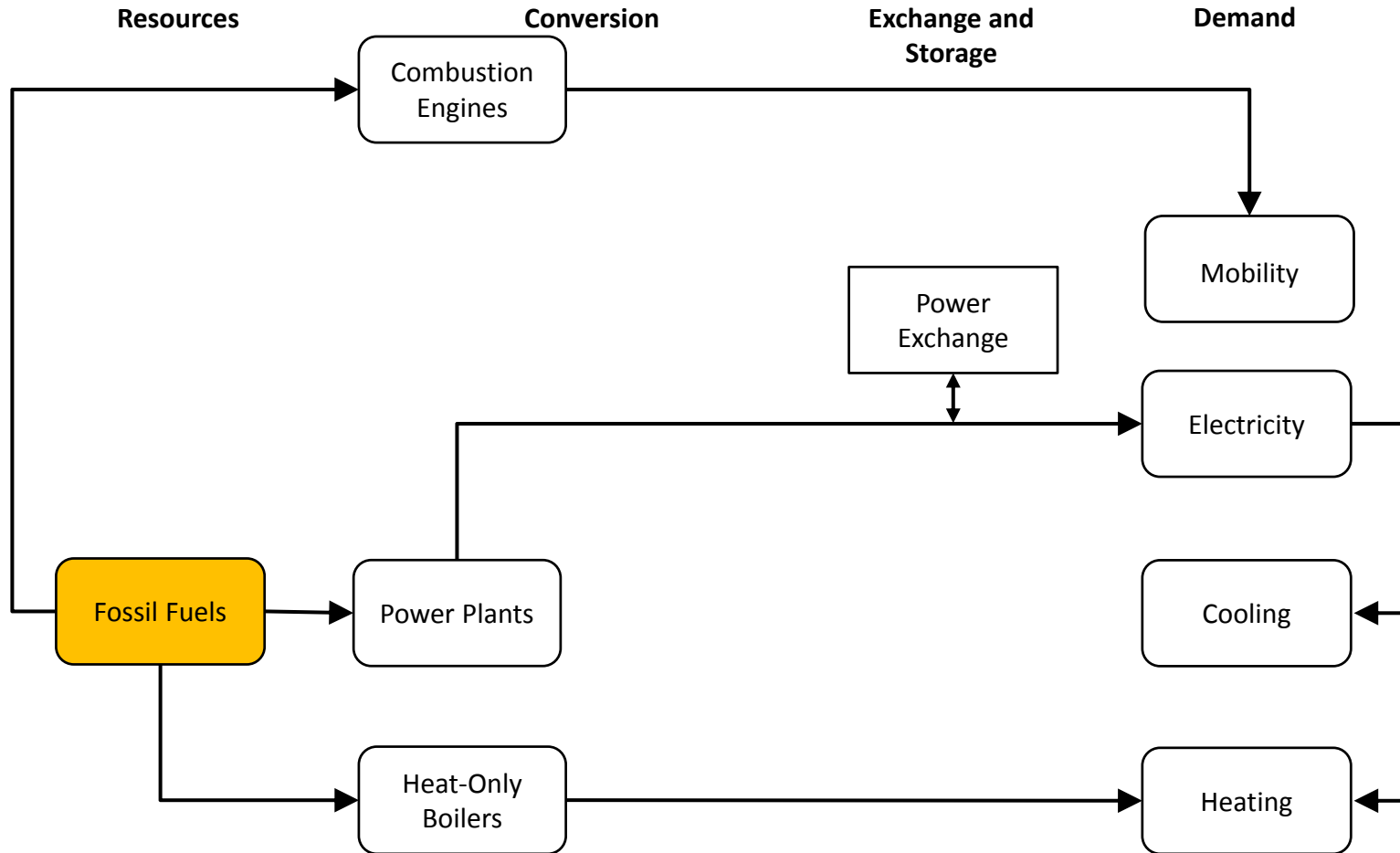


## Switzerland

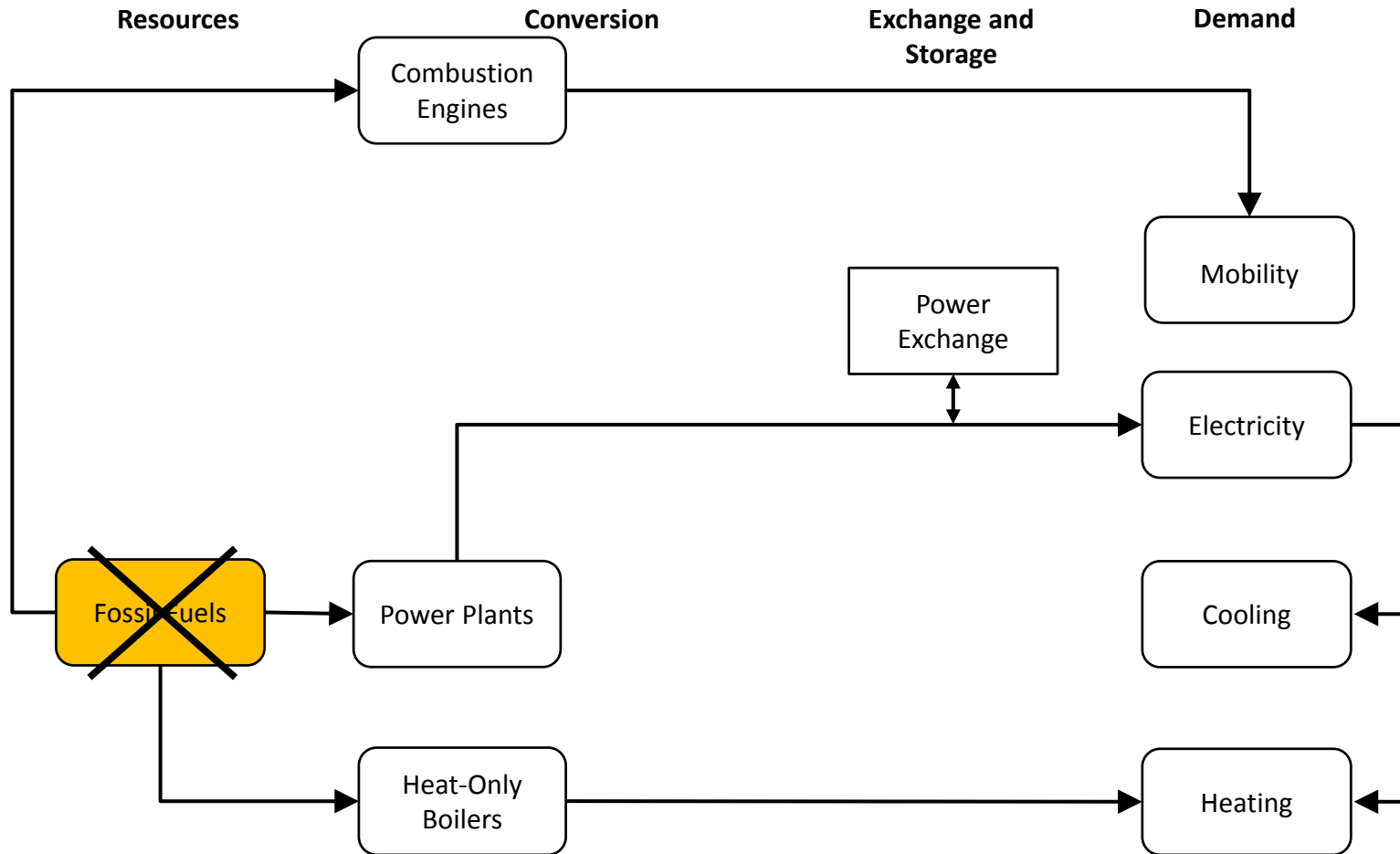
### Members List

- Jimeno Fonseca
- Jerome Faessler
- Fanny Bondaz
- Loic Quiquerez

# What are we missing in the future?



# Not Only Fuel, but also Energy Storage!





# Scale of Energy Storage in Denmark

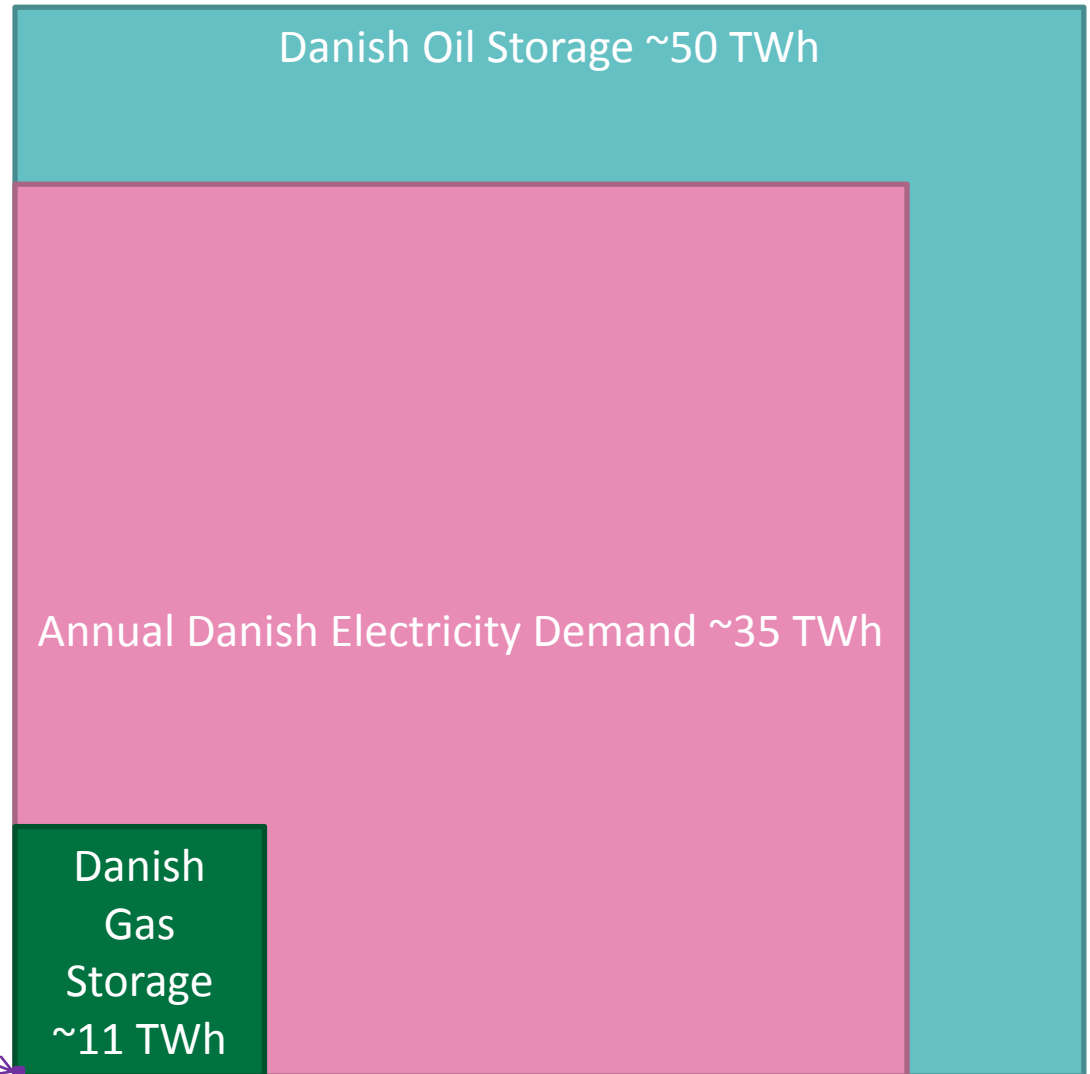
Electricity = €170/kWh

Thermal = €0.5-3/kWh

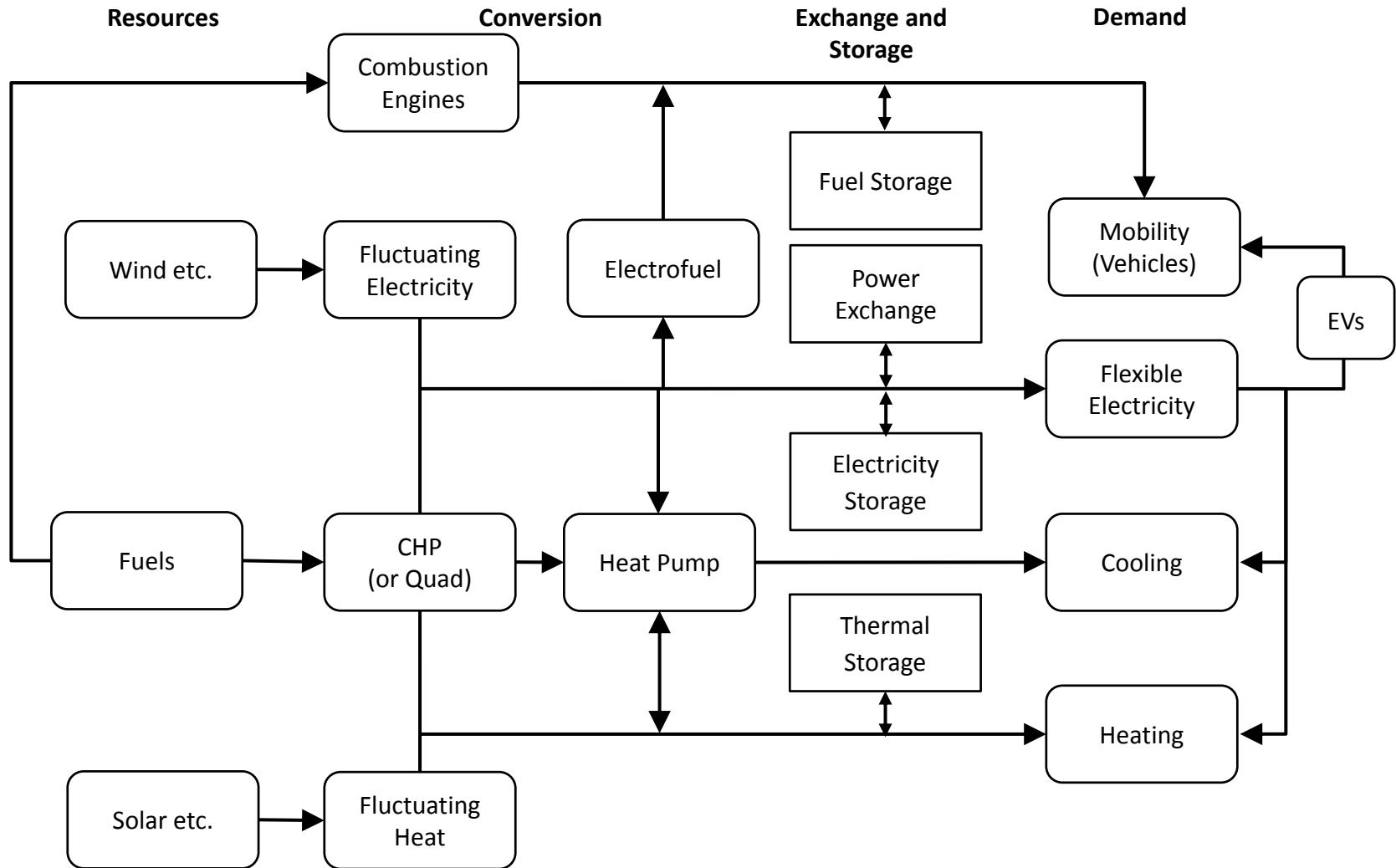
Gas = €0.05/kWh

Oil = €0.02/kWh

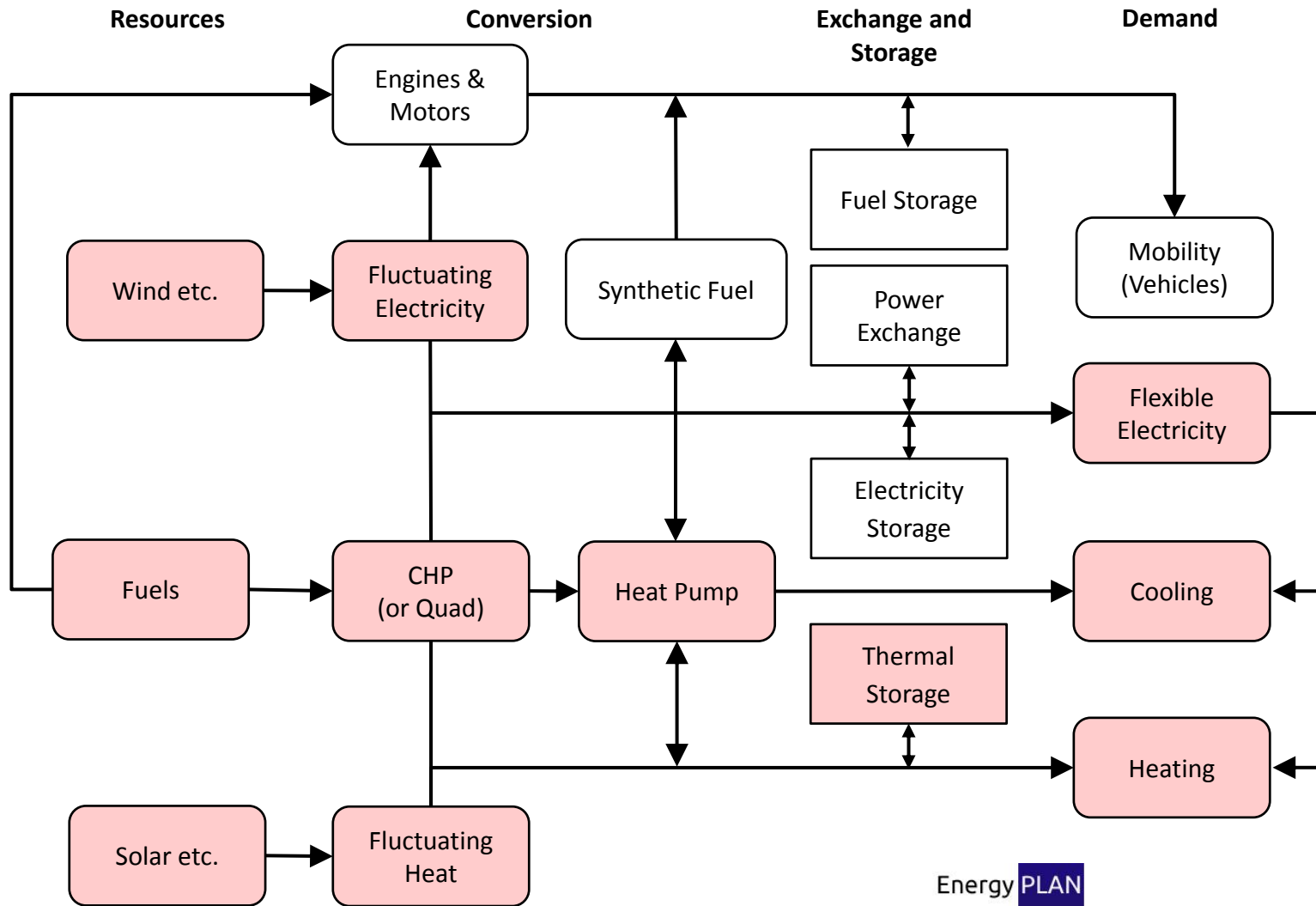
Thermal Storage  
~65 GWh?



# Smart Energy System (80% Wind/Solar)



# The New Heat Sector





# Heat Roadmap Europe 2050

STUDY FOR THE EU27

by

## Aalborg University

David Connolly  
Brian Vad Mathiesen  
Poul Alberg Østergaard  
Bernd Möller  
Steffen Nielsen  
Henrik Lund

## Halmstad University

Urban Persson  
Daniel Nilsson  
Sven Werner



**ECOFYS**

## Ecofys Germany GmbH

Jan Grözinger  
