Heat Roadmap Europe 2050

A low-carbon heating and cooling strategy

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Sustainable Energy Planning Research Group, Aalborg University

On the edge of DHC research and development

Smart energy systems, 4th generation District Heating and Heat Roadmap Europe

Celsius, Keynote, November 28, 2017

Göreborg, Sweden

www.heatroadmap.eu / www.4dh.eu / www.reinvestproject.eu

@HeatRoadmapEU / @4DHresearch / @REInvestEU

4DH

4th Generation District Heating Technologies and Systems

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 695989.

reINVEST

Innovation Fund Denmark

What does the future bring for you?

More or less district heating?

- Net zero emission buildings?
- Passive houses?
- Gas-electricity hybrid heat pumps?
- What types of district heating are fit for the future?
- Should district heating decrease or increase?
- Who should own and profit from district heating system?

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Who are we?
– Sustainable Energy Planning Research Group

- Smart Energy Systems and energy system modelling
- International GIS mapping
- Local/National/EU/international focus
- Strategic energy planning local implementation,
- EnergyPLAN tool development
- Transport and renewable fuels
- Public regulation,
- Ownership and market design

www.energyplan.eu
www.smartenergysystems.eu

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WHAT AND WHO ARE 4DH?

4DH
4th Generation District Heating Technologies and Systems

- Strategic Research Centre financed by the Danish Research Council and the partners
- 4DH is an **international research centre** which develops 4th generation district heating technologies and systems
- 4DH has **30 partners** from universities in Europe and China, district heating supply companies, municipalities, manufacturers and consulting companies
- 4DH is a 6 year project (2012-2018) funded by Innovation Fund Denmark.

PARTNERS IN 4DH

Contact 4DH:
Head, Professor Henrik Lund
Phone: +45 9940 8309
E-mail: lund@plan.aau.dk
Address: Skibbrogade 5
9000 Aalborg
Denmark

Funded by
Innovation Fund Denmark

www.4dh.dk @4DHresearch

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Who are you?

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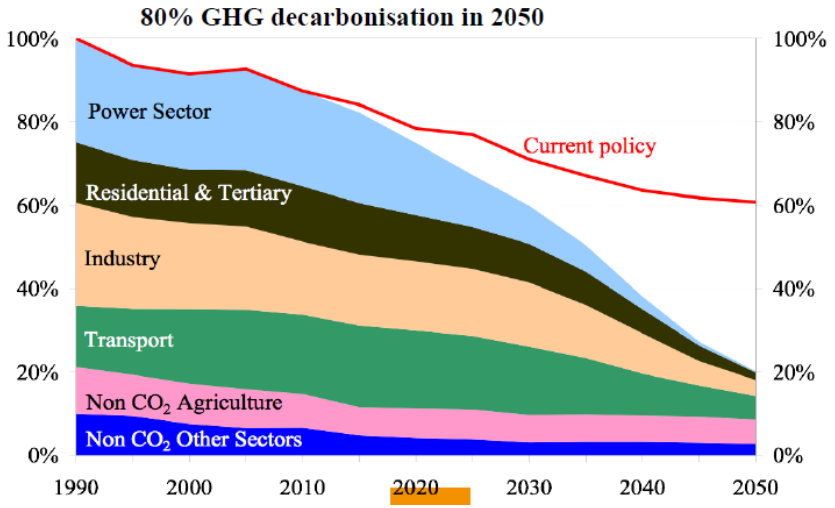
Targets and challenges in Europe

Long-term target (2011)

- 80-95% reduction of CO emissions in th energy sector

Short term in the energy union (2015)

- Security of supply (electricity and gas)
- An integrated marked
- Energy efficiency
- Lower CO2 emissions
- Research and innovation
- New directives (RED, EPBD, ED etc.)



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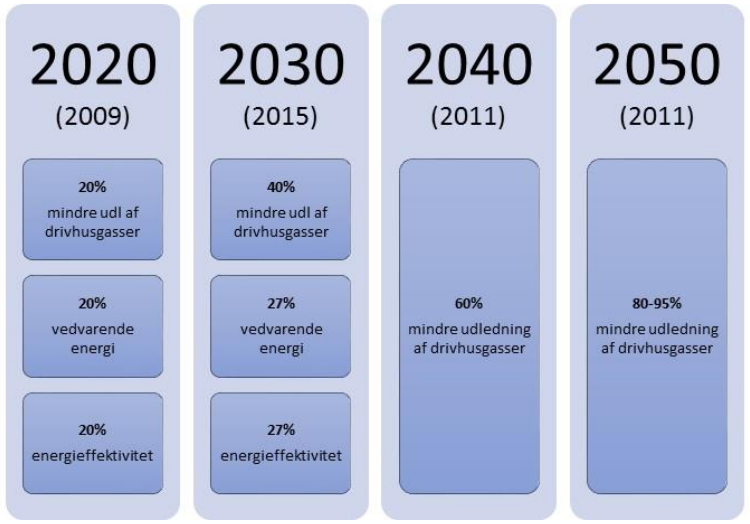
Focuses in Europe

- Energy Savings
- More electricity in the energy system-
- More decentral production
- Gas in a transition
- Contribution from nuclear
- Reductions in energy imports and prices
- Much more Renewable Energy
- More investments – less costs for fuels
- Increasing electricity prices until 2030 – then reductions
- Large reductions in emissions is technically and economically possible.



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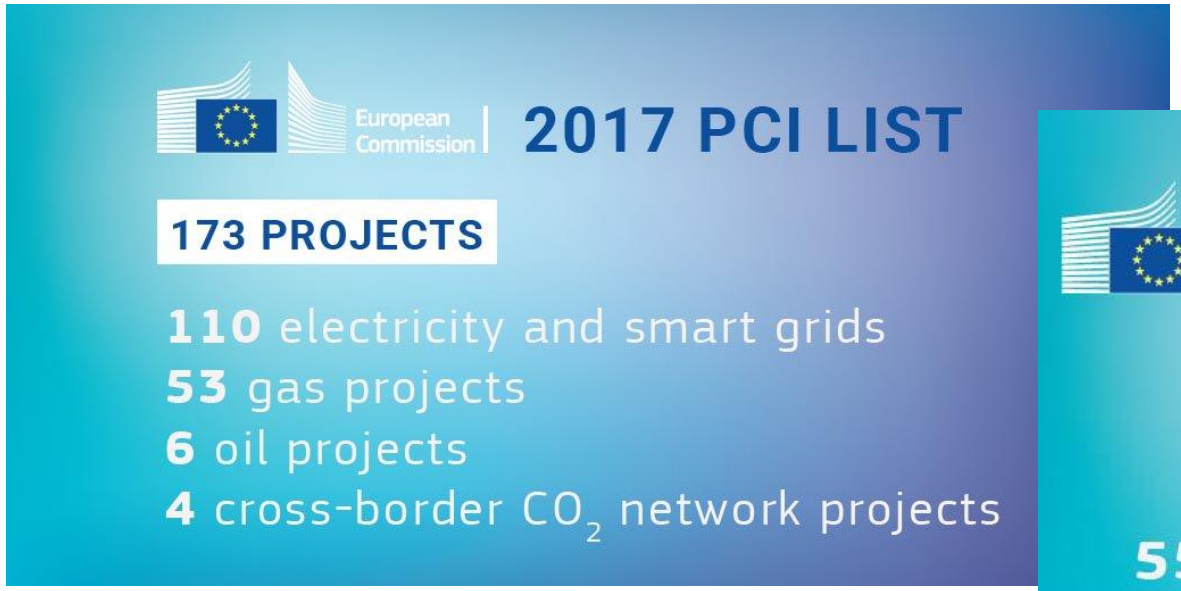
Examples of infrastructures promoted



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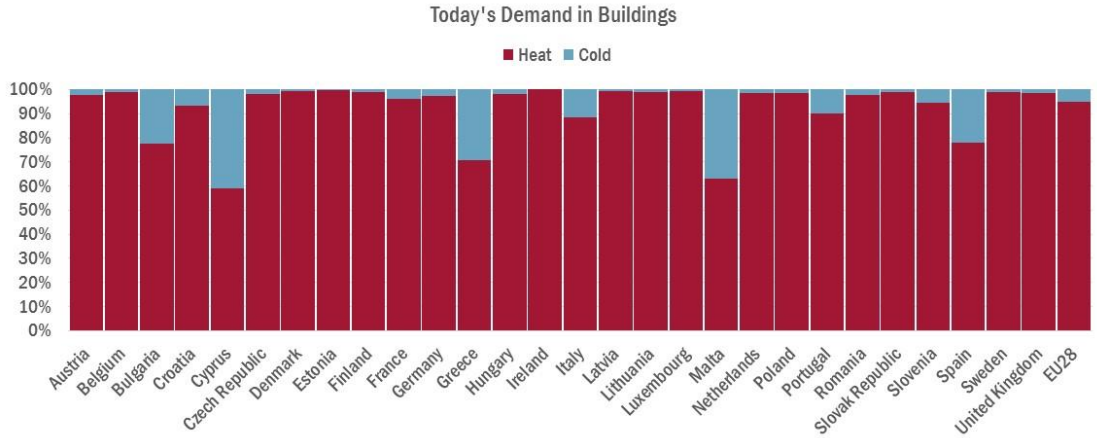
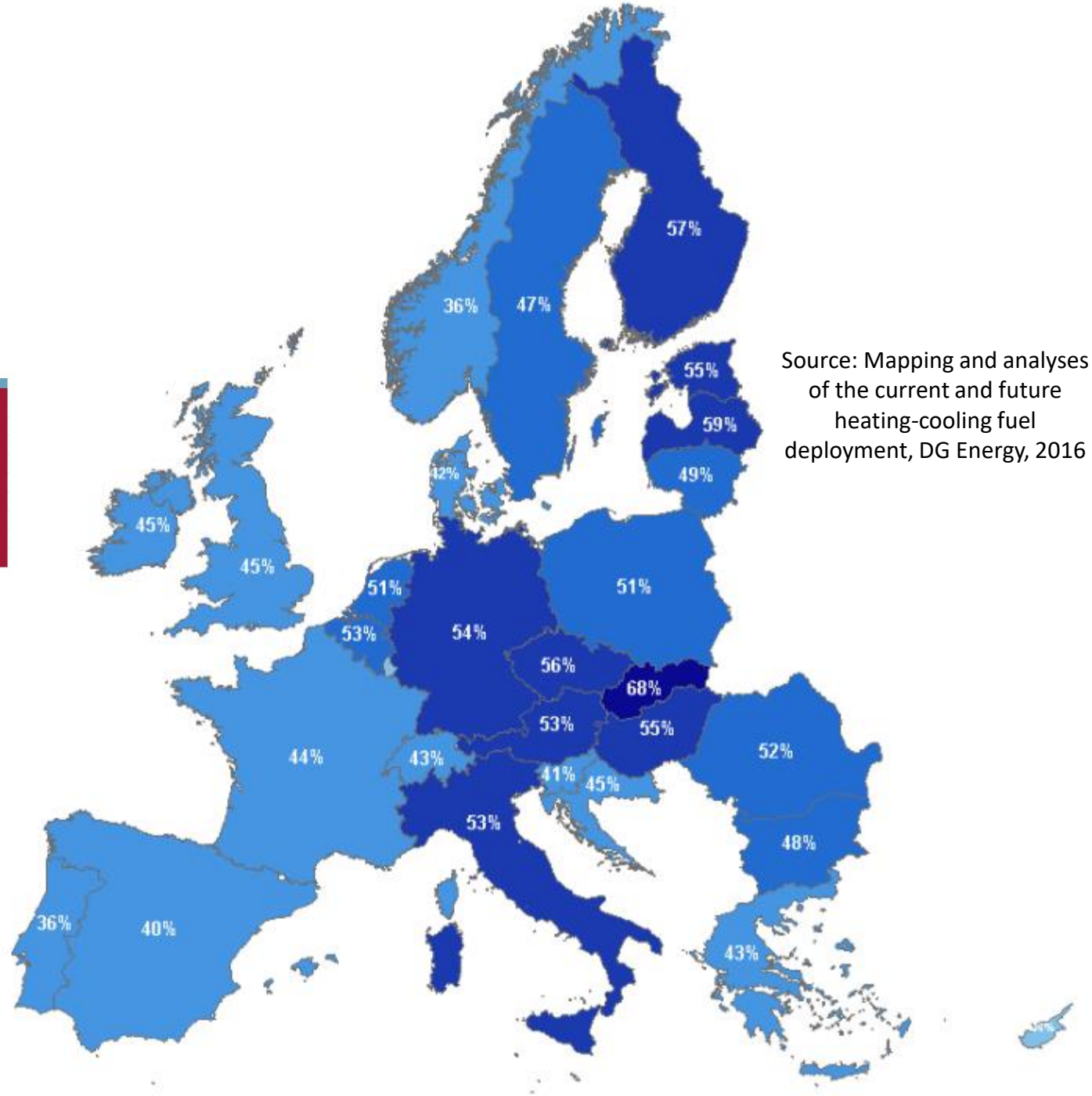
Current share of Heating & Cooling of final energy demand

- Largest Consumption
- Large for All Member States (not just the 'cold' North)





Source: Mapping and analyses of the current and future heating-cooling fuel deployment, DG Energy, 2016

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Who are you?

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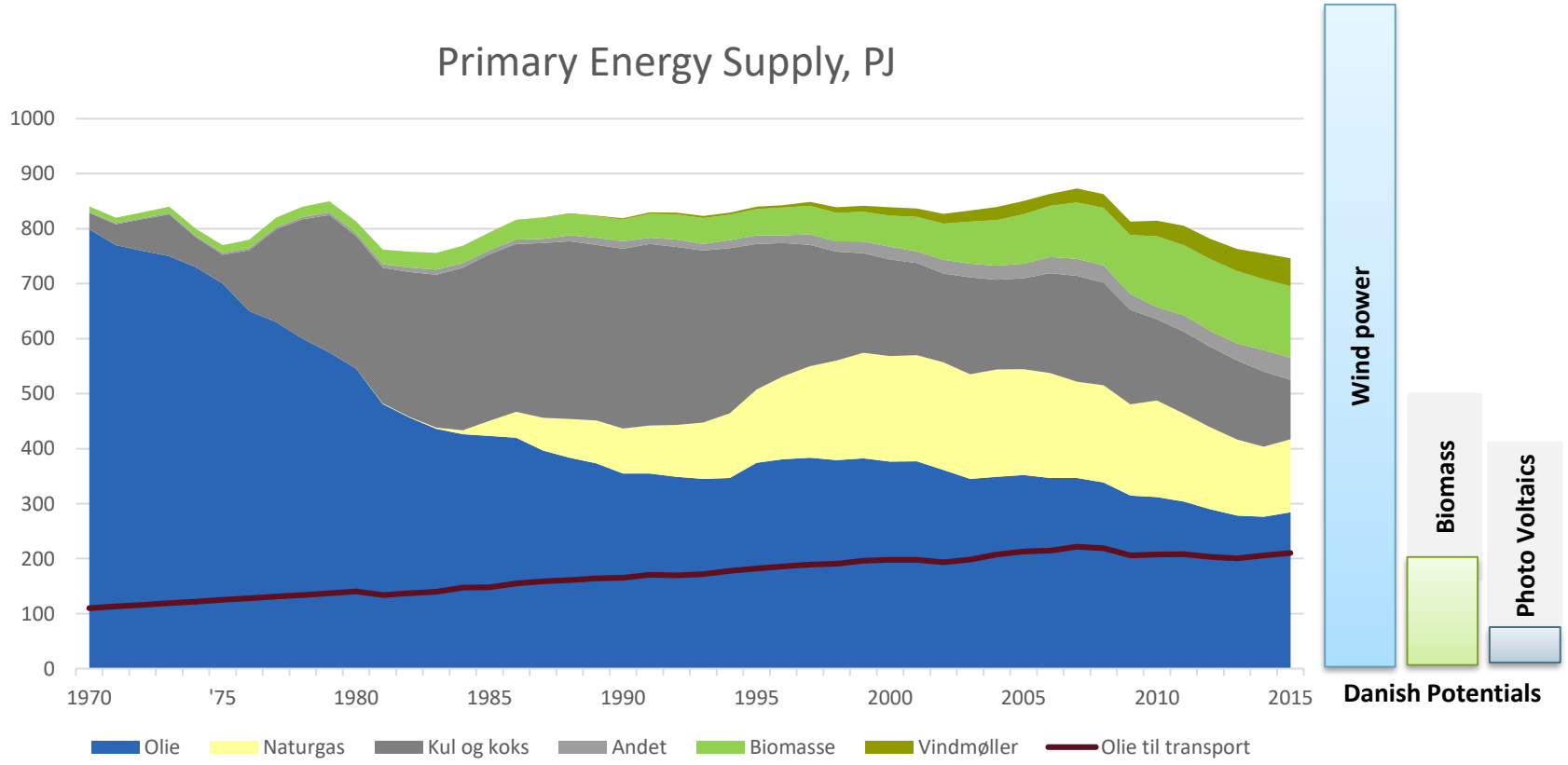
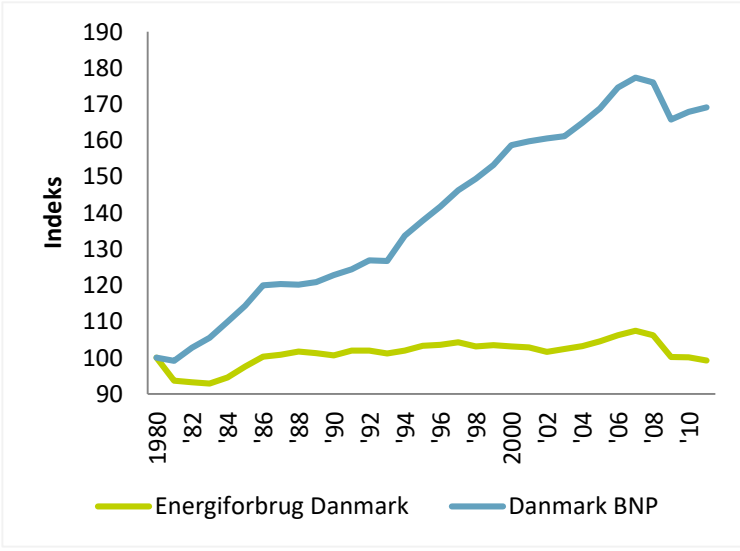
40 YEARS OF ENERGY PLANNING AND MARKET DESIGN

