HALMSTAD UNIVERSITY

Heat Roadmap Europe 2050

Urban Persson
Halmstad University
Sweden

HEAT ROADMAP EUROPE 2050

STUDIES 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

PlanEnergi
Daniel Trier

Ecofys Germany GmbH
Jan Grözinger
Thomas Boermans
Michelle Bosquet

for EUROHEAT & POWER

within The 4DH Project

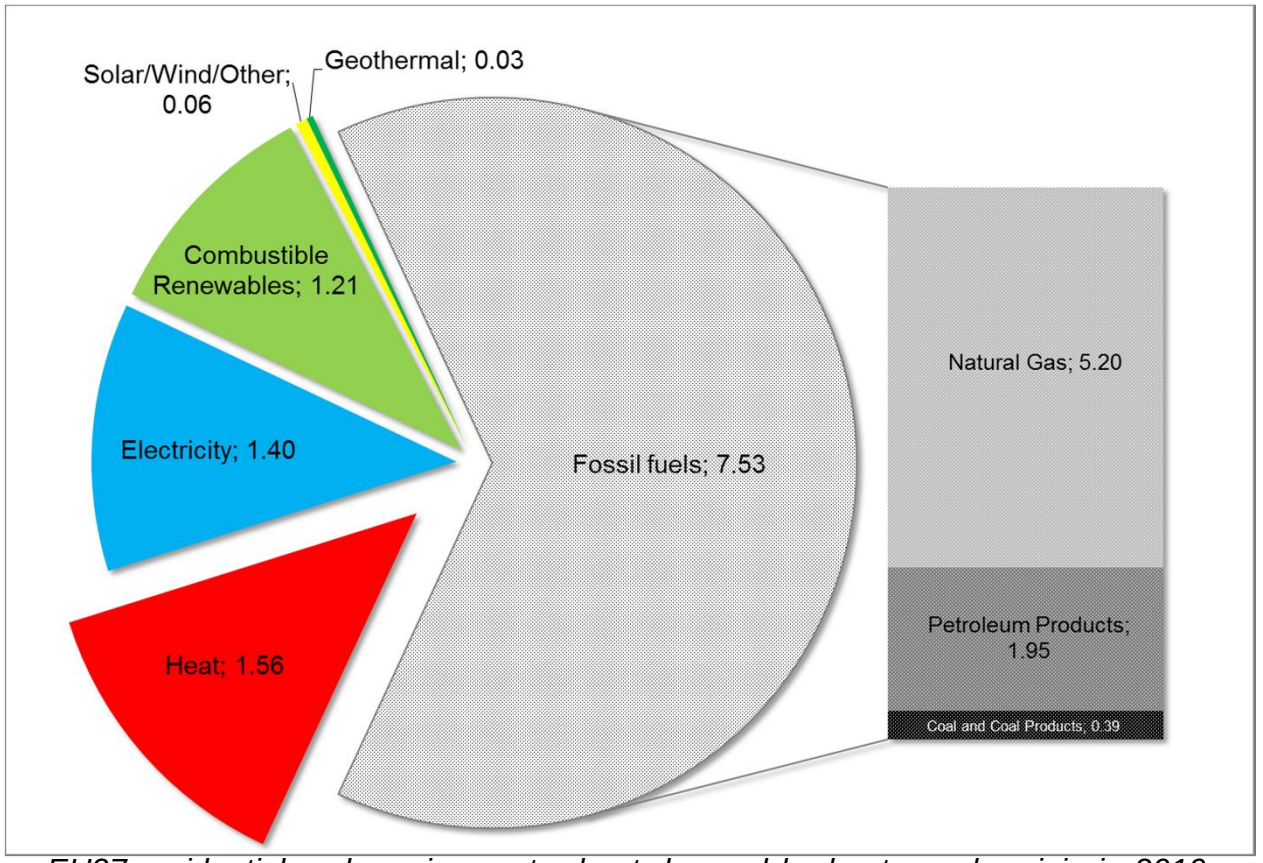
Overview

- Heat Roadmap Europe 2050
  - Background
  - Logic
  - Spatial mapping
  - Modelling
  - Results
  - Conclusions

Background

- District heating on the current European heat market

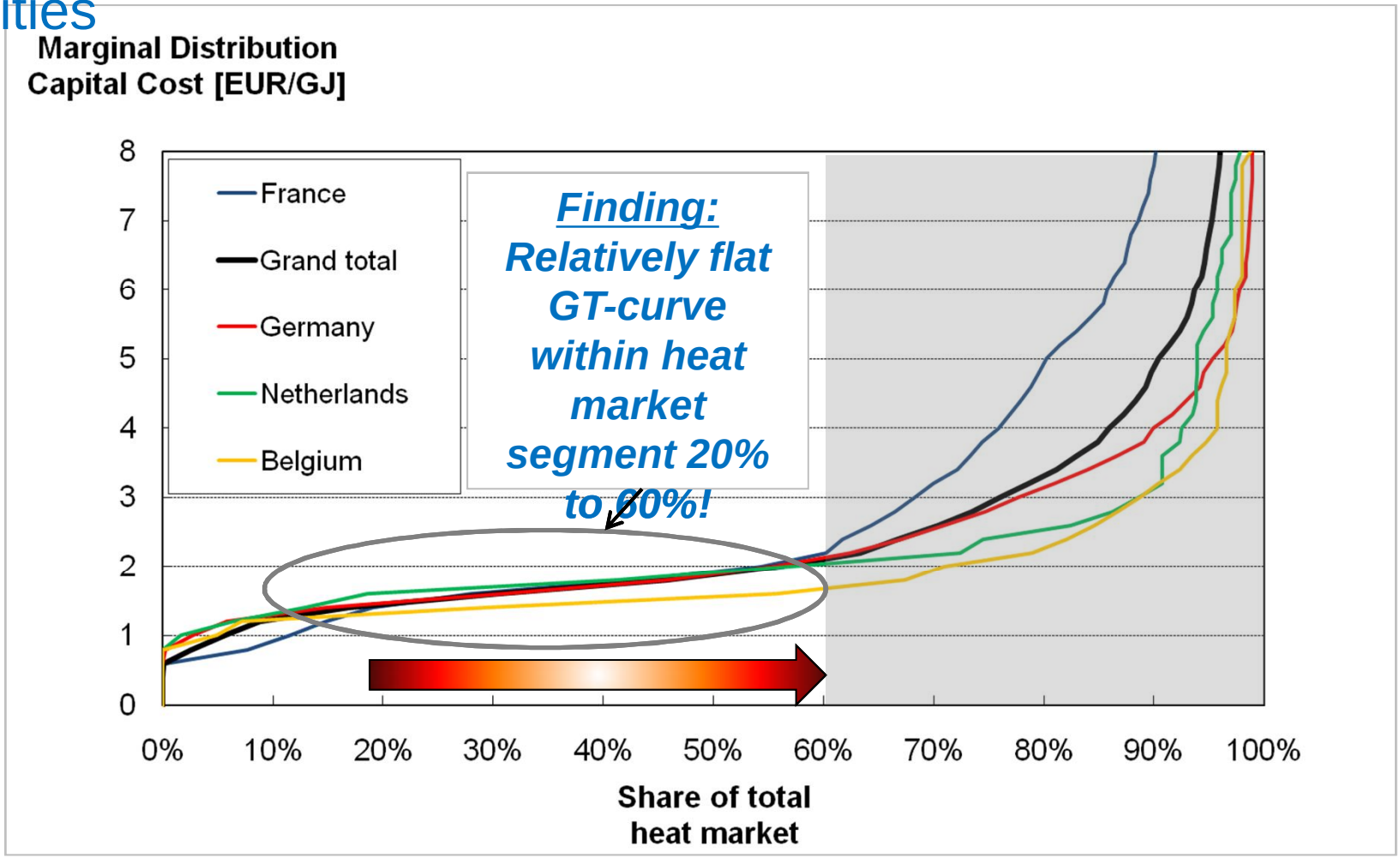
- Total heat market share for DH: ~13% (1.56 EJ of 11.80 EJ)
- Total urban heat market share for DH: ~18% (73% of population in cities)
- Individual use of fossil fuels: ~64% (7.53 EJ of 11.80 EJ)
- EU energy system objective: decarbonise 80% by 2050 (ref. 1990)



EU27 residential and service sector heat demand by heat supply origin in 2010, not including indirect heat supply from indoor electricity use or other internal heat gains (EJ). Sources: IEA Energy Balances (2012) and Bertoldi, P., & Atanasiu, B. (2007).

Background

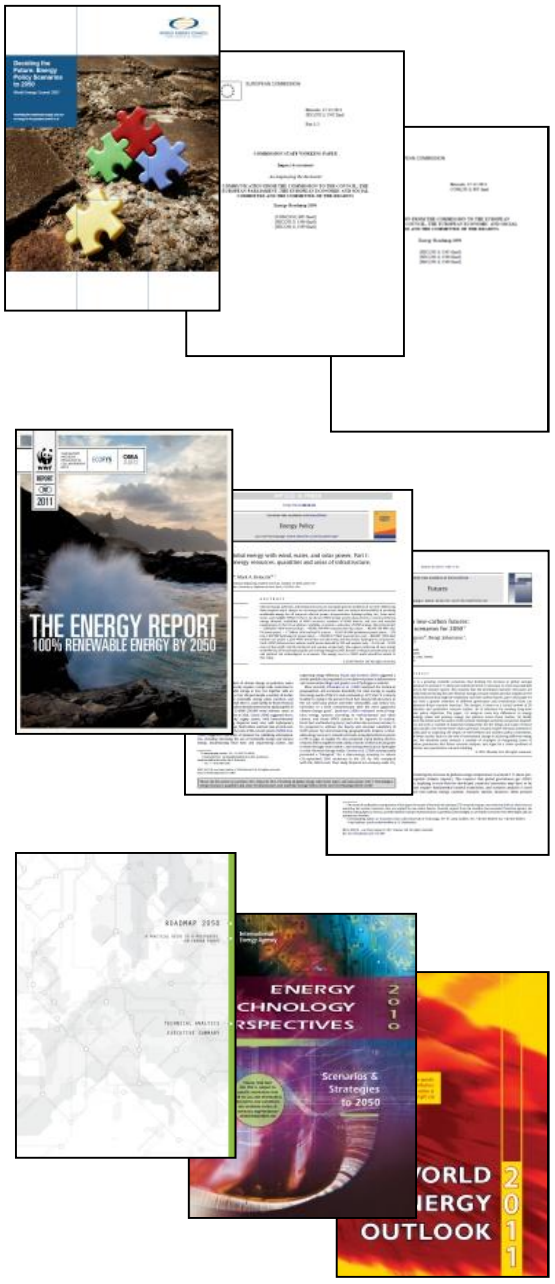
- Feasible expansion possibilities for district heating in European cities



Source: Persson & Werner, 2011.