Thosmas Boersmans  
Michelle Bosquet

## PlanEnergi

Daniel Trier

**PlanEnergi**

for



# Heat Roadmap Europe

## → Two Reports & One Ongoing:

- Study 1 (2012): is DHC beneficial in a business-as-usual scenario
- Study 2 (2013): is DHC beneficial in a low-heat demand scenario (a complete heat strategy)
- Study 3 (2014, IEE/13/650/SI2.675851): heating and cooling strategies for 5 member states





# 3 Options for the Heat Sector



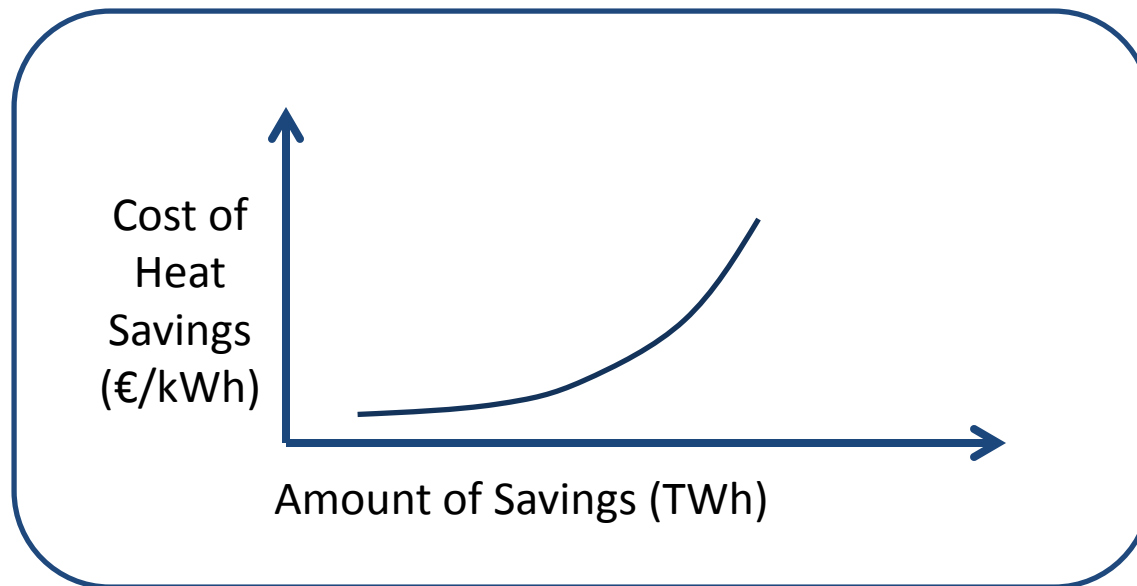
# 3 Options for the Heat Sector

## 1. Savings (Everywhere)

- Reduce our demand for heat:
  - Space heating
  - Hot water

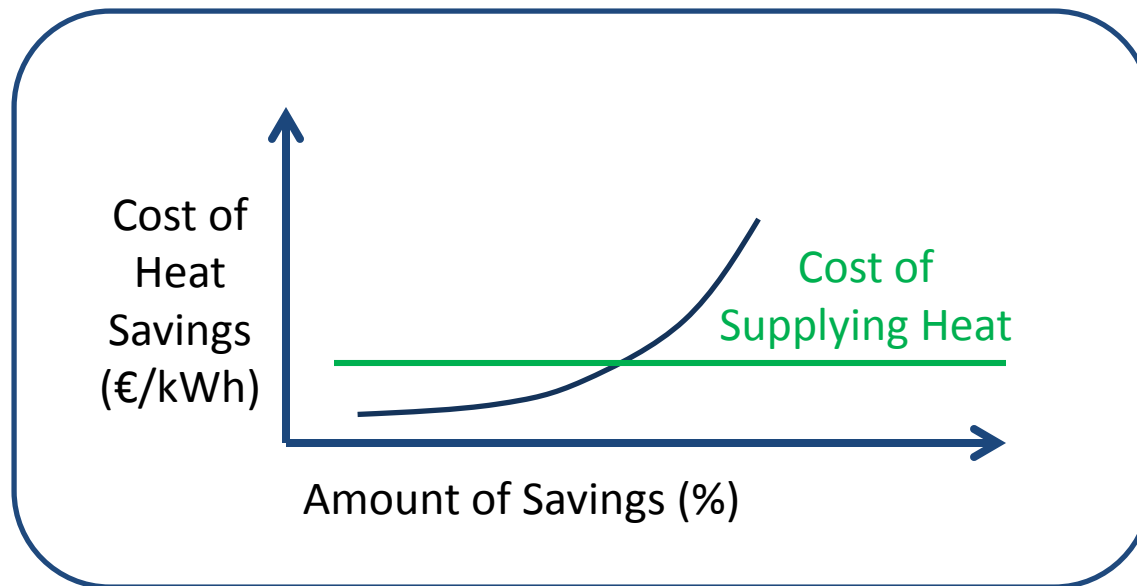
# How much Heat should we Save?

- We should implement heat savings until the price of sustainable supply is less than the marginal price of additional savings



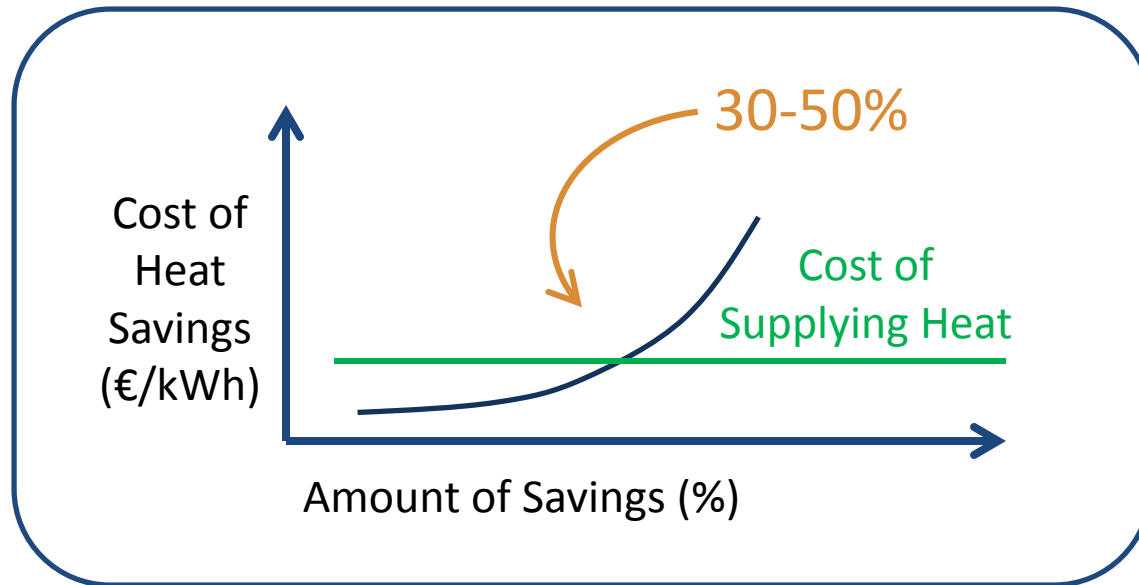
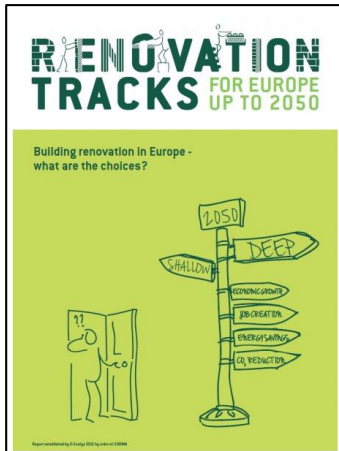
# How much Heat should we Save?

