SECURING LOCAL ENERGY SUPPLY THROUGH MUNICIPAL ENERGY AUTONOMY: ASSESSING THE FEASIBILITY OF INCREASED DISTRICT HEATING FROM GERMAN BIOGAS PLANTS

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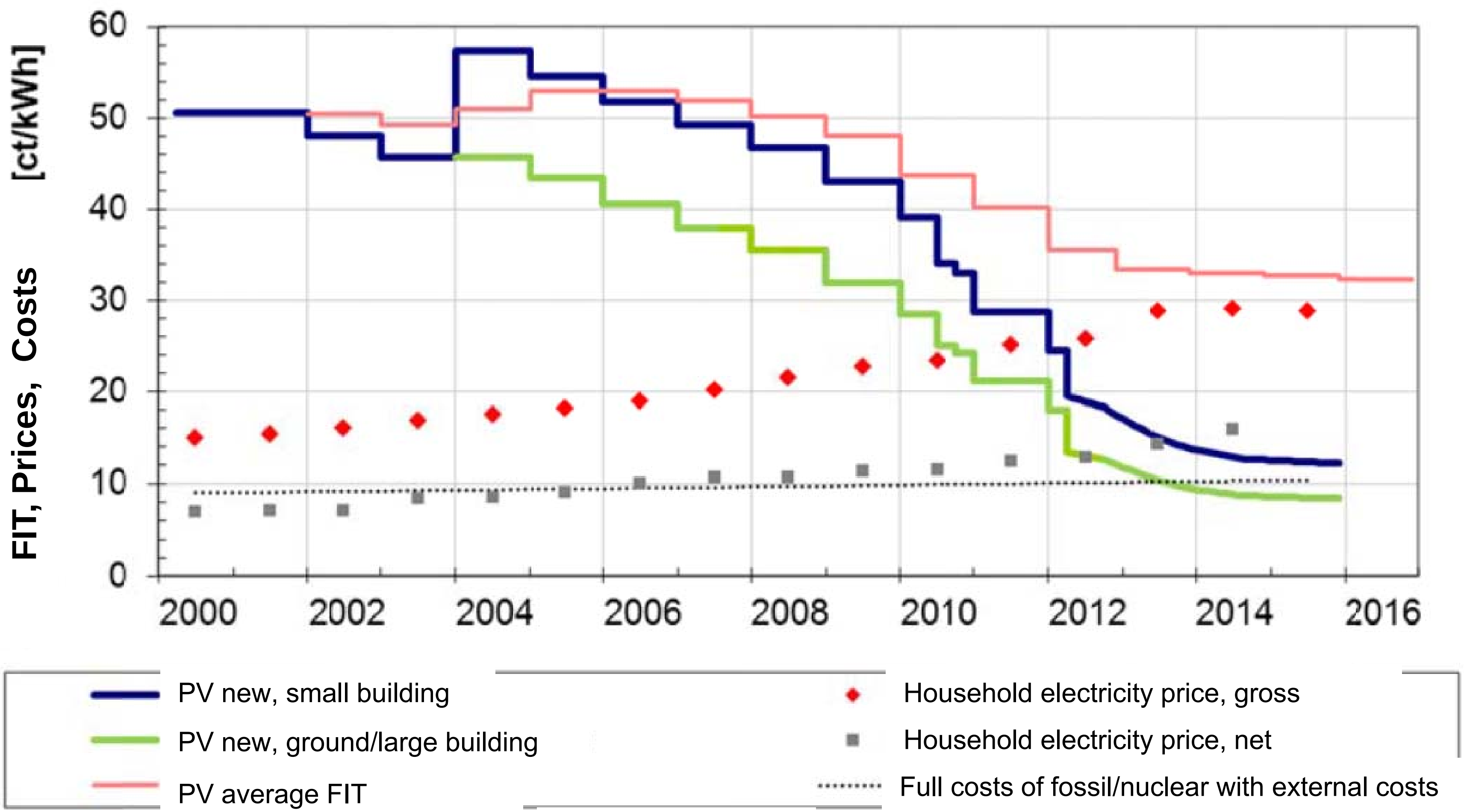
Agenda

- Background and motivation
- Biogas plants survey, research question and objectives
- Methodology for supply, demand and district heating assessment
- Preliminary results for survey plants and whole Germany
- Sensitivity analysis and critical appraisal of method
- Summary and outlook

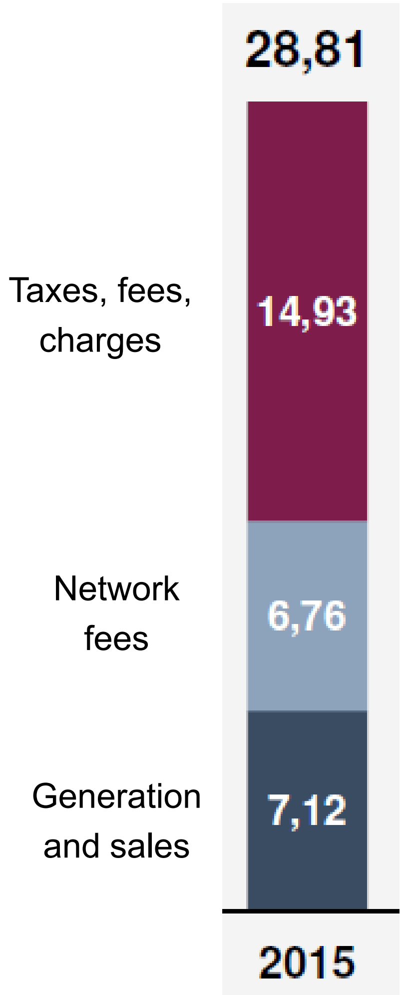
Motivation for energy autonomy

- Background: decreasing LCOEs for PV and “grid parity” make own generation/consumption increasingly economically attractive