LOW CONSUMPTION
LOW COSTS
SECURITY OF SUPPLY
LOW CO2-EMISSIONS





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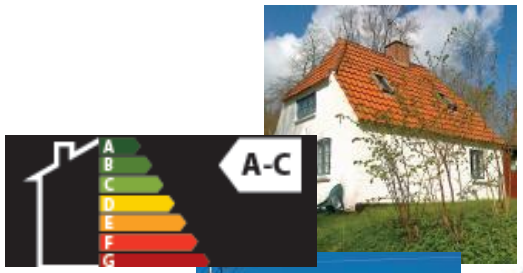
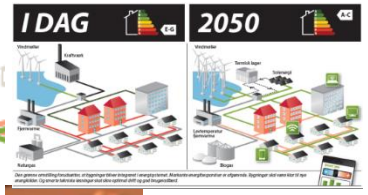
Three focus areas for buildings





Thermal performance of buildings

Building operation and user-behaviour

New energy supply mix

STOP BEFORE PASSIVE HOUSE STANDARDS

FUTURE GREEN BUILDINGS
A KEY TO COST-EFFECTIVE SUSTAINABLE ENERGY SYSTEMS

RENOVERING PÅ DAGSORDENEN

AALBORG UNIVERSITY DENMARK

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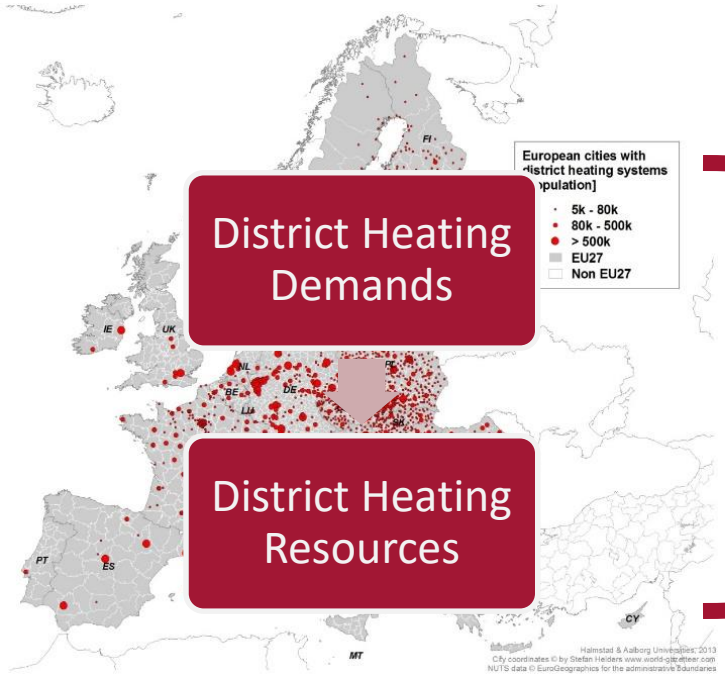
HRE Methodology

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

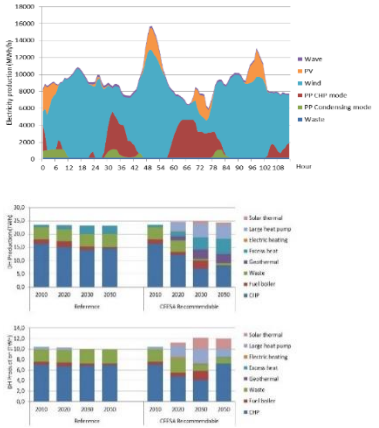
Energy System Modelling
(www.EnergyPLAN.eu)



BAU (References)

District Heating Alternatives

Results (PES, CO2, Costs)



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Heat Roadmap Europe 1, 2, 3, and 4

- Study 1 (2012): will district heating play a role in the decarbonisation of the European energy system?
- Study 2 (2013): what is the balance between heat savings and heat supply at an EU level?
- Study 3 (2015, STRATEGO WP2): low-carbon heating and cooling strategies for 5 member states
- Study 4 (2016-2019): low-carbon heating and cooling strategies for 14 member states

4.
2016-
2019

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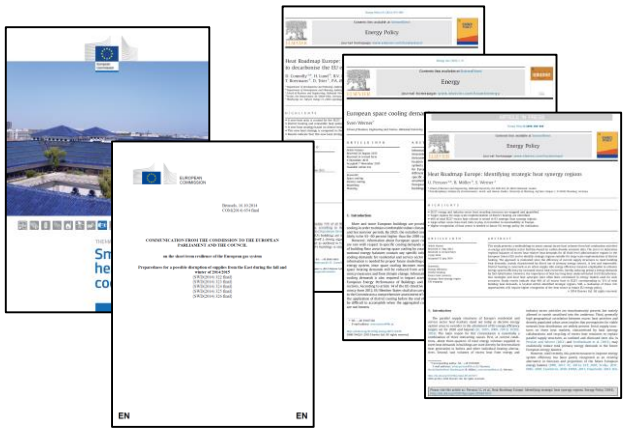
From Research to Implementation in 4DH and Heat Roadmap Europe, Impact at EU Level

(EC: European Commission)

Research: Internal & External to EC



>5 journal articles published with over 100 citations in other peer-reviewed scientific articles since their release in 2014

Short-Term EC Communication

Paul Hodson, who is head of the Energy Efficiency Unit in DG Energy, referred to HRE/STRATEGO as "the most advanced on the EU's heating and cooling sector as a whole"

Long-Term EC Strategy

Referenced >20 times in the EU's first ever Heating and Cooling Strategy, which was launched in 2016

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4DH
4th Generation District Heating Technologies and Systems

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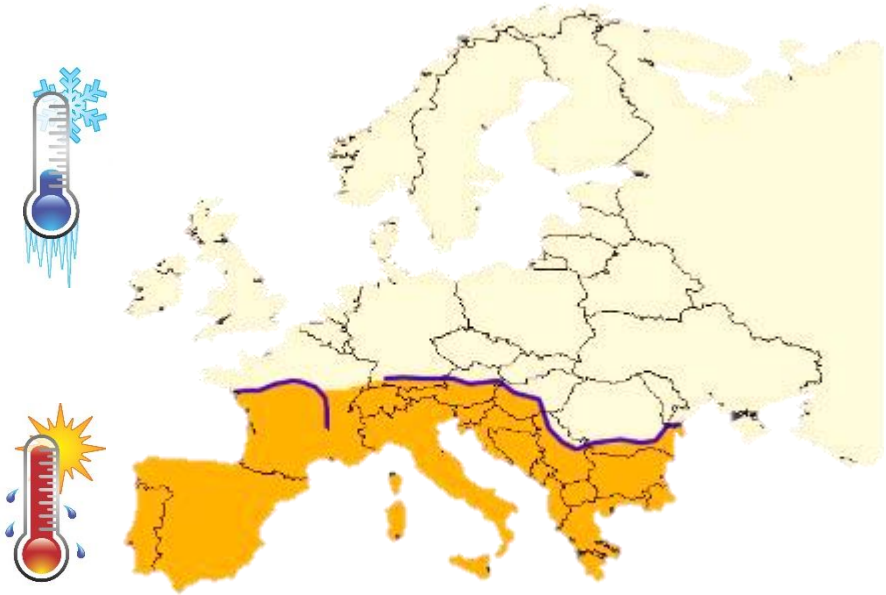
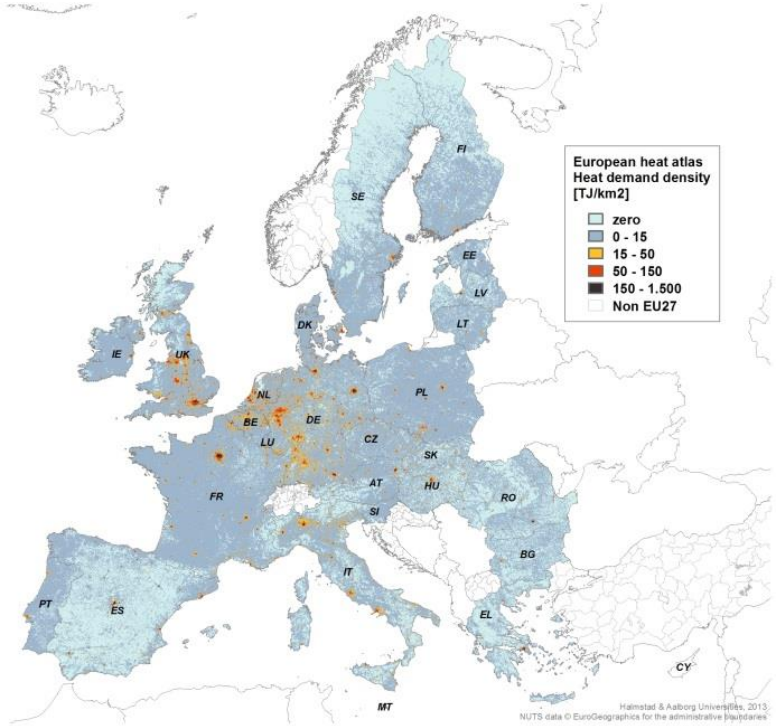
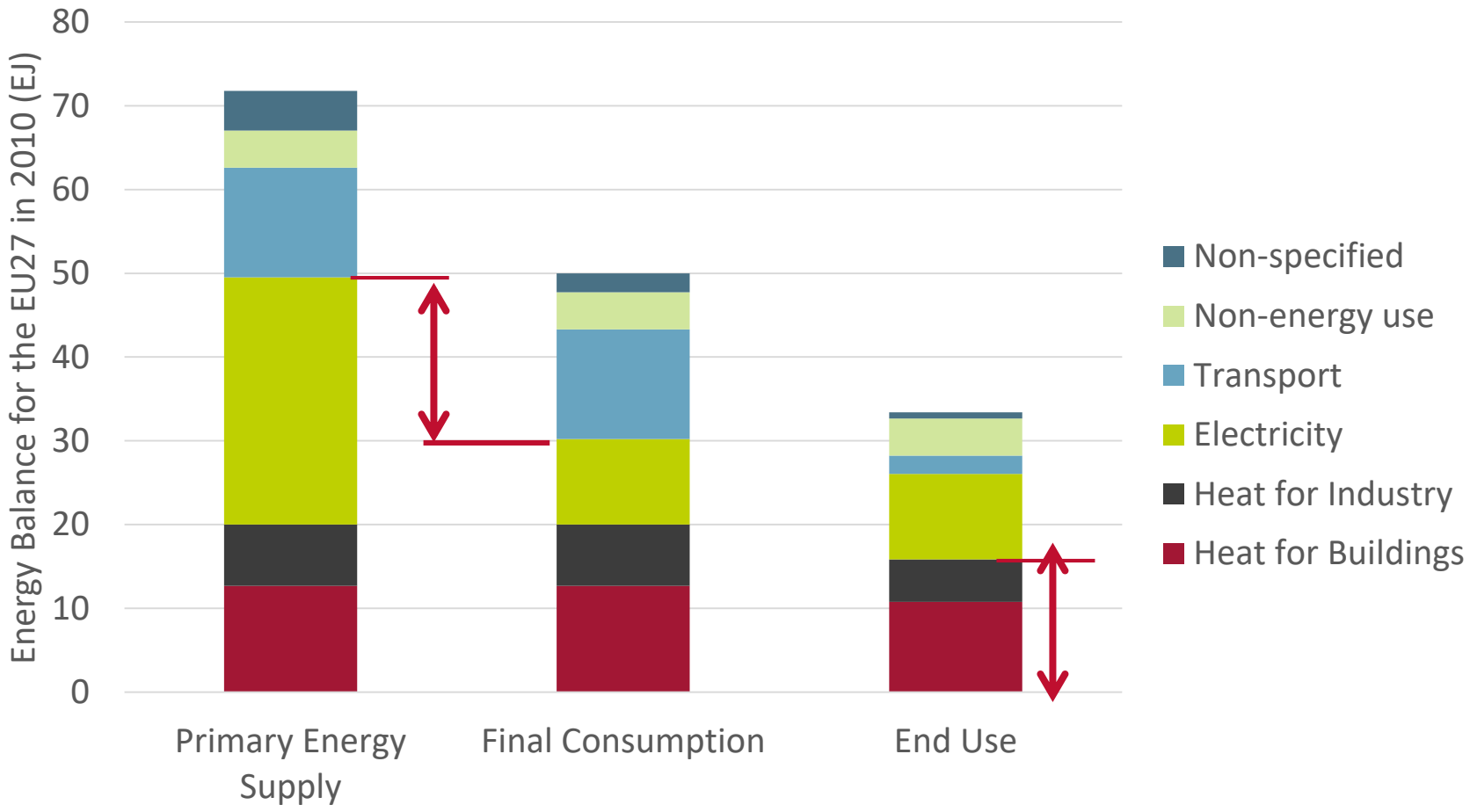
50% of the heat demand in Europe can be supplied with district heating (www.HeatRoadmap.eu)