- We should implement heat savings until the price of sustainable supply is less than the marginal price of additional savings



# How much Heat should we Save?

- We should implement heat savings until the price of sustainable supply is less than the marginal price of additional savings





# 3 Options for the Heat Sector

















## 1. Savings (Everywhere)

- Reduce our demand for heat:
  - Space heating
  - Hot water

## 2. Individual Units (Everywhere)

- Use a heating unit in each building:
  - Boilers:
    - Oil
    - Biomass
  - Heat Pumps
  - Electric Heating

# 2. Individual Heating Options

Heating Unit	Sustainable Resources	Efficient	Cost	Cost Sensitivity
Electric Heating				
Heat Pumps				
Oil Boilers				
Biomass Boilers				

# 3 Options for the Heat Sector

## 1. Savings (Everywhere)

- Reduce our demand for heat:
  - Space heating
  - Hot water

## 2. Individual Units (Everywhere)

- Use a heating unit in each building:
  - Boilers:
    - Oil
    - Biomass
  - Heat Pumps
  - Electric Heating

## 3. Networks (Urban Areas)

- Share a heating network:
  - Gas Grid
  - Water (i.e. district heating)

# 3 options for the Heat Sector

## 1. Savings

- ↳ Reduce our demand for heat:
  - ↳ Space heating
  - ↳ Hot water

30-50%

Marginal

## 2. Individual Units

- ↳ Use a heating unit in each building:
  - ↳ Oil
  - ↳ Biomass
  - ↳ Heat Pumps
  - ↳ Electric Heating

~50%

Heat Pumps

## 3. Networks

- ↳ Share a heating network:
  - ↳ Gas Grid
  - ↳ Water (i.e. district heating)

~50%

District Heating

**OR**

**FACT**

**MYTH?**





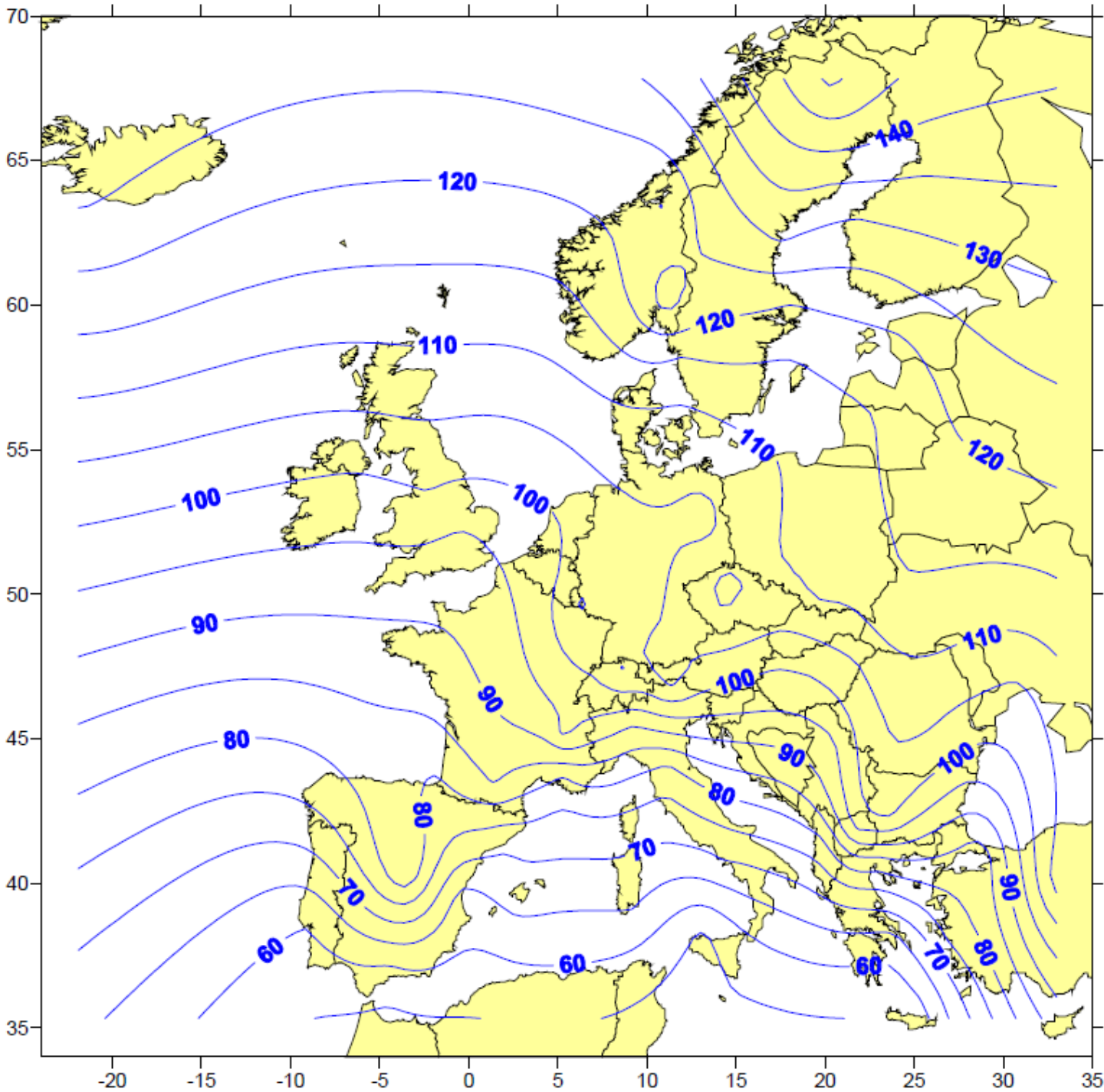
1. District Heating is only for Cold Parts of Europe

2. District Heating is a Local Solution for a Local Problem

3. District Heating is Expensive

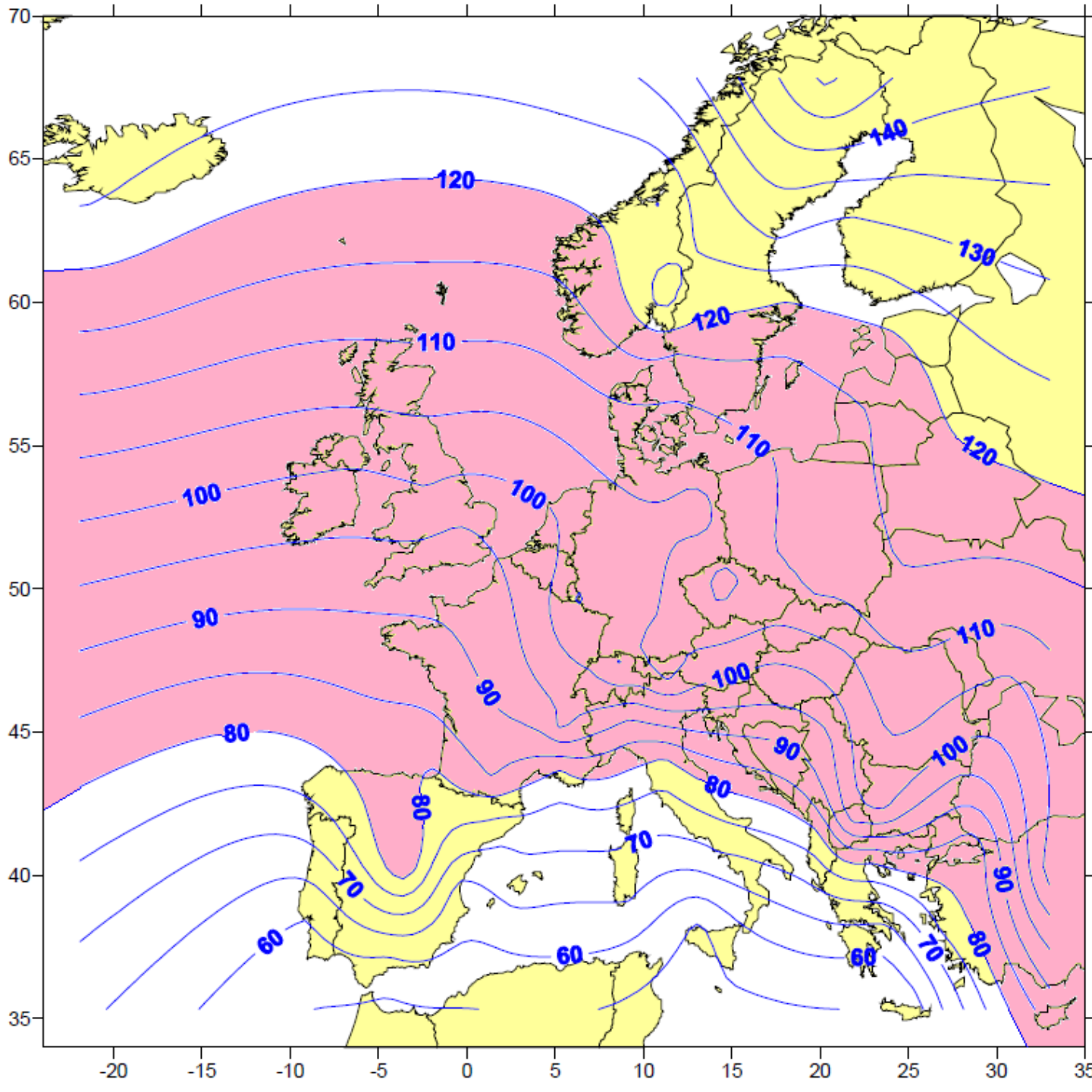
... and How can I investigate these for my country?

1. District Heating is for only  
for Cold Parts of Europe



# European Heating Index

(Source: ecoheatcool)



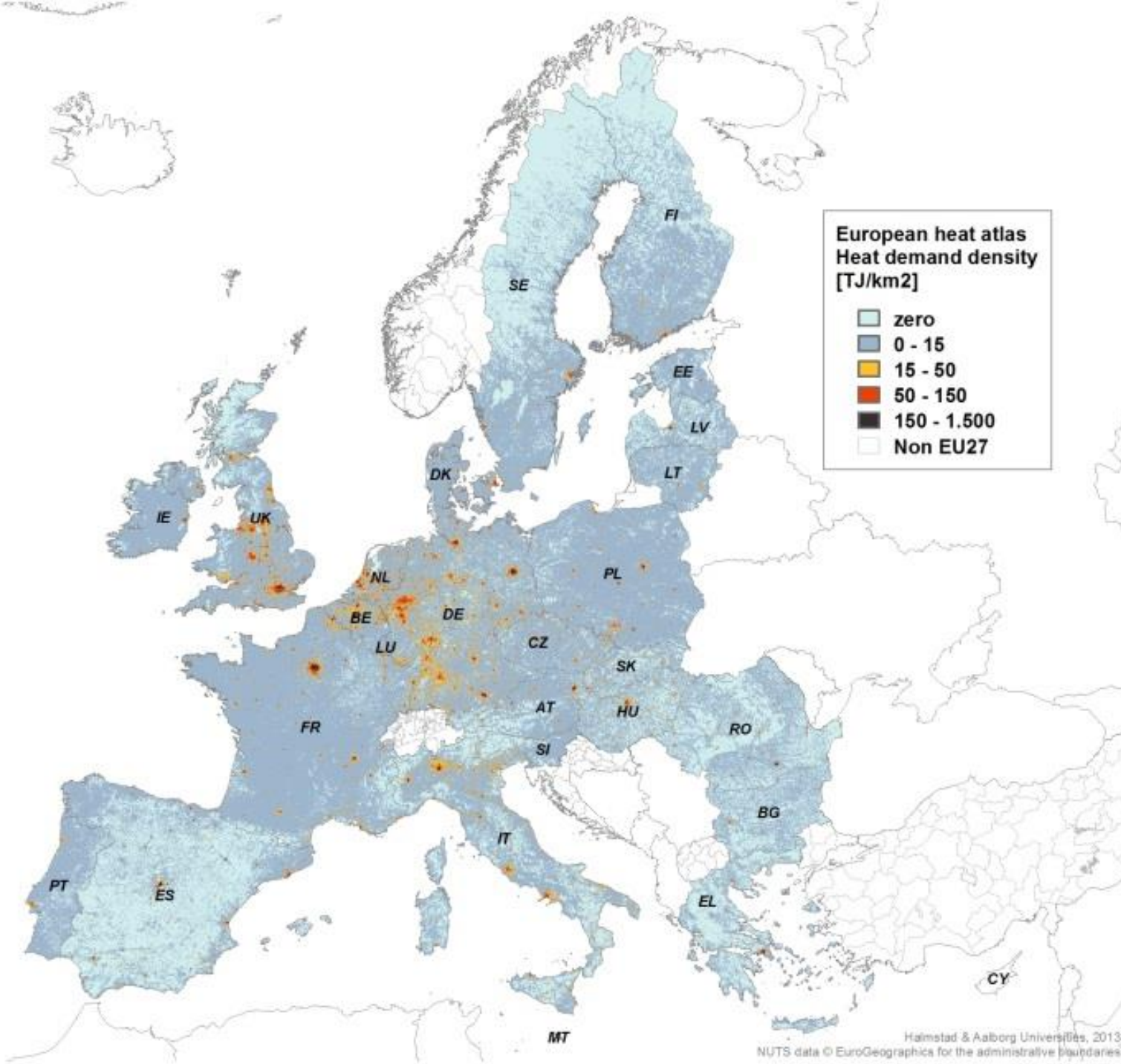
# European Heating Index

(Source: ecoheatcool)