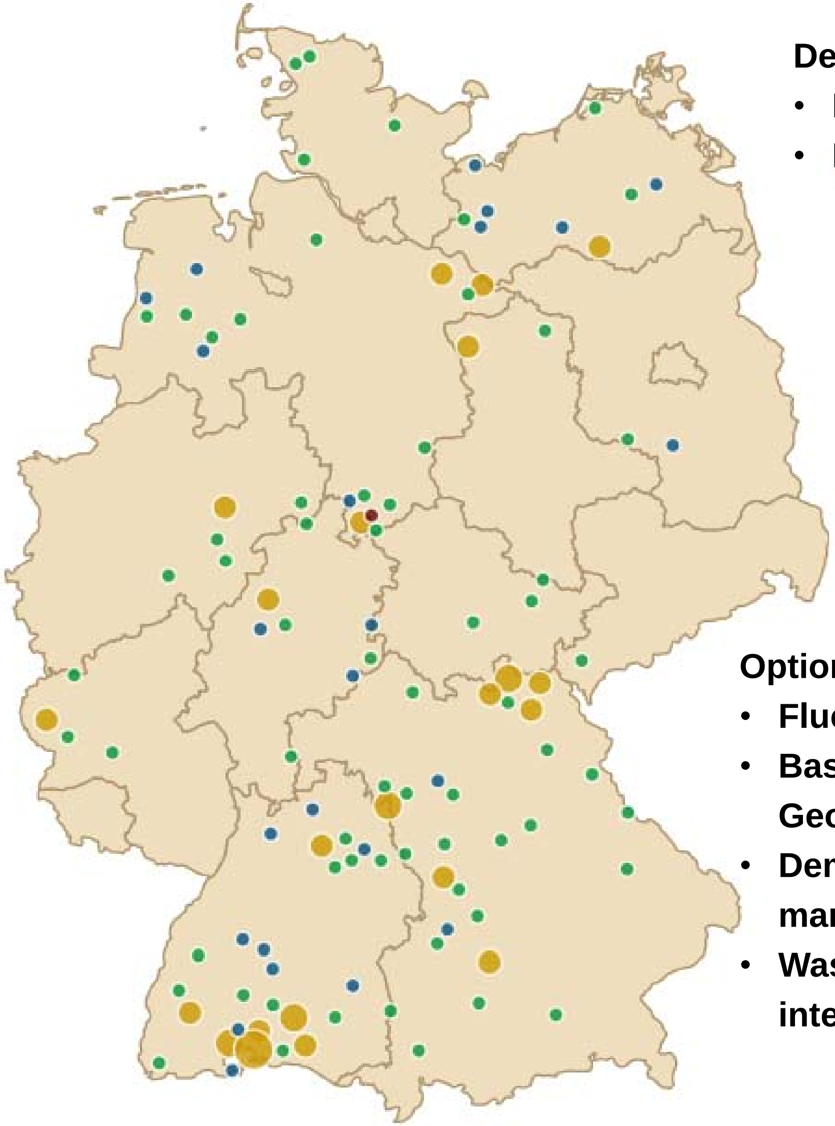
FIT = feed-in tariff

End customer electricity price in €ct/kWh



BDEW, 2015; Fraunhofer-ISE 2015

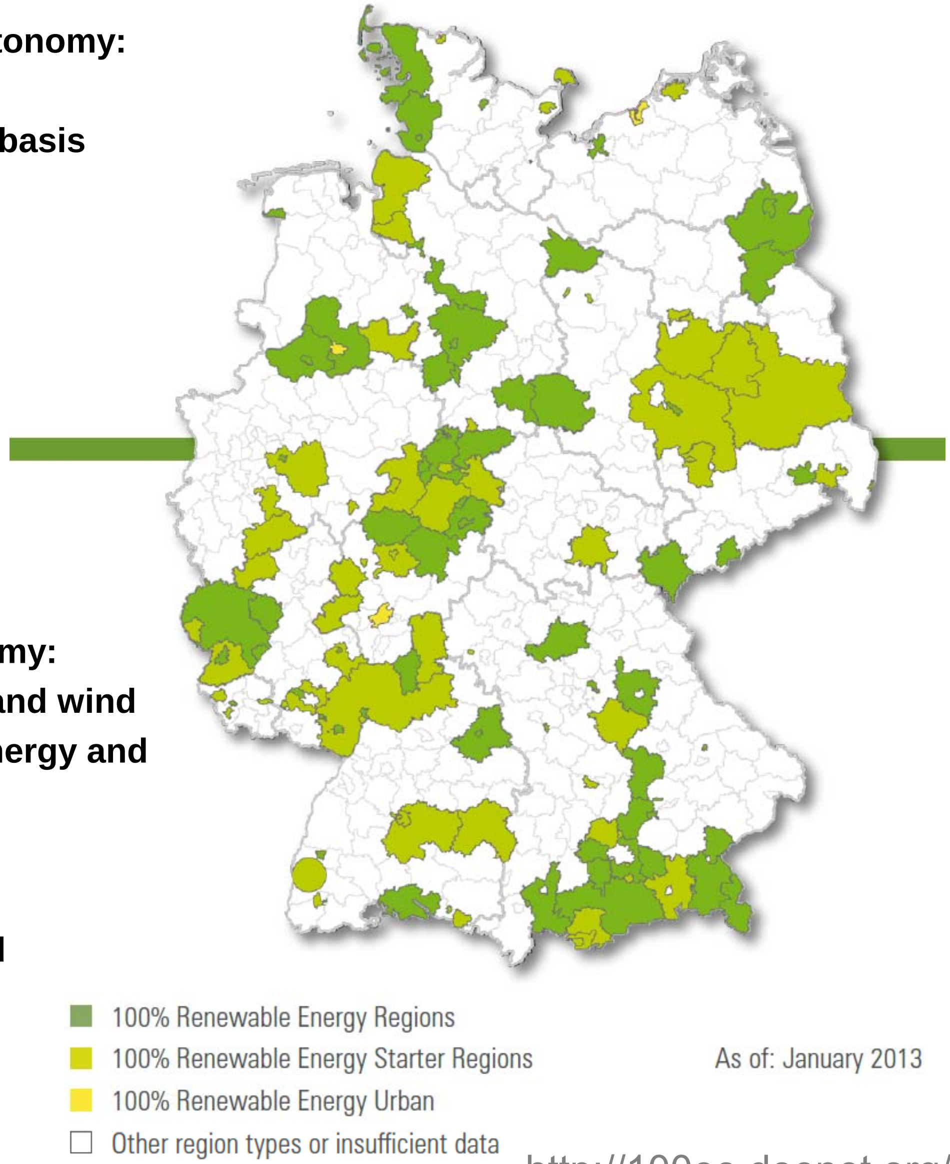
Energy autonomous villages and regions



Definition of energy autonomy:
- **Mostly electricity**
- **Mostly on an annual basis**

Options for energy autonomy:
- **Fluctuating supply: PV and wind**
- **Base-load supply: Bioenergy and Geothermal**
- **Demand reduction and management**
- **Waste heat recovery and integration**

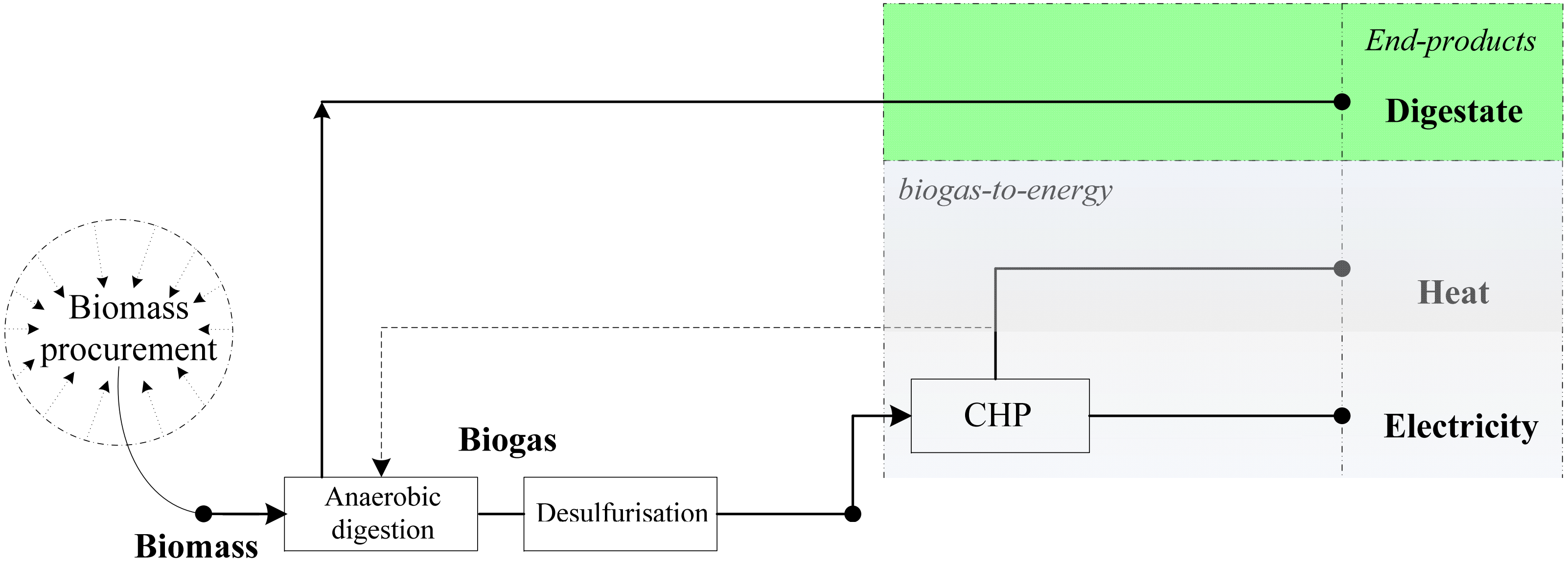
http://www.wege-zum-bioenergiedorf.de/bioenergiedoerfer/



http://100ee.deenet.org/

Survey of biogas plant operators

- January to September 2016, 2724 contacted, of which 602 surveyed
- Based on members of the Biogas Trade Assocation, hence southern Germany is over-represented
- Representative survey in terms of year of installation and size of plant
- Survey focussed on heat generation and use
- Most plants use only a small proportion of the heat
- Most common reasons e.g. low summer demand, expiry of EEG support, not economical, large distance to nearest heat sink, users not willing to pay heat price etc.