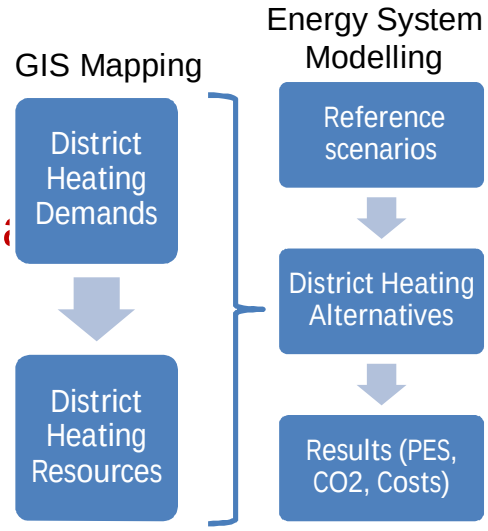
Logic

- Poor recognition of these possibilities
- Heating and cooling sector has largely been overlooked in most scenarios exploring the EU energy future towards 2050
  - Prevailing 2050 assumptions: high shares of electric heating and low heat consumption
  - General consensus: “combined heat & power and district heating are important” – but no quantification as to which extent these options can be used in the future energy system . . .
  - Often too low time and geographical resolution to model energy market realities
  - General knowledge gap in Europe regarding possibilities and benefits of district heating
  - Depreciation of district heating as an effective tool in reaching energy and climate targets



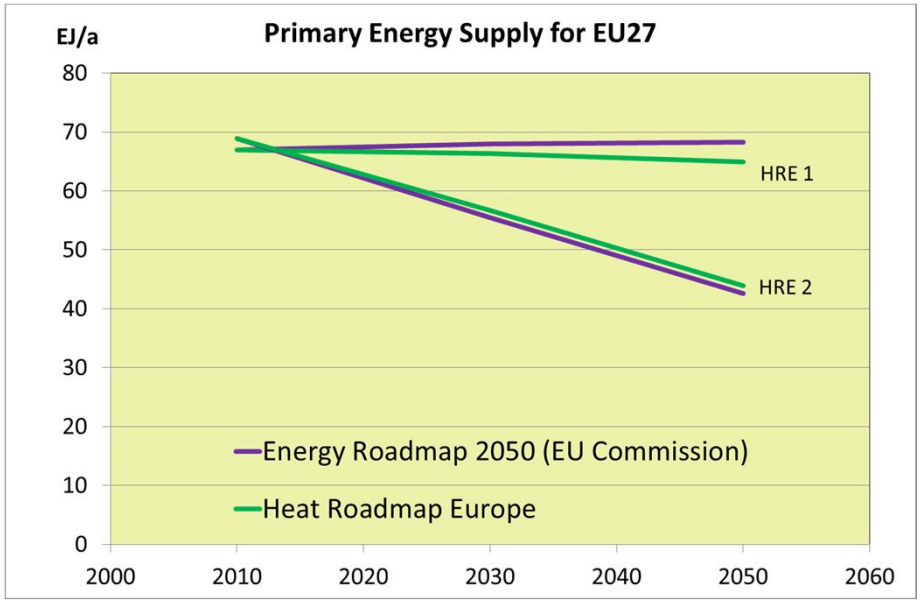
Logic

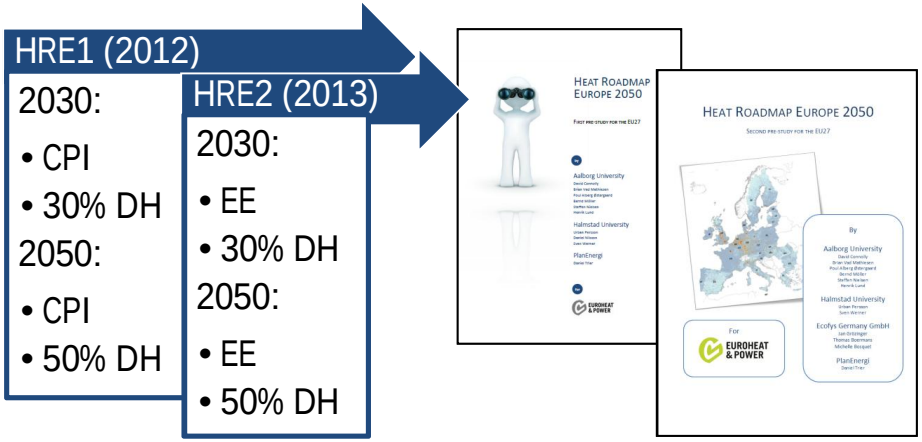
- Counteracting these tendencies and comprehensions
- A need for developing a major European research project focusing on the future European heating & cooling market
  - Initiators: Euroheat & Power, Aalborg University, Halmstad University
- Dissolving the national perspective
  - Traditional European energy scenarios typically based on national Member State energy balances
  - Heat Roadmap Europe 2050 Project uses a higher resolution: the ~1300 NUTS3 regions
- Focusing on local and regional solutions
  - Existing district heating and cooling systems
  - Utilisation of energy and industry sector excess hea
  - Integration of local renewable heat resources
  - Interactions with other parts of the energy market
- A new methodological approach
  - Combining energy modelling and spatial mapping



Logic

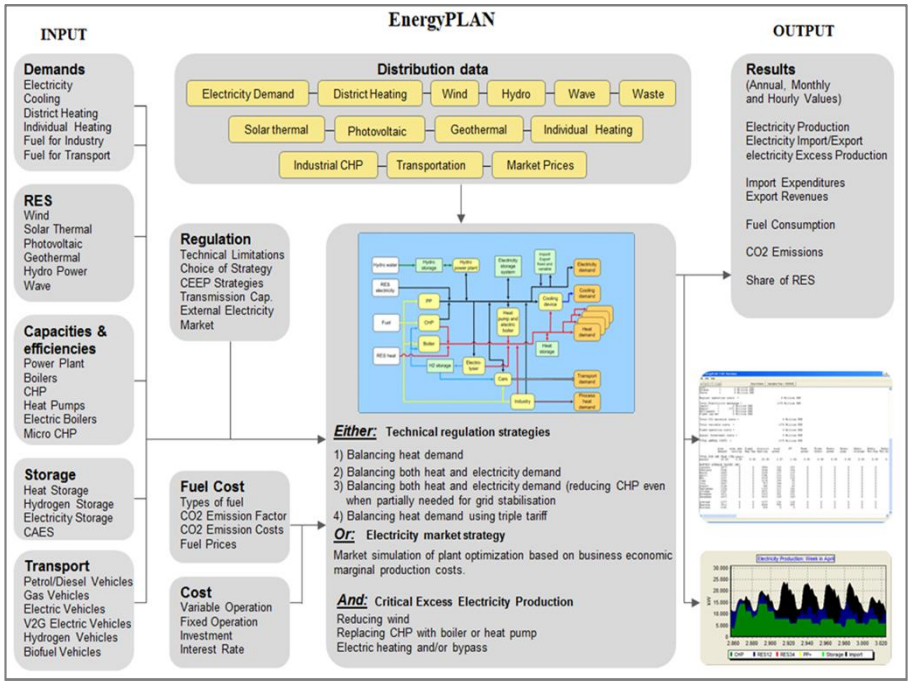
- Reference scenarios for the two Heat Roadmap Europe pre-Studies
- Study results are compared to the Energy Roadmap 2050
  - District heating has a dark future herein – total heat market share of only 10%
- Energy Roadmap 2050 presents energy scenarios for the EU27:
  - Reference: Business-as-usual
  - CPI: Updated business-as-usual – RS for pre-study 1. Unaltered heat demands
  - EE: Energy Efficiency – RS for pre-study 2. Reduced heat demands
  - CCS: Carbon Capture and Storage
  - Nuclear
  - High Renewable Energy