+/- 20%

# EU Heat Atlas

30-50% of Heat Currently Feasible for DH





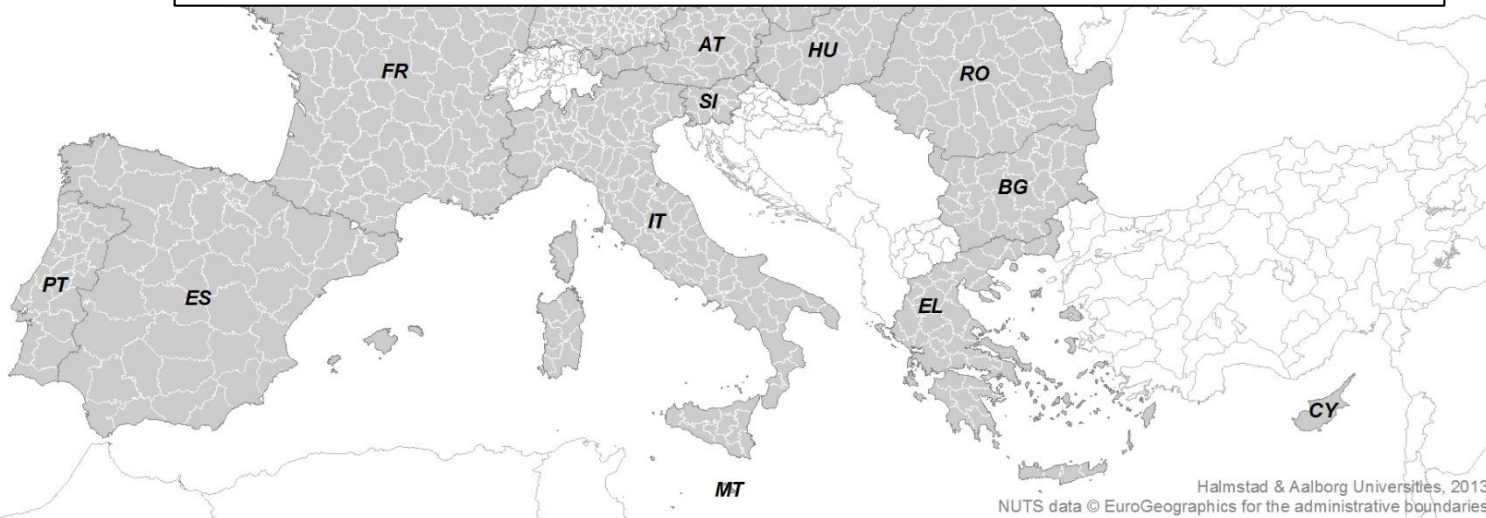


# Stratego

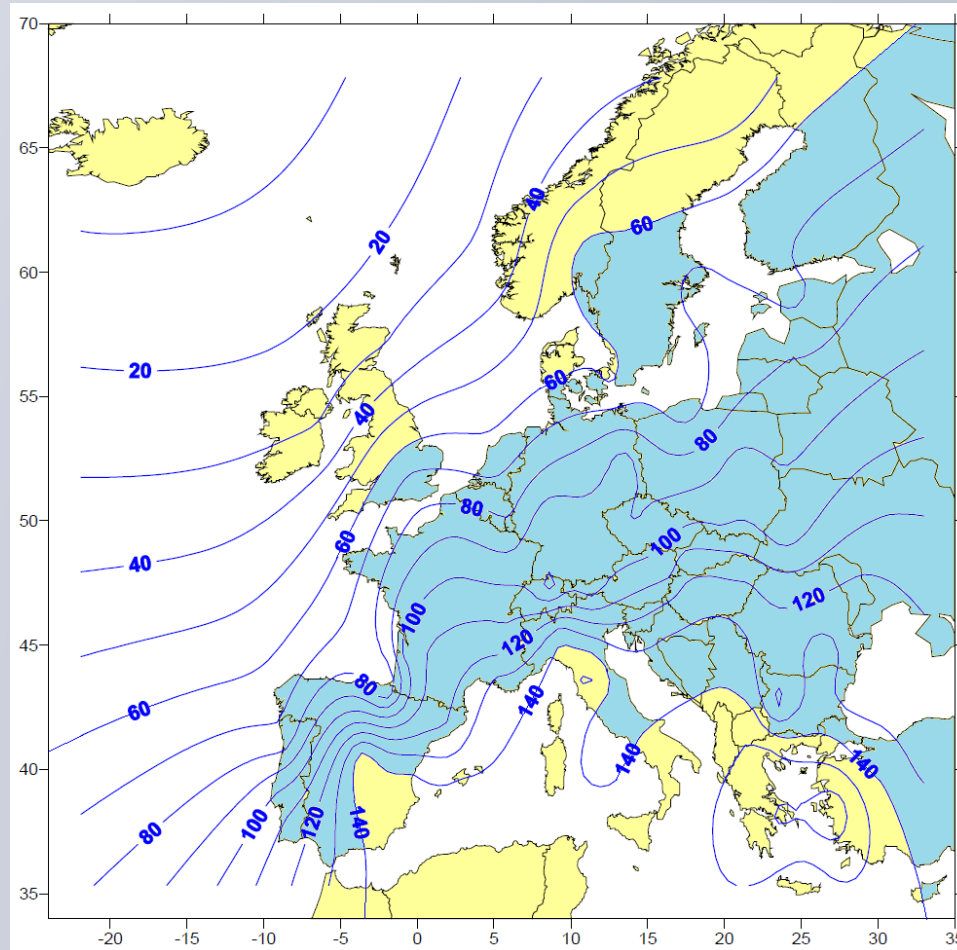
ENHANCED HEATING  
& COOLING PLANS

# EU Cooling Atlas

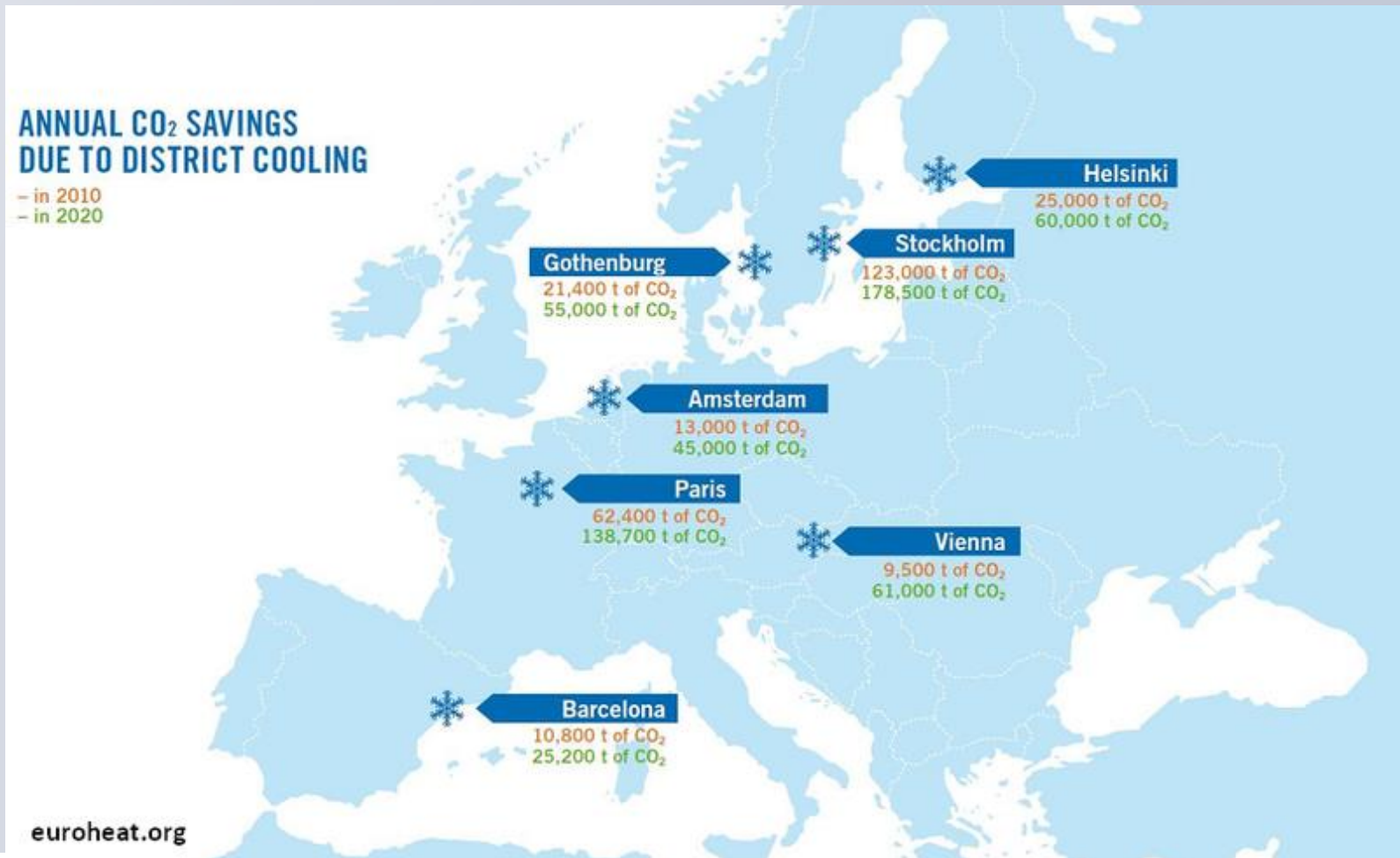
# Spring 2015



# EU Cooling Demand



# District Cooling in Europe

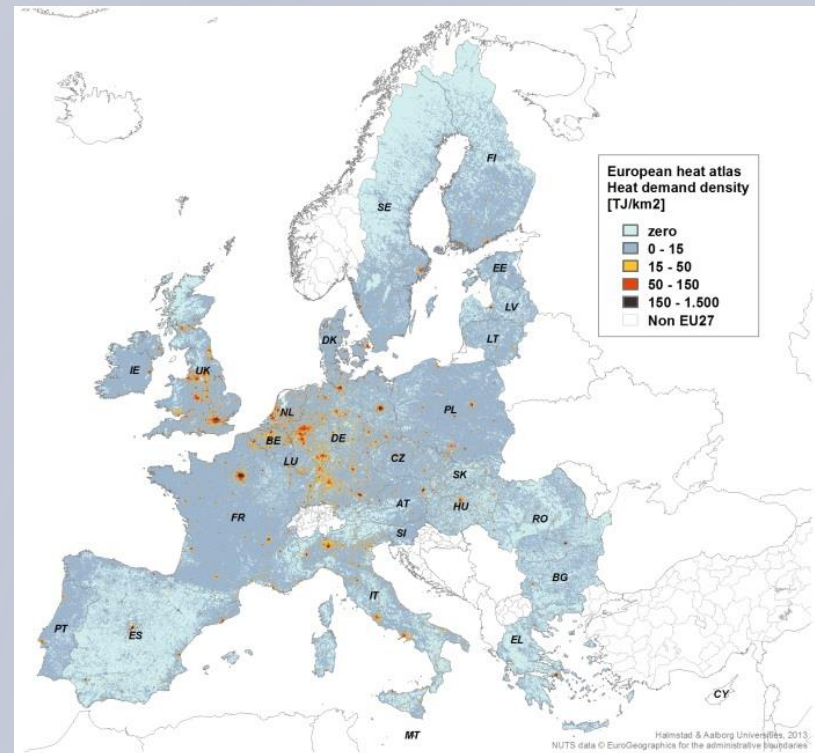


# Applying this Methodology at MS Level

## Mapping

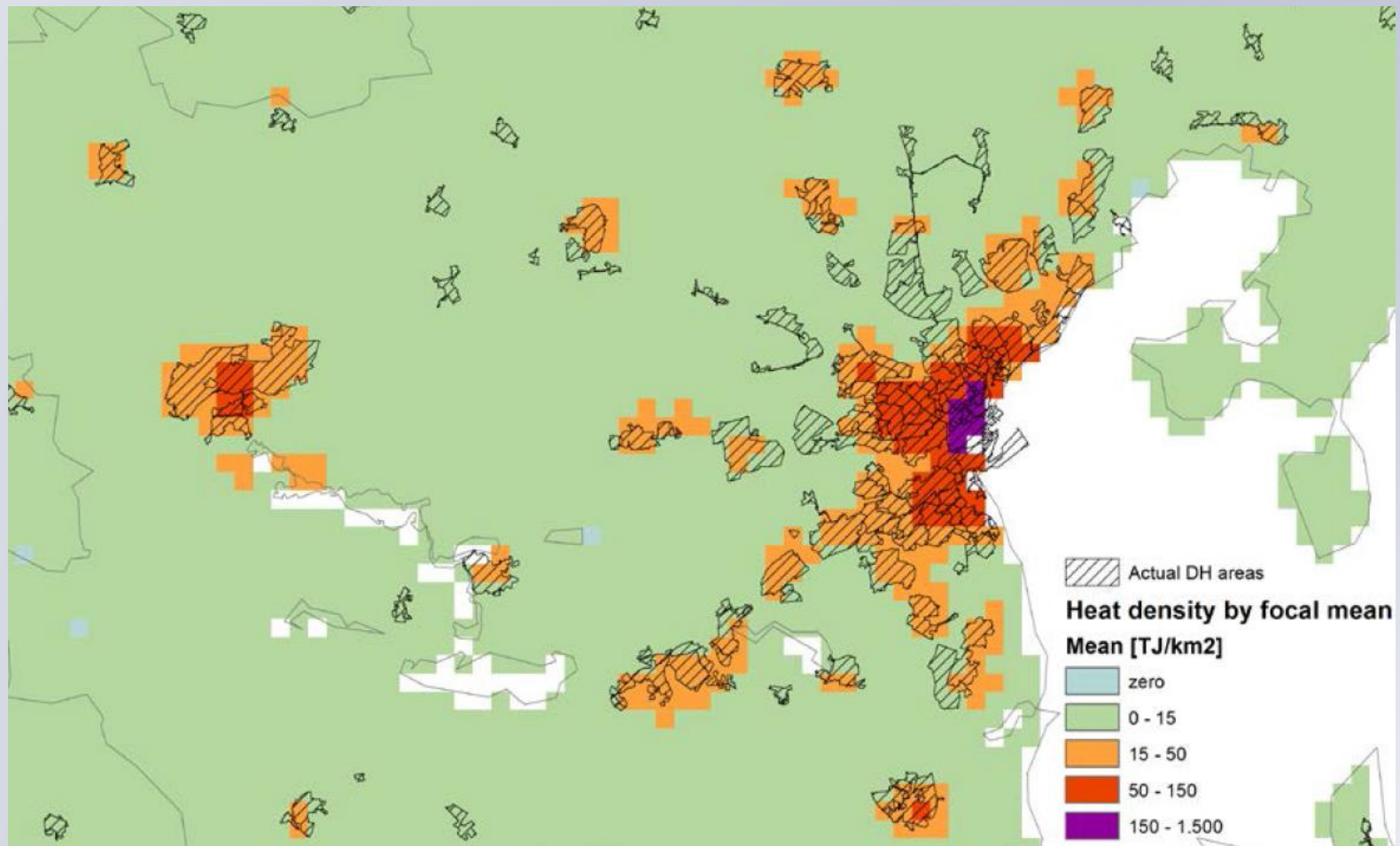
- ➔ Data can be extracted at MS level
  - ➔ Heat Demands
  - ➔ Cooling Demands (after STRATEGO)
  - ➔ Renewable Heat Potentials
- ➔ Some potentials already extracted in HRE:
  - ➔ Heat Demand
  - ➔ Power plant surplus heat
  - ➔ Industrial surplus heat
  - ➔ Waste incineration
- ➔ STRATEGO:
  - ➔ Static data already provided online:  
[www.heatroadmap.eu](http://www.heatroadmap.eu)
  - ➔ Interactive maps being developed.  
Delivery date: Spring 2015

## Heat Demand at MS Level

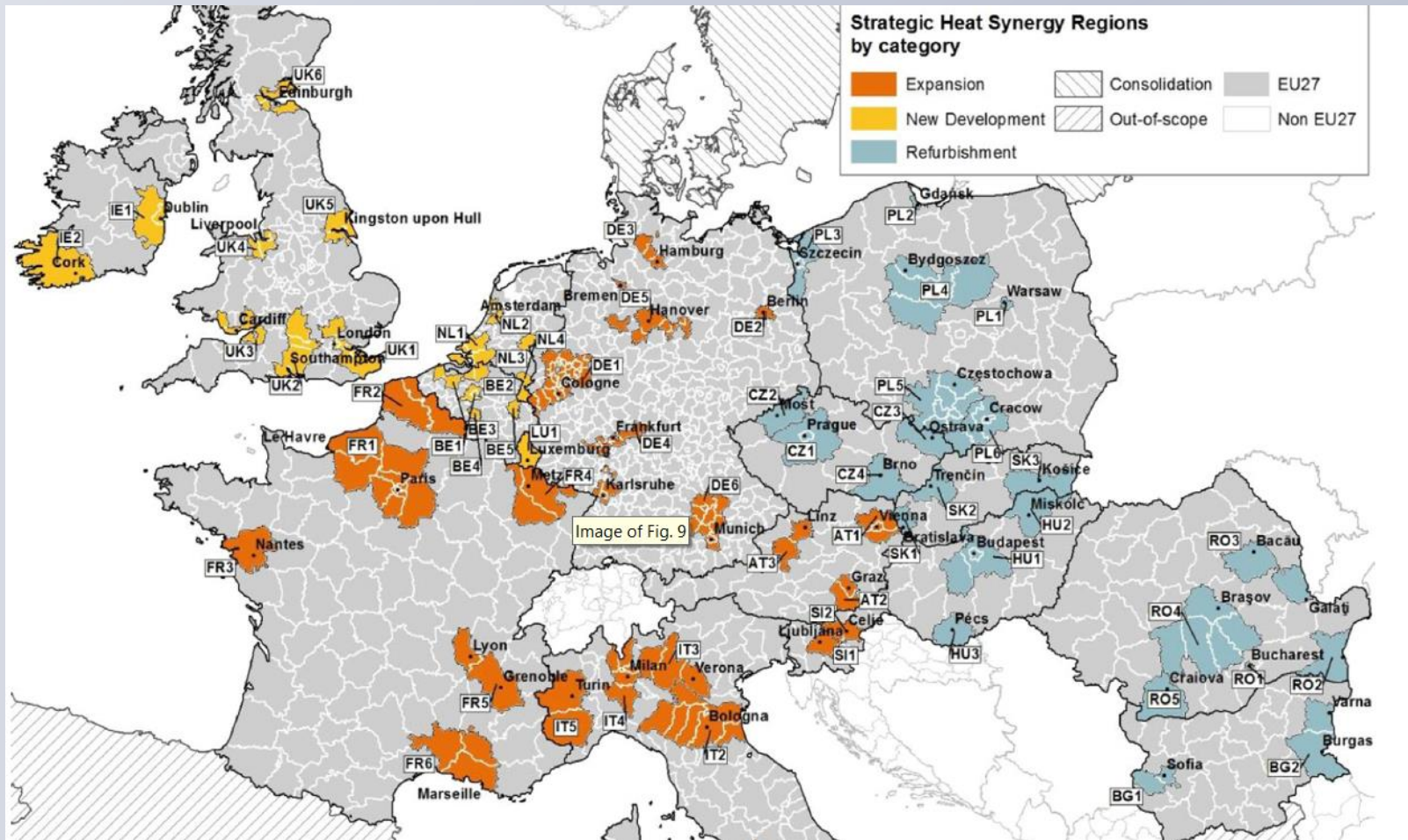




# HRE Heat Atlas at a Local Level



# HRE Mapping: Best Places to Start District Heating in the EU



# Surplus Heat in Different MS

**Table 7**  
 NUTS3 regions (N3R) in EU27 Member States (MS), all in study (left), all with excess heat ratio (right) by population (P), heat demand (HD), primary energy supply (PES), and excess heat (EH). Excess heat specified by sectors: Thermal power (TP), Waste-to-Energy (WTE), and Industrial (Ind). Energy volumes in PJ/a. Population in millions.

MS	EU27			EU27 with excess heat ratio value > 0								
	N3R	P	HD	N3R	P	HD	PES	EH	TP	WTE	Ind	
AT	35	8.4	261	20	6.4	200	456	167	63	21	84	