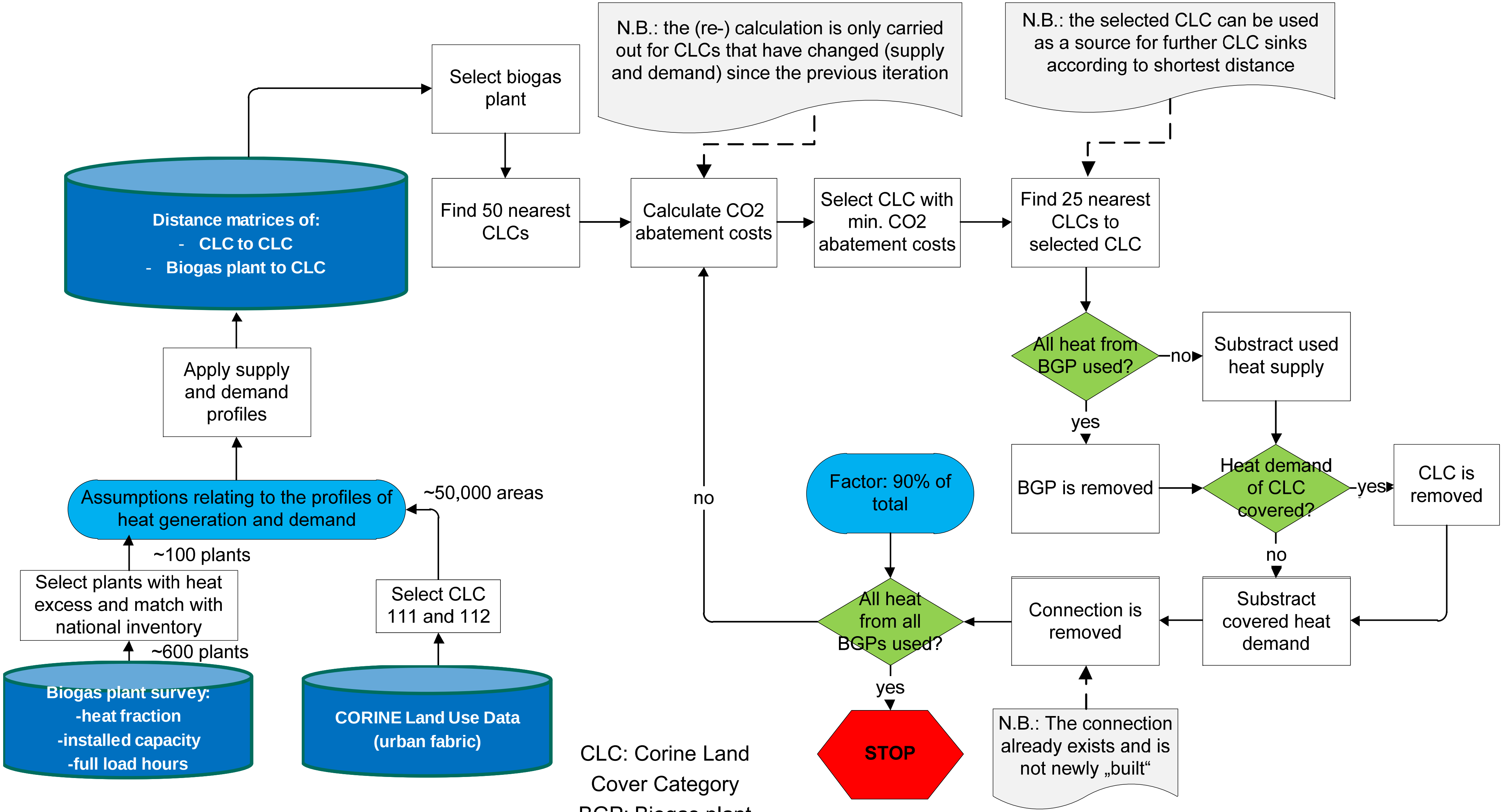
Herbes et al. 2017

Research question and objectives

- **Research question:** how can this excess heat be optimally connected to neighbouring heat sinks and what are the associated costs for the survey plants and the whole of Germany?

- **Objectives:**
  - Determine the nearest nearby sinks for heat demand
  - Estimate the total costs and CO2 savings to connect these sources and sinks through district heating
  - Determine the optimal allocation of sources to sinks based on:
    - The best temporal agreement between demand and supply (energy autonomy idea)
    - The lowest CO2-abatement costs
  - Scale up the results from the survey to the whole of Germany

Overall methodology



CLC: Corine Land Cover Category
BGP: Biogas plant

Method for district heating costs

1. From biogas plant to the settlement, $C_{pipeline}$ = 200 €/m
2. Within the settlement based on distibution capital cost C_d:

$$C_d = \frac{a \cdot I}{Q_s} = \frac{a \cdot (C_1 + C_2 \cdot d_a)}{p \cdot \alpha \cdot q \cdot w} \quad (€/GJ)$$

The four new parameters in the denominator are defined as:

$$p = P/A_L \quad (\text{number}/m^2)$$
$$\alpha = A_B/P \quad (m^2/\text{capita})$$
$$q = Q_s/A_B \quad (GJ/m^2 a)$$
$$w = A_L/L \quad (m)$$

$$\textit{Linear Heat Density Reformulation}\ (LHDR) = p.\alpha.q.w\ [\frac{GJ}{m^2.a}]$$