Logic

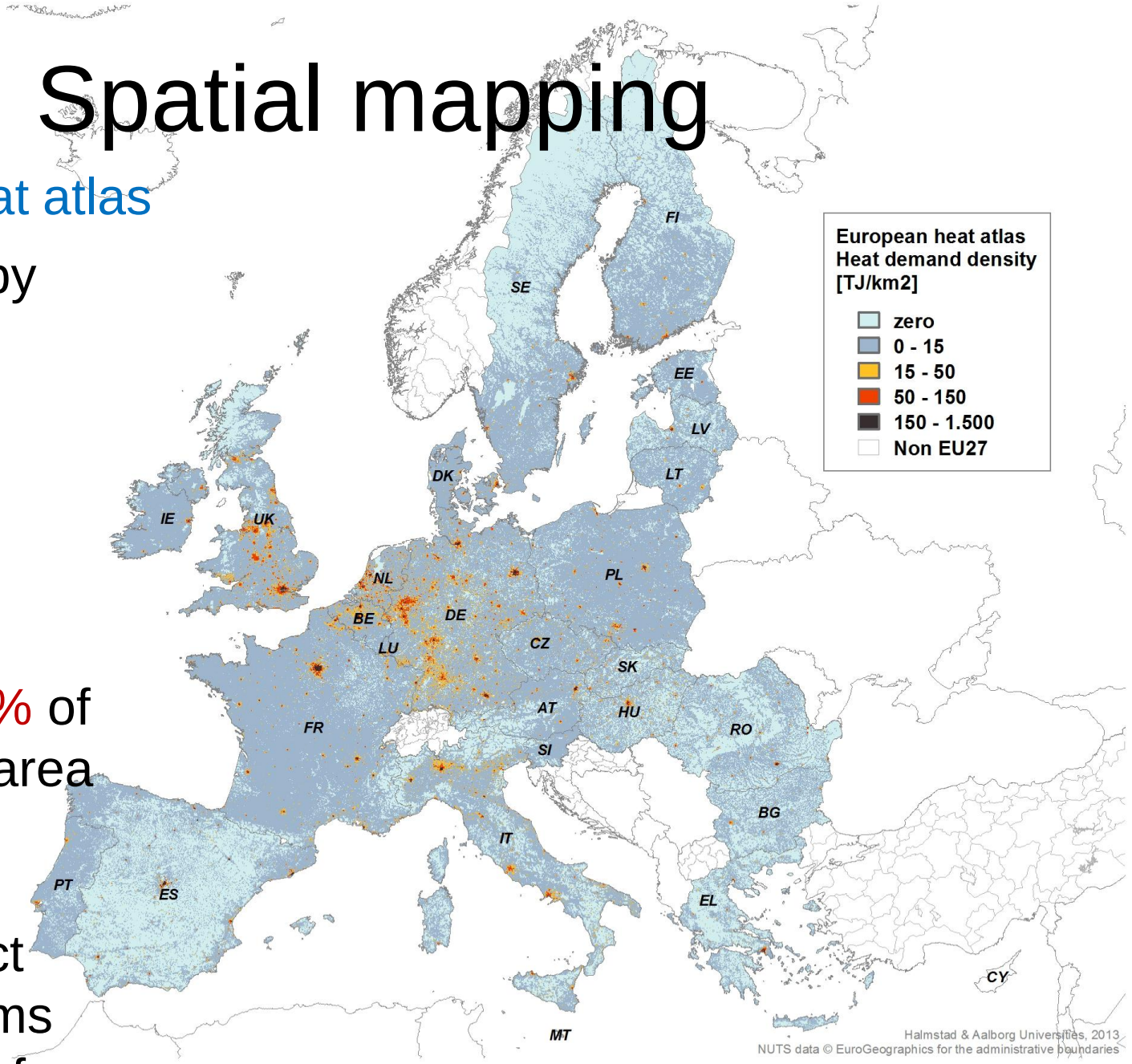
- Combining energy modelling and spatial mapping
- Rationale: Only by considering local and regional resources in energy modelling can heat synergy opportunities be identified!
- GIS mapping:
  - NUTS3 regions
  - Land use & population
  - Heat demands
  - District heating systems
  - Thermal power generation
  - Waste-to-Energy
  - Energy intensive industries
  - Geothermal resources
  - Solar irradiation
  - Bioenergy assetts
- Energy system modelling



The structure of the EnergyPLAN tool. Aalborg University. EnergyPLAN: Advanced Energy System Analysis Computer Model. Available at: http://www.energyplan.eu/.

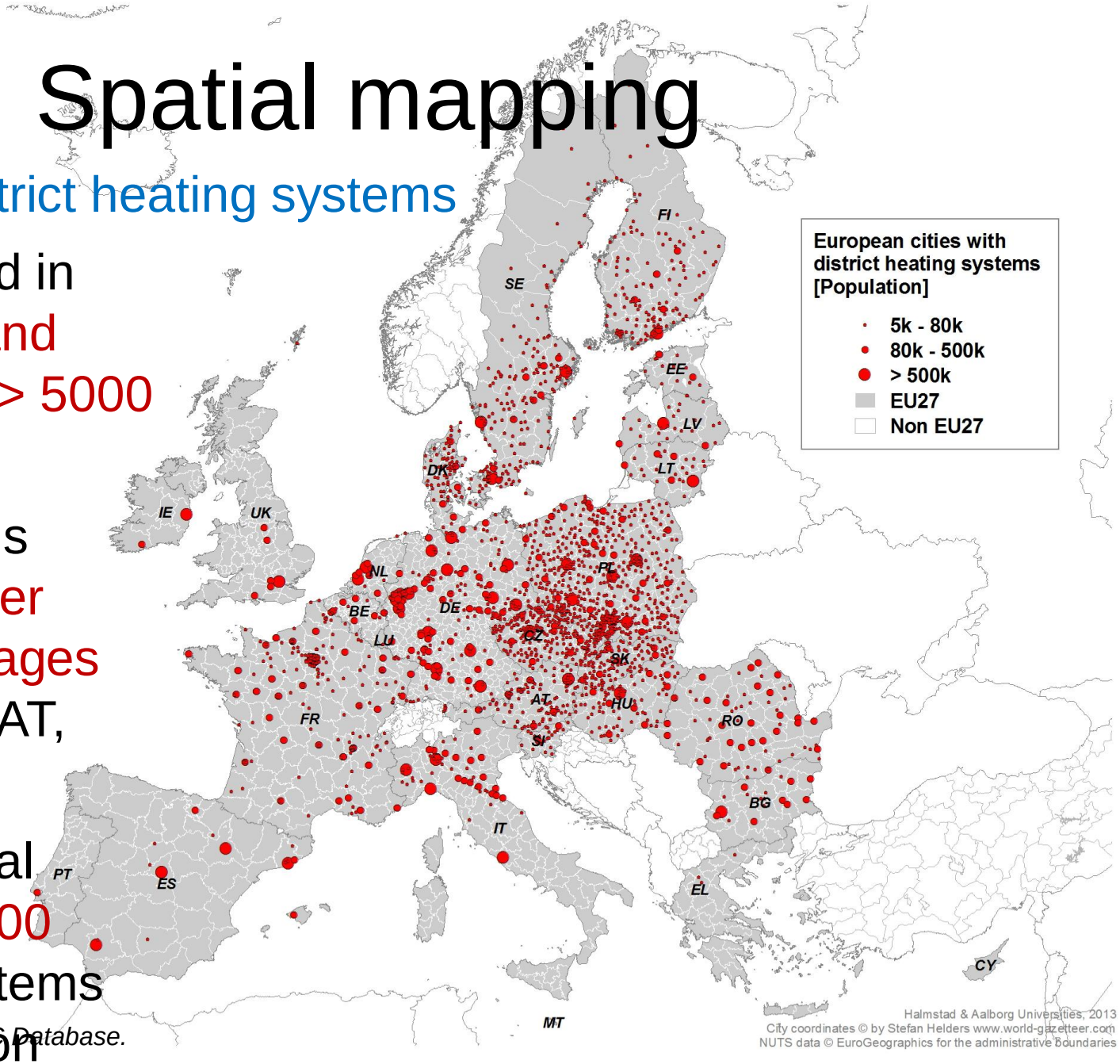
Spatial mapping

- European heat atlas
- Heat density by km^2 (~4 million squares)
- ~2/3 of EU population inhabitates 4 % of the total land area (i.e. in cities)
- Existing district heating systems cover ~0.3% of the total land area



Spatial mapping

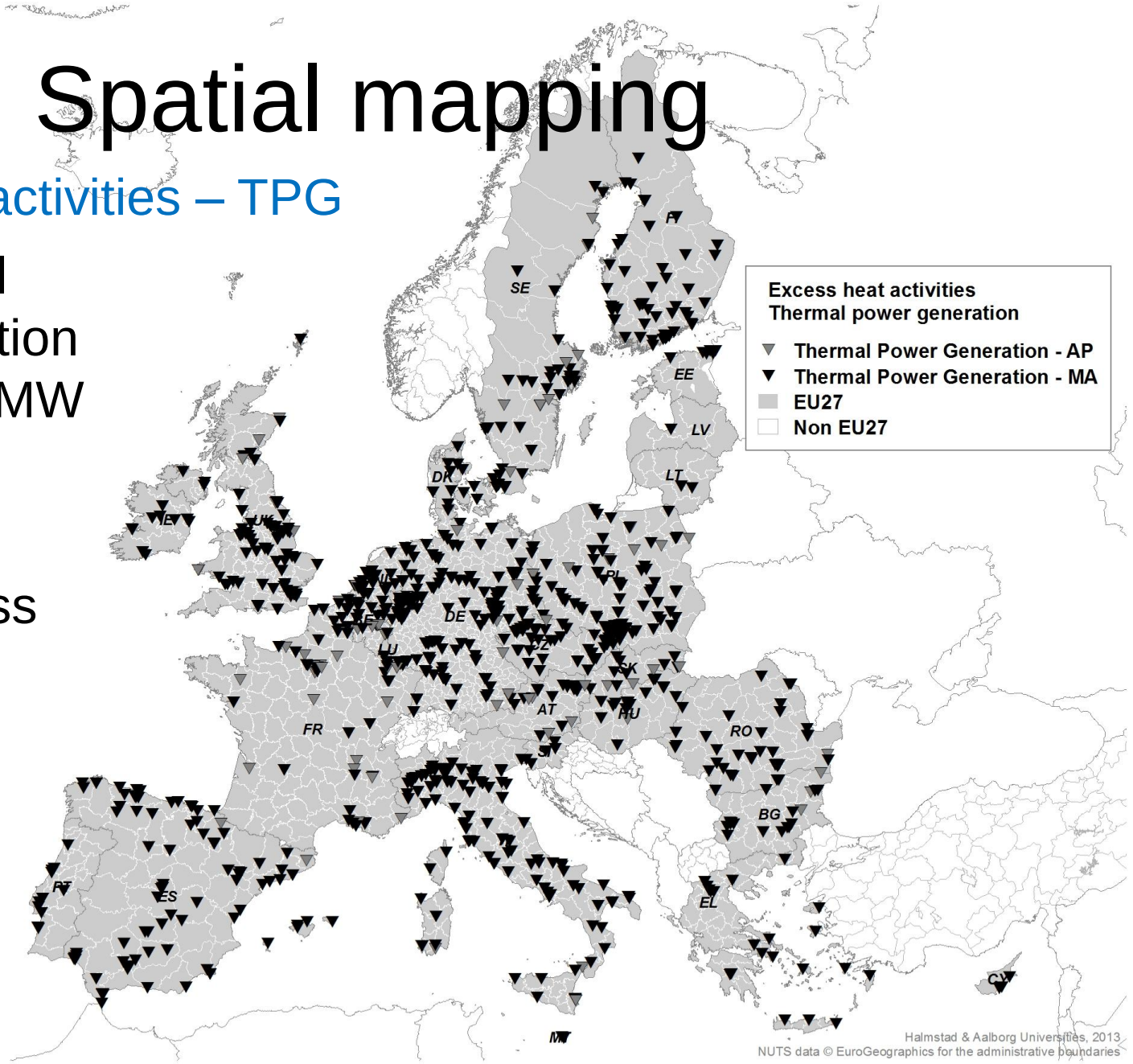
- European district heating systems
- Systems found in ~2200 cities and towns having > 5000 inhabitants
- ~1400 systems found in smaller towns and villages (DK, SE, CH, AT, CZ, and SK)
- Acc. to national statistics, ~1500 additional systems are in operation today