BE	44	10.8	353	32	9.5	311	805	313	157	17	138	
BC	28	7.6	71	18	5.7	54	382	180	161	0	19	

**Table 7**  
 NUTS3 regions (N3R) in EU27 Member States (MS), all in study (left), all with excess heat ratio (right) by population (P), heat demand (HD), primary energy supply (PES), and excess heat (EH). Excess heat specified by sectors: Thermal power (TP), Waste-to-Energy (WTE), and Industrial (Ind). Energy volumes in PJ/a. Population in millions.

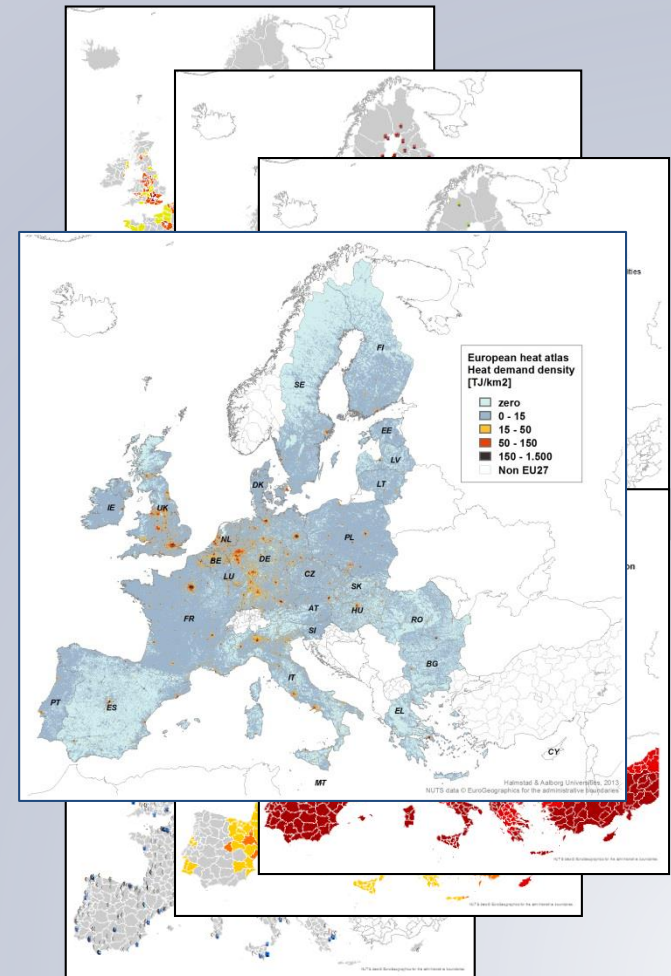
MS	EU27			EU27 with excess heat ratio value > 0								
	N3R	P	HD	N3R	P	HD	PES	EH	TP	WTE	Ind	
AT	35	8.4	261	20	6.4	200	456	167	63	21	84	
LT	10	3.3	66	4	2.0	41	100	42	21	0	21	
LU	1	0.5	22	1	0.5	22	35	13	8	1	4	
LV	6	2.2	64	2	1.0	28	13	4	2	0	2	
MT	2	0.4	2	1	0.4	2	25	13	13	0	0	
NL	40	16.6	549	27	13.1	433	1348	583	366	46	171	
PL	66	38.2	835	56	33.1	724	2171	975	809	0	165	
PT	28	10.1	92	16	8.1	72	373	147	76	10	61	
RO	42	21.5	294	28	16.0	217	613	252	177	0	75	
SE	21	9.3	302	21	9.3	302	594	217	82	30	106	
SI	12	2.0	46	6	1.3	30	81	37	34	0	3	
SK	8	5.4	120	7	4.9	108	258	90	41	1	48	
UK	139	61.9	1450	82	40.3	944	3229	1477	1140	40	297	
<b>Total</b>	<b>1281</b>	<b>496.6</b>	<b>11,724</b>	<b>834</b>	<b>402.4</b>	<b>9453</b>	<b>26,123</b>	<b>11,274</b>	<b>7842</b>	<b>508</b>	<b>2924</b>	
<b>Share (%)</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>65</b>	<b>81</b>	<b>81</b>	<b>100</b>	<b>100</b>	<b>70</b>	<b>4</b>	<b>26</b>	

Please cite this article as: Persson, U., et al., Heat Roadmap Europe: Identifying strategic heat synergy regions. Energy Policy (2014), <http://dx.doi.org/10.1016/j.enpol.2014.07.015>