KEY ROLE FOR CITIES

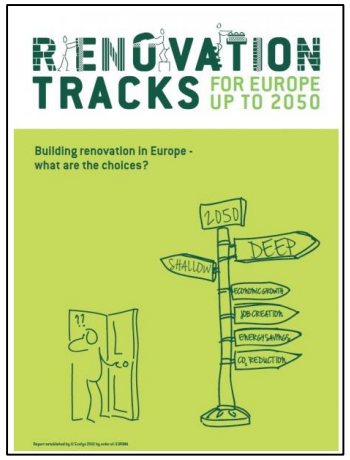


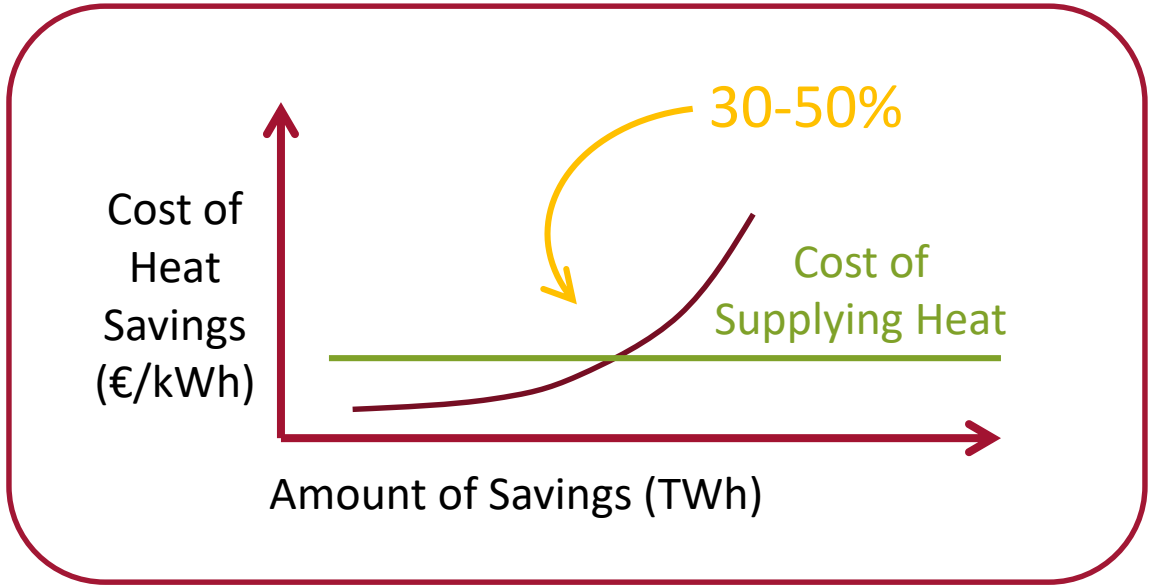


There is more excess heat in Europe than all of the heat demand in buildings

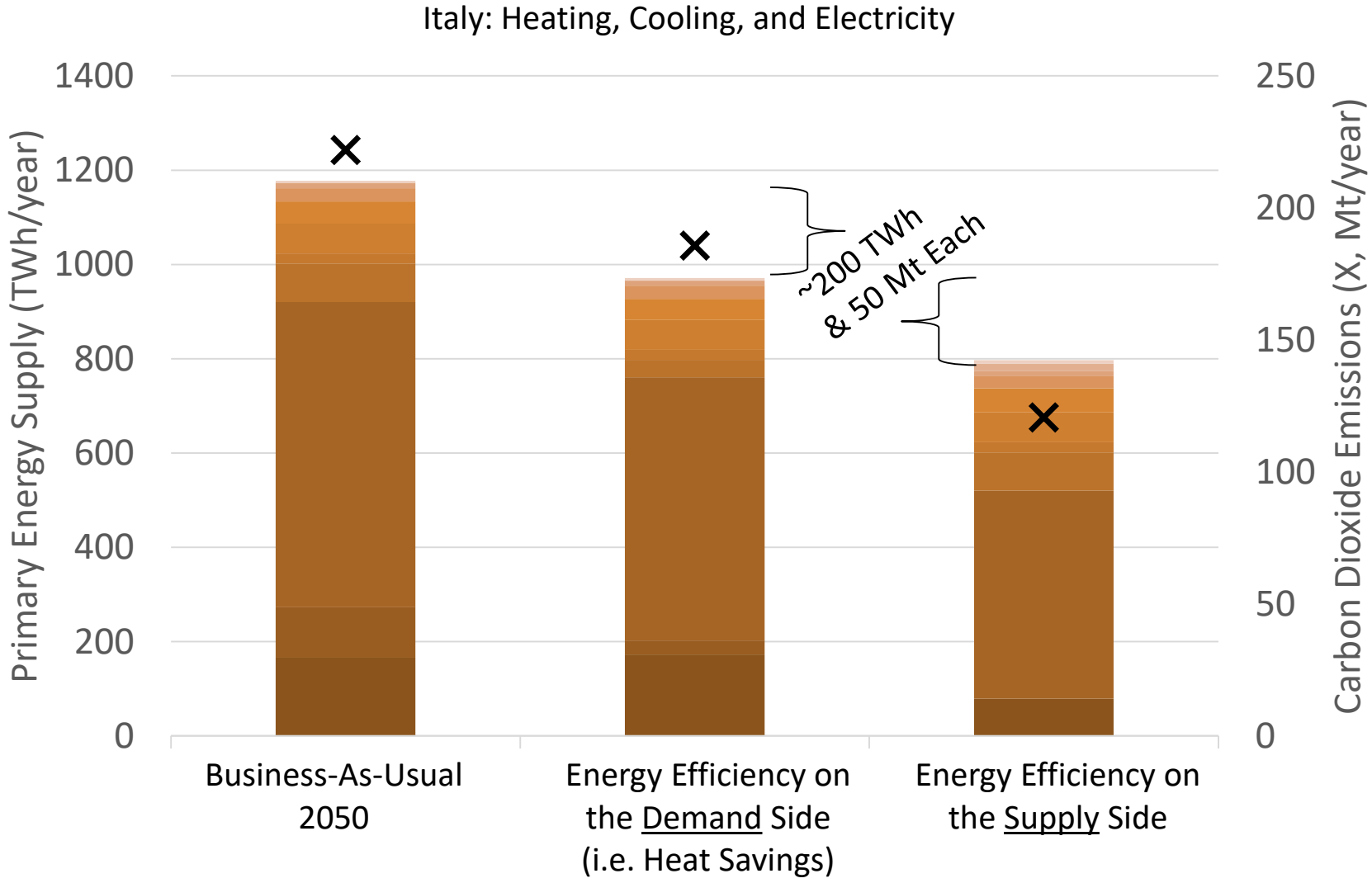


Number 3: Energy efficiency is required on both the demand and supply side of the heat sector

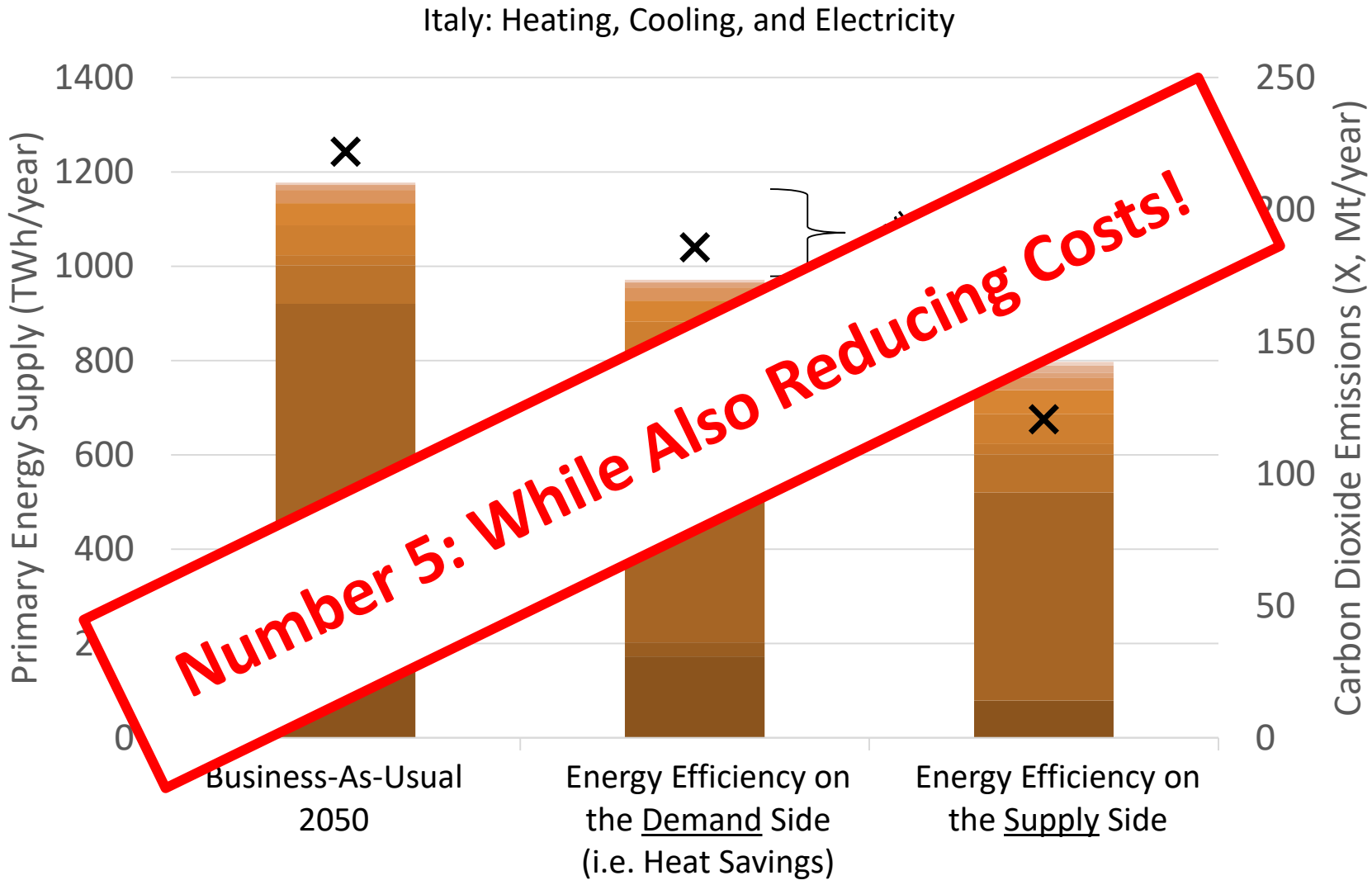




Number 4: Energy Efficiency on Both Sides Can Save Similar Levels of Energy & CO2

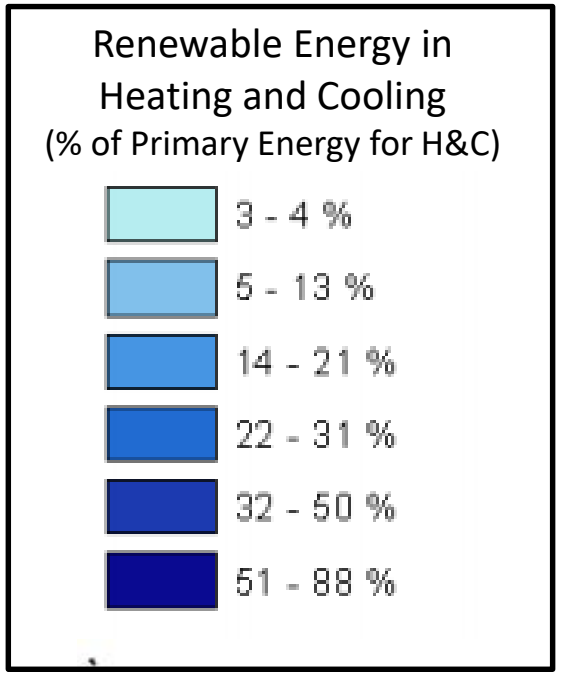


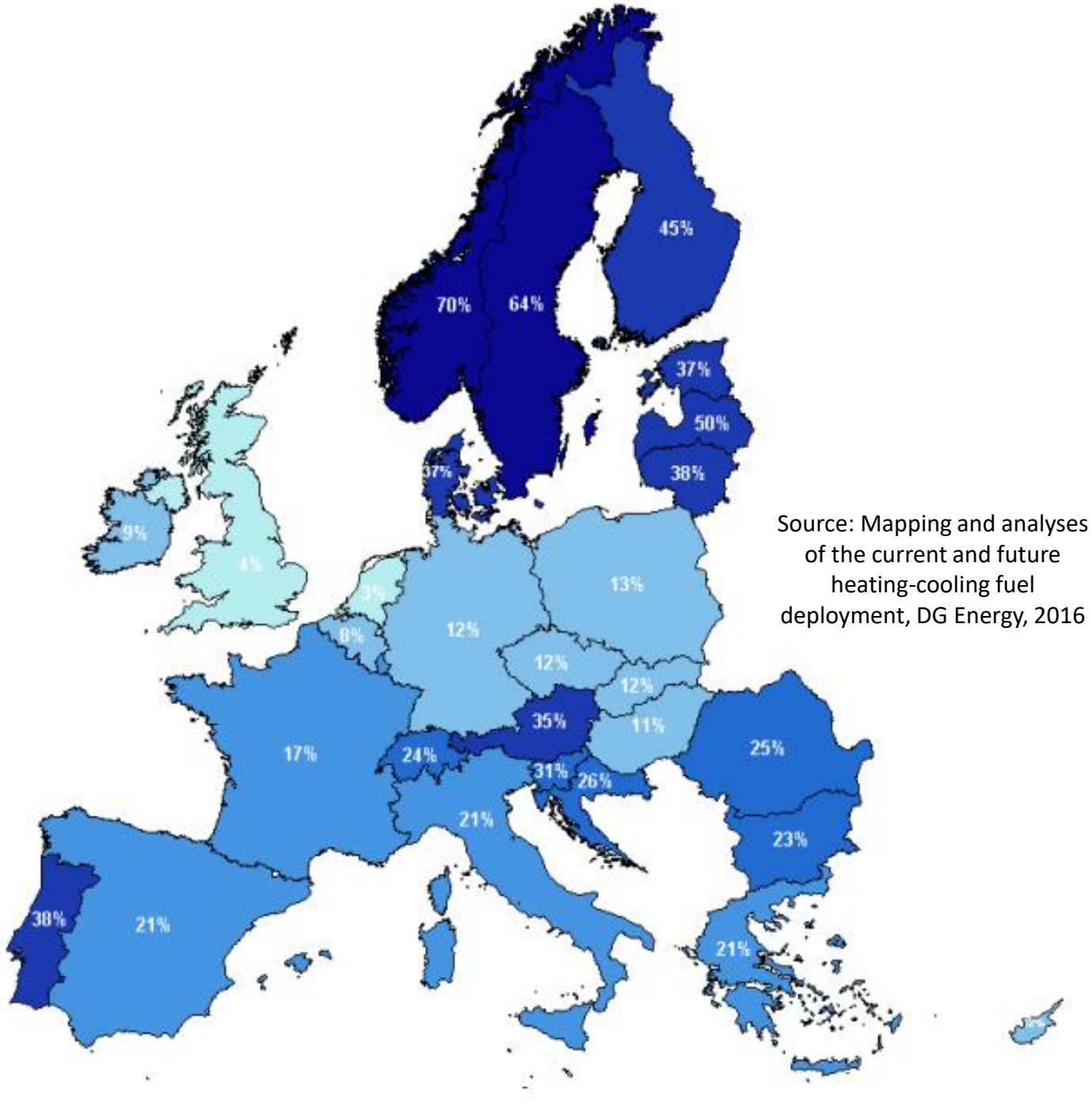
Number 5: Energy Efficiency on Both Sides Can Save Similar Levels of Energy & CO2



KEY ROLE FOR CITIES

Why should we have more district heating?