Source: Halmstad University CHC Database.

Spatial mapping

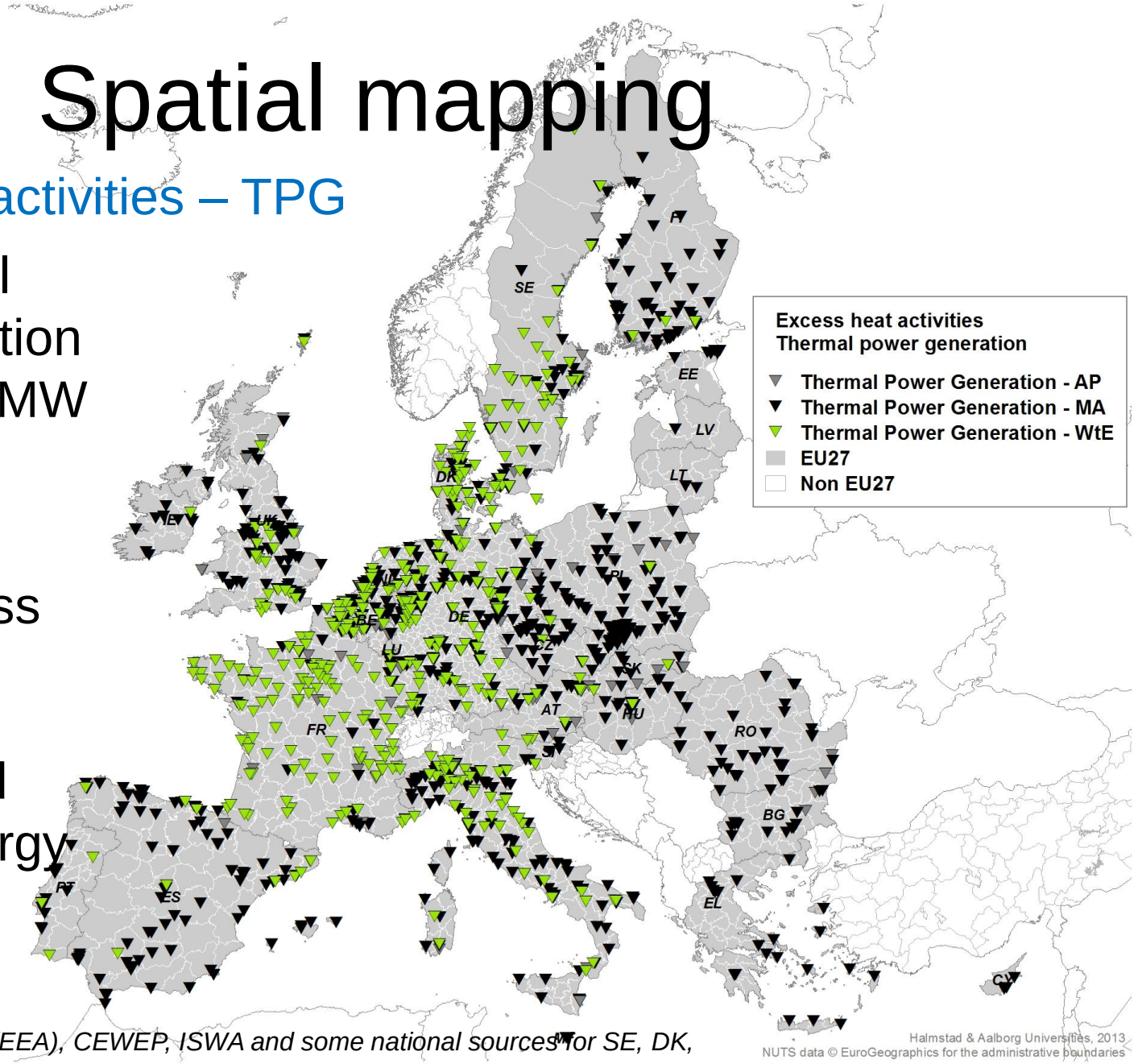
- Excess heat activities – TPG
- ~1100 thermal power generation facilities > 50 MW
- ~7 EJ of recoverable rejected excess heat



Source: E-PRTR v3.3 Database (EEA).

Spatial mapping

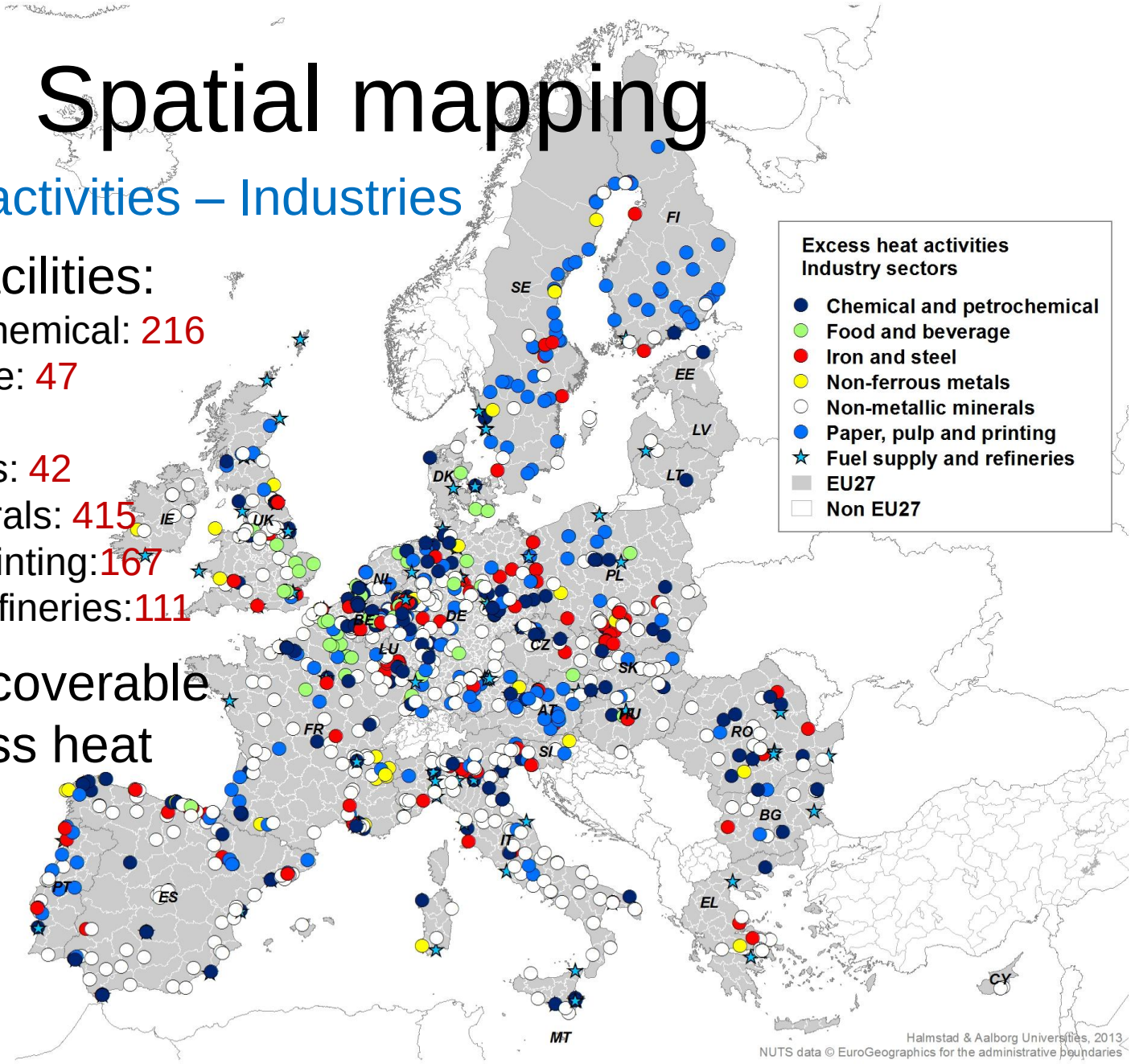
- Excess heat activities – TPG
- ~1100 thermal power generation facilities > 50 MW
- ~7 EJ of recoverable rejected excess heat
- 410 dedicated Waste-to-Energy facilities
- ~0.5 EJ of recoverable rejected excess



Source: E-PRTR v3.3 Database (EEA), CEWEP, ISWA and some national sources for SE, DK, and FR.