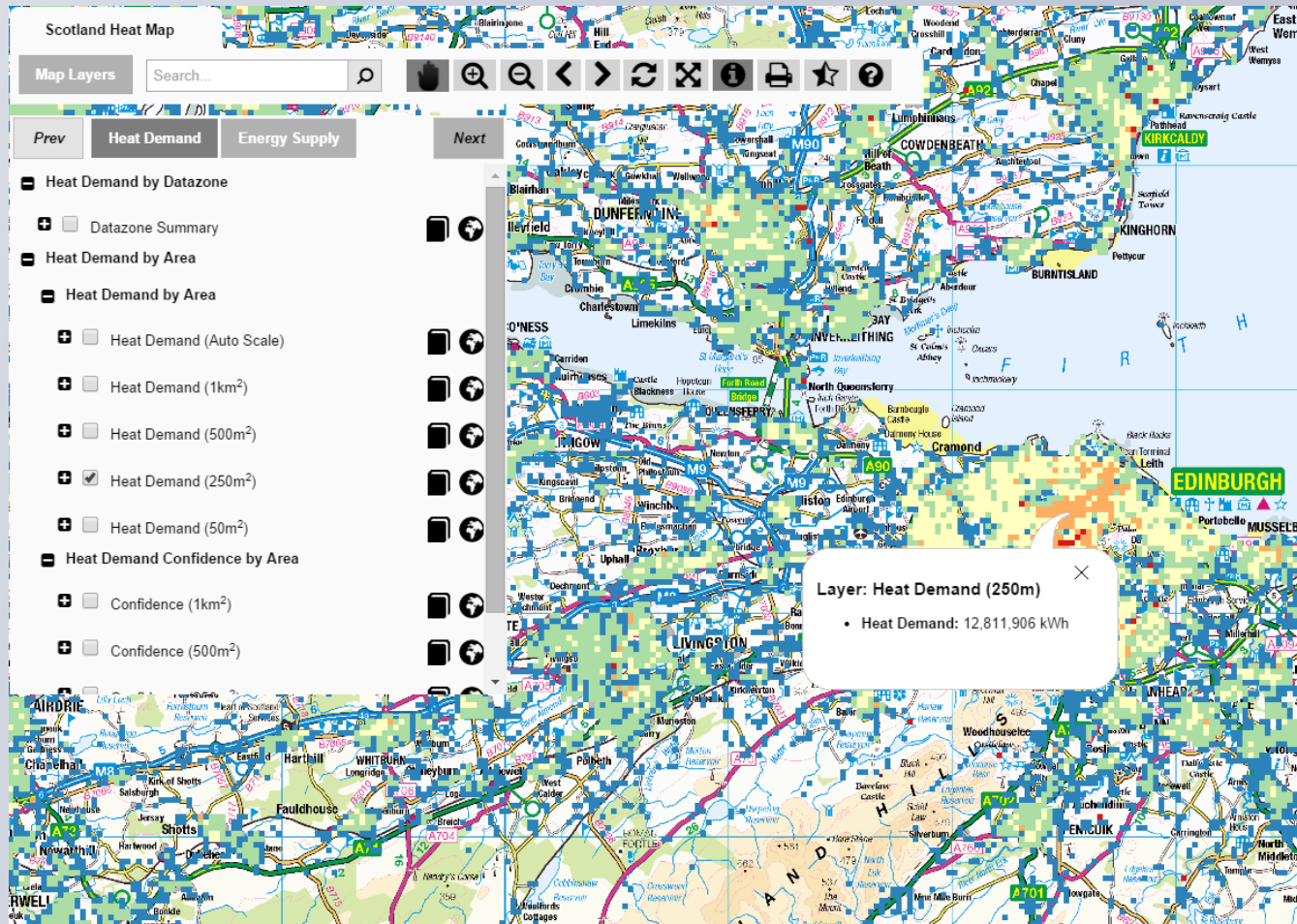
# GIS Mapping: Many Heat Sources

- ➔ Heating and Cooling Demands
- ➔ Power and Heat Generation
- ➔ Waste Incineration
- ➔ Industrial waste heat potential
- ➔ Geothermal heat
- ➔ Solar Thermal
- ➔ Bioenergy Potential