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if      LHDR > 1.5: da = 0.0486 * log (LHDR) + 0.007
else:   da = 0.02
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$e = p.\alpha$ if e < 0.4: w = 137.5
else: w = 60

α:	specific building space [m^2/capita]
a	annuity factor [-]
A_L:	living area [m2]
A_B:	building floor area [m2]
Cd:	distribution capital cost [€]
C1:	construction cost constant [€/m]
C2:	construction cost coefficient [€/m2]
da:	average pipe diameter [m]
e:	plot ratio [-]
I:	total network investment [€]
L:	distribution heat network length [m]
p:	population density [number/m^2]
P:	population [-]
Qs:	heat sold [GJ/a]
q:	specific heat demand [GJ/m^2.a]
w:	effective width [m]

Persson & Werner 2011, Persson et al. 2017

Method for heat demand and CO2 abatement

- Heat demand for CLC area i, $H_{CLC,i}$ estimated based on:
  - Area, type and age of buildings within a municipality
  - Building typologies given annual specific heating demands

$$H_{CLC,i} = \sum_{i=1}^{n} SH_i A_{L,i}$$

$H_{CLC,i}$:	total heat demand for CLC area [kWh/a]
SH_i	specific heat demand for building type i [kWh/m2.a]

- CO2 abatement for CLC area i $CO2_{SAVE,i}$ is determined as the CO2 emissions from object-based heating that are displaced by the (new) district heating

$$CO2_{SAVE,i} = H_{CLC,i} \cdot \sum_{i=1}^{n} SH_i \sum_{j=1}^{n} EF_{i,j} f_{i,j}$$

$EF_{i,j}$	CO2 emissions factor [tCO2/kWh]
$f_{i,j}$	Fraction of fuel j used for heating

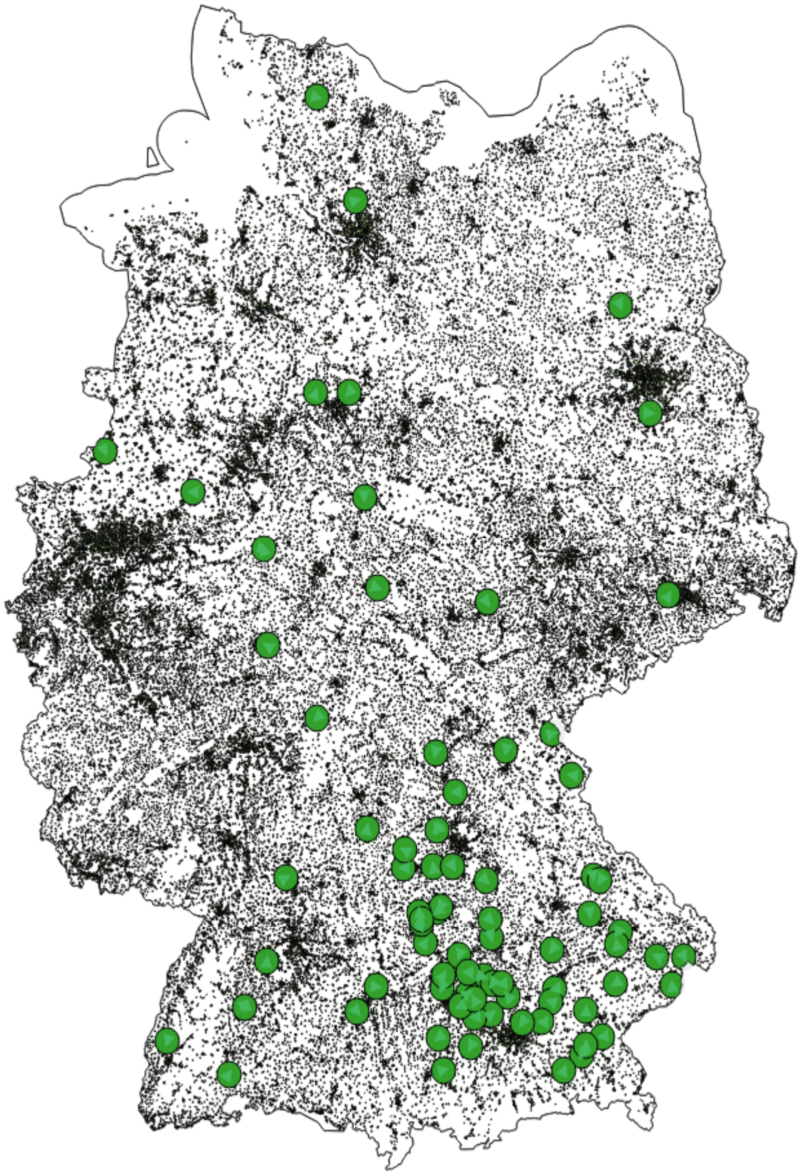
- CO2 abatement costs are the total costs of district heating divided by the total CO2 abatement