Spatial mapping

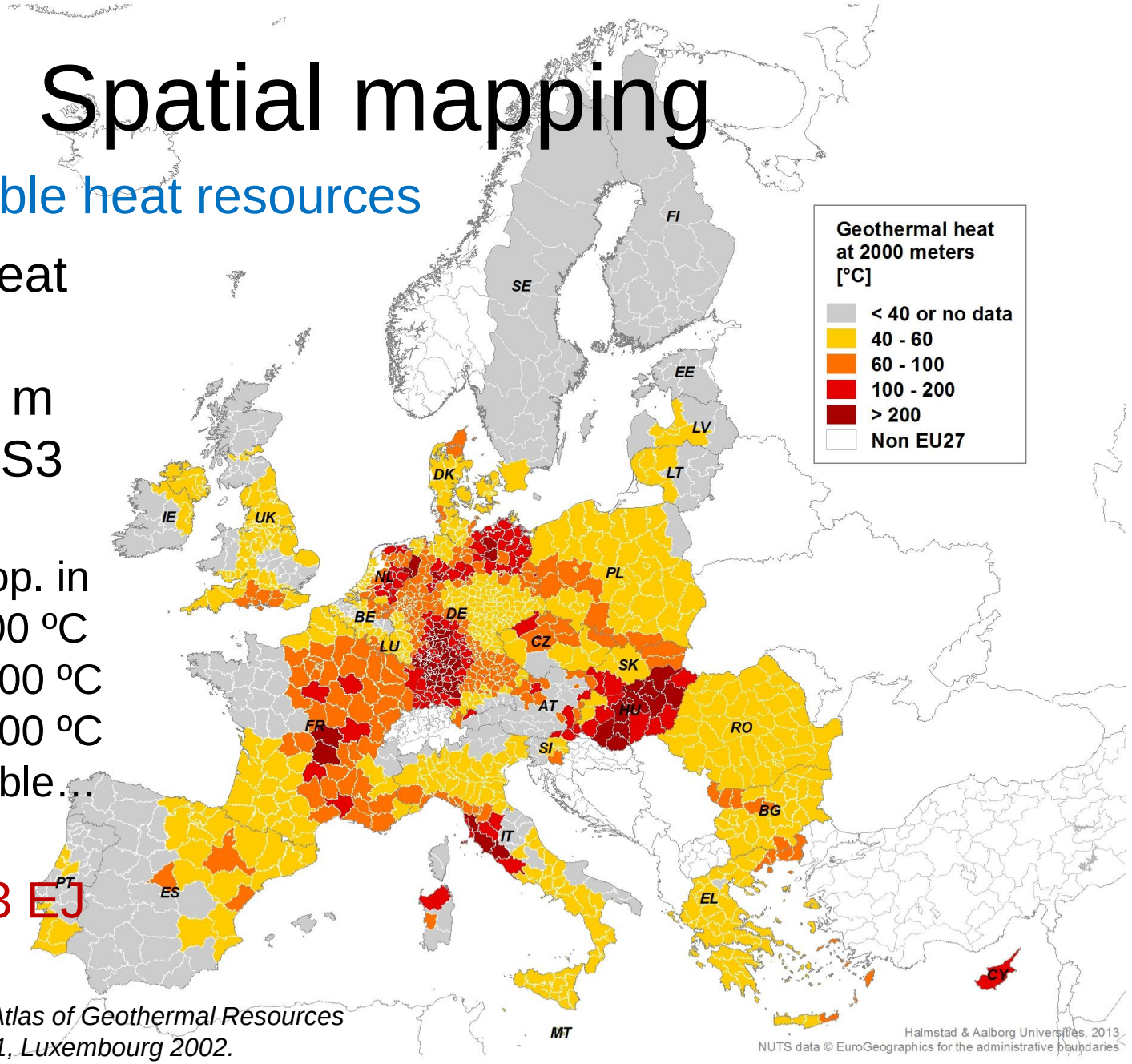
- Excess heat activities – Industries
- Considered facilities:
  - Chem. and petrochemical: 216
  - Food and beverage: 47
  - Iron and steel:123
  - Non-ferrous metals: 42
  - Non-metallic minerals: 415
  - Paper, pulp and printing:167
  - Fuel supply and refineries:111
- ~ 2.7 EJ of recoverable rejected excess heat



Source: E-PRTR v3.3 Database (EEA).

Spatial mapping

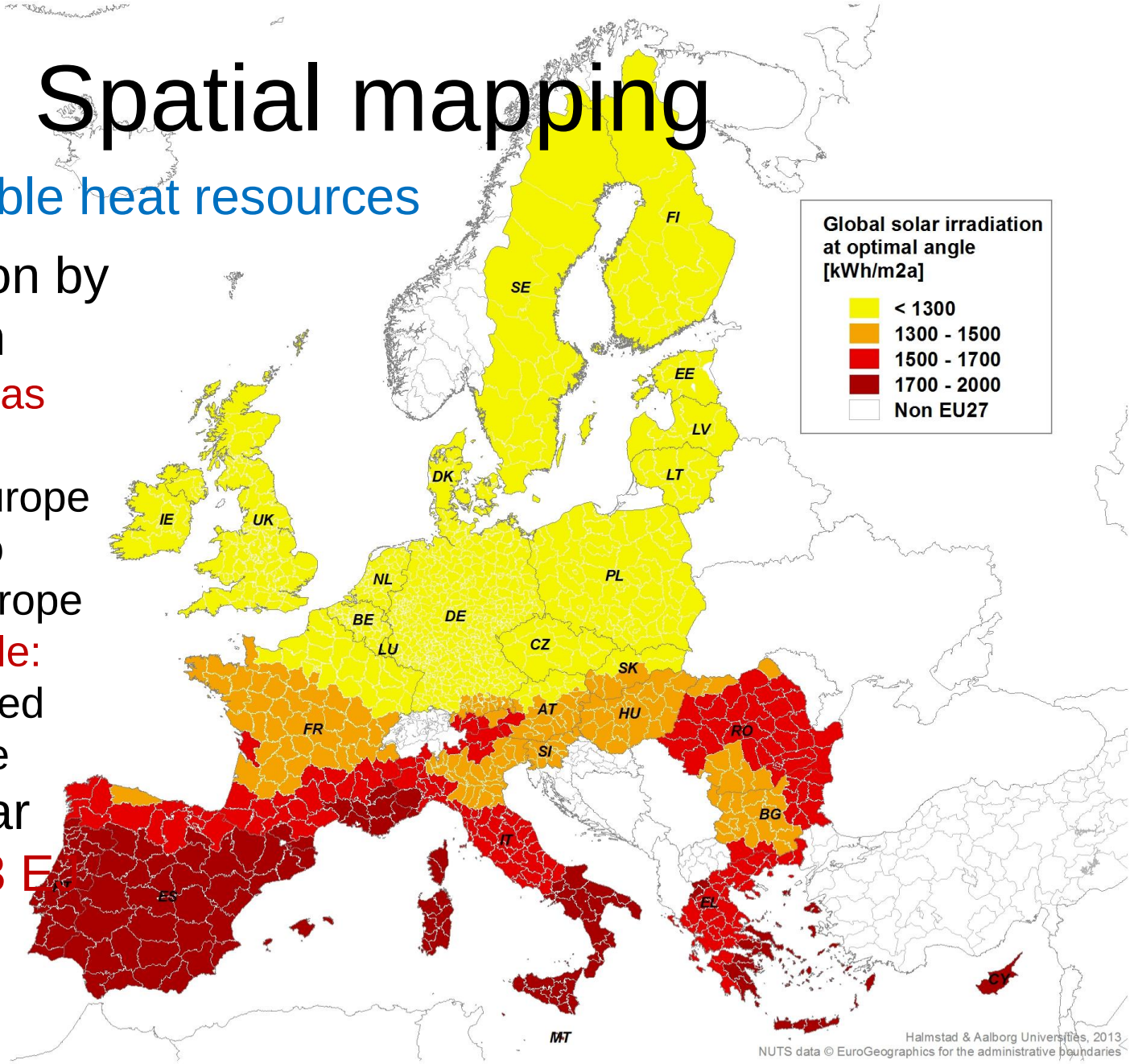
- Local renewable heat resources
- Geothermal heat resources by temp. at 2000 m depth by NUTS3 region
  - 4% of EU pop. in regions > 200 ºC
  - 8%: 100 – 200 ºC
  - 20%: 60 – 100 ºC
  - 26% reachable…
- Potential: 0.43 EJ



Source: European Commission, Atlas of Geothermal Resources in Europe. Publication EUR 17811, Luxembourg 2002.