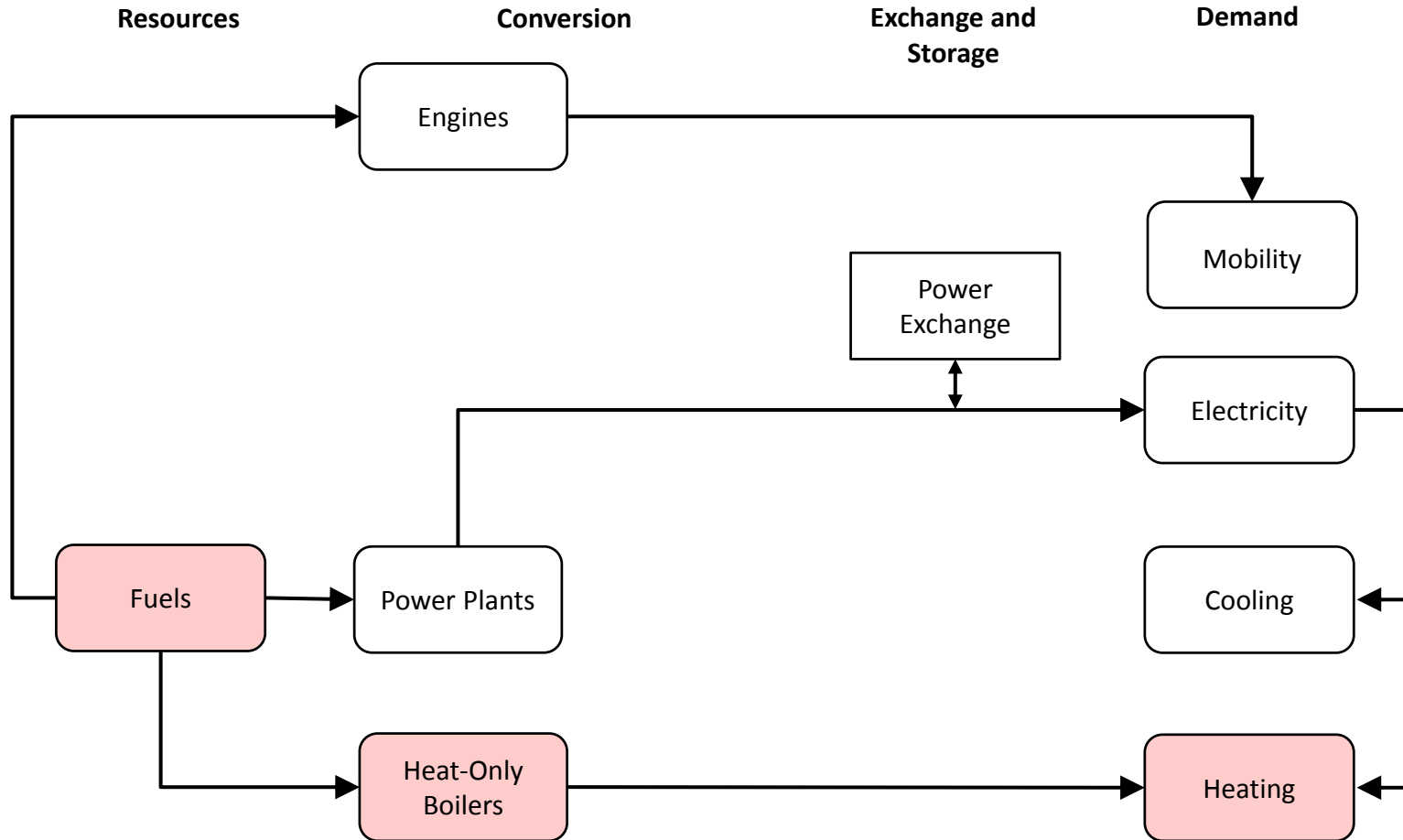


# Interactive Online Maps

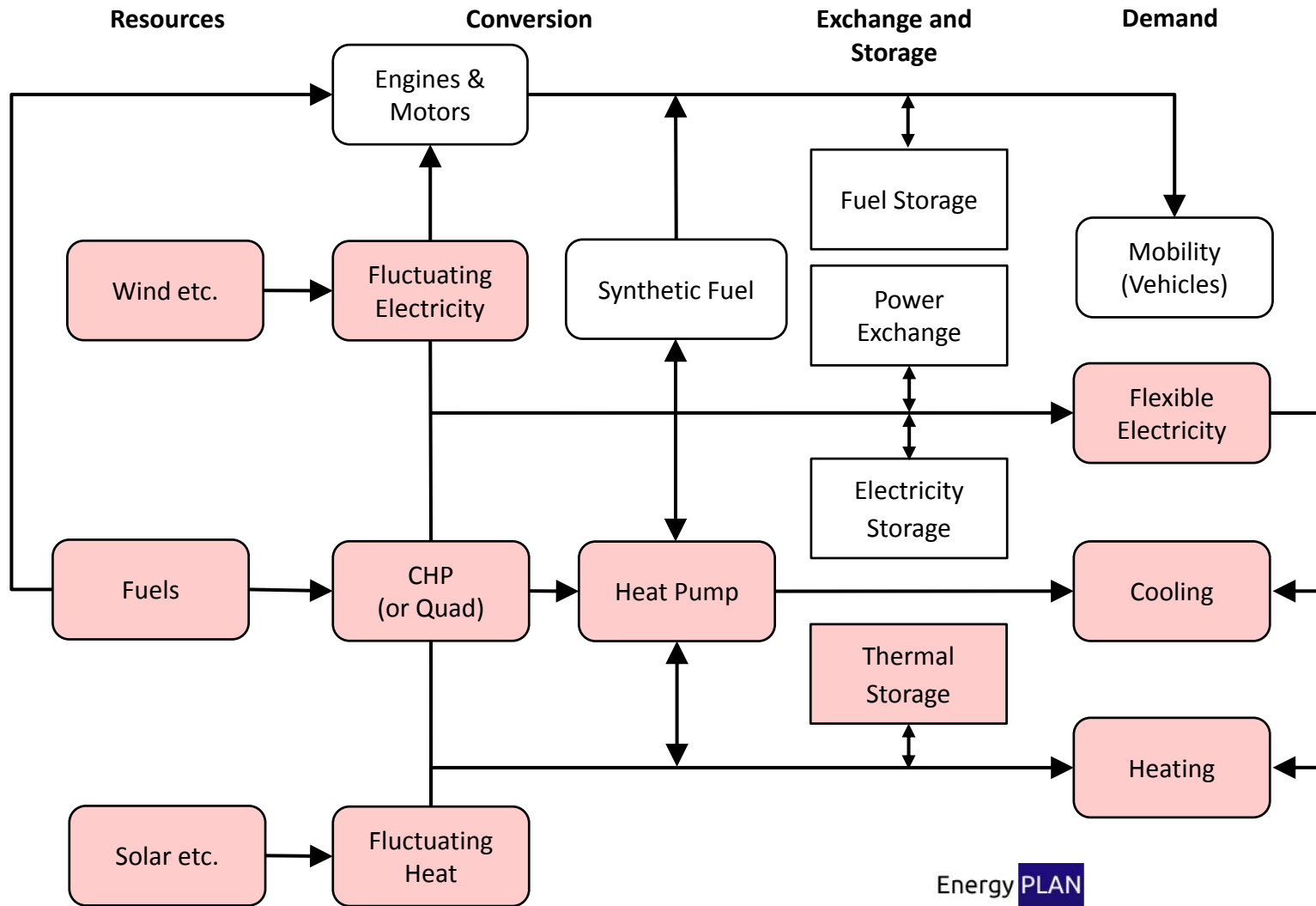


## 2. District Heating is a Local Solution for a Local Problem

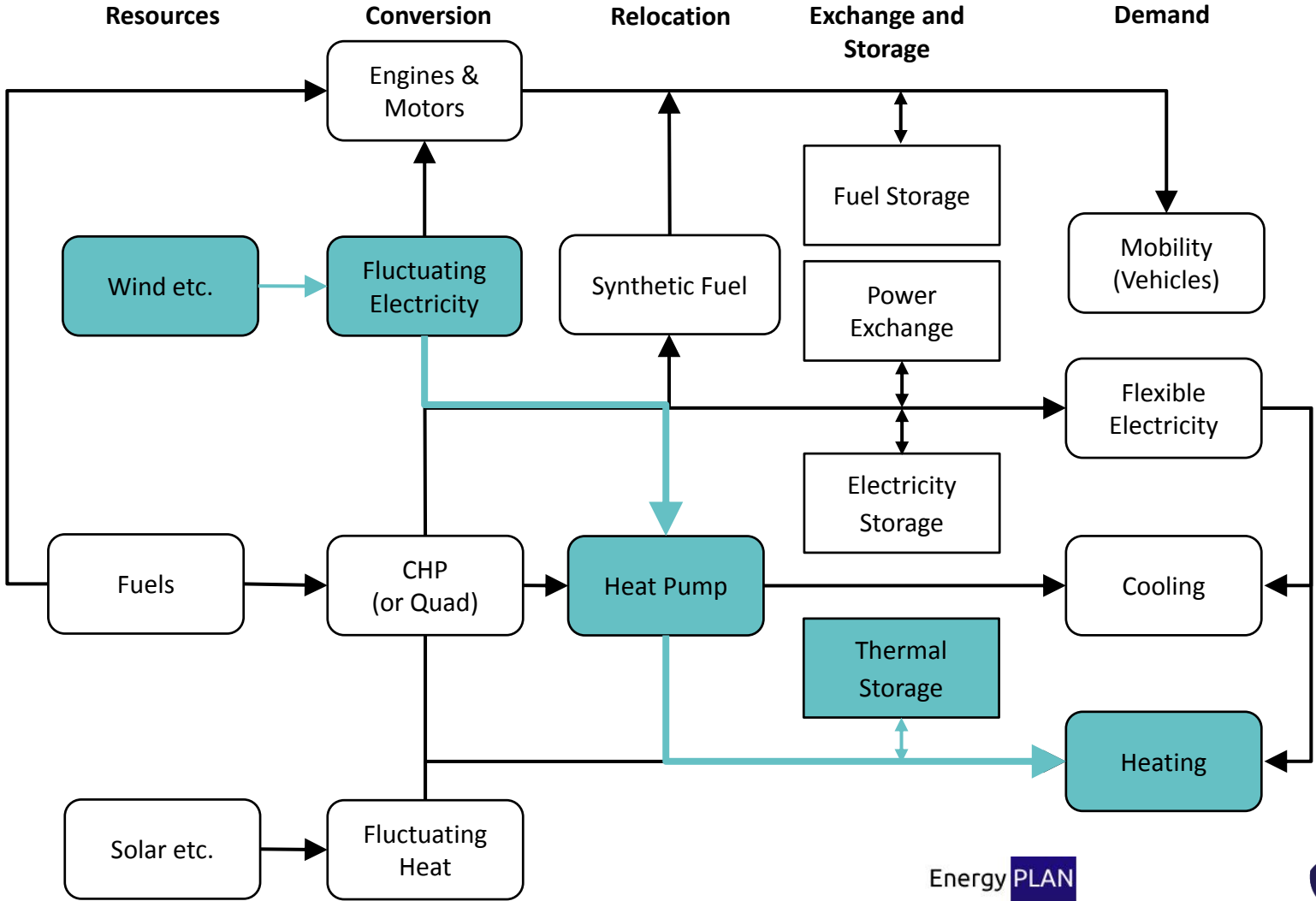
# Today's Heat Sector



# The New Heat Sector



# Integrating 40% Wind Power with District Heating



# Denmark

## 50% Wind for December 2013

Skagen District Heating, Thursday, 2010-05-13 to Wednesday, 2010-05-19





# (Marstal: >50% solar in heat supply)



# Storage Costs

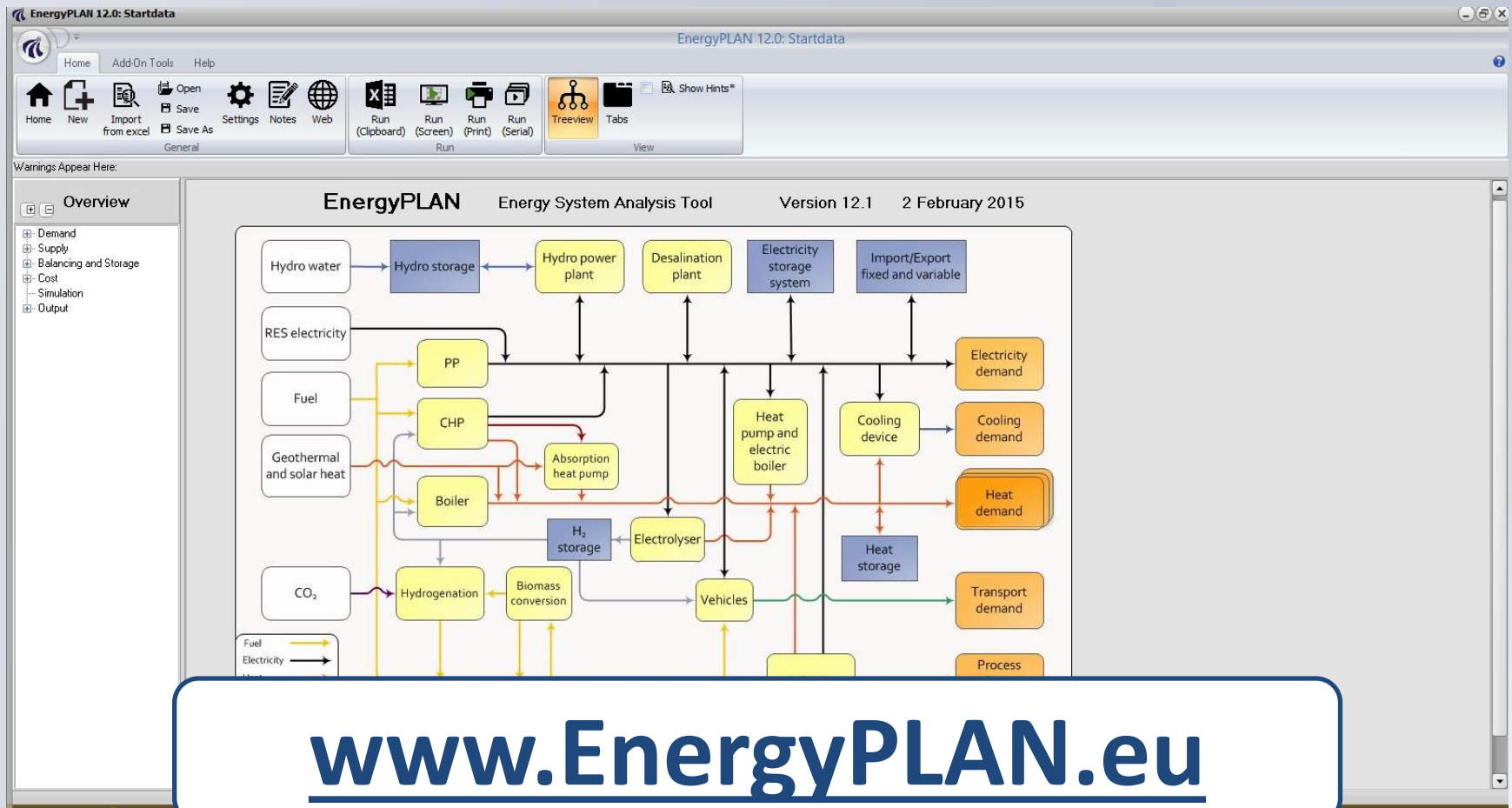
→ Electricity = €170/kWh

→ Thermal = €0.5-3/kWh





## Hourly Model of the Complete Energy System



[www.EnergyPLAN.eu](http://www.EnergyPLAN.eu)

### 3. District Heating is Expensive

# 3 options for the Heat Sector

## 1. Savings

- Reduce our demand for heat:
  - Space heating
  - Hot water

30-50%

Marginal

## 2. Individual Units

- Use a heating unit in each building:
  - Oil
  - Biomass
  - Heat Pumps
  - Electric Heating

~50%

Heat Pumps

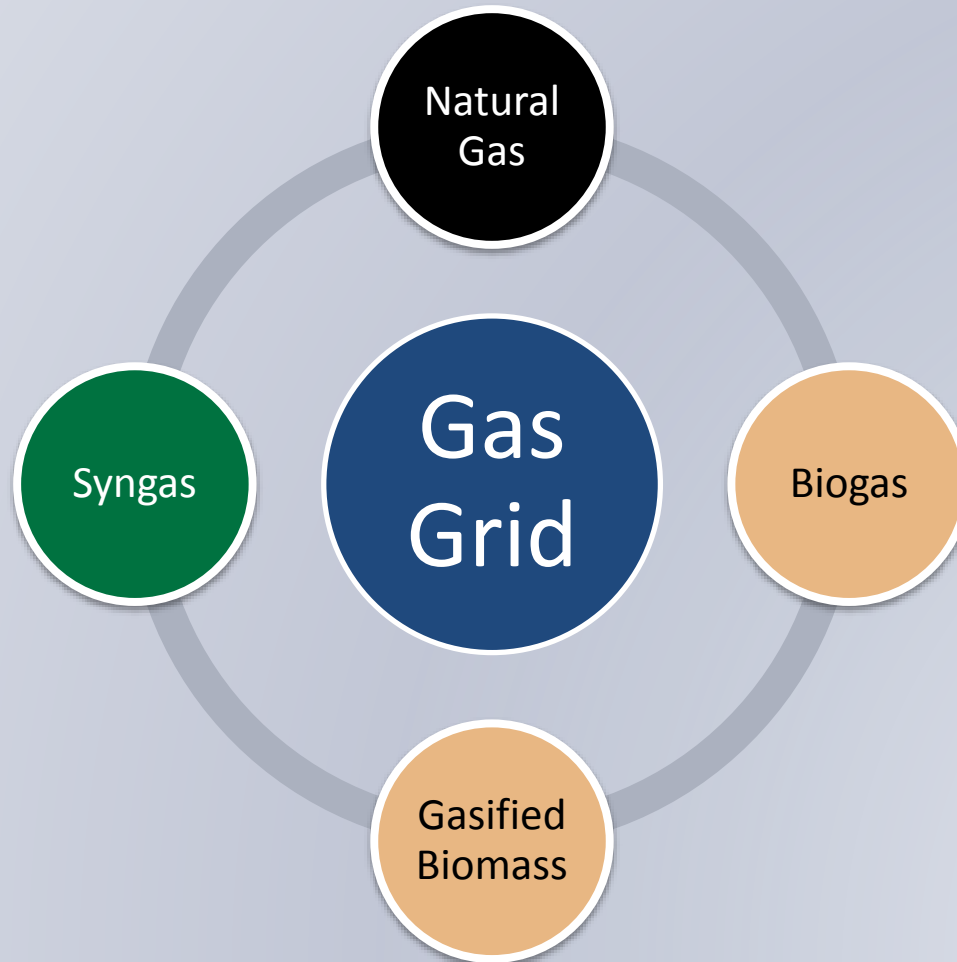
## 3. Networks

- Share a heating network:
  - Gas Grid
  - Water (i.e. district heating)

