This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.101000785

ECONOMICAL AND ECOLOGICAL OPTIMIZATION OF RENEWABLE ENERGY SOLUTIONS FOR THERMAL DEMAND OF LIVESTOCK BARNS

ECOS 2023

Manon Everaert – Willem Faes – Steven Lecompte – Jarissa Maselyne

June 29th, 2023

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FACULTY OF ENGINEERING AND ARCHITECTURE

ILVO
Instituut voor Landbouw-, Visserij- en Voedingsonderzoek

RES4LIVE
ENERGY SMART LIVESTOCK FARMING TOWARDS ZERO FOSSIL FUEL CONSUMPTION

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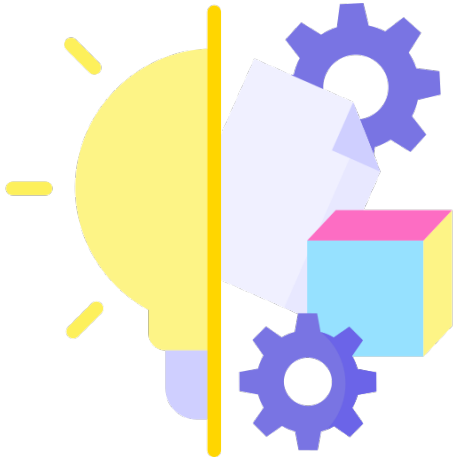
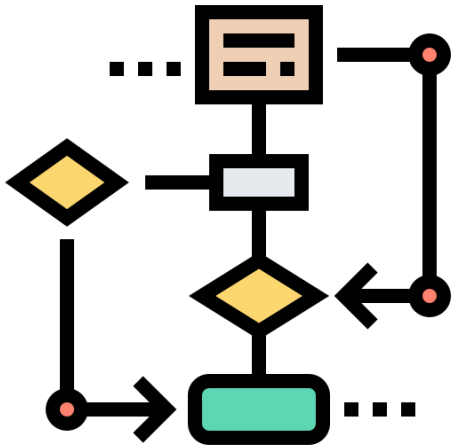
Problem

RES4LIVE project



Simulation model



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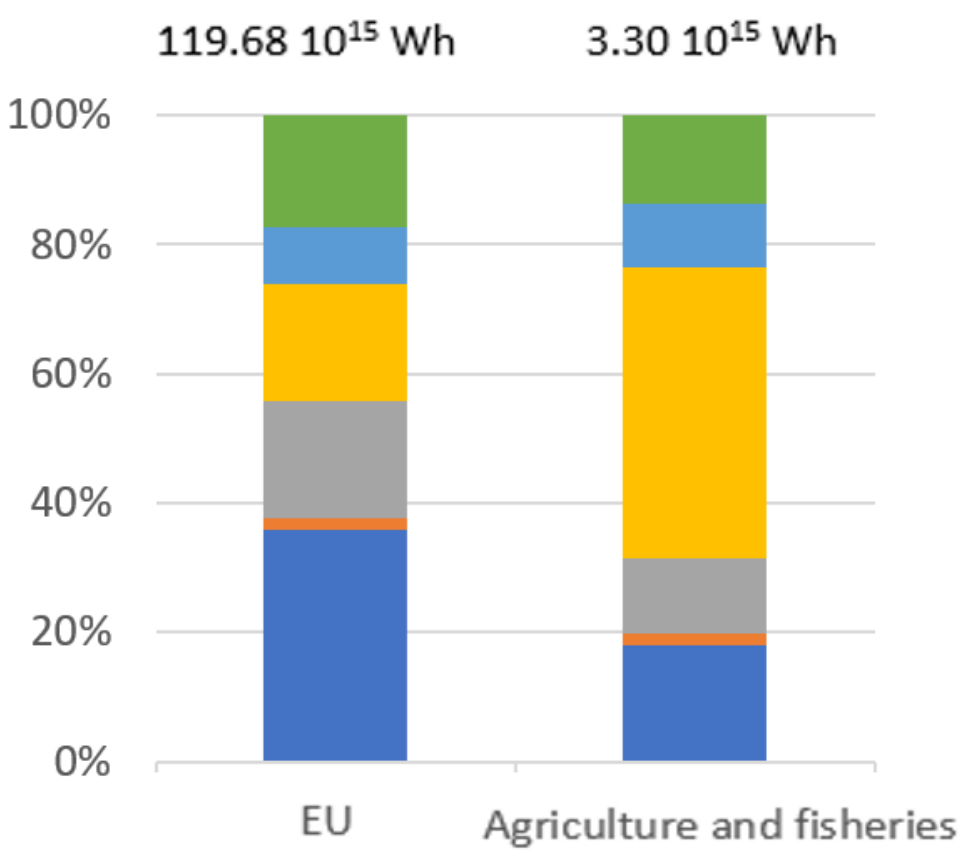
DISTRIBUTION OF ENERGY CARRIERS



- Electricity
- Renewables and biofuels
- Gas oil and diesel oil (excluding biofuel portion)
- Natural gas
- Solid fossil fuels
- Others

For livestock?