Spatial mapping

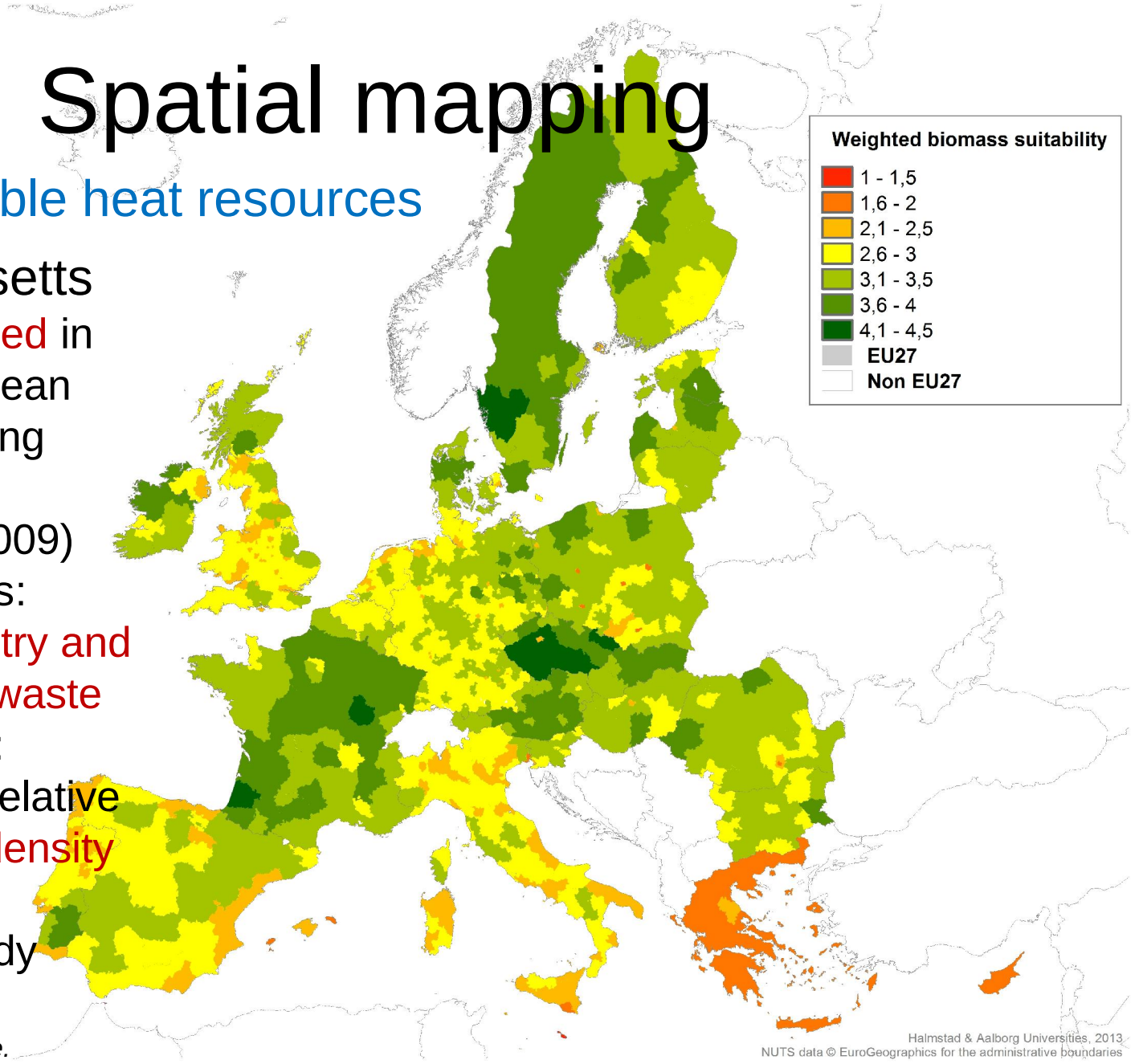
- Local renewable heat resources
- Solar irradiation by NUTS3 region
  - About twice as intense in Southern Europe compared to Northern Europe
  - Optimal angle: South oriented tilted surface
- Potential, solar thermal: ~1.3 E



Source: EU JRC.

Spatial mapping

- Local renewable heat resources
- Bioenergy assetts
  - Currently used in many European district heating systems
  - 0.241 EJ (2009)
  - Fuel sources: mainly forestry and agricultural waste
- Suitability score:
  - Availability relative population density
- Potential: Not quantified in study



Source: European Forest Institute.

Modelling

- Energy modelling
- Review of existing models
  - Simulation
  - Scenario
  - Equilibrium
  - Etc.
- Main criteria:
  - Integrated analysis of electricity and heat sectors (and transport)
  - Include hourly changes in energy supply and demand
- Main objectives:
  - 2050: 80% lower CO2 emissions (ref. 1990)
  - Energy system alternatives with lowest socio-economic costs

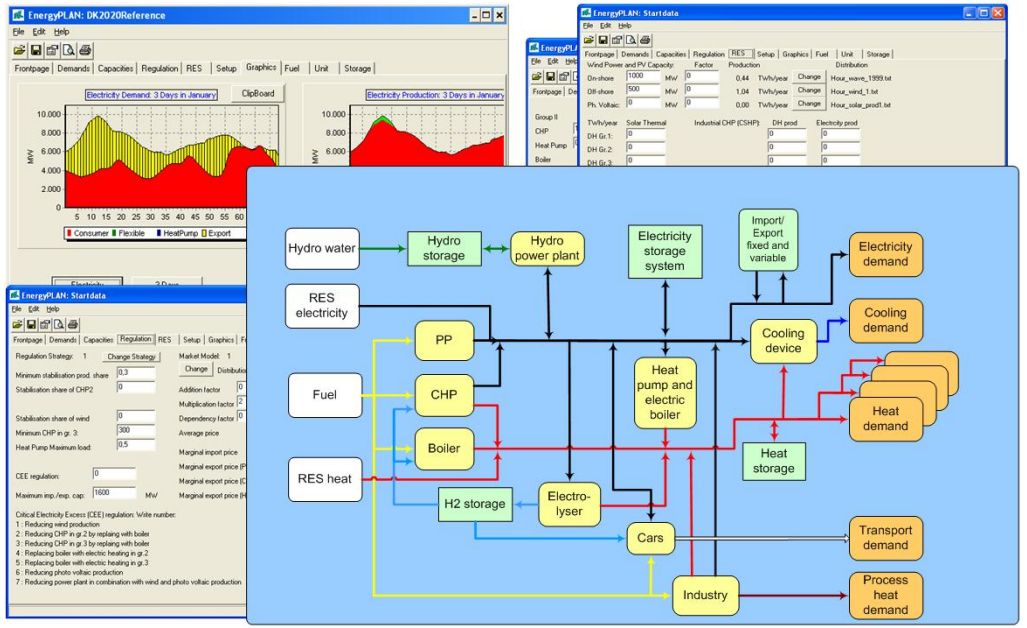
Tool	Type						
	Simulation	Scenario	Equilibrium	Top-Down	Bottom-Up	Operation Optimisation	Investment Optimisation
AEOLIUS	Yes	-	-	-	Yes	-	-
BALMOREL	Yes	Yes	Partial	-	Yes	Yes	Yes
BCHP Screening Tool	Yes	-	-	-	Yes	Yes	-
COMPOSE	-	-	-	-	Yes	Yes	Yes
E4cast	-	Yes	Yes	-	Yes	-	Yes
EMCAS	Yes	Yes	-	-	Yes	-	Yes
EMINENT	-	Yes	-	-	Yes	-	-
EMPS	-	-	-	-	-	Yes	-
EnergyPLAN	Yes	Yes	-	-	Yes	Yes	Yes
energyPRO	Yes	Yes	-	-	-	Yes	Yes
ENPEP-BALANCE	-	Yes	Yes	Yes	-	-	-
GTMax	Yes	-	-	-	-	Yes	-
H2RES	Yes	Yes	-	-	Yes	Yes	-
HOMER	Yes	-	-	-	Yes	Yes	Yes
HYDROGEMS	-	Yes	-	-	-	-	-
IKARUS	-	Yes	-	-	Yes	-	Yes
INFORSE	-	Yes	-	-	-	-	-
Invert	Yes	Yes	-	-	Yes	-	Yes
LEAP	Yes	Yes	-	Yes	Yes	-	-
MARKAL/TIMES	-	Yes	Yes	Partly	Yes	-	Yes
Mesap PlaNet	-	Yes	-	-	Yes	-	-
MESSAGE	-	Yes	Partial	-	Yes	Yes	Yes
MiniCAM	Yes	Yes	Partial	Yes	Yes	-	-
NEMS	-	Yes	Yes	-	-	-	-
ORCED	Yes	Yes	Yes	-	Yes	Yes	Yes
PERSEUS	-	Yes	Yes	-	Yes	-	Yes
PRIMES	-	-	Yes	-	-	-	-
ProdRisk	Yes	-	-	-	-	Yes	Yes
RAMSES	Yes	-	-	-	Yes	Yes	-
RETScreen	-	Yes	-	-	Yes	-	Yes
SimREN	-	-	-	-	-	-	-
SIVAEL	-	-	-	-	-	-	-
STREAM	Yes	-	-	-	-	-	-
TRNSYS16	Yes	Yes	-	-	Yes	Yes	Yes
UniSyD3.0	-	Yes	Yes	-	Yes	-	-
WASP	Yes	-	-	-	-	-	Yes
WILMAR Planning Tool	Yes	-	-	-	-	Yes	-

Source: Connolly D., Lund H., Matiesen B.V. & Leahy M. A review of computer tools for analysing the integration of renewable energy into various energy systems. Applied Energy 2010;87(4):1059-1082.