~50%

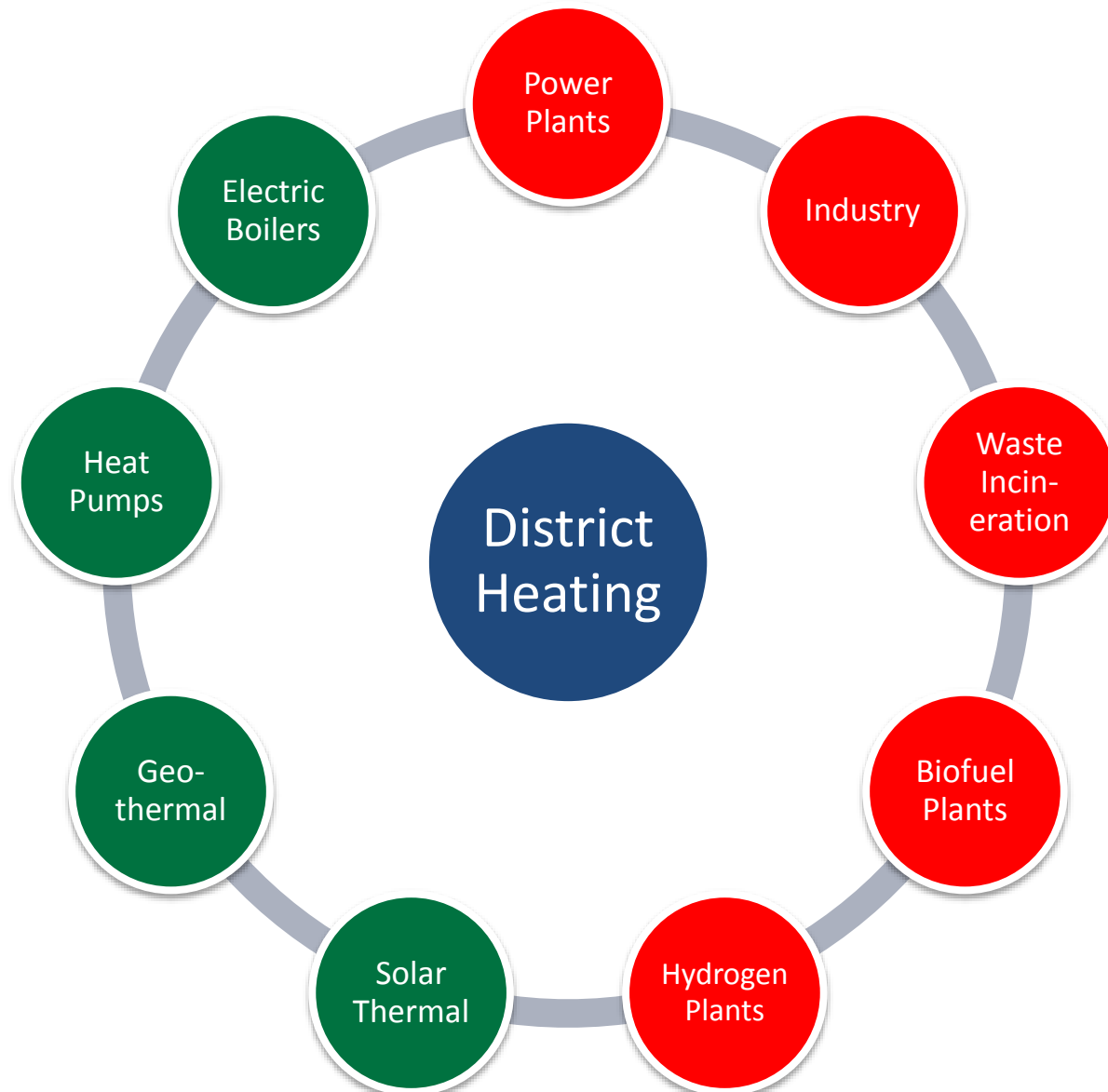
District Heating

## High quality energy for a low quality demand

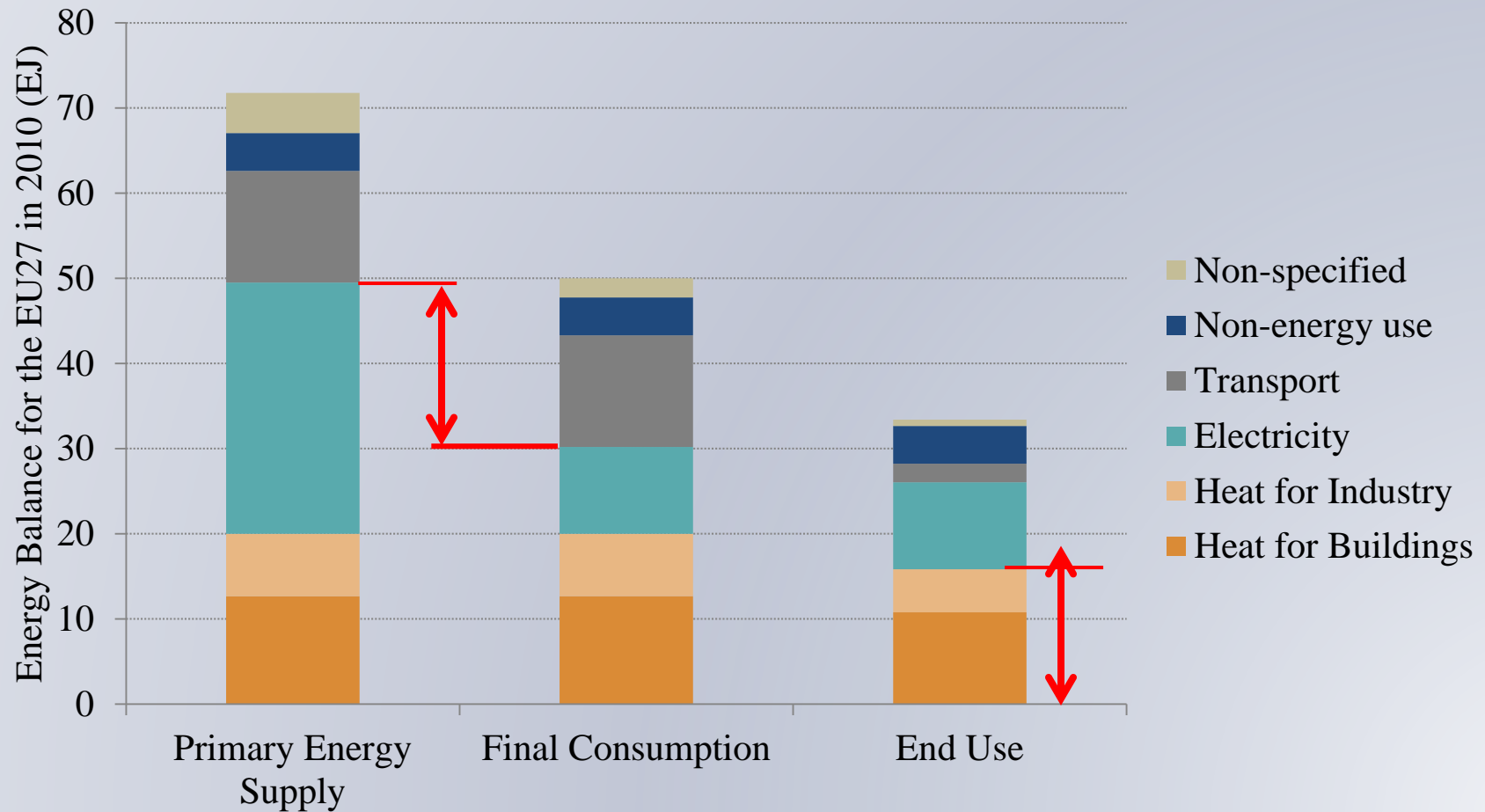


# District Heating

Low quality energy for a low quality demand

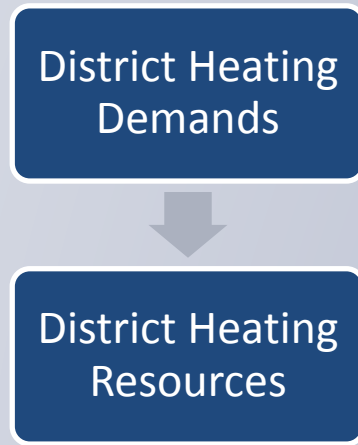


# The Current Situation

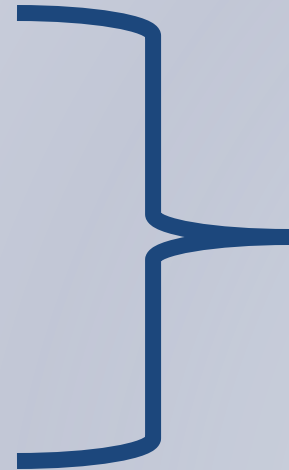


# HRE Methodology

**GIS Mapping**  
(could be another technology, resource, etc)



**Energy System Modelling  
(EnergyPLAN)**

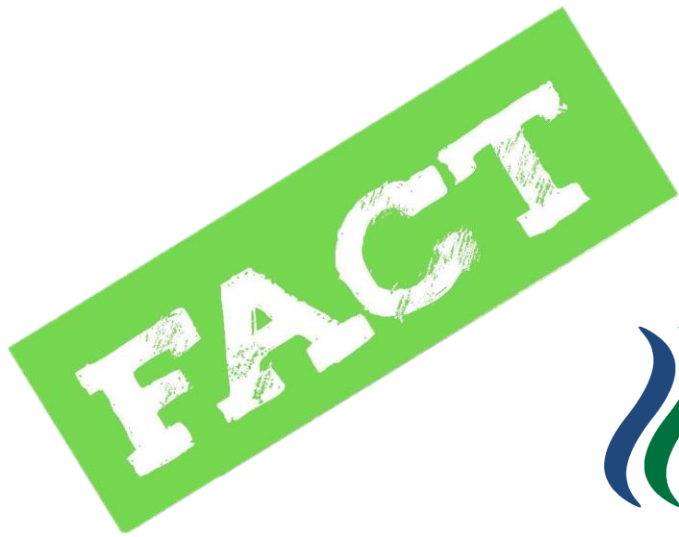


# HRE2: Key Conclusion

- ↳ A combination of:
  - ↳ 50% District Heating (*Cities*)
  - ↳ 50% Heat Pumps (*Rural Areas*)
  - ↳ 35% Energy Savings (*Everywhere*)

Can enable the EU to reach its CO<sub>2</sub> target in 2050 for **€100 billion/year less** than energy savings on their own.





# Heat Roadmap Europe 2050

1. District Heating is **not** only for Cold Parts of Europe
2. District Heating is a Local Solution for an **EU** Problem
3. District Heating can **reduce the cost of energy in the EU**

The HRE methodology can be repeated at Member State Level... **and will be in STRATEGO**

# Moving from EU to Member State Level (STRATEGO)

<http://www.stratego-project.eu/>

# Applying this Methodology at MS Level

## Modelling

- ↳ EnergyPLAN is available as a freeware:  
[www.EnergyPLAN.eu](http://www.EnergyPLAN.eu)
- ↳ Lot of training provided:
  - ↳ Exercises with solutions
  - ↳ FAQs
  - ↳ Forum
  - ↳ Quarterly online workshops
  - ↳ User Manual
- ↳ Can be used to model any national energy system

## Developing MS Models

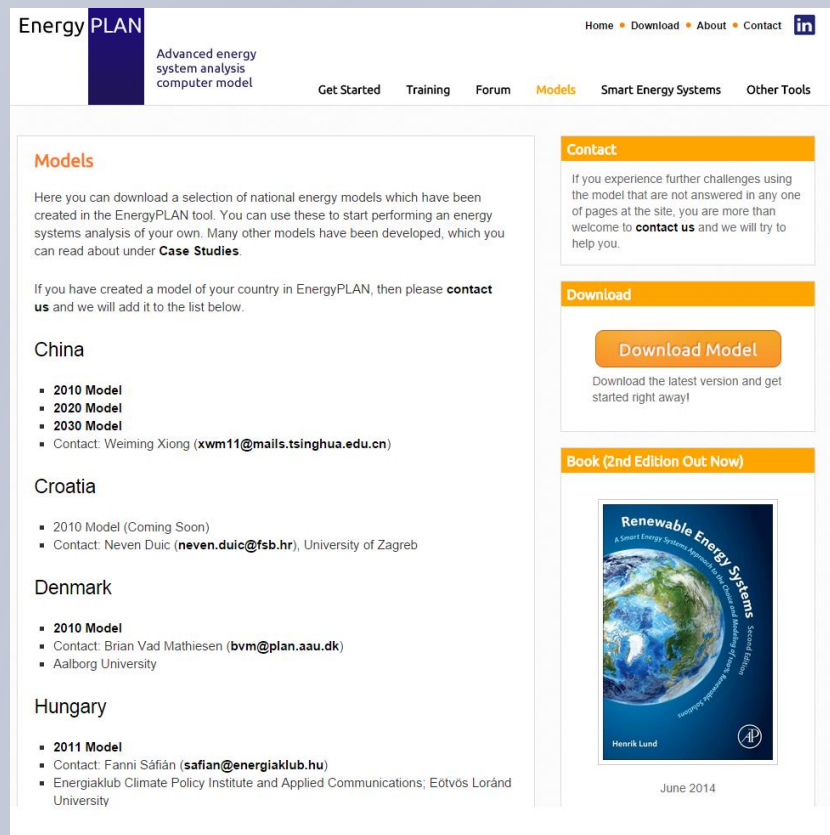
- ↳ STRATEGO:
  - ↳ Streamlining the process of developing MS 'reference' models
- ↳ Countries:
  - ↳ Croatia
  - ↳ Czech Republic
  - ↳ Italy
  - ↳ Romania
  - ↳ United Kingdom

# Existing Reference Models

## Existing Models

- ➔ China
- ➔ Denmark
- ➔ Hungary
- ➔ Ireland
- ➔ Latvia
- ➔ Macedonia
- ➔ Mexico
- ➔ New Zealand
- ➔ Norway
- ➔ Sweden
- ➔ United Kingdom

## [www.EnergyPLAN.eu/models](http://www.EnergyPLAN.eu/models)



The screenshot shows the 'Models' page on the EnergyPLAN website. The page header includes the EnergyPLAN logo and navigation links: Home, Download, About, Contact, and LinkedIn. Below the header, there are tabs for 'Get Started', 'Training', 'Forum', 'Models', 'Smart Energy Systems', and 'Other Tools'. The main content area is titled 'Models' and contains the following text:

Here you can download a selection of national energy models which have been created in the EnergyPLAN tool. You can use these to start performing an energy systems analysis of your own. Many other models have been developed, which you can read about under **Case Studies**.

If you have created a model of your country in EnergyPLAN, then please **contact us** and we will add it to the list below.

**China**

- 2010 Model
- 2020 Model
- 2030 Model
- Contact: Weiming Xiong ([xwm11@mails.tsinghua.edu.cn](mailto:xwm11@mails.tsinghua.edu.cn))

**Croatia**

- 2010 Model (Coming Soon)
- Contact: Neven Duic ([neven.duic@fsb.hr](mailto:neven.duic@fsb.hr)), University of Zagreb

**Denmark**

- 2010 Model
- Contact: Brian Vad Mathiesen ([bvm@plan.aau.dk](mailto:bvm@plan.aau.dk))
- Aalborg University

**Hungary**

- 2011 Model
- Contact: Fanni Sáfán ([safian@energiaklub.hu](mailto:safian@energiaklub.hu))
- Energiaklub Climate Policy Institute and Applied Communications; Eötvös Loránd University

On the right side of the page, there are three sections: 'Contact' (with a text box for inquiries), 'Download' (with a 'Download Model' button and text: 'Download the latest version and get started right away!'), and 'Book (2nd Edition Out Now)' (with a book cover for 'Renewable Energy Systems: A Smart Energy System Approach to the Transition to a Sustainable Energy Future' by Henrik Lund, published June 2014).

# Our Philosophy

Consequences for a  
Variety of Alternatives



- Where will we **end up**, rather than where should we start: **2030/2050 Analysis**
- The future will require **radical technological change**: **EnergyPLAN**
- **All sectors** of the energy system will need to be connected: **EnergyPLAN**
- Account for the **intermittency** of renewables such as wind: **Hourly Analysis**
- **Free from existing market regulations**  
**Socio-Economic Analysis**

# Conclusions: 100% Renewable Energy

- ↳ 100% Renewable Energy is Technically Possible
- ↳ 100% Renewable Energy will cost approximately the same price as a Fossil Fuel alternative
- ↳ New forms of Flexibility/Storage are essential
- ↳ The most economic way to create flexibility is by utilising the synergies between the electricity, heating, and transport sectors

# Conclusions: Heat Sector

## ↳ Savings:

- ↳ There is an economic balance between reducing heat and supplying heat
- ↳ 30-50% heat savings is a good proxy for the economic limit of heat savings

↳ **Individual:** Heat pumps are the most suitable individual heating solution in a 100% renewable context

↳ **Networks/Urban:** District heating is the most suitable urban heating in a 100% renewable energy context

# Thank you

➔ Want to find out more?

➔ [david@plan.aau.dk](mailto:david@plan.aau.dk)

➔ [www.heatroadmap.eu](http://www.heatroadmap.eu)

➔ [www.EnergyPLAN.eu](http://www.EnergyPLAN.eu)