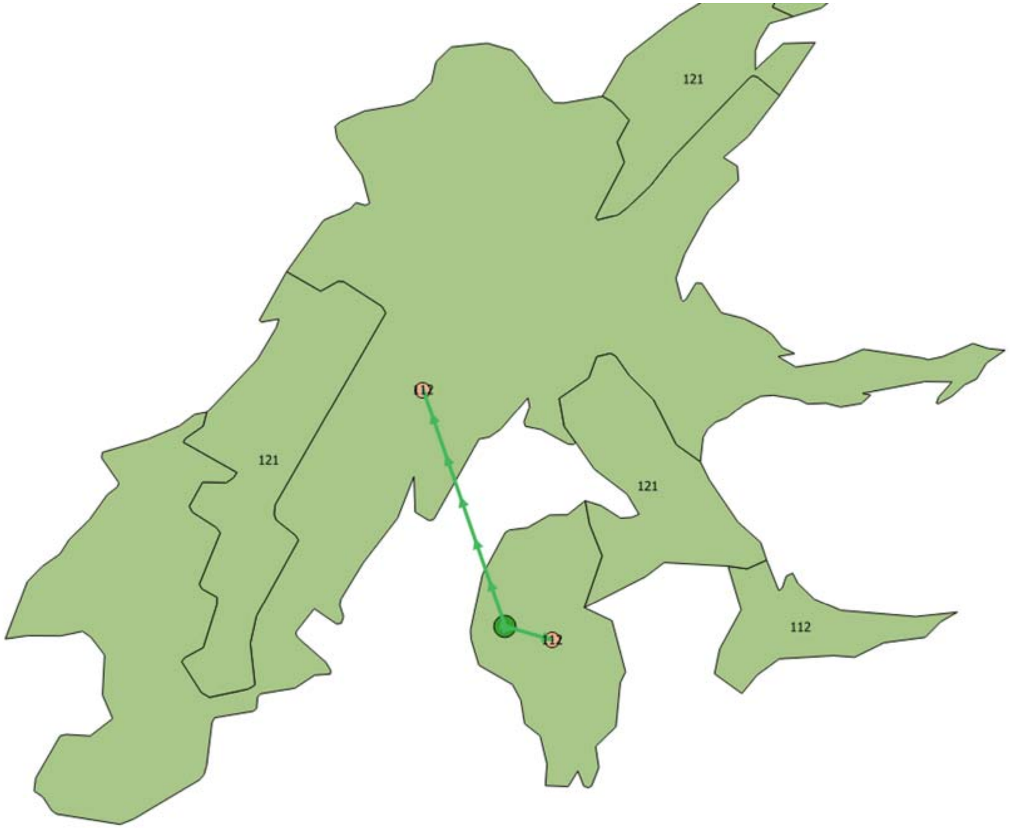
$$CO2_{COST,i} = \frac{C_{d,i} + l_{pipeline,i} \cdot C_{pipeline,i}}{CO2_{SAVE,i}}$$

C_d:	distribution capital cost [€]
$C_{pipeline}$	district heating pipeline cost [€/m]
$l_{pipeline}$	distance from biogas plant to urban area [m]

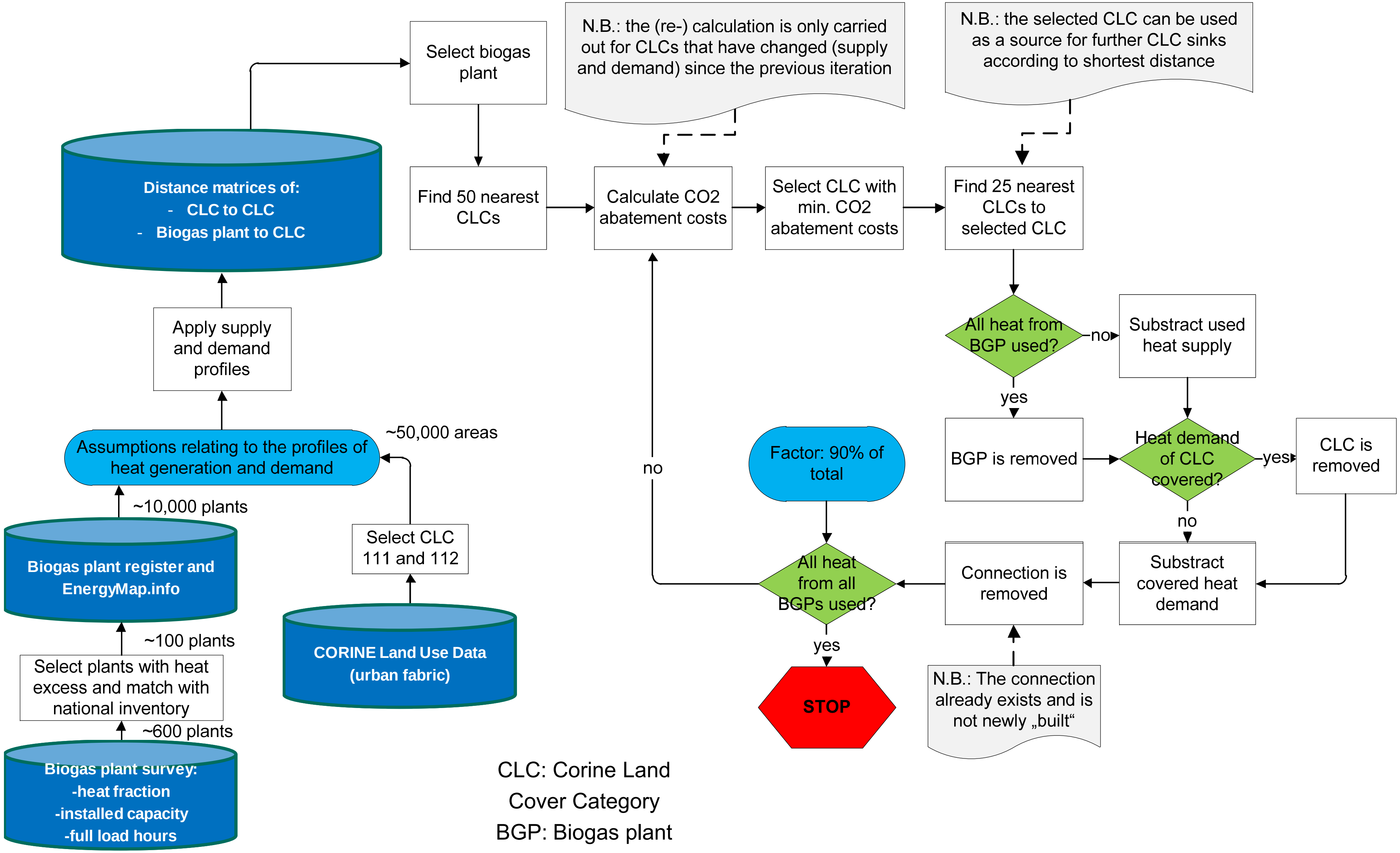
Preliminary results for ~100 survey plants