Source: Mapping and analyses of the current and future heating-cooling fuel deployment, DG Energy, 2016

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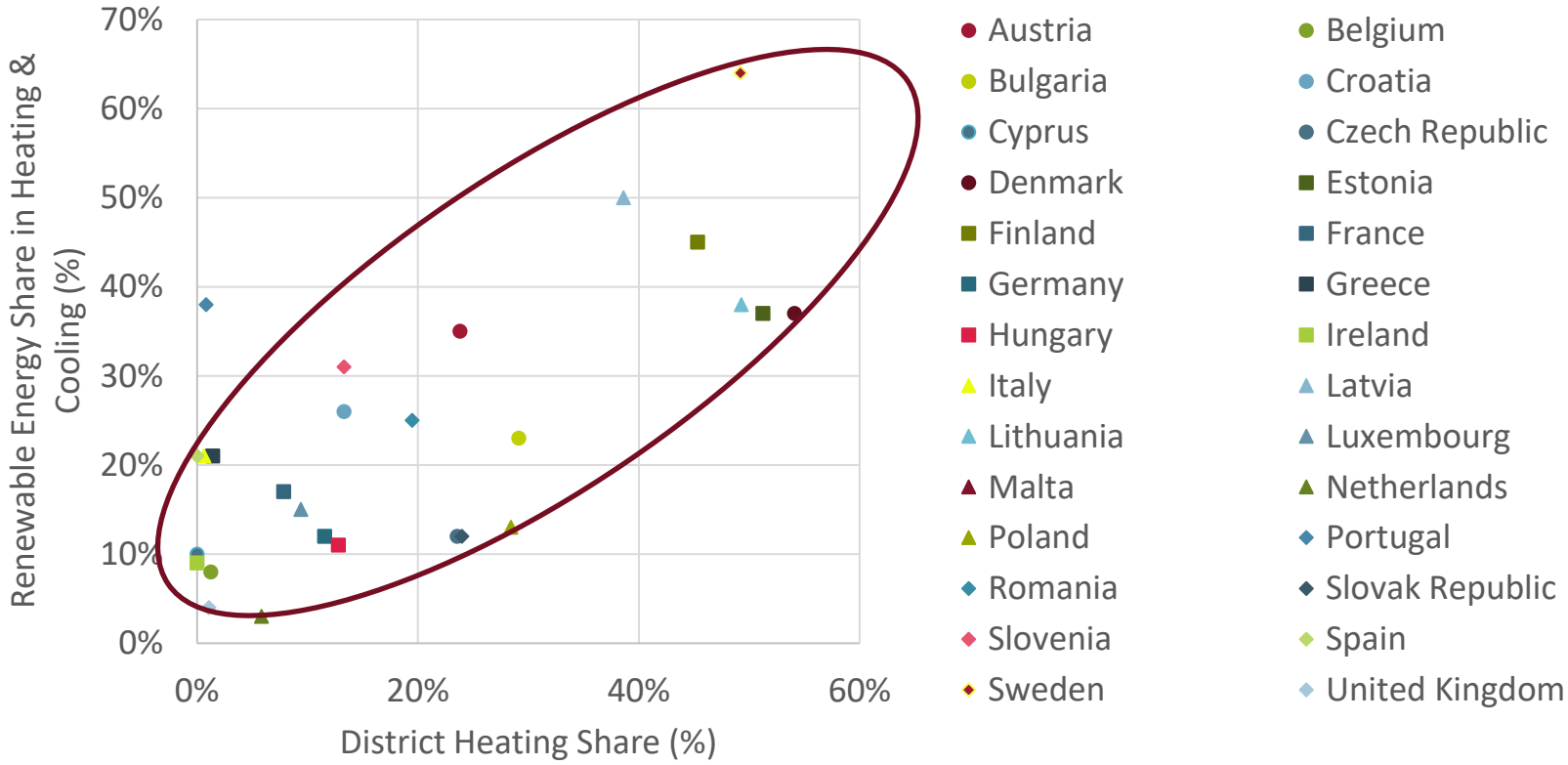
Proven Technology!
Renewable Energy vs. District Heating



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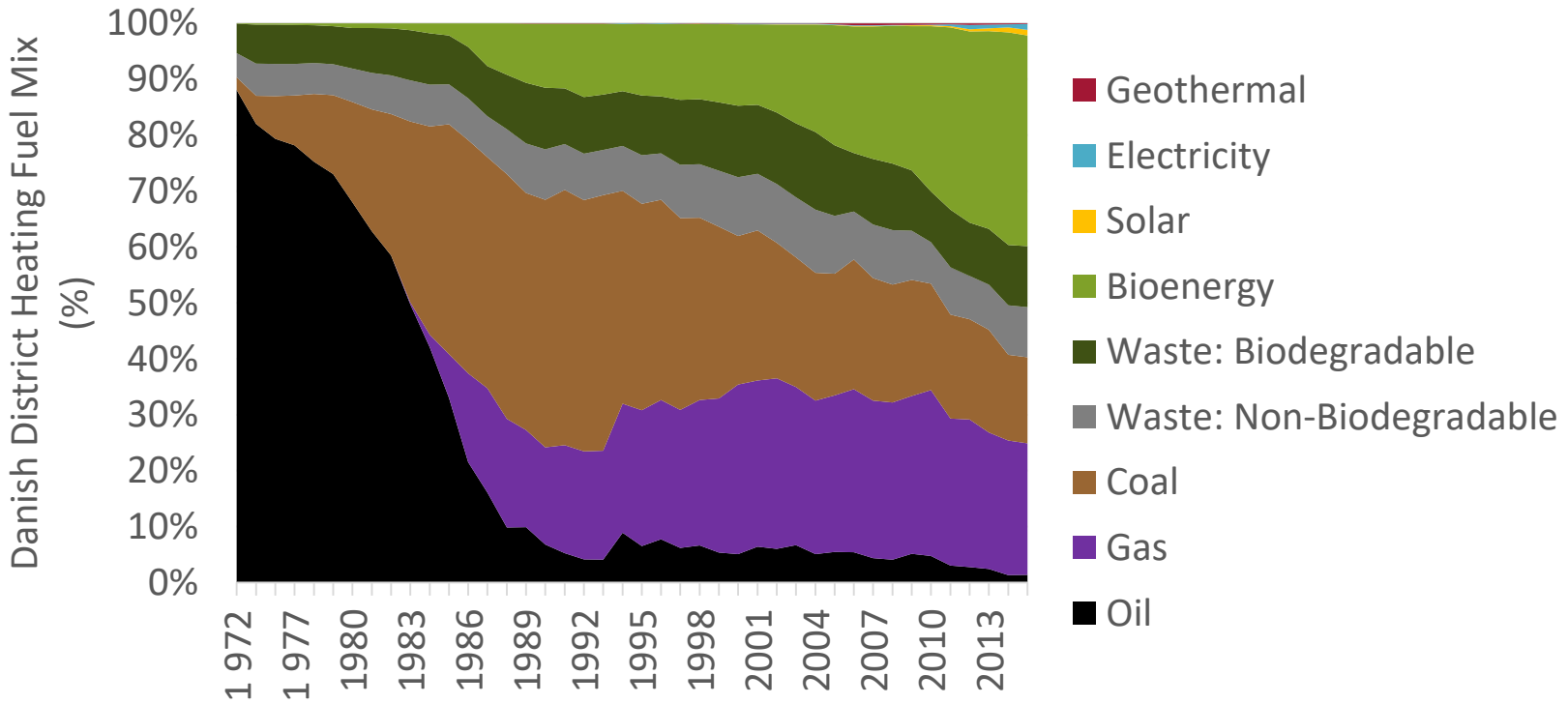
Resources for Danish District Heating1972-2015



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Why isn’t it happening?

- Heating is complex
- Heating is local
- Heating is long term
- Heat savings and district heating have large investment costs
- Heating is cultural, ownership problems and profit margins!

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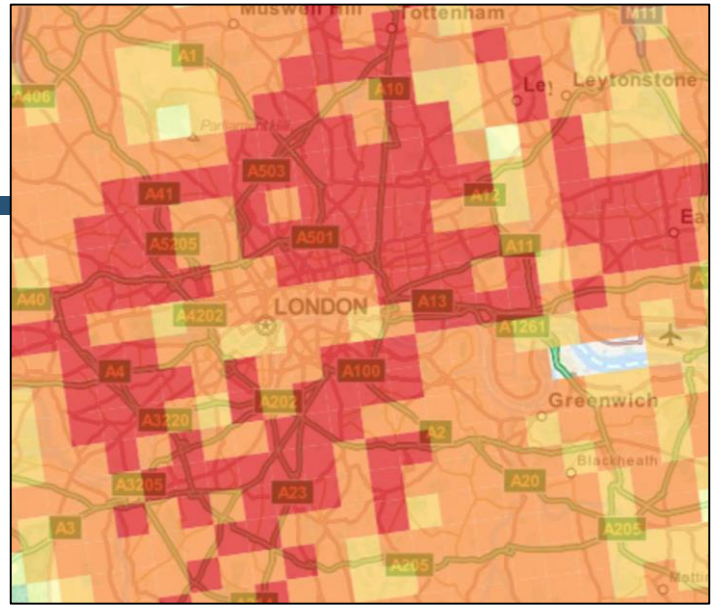
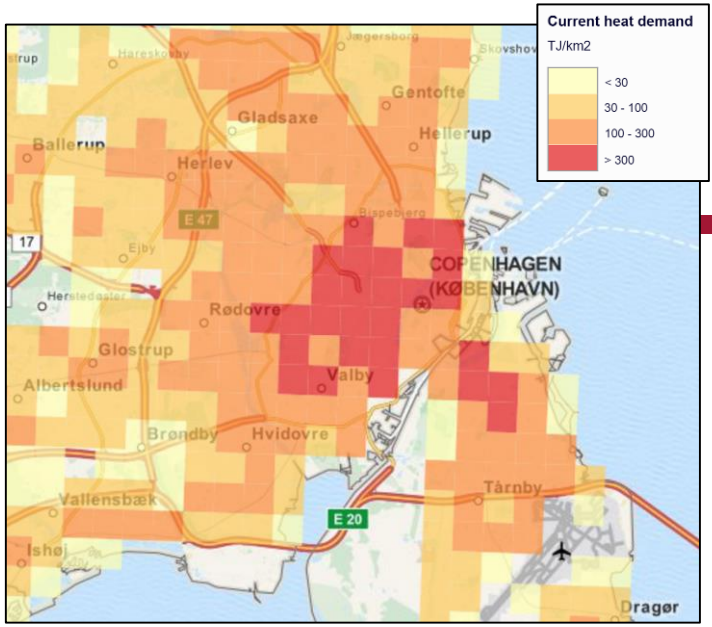
Today's Heat Demand from Peta3 (www.heatroadmap.eu)



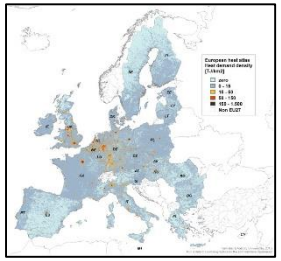
London

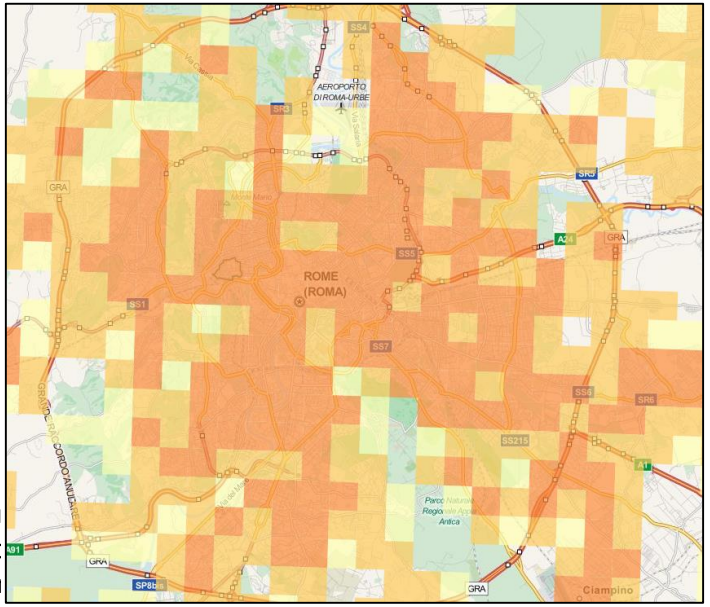
←<5% DH



Copenhagen

>90% DH →





Roma

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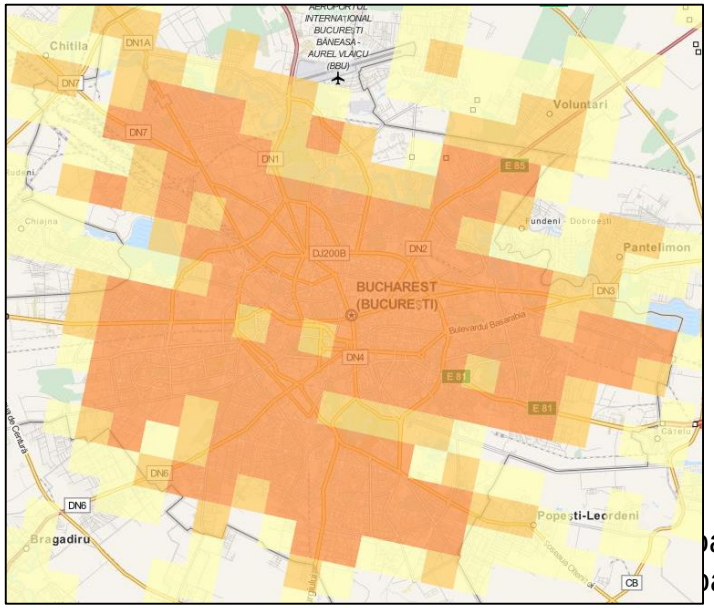

Bucharest

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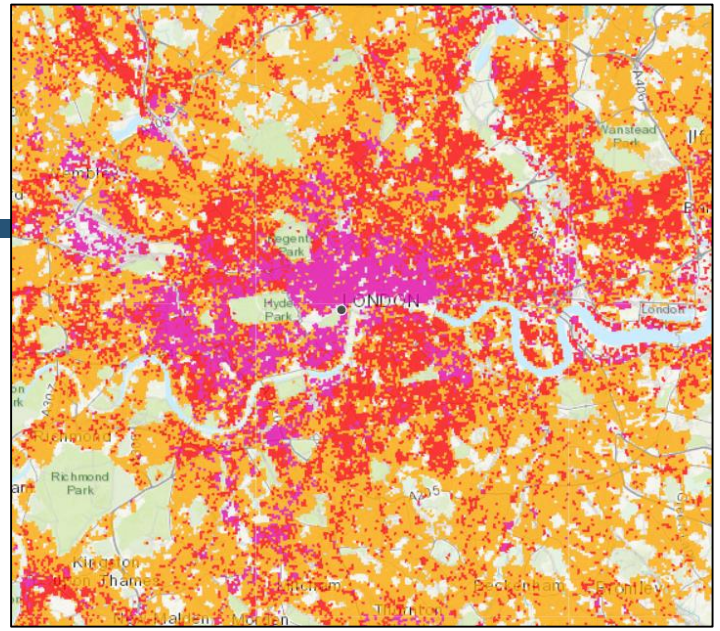
Today's Heat Demand from Peta 4.2 (www.heatroadmap.eu)