HALMSTAD UNIVERSITY

Modelling

- Energy modelling
- The EnergyPLAN tool
  - Simulation & scenario model
  - Hourly time-steps over one-year periods
  - Uses bottom-up inputs (spatial mapping)
  - Identifies investment options and alternatives
  - Uses different regulation strategies to optimise operation
  - Seeks efficiency improvements in central energy conversion to reduce primary energy supply
  - Shows socio-economic results – costs for society

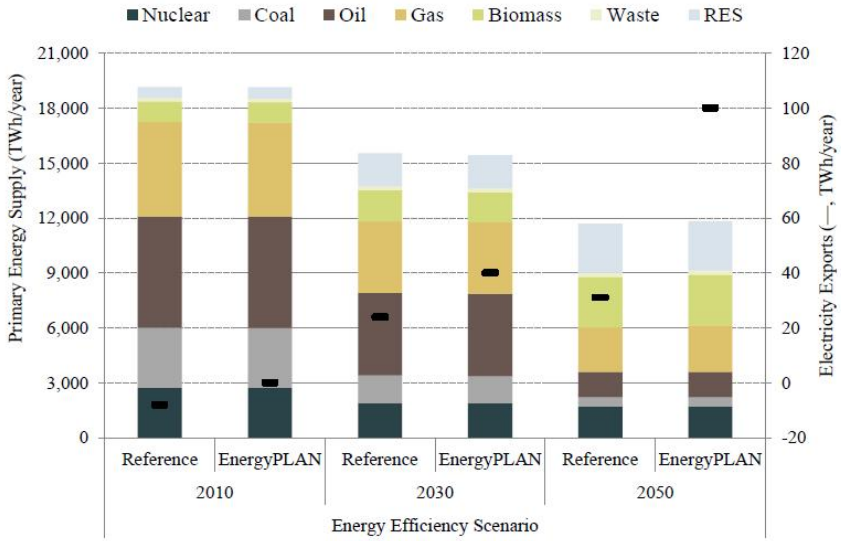


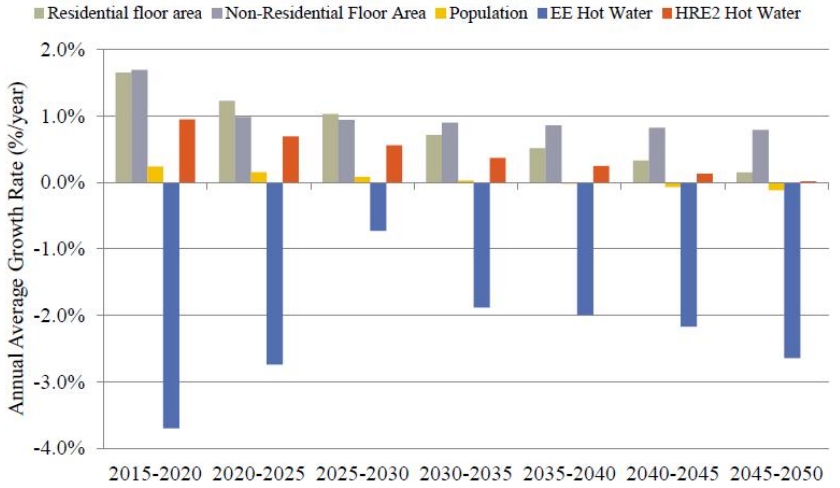
The EnergyPLAN tool. Aalborg University. EnergyPLAN: Advanced Energy System Analysis Computer Model. Available at: http://www.energyplan.eu/.

The EnergyPLAN tool is open source, free of costs, and available online!

Modelling

- Energy modelling
- Calibrating the model
  - Interpreting the reference scenarios in Energy Roadmap 2050
- Alternative view on domestic hot water use compared to reference
  - Anticipated population growth
  - Increasing individual use
  - More single households
  - Building area expected to grow (35% from 2015 to 2050)

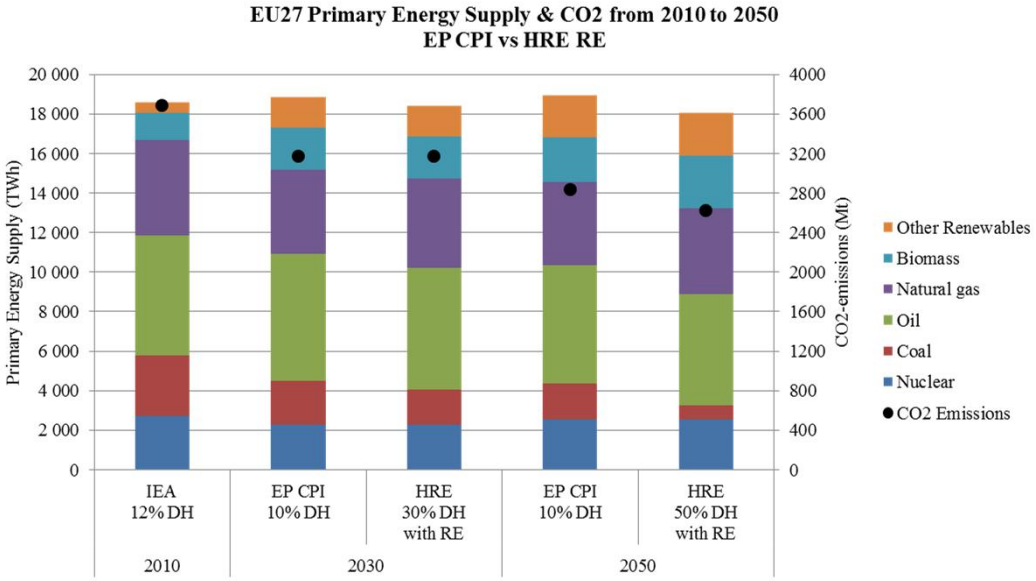


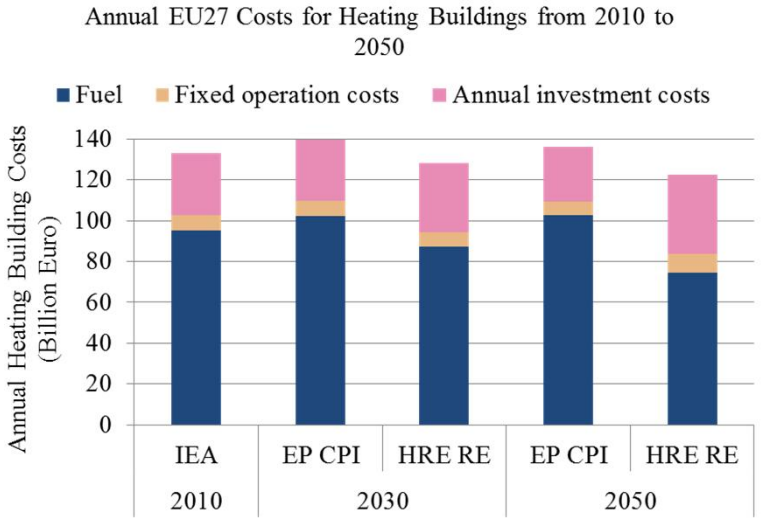


Results

- Pre-study 1

- HRE 2050 compared to EU CPI 2050:
  - 5% reduction in PES
  - 10% reduction in fossil fuels
  - 13% reduction in CO2-emissions
- Costs and job creation
  - Total cost reduced by 14 Bn €/a in 2050
  - Saved fuel costs ~30 Bn €/a in 2050
  - Total additional investments of 500 Bn €
  - Additional jobs from to 2013 to 2050: 8-9 million person-years in total (~220,000 jobs)



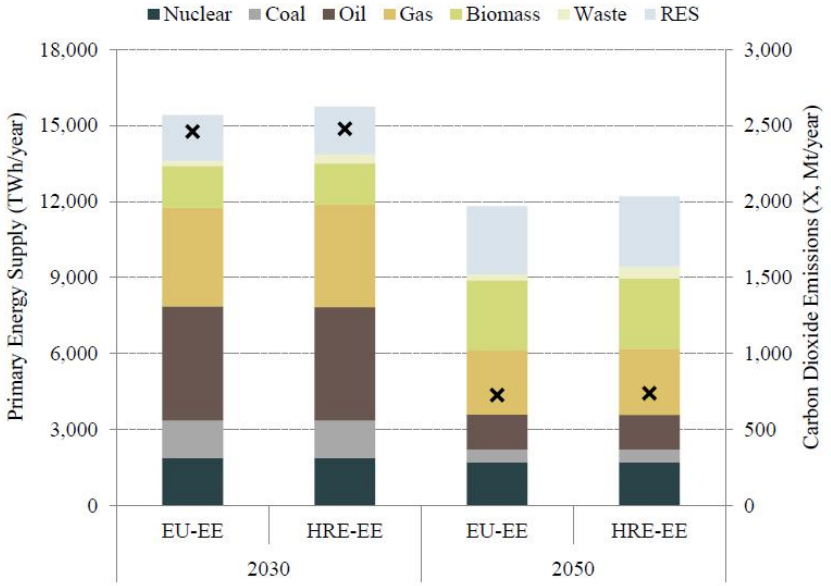


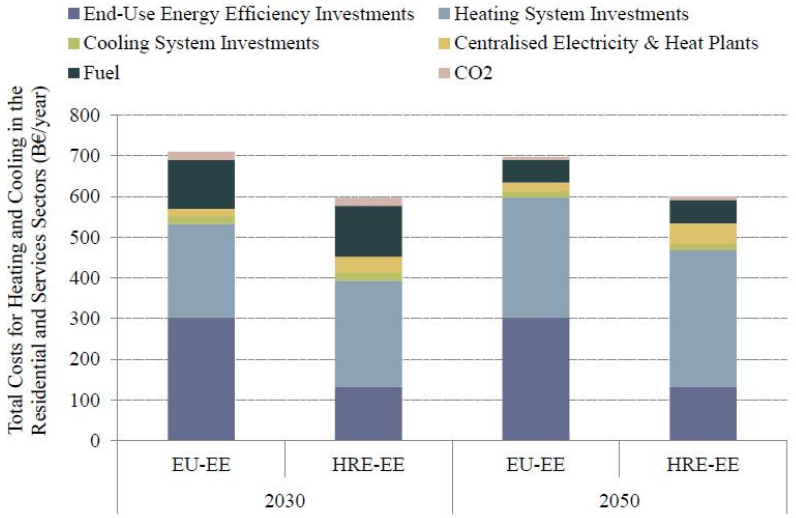
Results

- Pre-study 2

- HRE 2050 compared to EU-EE 2050:
  - ~2% marginal increase in PES
  - Inclusion of additional resources that would otherwise be wasted (WtE, geothermal, solar thermal)
  - Added flexibility by integating electricy and heat sectors: ~5% more wind power