Location of survey plants and allocation procedure





Scale-up methodology for ~10,000 German plants



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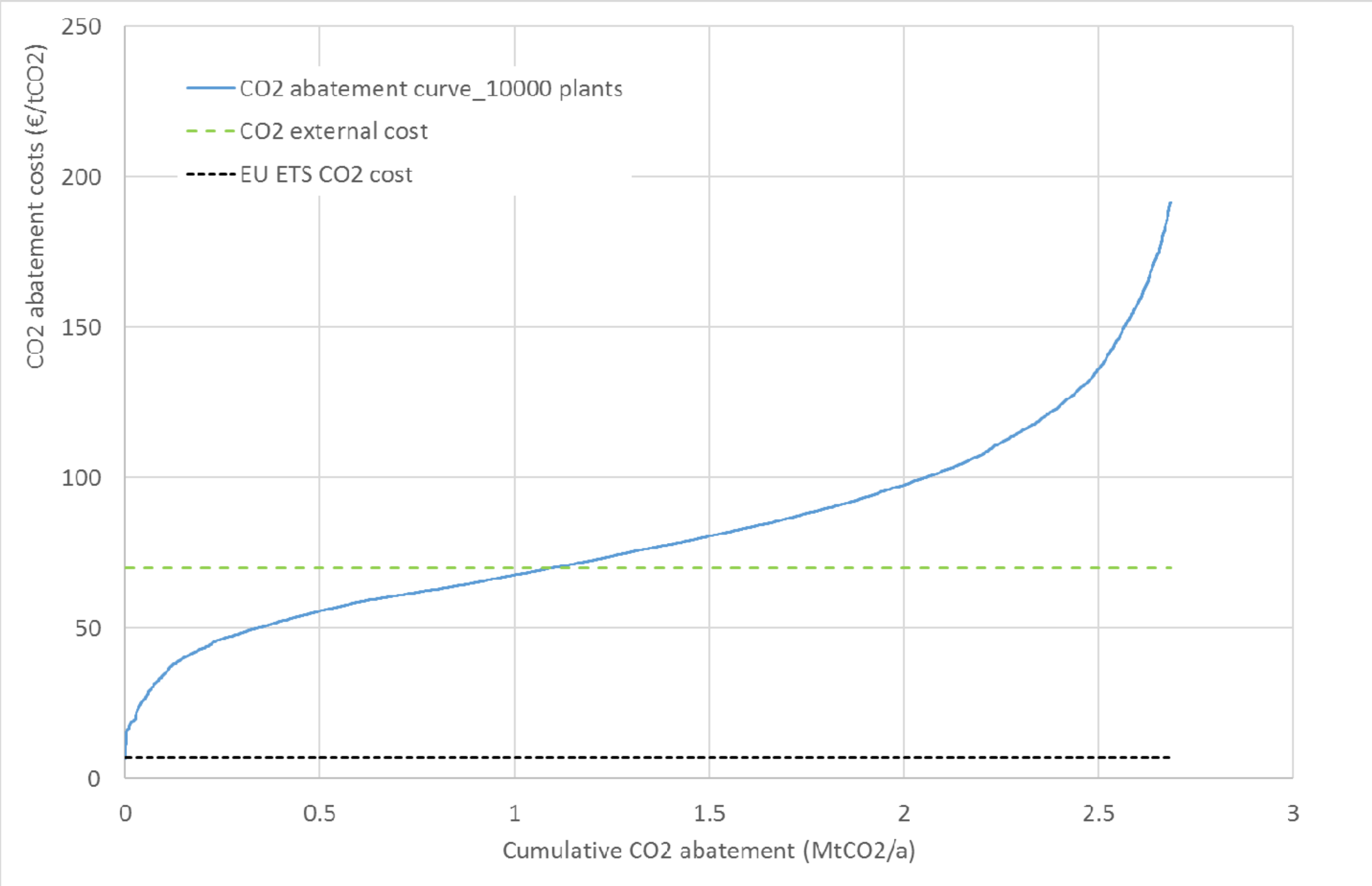
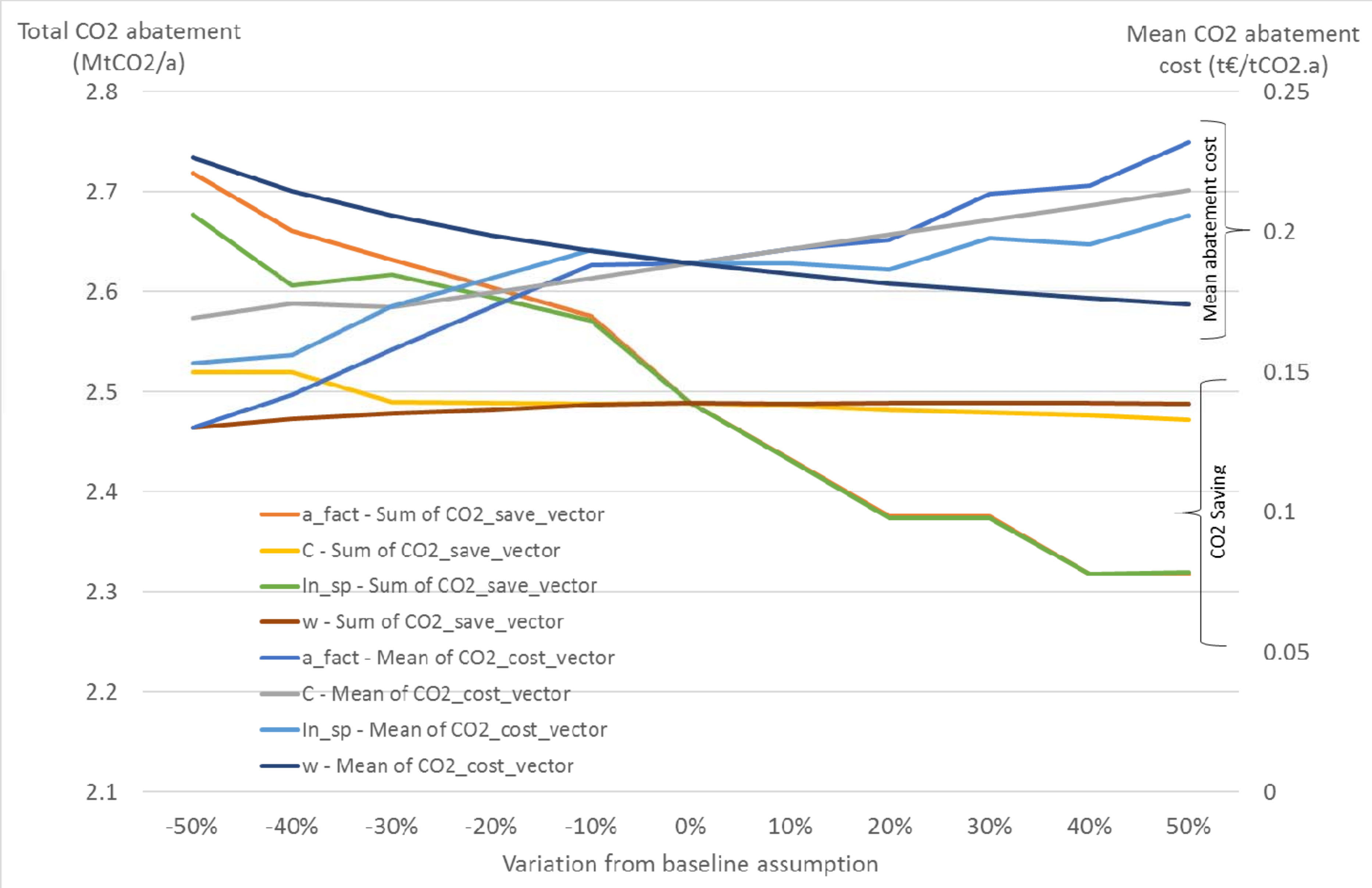
Preliminary results for all German biogas plants