London

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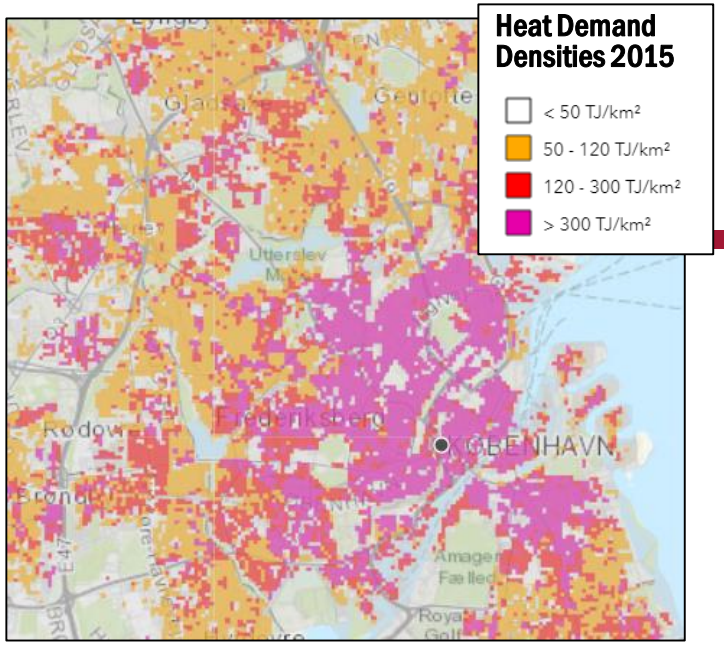
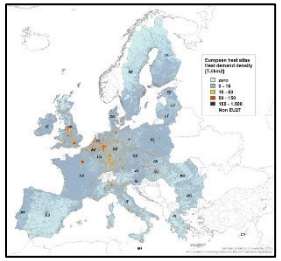
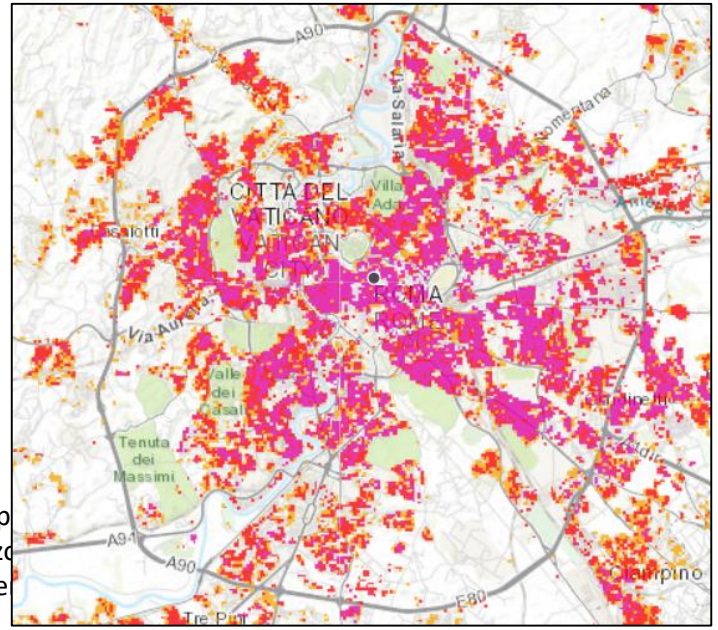


Copenhagen

>90% DH →





Roma

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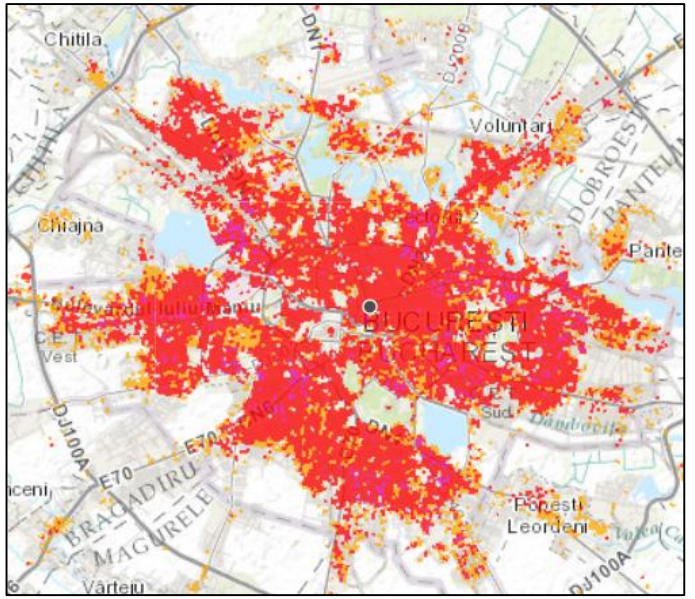

Bucharest

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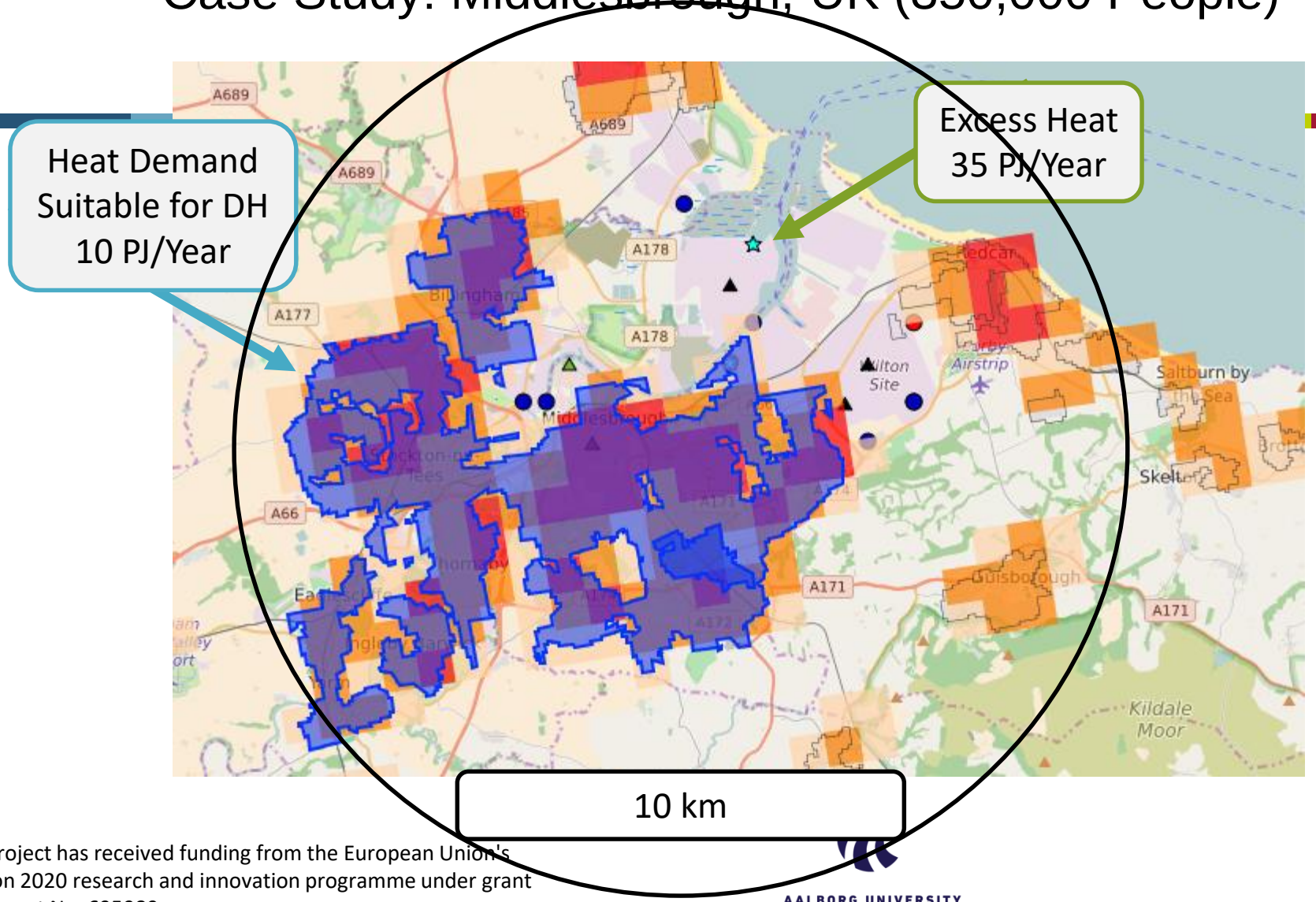
WP2: Pan-European Thermal Atlas: www.heatroadmap.eu

Case Study: Middlesbrough, UK (350,000 People)



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AALBORG UNIVERSITY
DENMARK

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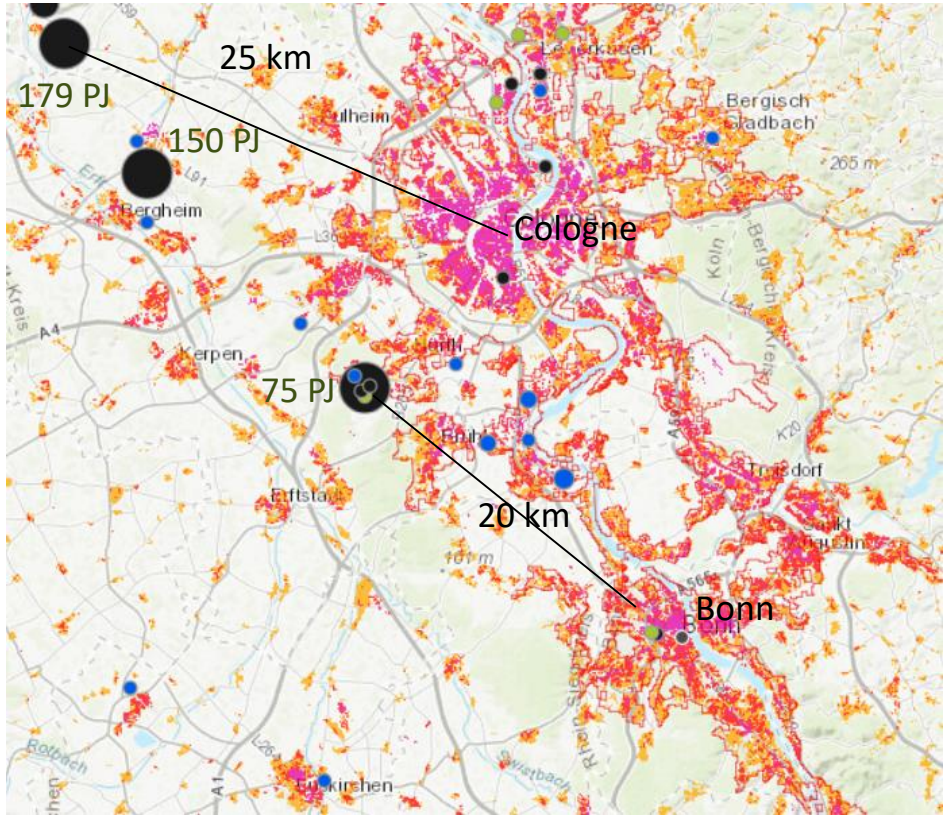
Bonn-Cologne

- **Population**:
  1.76 million
- **Area**:
  511 km^2
- **Total Heat Demand (HD)**:
  64 PJ
  - HD in density > 300 TJ/km^2: 26 PJ
  - HD in density 120-300 TJ/km^2: 24 PJ
- **Biomass resourses in the region:**
  - Forest residues: 1 PJ
  - Biowaste: 3 PJ
  - Straw: 2 PJ
- **Estimated excess heat**:
  > 450 PJ



Heat Demand Densities 2015 [PETA 4.2]

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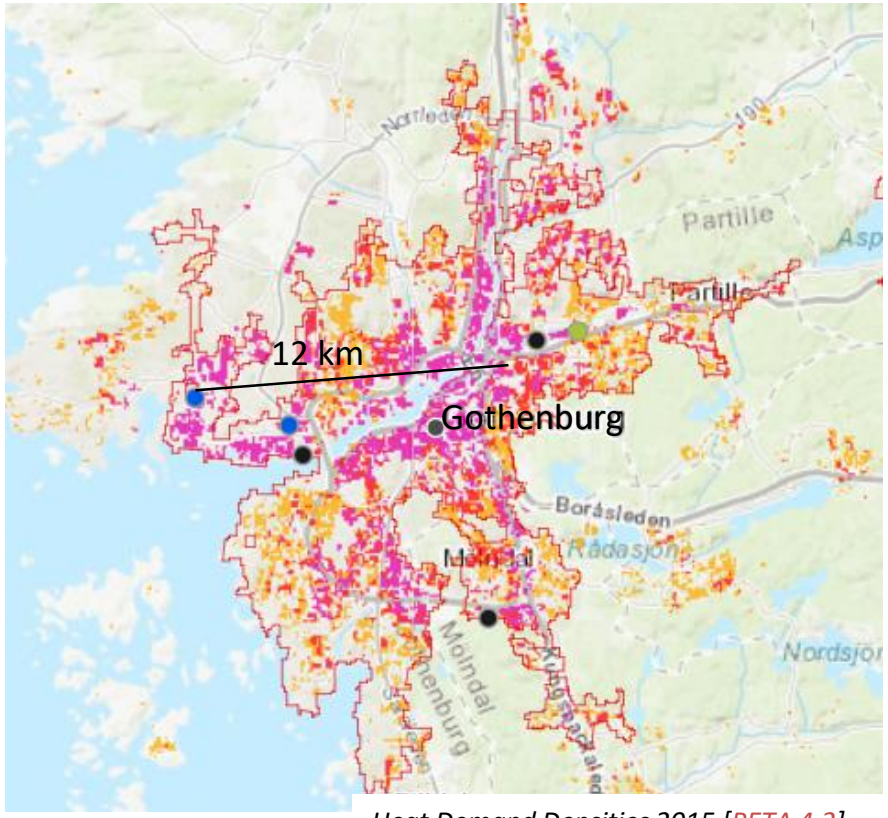
Gothenburg

- **Population**:
  520 thousands
- **Area**:
  188 km^2
- **Total Heat Demand (HD)**:
  23 PJ
  - HD in density > 300 TJ/km^2: 15 PJ
  - HD in density 120-300 TJ/km^2: 5 PJ
- **Biomass resourses in the region:**
  - Forest residues: 12 PJ
  - Biowaste: 1 PJ
  - Straw: 1 PJ
- **Estimated excess heat**:
  13 PJ



Heat Demand Densities 2015 [PETA 4.2]

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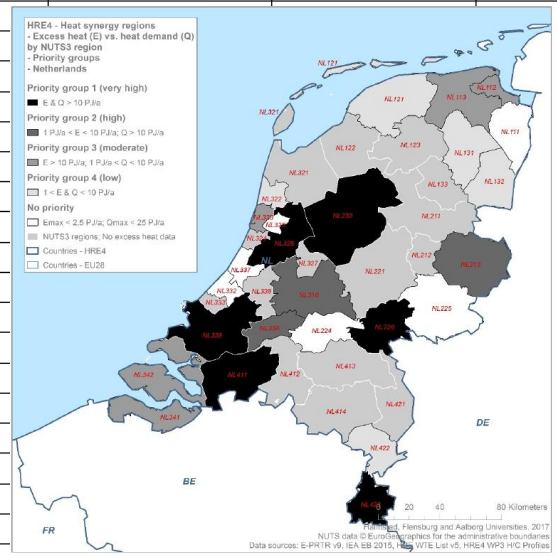
Heat synergies map in PETA4 example: Netherlands

- Heat demands: 296 PJ/y
- Excess heat: 560 PJ/y
- District heating share: 5%
- Renewable energy in heating: 3%

- Not a Technical barrier to improve energy efficiency

NUTS3 Regions	Heat demand [PJ/a]	Excess heat [PJ/a]	Excess heat ratio [-]
NL111	3.83	0.20	0.05
NL112	1.22	11.32	9.28
NL113			1.75
NL121			0.25
NL131			0.92
NL132			0.55
NL213			0.48
NL224			0.08
NL225			0.09
NL226			1.40
NL230			0.99
NL310			0.12
NL322			1.16
NL323			12.27
NL325			0.05
NL326			1.05
NL332			0.05
NL337			0.09
NL339			5.06
NL33A			0.39
NL341	2.62	32.46	12.41
NL342	6.82	32.59	4.78
NL411	15.57	73.27	4.71
NL422	5.96	8.10	1.36
NL423	15.28	39.67	2.60
Grand Total	**295.84**	**559.23**	**1.89**