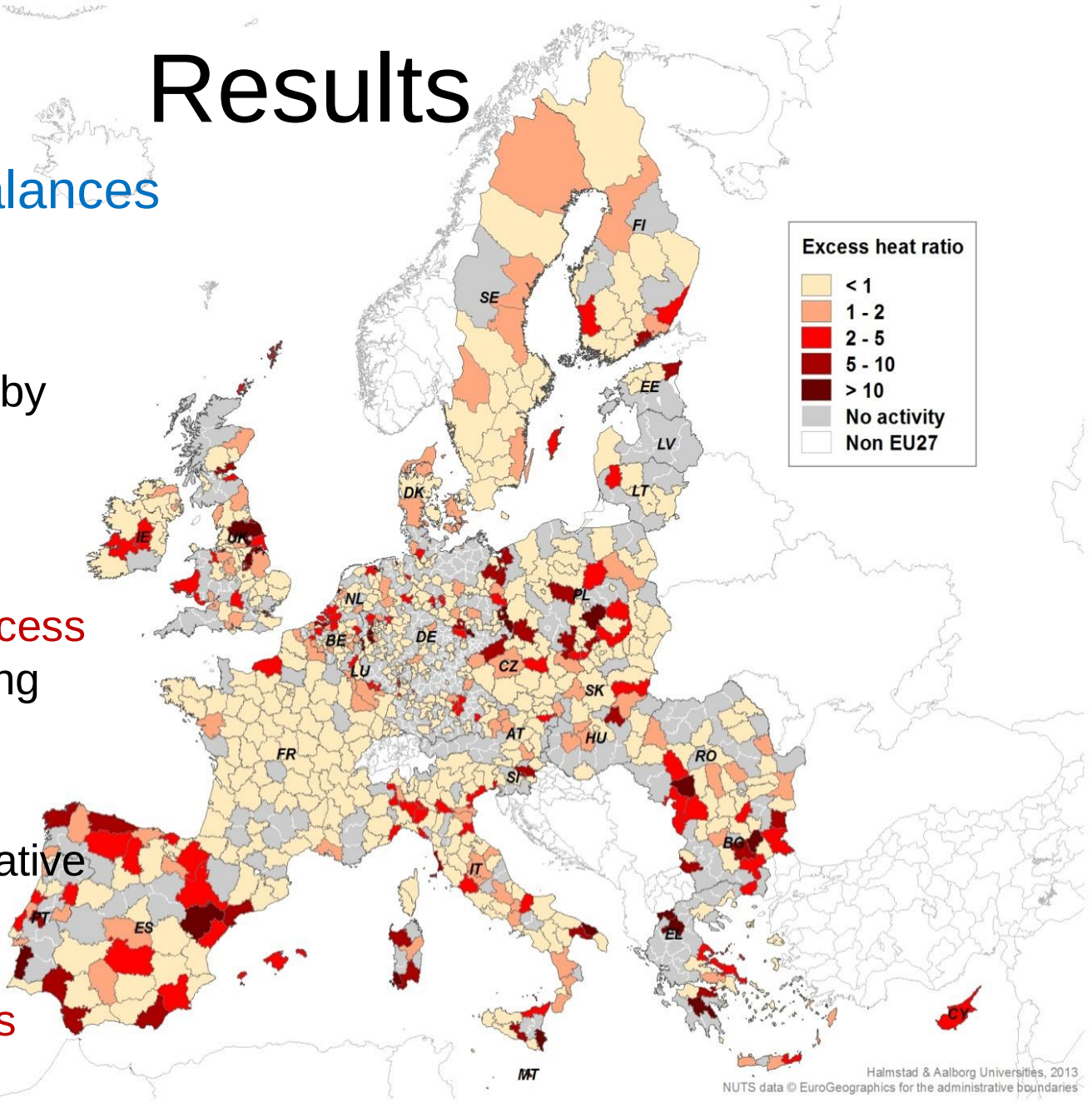
- Costs
  - Less investments in end-use energy savings
  - More investments in redesigning the heating sector
  - 15% lower total cost in





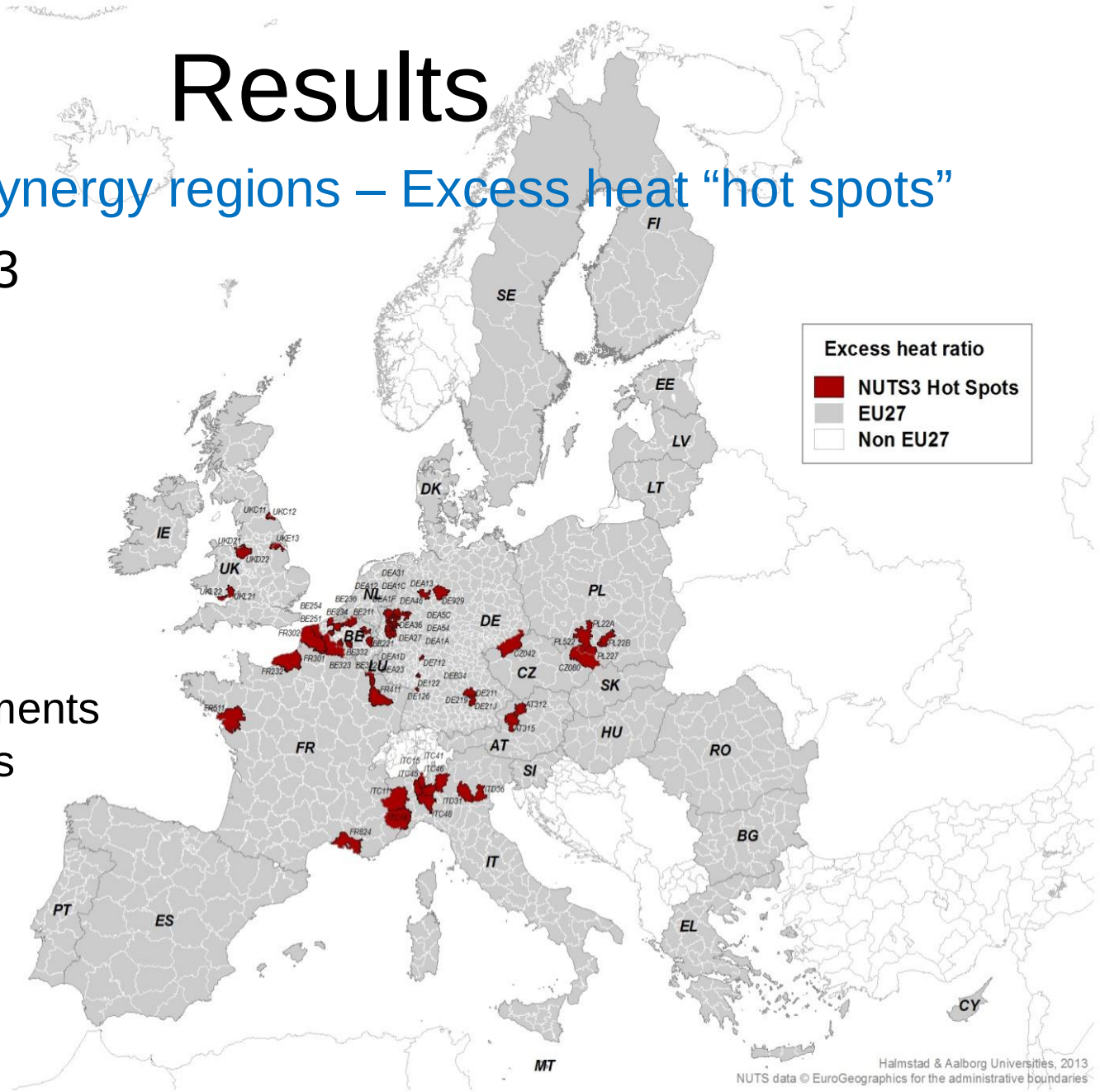
Results

- Regional heat balances
- Main result from spatial mapping
  - Heat balances by EU27 NUTS3 regions
  - Quota of recoverable excess heat and building heat demands (ratio)
  - Basis for qualitative assessment of strategic heat synergy regions



Results

- Strategic heat synergy regions – Excess heat “hot spots”
- Identified NUTS3 regions with favourable heat synergy opportunities
- Categories:
  - New establishments
  - Refurbishments
  - Expansions



Conclusions

- Key study messages
- Increase competitiveness in Europe
  - Annual savings while still achieving decarbonisation
  - Reduced energy imports
  - Job creation
- Recycle heat losses and expanding renewables
  - More efficient use of renewable heat and electricity
  - Recycling of heat otherwise wasted
  - Large heat savings and more efficient energy conversion
- Reduce risks in the European energy supply
  - Increased security of supply with local resources and RES
  - Creating more flexible infrastructures
  - Enhanced energy efficiency with a balanced choice of technologies
  - Reducing risks from adverse effects of technology lock-ins

Conclusions

- Key study experiences
- A premiere
  - For the first time ever, we have managed to quantify the benefits of district heating in the future European energy system – and developed a smarter system solution than those found in other studies
- A possibility
  - By avoiding the most expensive energy saving measures, and instead using district heating, EU climate targets are within reach at lower total system costs
- A paradox
  - District heating, apparantly, has a higher competitiveness in a more energy efficient Europe!

HALMSTAD UNIVERSITY

- Thank you!

– Contact: urban.persson@hh.se

– Download the two Heat Roadmap Europe 2050 pre-studies at: www.4dh.dk/hre