Sensitivity analysis of key parameters



Critique of method

PETA: Pan European Thermal Atlas,
Heat Roadmap Europe

- Uncertain costs: sensitivity analysis
- Heat supply:
  - Existing district heating networks not considered (cf. PETA)
  - Possible double counting of heat supply where some plants already supply nearby settlements
- Heat demand:
  - Energy mix for heating: national averages used
  - Only CLC areas 111 and 112 (no industry) >> better coherent urban areas (cf. PETA)
- Connection of supply and demand
  - Assumed profiles for supply and demand
  - Topology and obstacles not considered
  - Distance to centre of settlement >> overestimate costs

Summary and outlook

- Survey of around 600 biogas plants used to estimate potential for district heating for local settlements
- Only 100 plants used due to lack of heat and issues with matching these plants with the national inventory >> suggest a technical potential of 25 $ktCO_2/a$, with 15 $ktCO_2/a$ at costs lower than 70 €/tCO_2
- If scaled up to Germany, with 10000 plants, the technical potential is about 2.5 $MtCO_2/a$ or 0.1% of total annual CO_2 emissions (1 $MtCO_2/a$ below 70 €/tCO_2)
- Strongest cost sensitivities to the annuity factor and the LHDR (w)
- Weaknesses especially relate to use of national averages (fuel mix) and neglecting existing DH networks
- Key aspect to consider is the financing and business model, e.g. partnership of plant operator and local utility, considering that the heat is currently wasted
- Most of these will be addressed in the final stages of this work

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Thank you very much for your attention!

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