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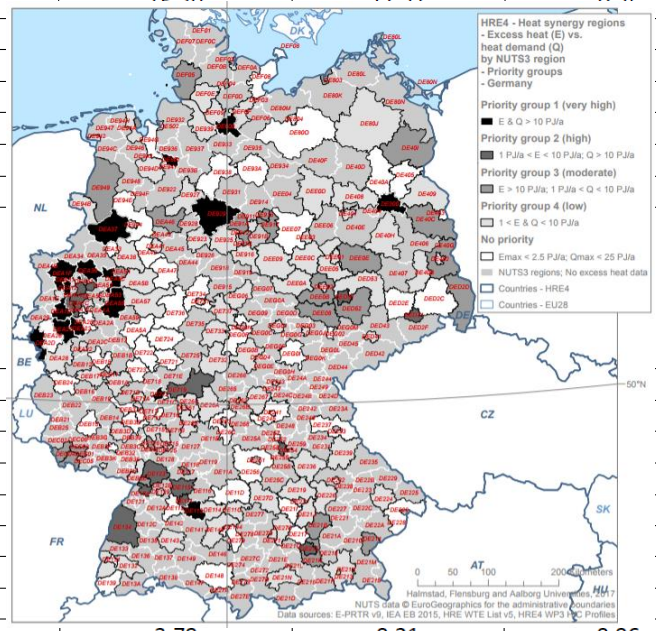
Heat synergies map in PETA4 example: Germany

- Heat demands: 1,529 PJ/y
- Excess heat: 2,470 PJ/y
- District heating share: 12%
- Renewable energy in heating: 12%

- Not a Technical barrier to improve energy efficiency

NUTS3 Regions	Heat demand [PJ/a]	Excess heat [PJ/a]	Excess heat ratio [-]
DE111	18.22	5.33	0.29
DE112	11.10	0.92	0.08
DE113			
DE114			
DE115			
DE117			
DE11C			
DE11D			
DE122			
…			
DEF0E			
DEF0F			
DEG01			
DEG02			
DEG03			
DEG06			
DEG0B			
DEG0I			
DEG0P	3.79	0.21	0.06
Grand Total	**1529.35**	**2469.48**	**1.61**



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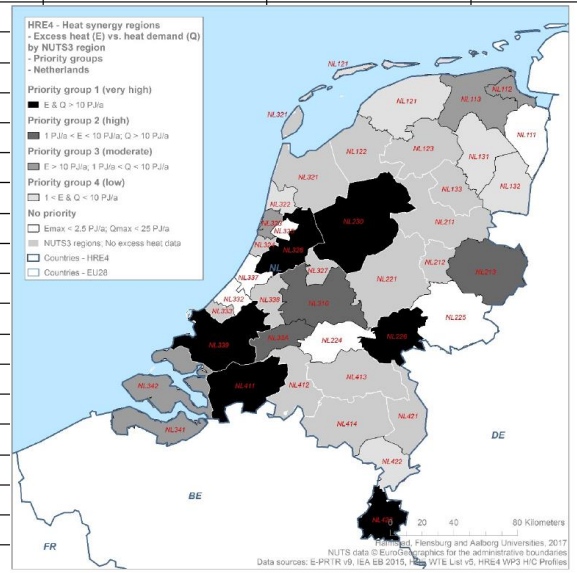
Heat synergies map in PETA4 example: Netherlands

- Heat demands: 296 PJ/y
- Excess heat: 560 PJ/y
- District heating share: 6%
- Renewable energy in heating: 3%

- Not a Technical barrier to improve energy efficiency

NUTS3 Regions	Heat demand [PJ/a]	Excess heat [PJ/a]	Excess heat ratio [-]
NL111	3.83	0.20	0.05
NL112	1.22	11.32	9.28
NL113	9.90	17.30	1.75
NL121			25
NL131			92
NL132			55
NL213			48
NL224			08
NL225			09
NL226			40
NL230			99
NL310			12
NL322			16
NL323			.27
NL325			05
NL326			05
NL332			05
NL337			09
NL339			06
NL33A			39
NL341			.41
NL342			78
NL411	15.57	73.27	4.71
NL422	5.96	8.10	1.36
NL423	15.28	39.67	2.60
Grand Total	**295.84**	**559.23**	**1.89**



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 695989.

Access to More Sustainable Resources: These Can Only Be Used with District Heating

- Excess heat from Power Plants
- Industrial Excess Heat
- Waste Incineration
- Bio-refinary Excess Heat
- Synthetic fuel Excess Heat (electrofuels)
- Large-Scale Solar Thermal
- Geothermal
- Large-Scale Heat Pumps (new study out)
- Large-Scale Electric Boilers
- Bioenergy for Urban Heating

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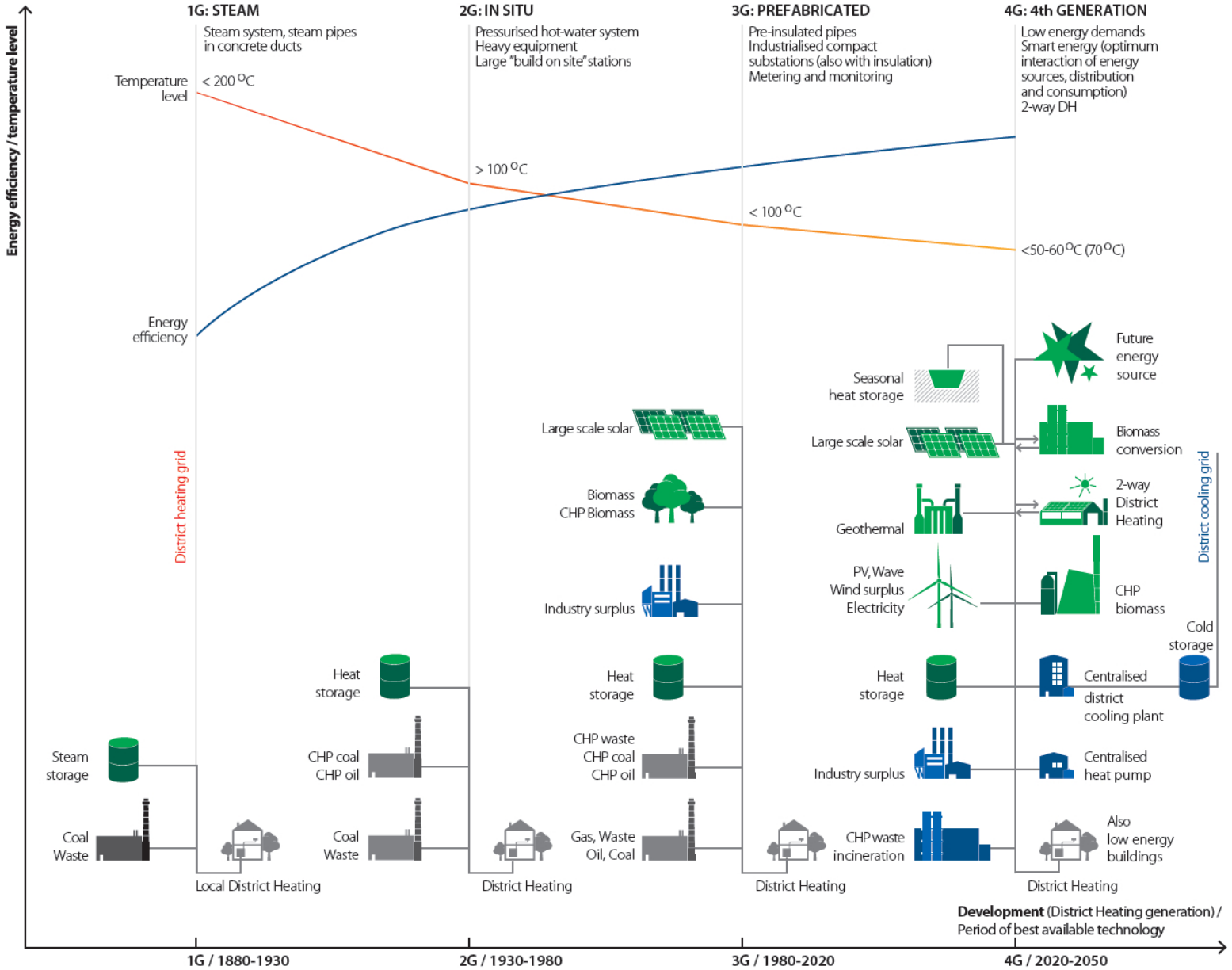
4DH
4th Generation District Heating Technologies and Systems

- Coherent concept
- Low energy demands
- Low distribution temperatures
- Recycle and use new, renewable sources of heat
- Interactions with integrated smart energy systems (mainly through thermal storage)
- Ensure strategic planning to transform to future sustainable energy systems



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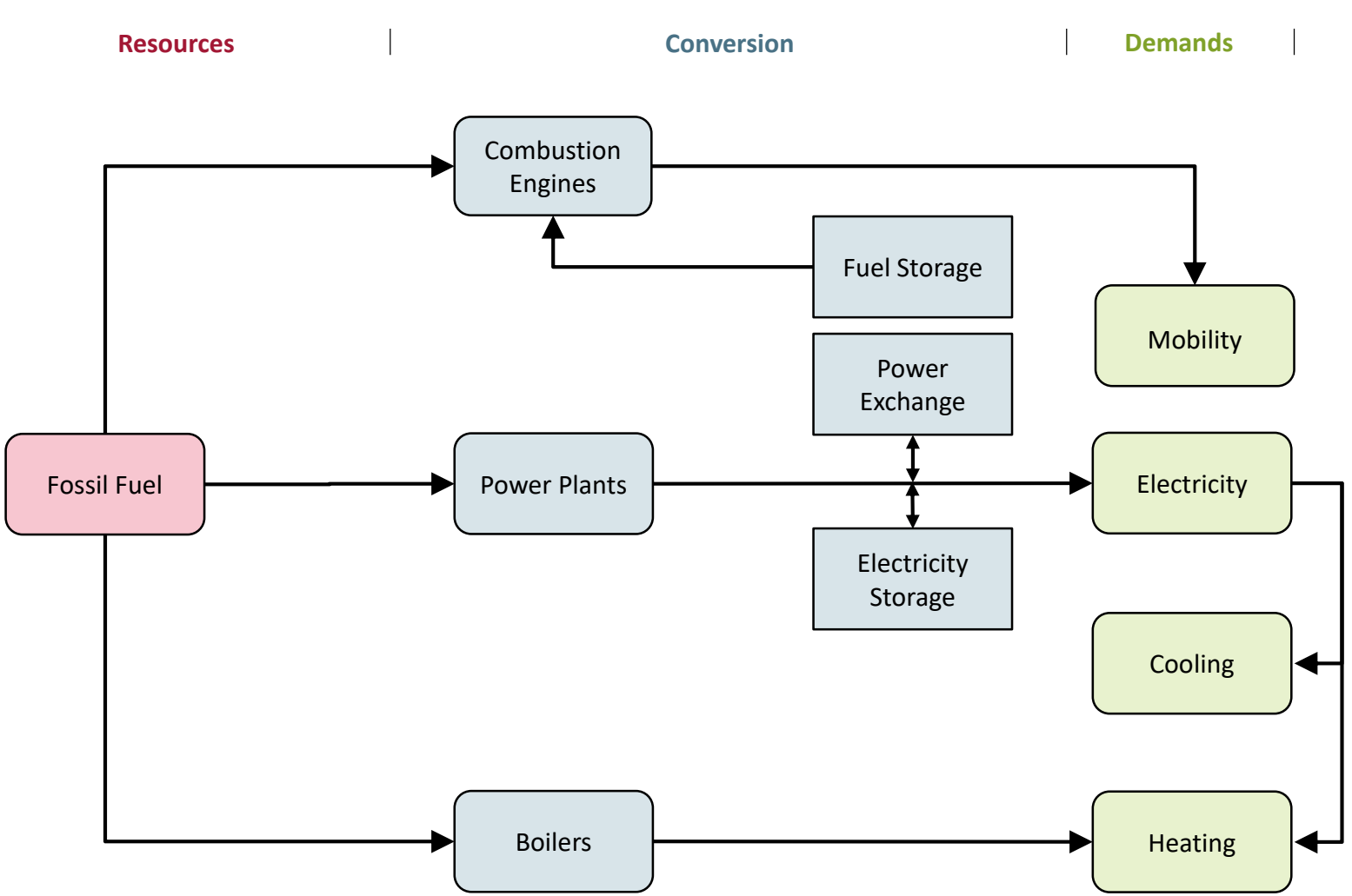
Today's Energy System



Smart Energy System

(www.SmartEnergySystem.eu)

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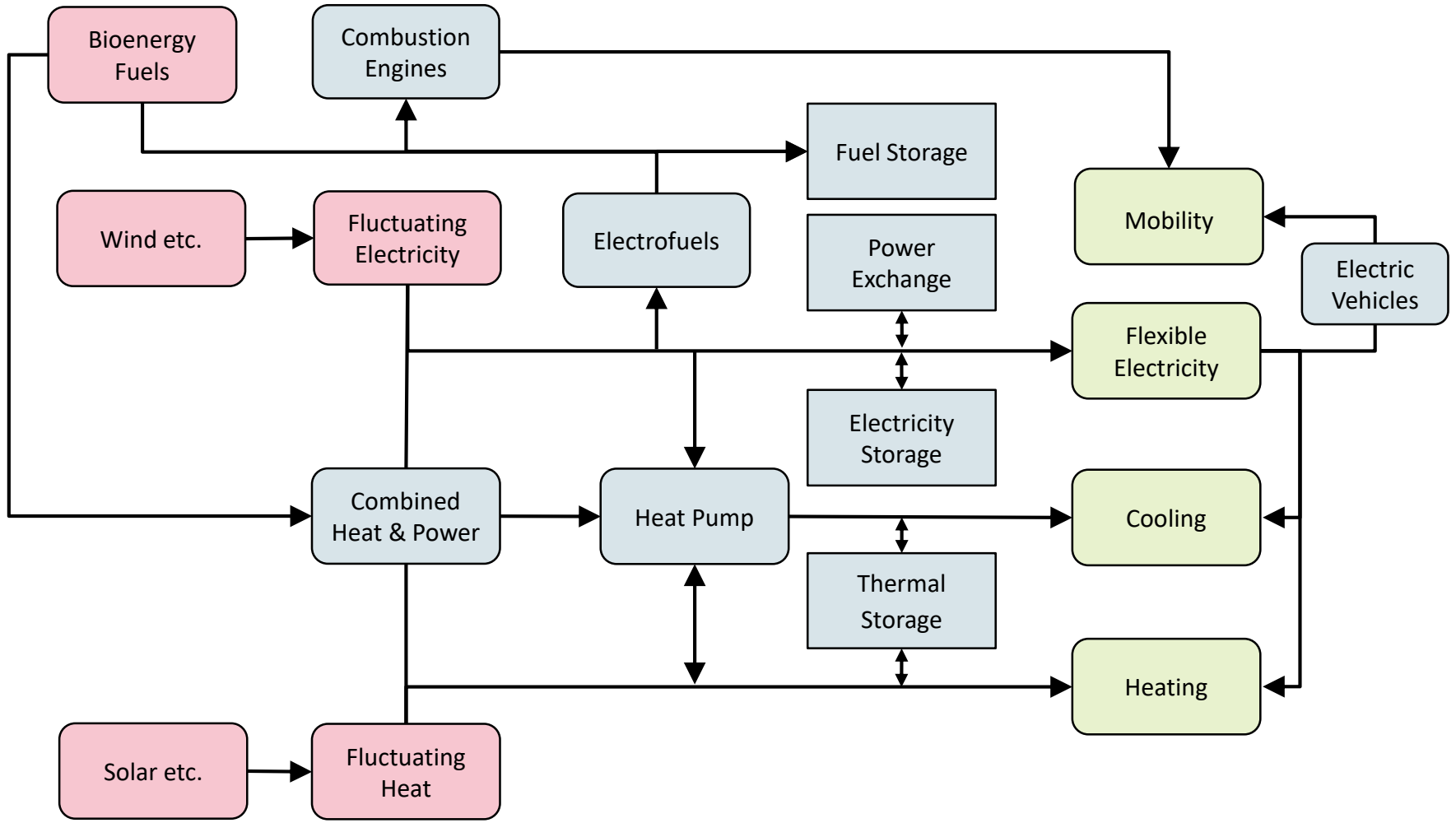
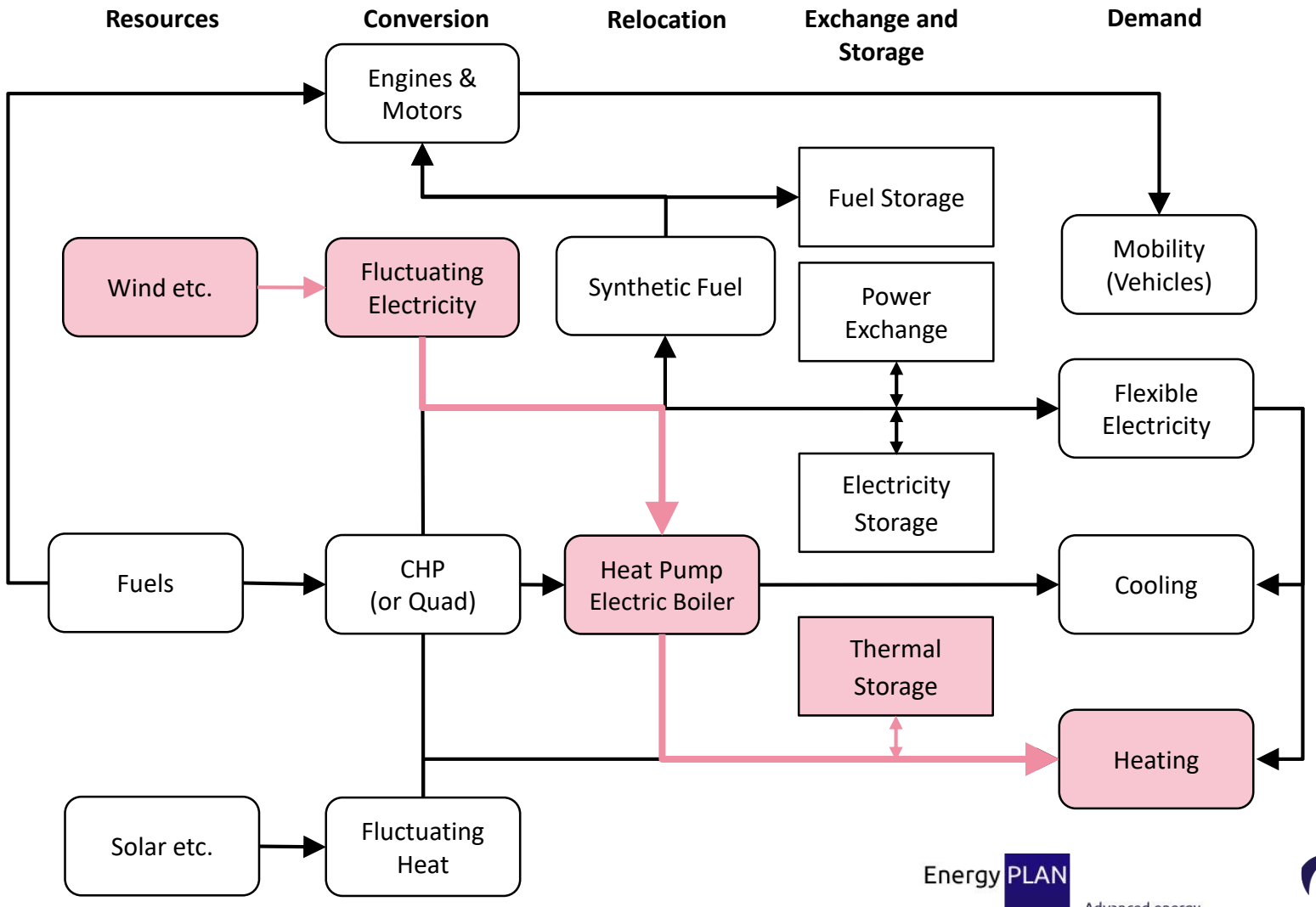


Integrating Wind Power with Thermal Storage (~€1-3/kWh) is much cheaper than Electricity Storage (~€125/kWh)



Energy PLAN
Advanced energy system analysis computer model

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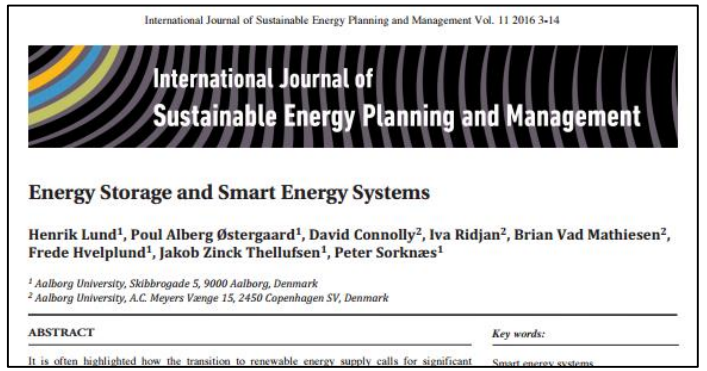
Unit Investment Costs for Energy Storage


International Journal of Sustainable Energy Planning and Management Vol. 11 2016 3-14

International Journal of Sustainable Energy Planning and Management

Energy Storage and Smart Energy Systems

Henrik Lund[1], Poul Alberg Østergaard[1], David Connolly[2], Iva Ridjan[2], Brian Vad Mathiesen[2], Frede Hvelplund[1], Jakob Zinck Thellufsen[1], Peter Sorknæs[1]

[1] Aalborg University, Skibbrogade 5, 9000 Aalborg, Denmark
[2] Aalborg University, A.C. Meyers Vænge 15, 2450 Copenhagen SV, Denmark

ABSTRACT

Key words:

Smart energy systems

Electricity

Thermal

This p
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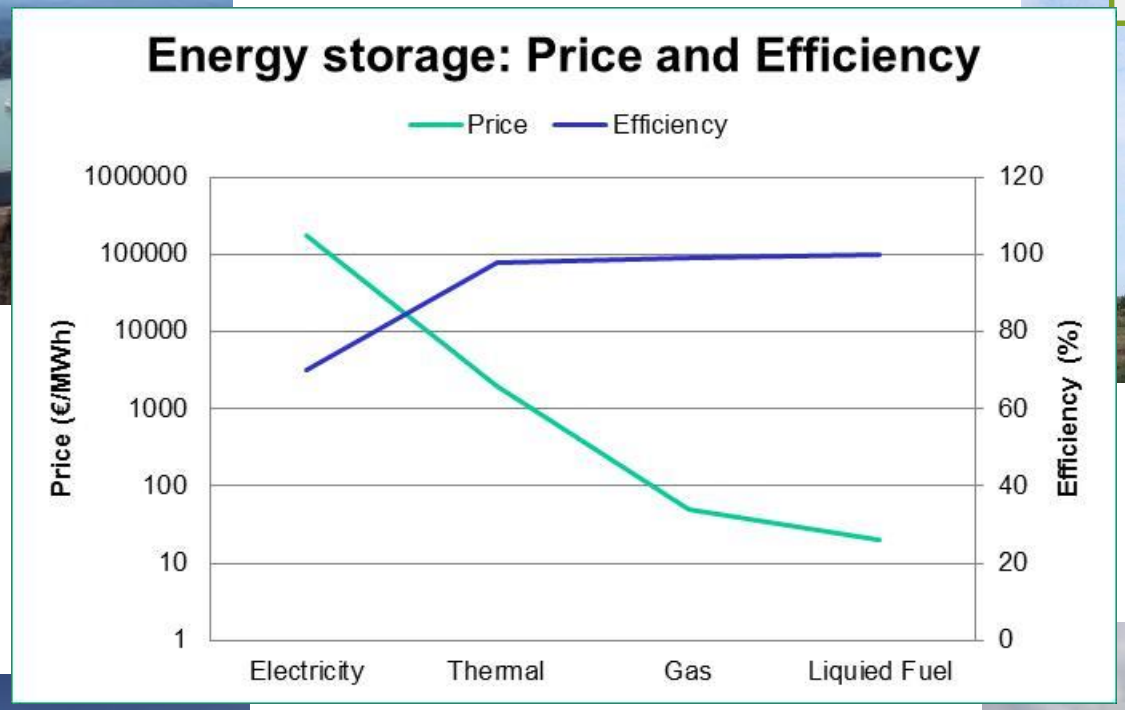
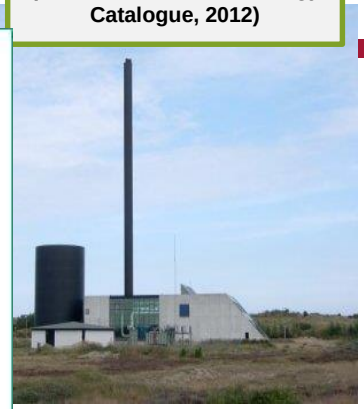
agreer

Energy Storage

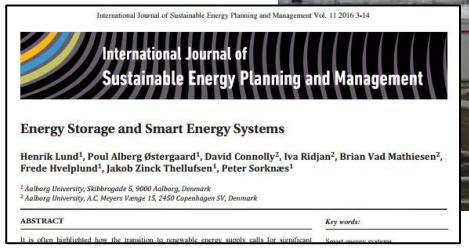
Pump Hydro Storage
175 €/kWh
(Source: Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits. Electric Power Research Institute, 2010)



Thermal Storage
1-4 €/kWh
(Source: Danish Technology Catalogue, 2012)



Natural Gas Underground Storage
0.05 €/kWh
(Source: Current State Of and Issues Concerning Underground Natural Gas Storage. Federal Energy Regulatory Commission, 2004)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[1] Aalborg University, Skibbrogade 5, 9000 Aalborg, Denmark
[2] Aalborg University, A.C. Meyers Vænge 15, 2450 Copenhagen SV, Denmark

ABSTRACT

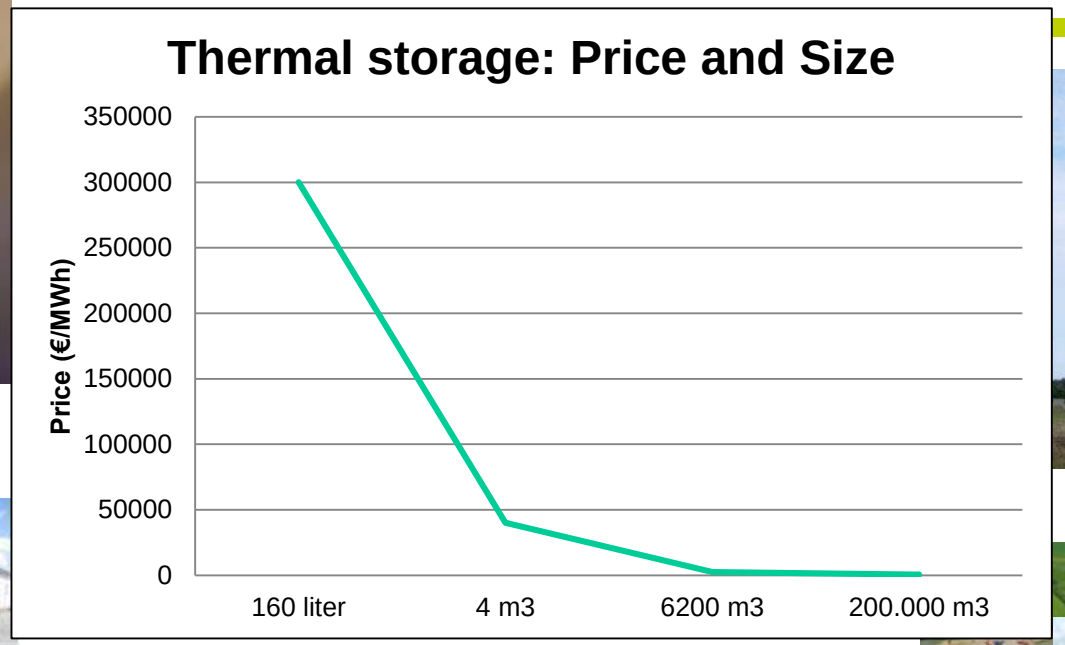
Key words:

Oil Tank
0.02 €/kWh
(Source: Dahl KH, Oil tanking Copenhagen A/S, 2013: Oil Storage Tank. 2013)

This pro
Horizon
agreement No. 695989.

Thermal Storage

0.16 m3 Thermal Storage
300.000 €/MWh
(Private house: 160 liter for 15000 DKK)



6200 m3 Thermal Storage
2500 €/MWh
(Skagen: 6200 m3 for 5.4 mio. DKK)

4 m3 Thermal Storage
40,000 €/MWh
(Private outdoor: 4000 m3 for 50,000 DKK)

200,000 m3 Thermal Storage
500 €/MWh
(Vojens: 200,000 m3 for 30 mio. DKK)

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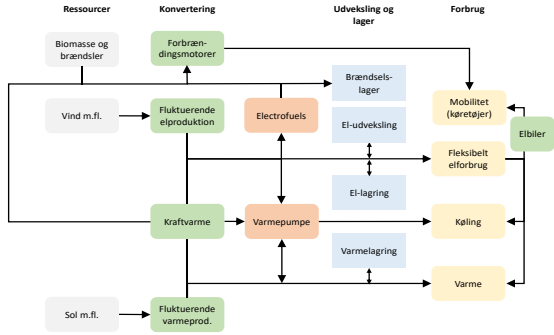
How should storage be used in te long term?

- Three crucial grids in Smart Energy Systems,
  - Smart electricity grids, Smart thermal grids, Smart gas grids
- High capacity electrolyses (Power-to-gas)
- More district heating and district cooling
- Large and small-scale heat pumps (Power-to-heat)
- CHP, solar thermal, etc.
- Electricity storage in transport (batteries and electrofuels)
- Production of green gasses and synthetic fuels



WWW.SMARTENERGYSYSTEMS.EU

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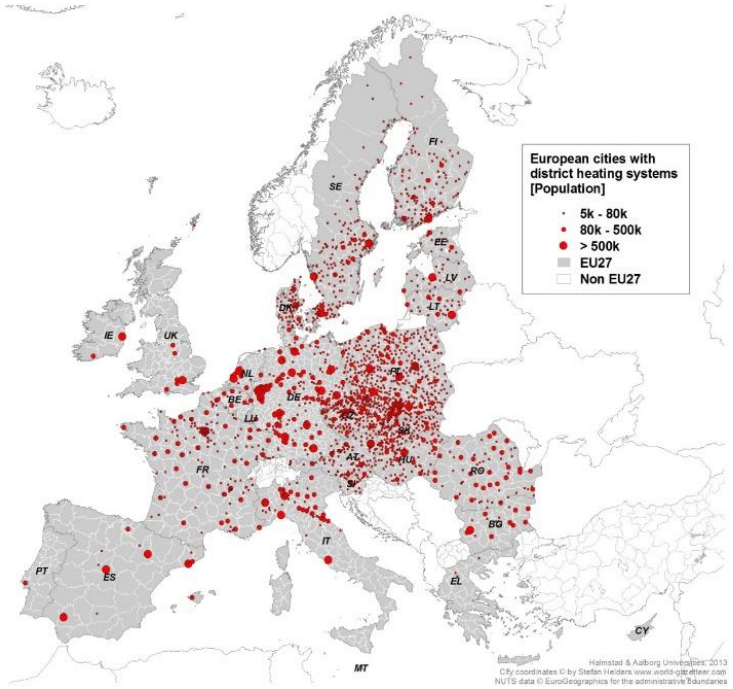
ENERGINET.DK AND OTHER TSO'S WOULD LIKE MORE INTERCONNECTIONS

Figur 18: Eksisterende, kommende og mulige danske udvekslingsforbindelser (importkapacitet).



Ref: Systemplan 2013 Energinet.dk

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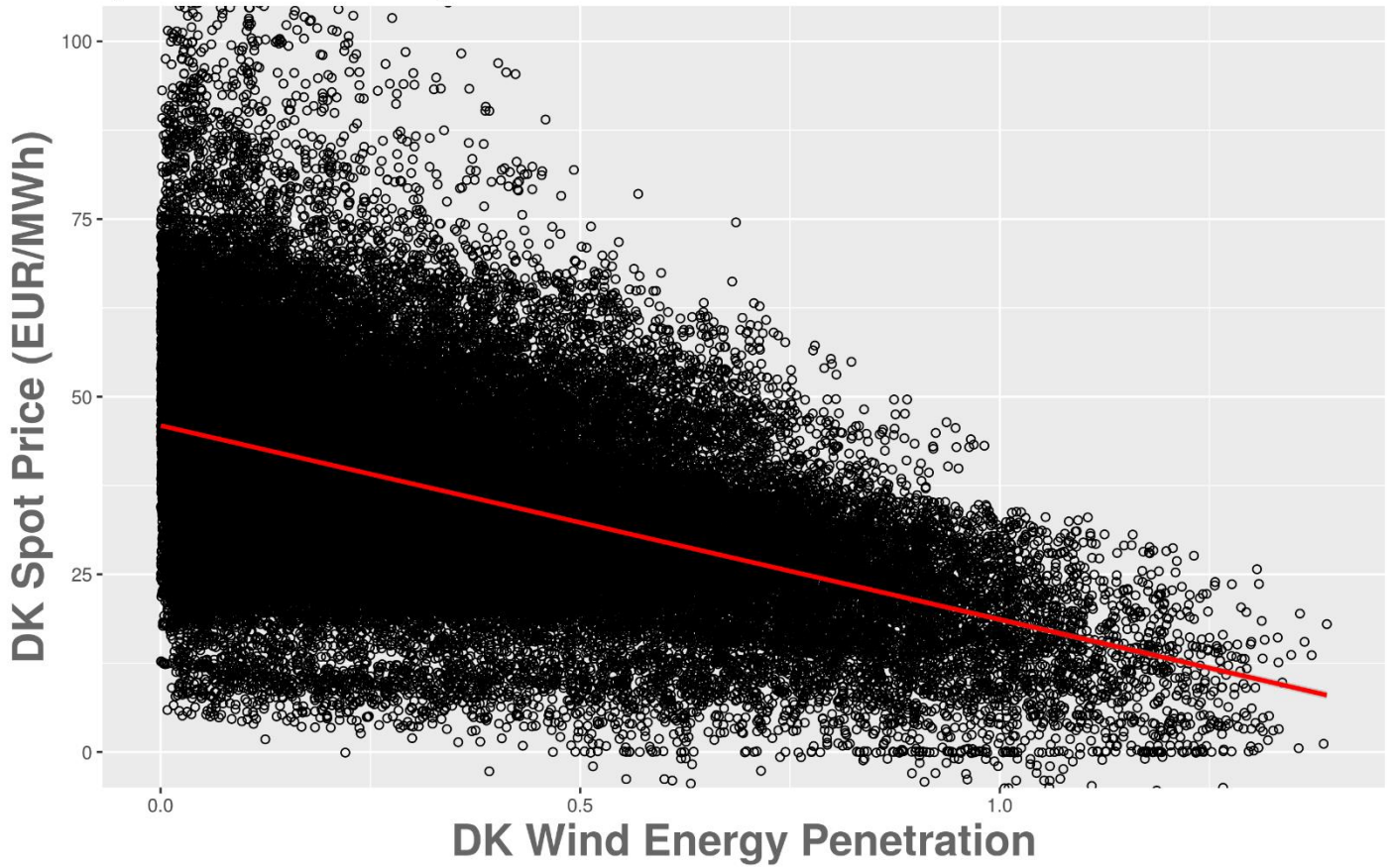
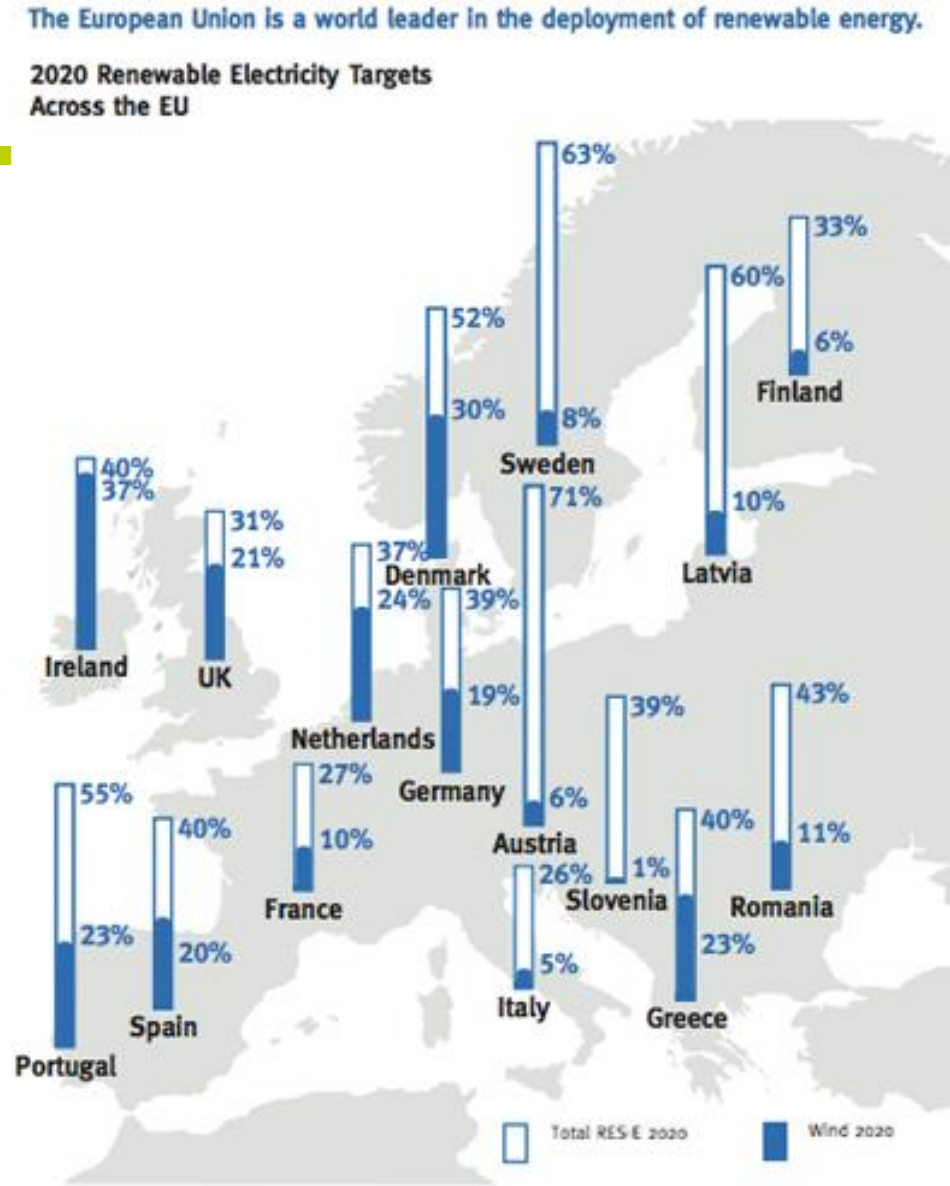
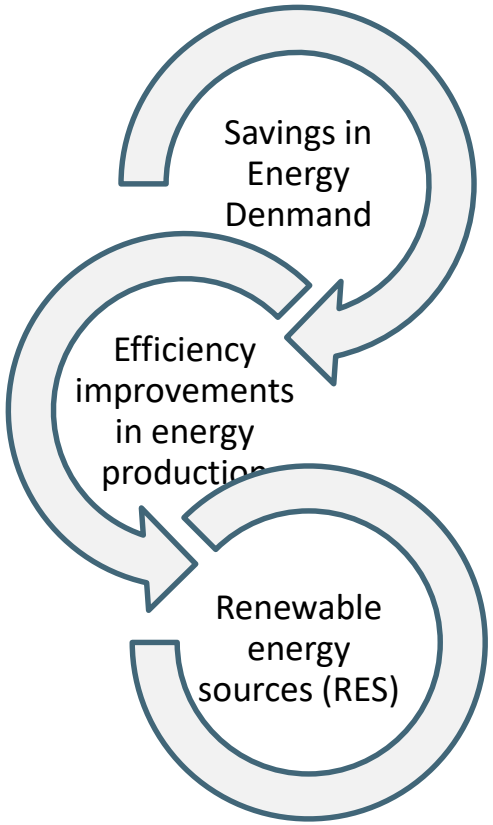
Danish Elspot Price by Danish Wind Power Penetration (2009-2016)





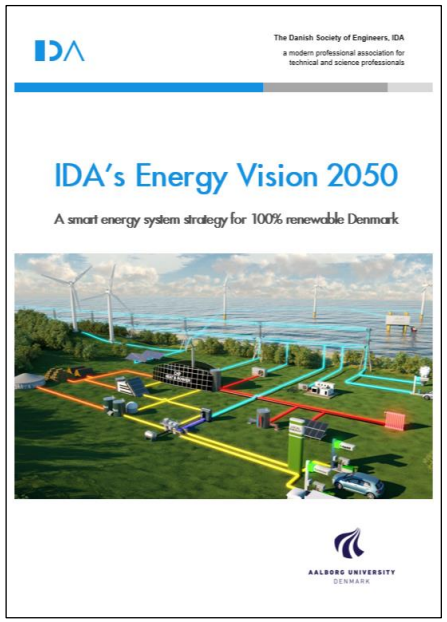
agreement No. 695989.

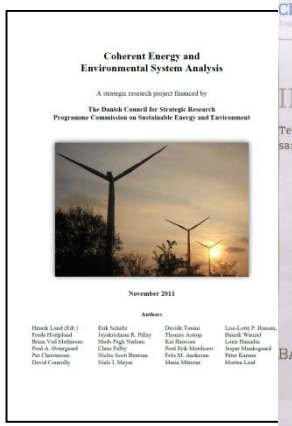
STATE-OF-THE-ART-KNOWLEDGE ON 100% RENEWABLE ENERGY IN 2050

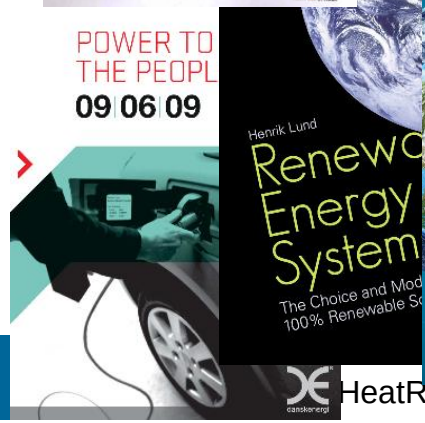


FLEXIBLE TECHNOLOGIES

INTEGRATED ENERGY SYSTEMS







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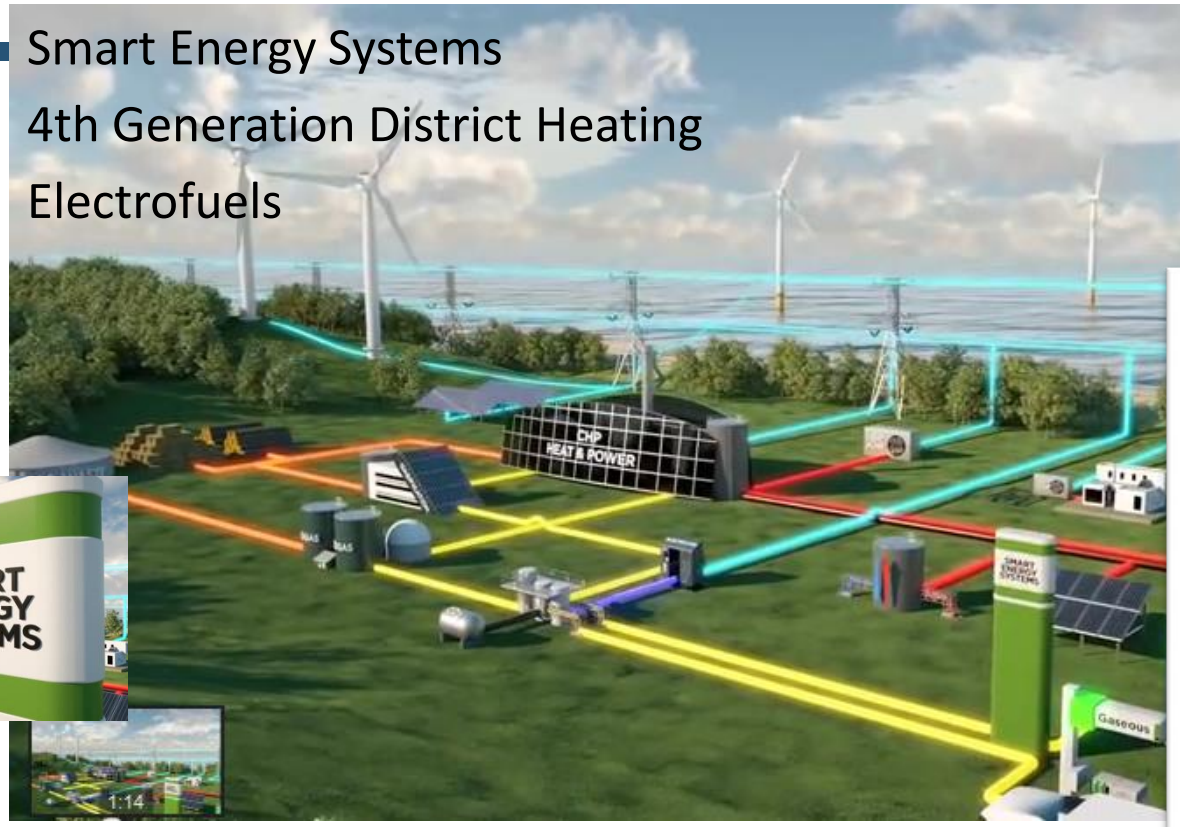
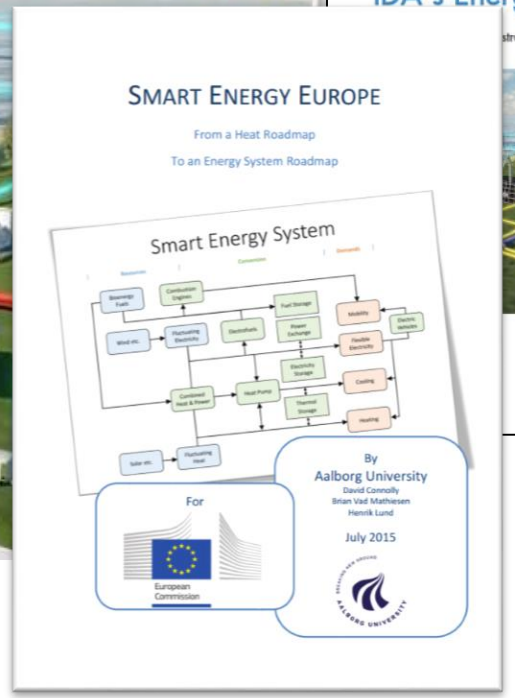
NEW CONCEPTS (AND VIDEOS)

Smart Energy Systems

4th Generation District Heating

Electrofuels





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