Source: Eurostat

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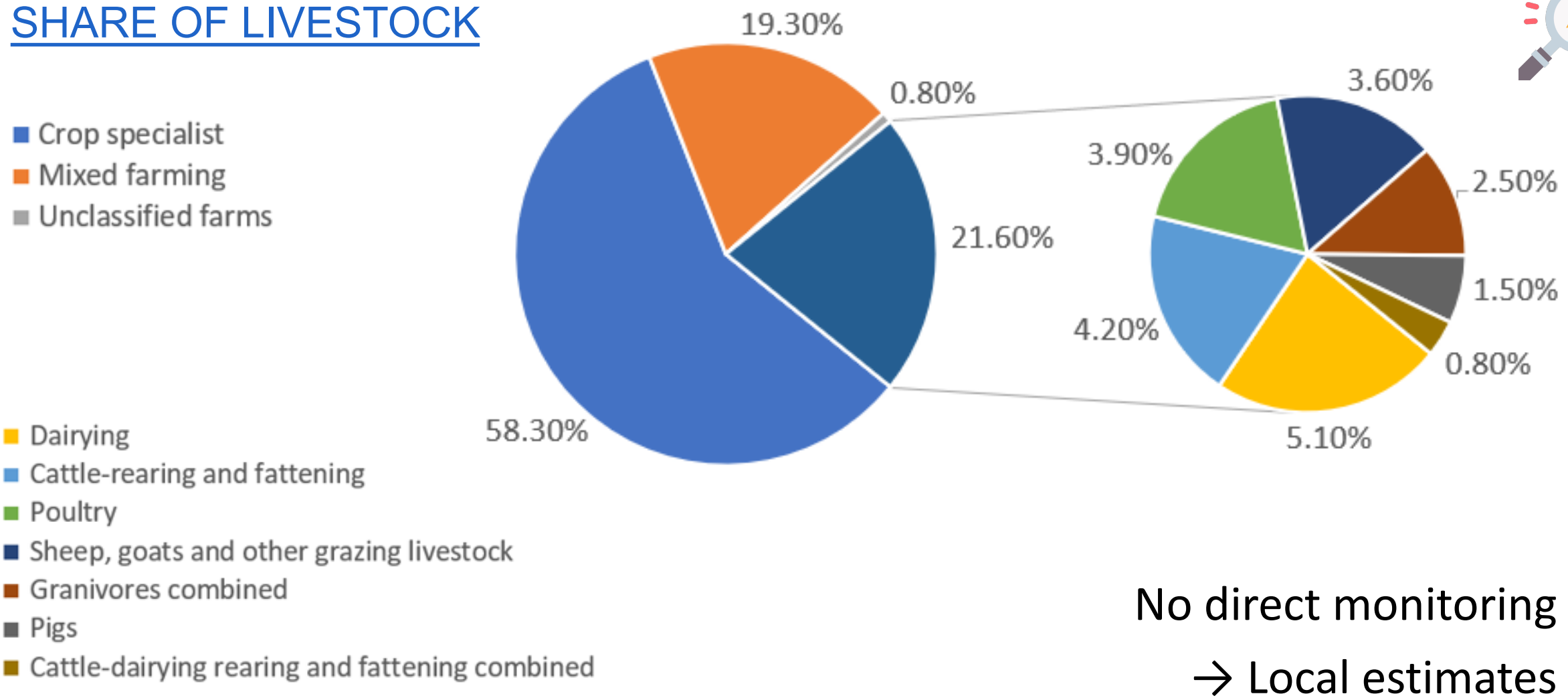
SHARE OF LIVESTOCK



No direct monitoring

→ Local estimates

Source: Eurostat

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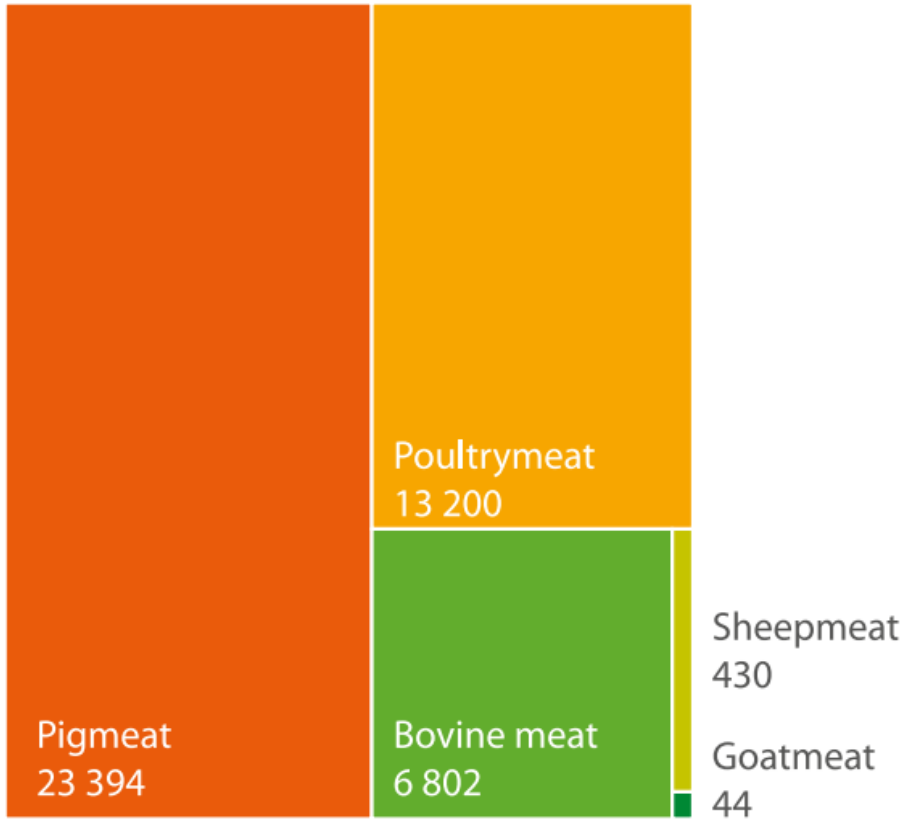
LIVESTOCK PRODUCTION

Production of milk

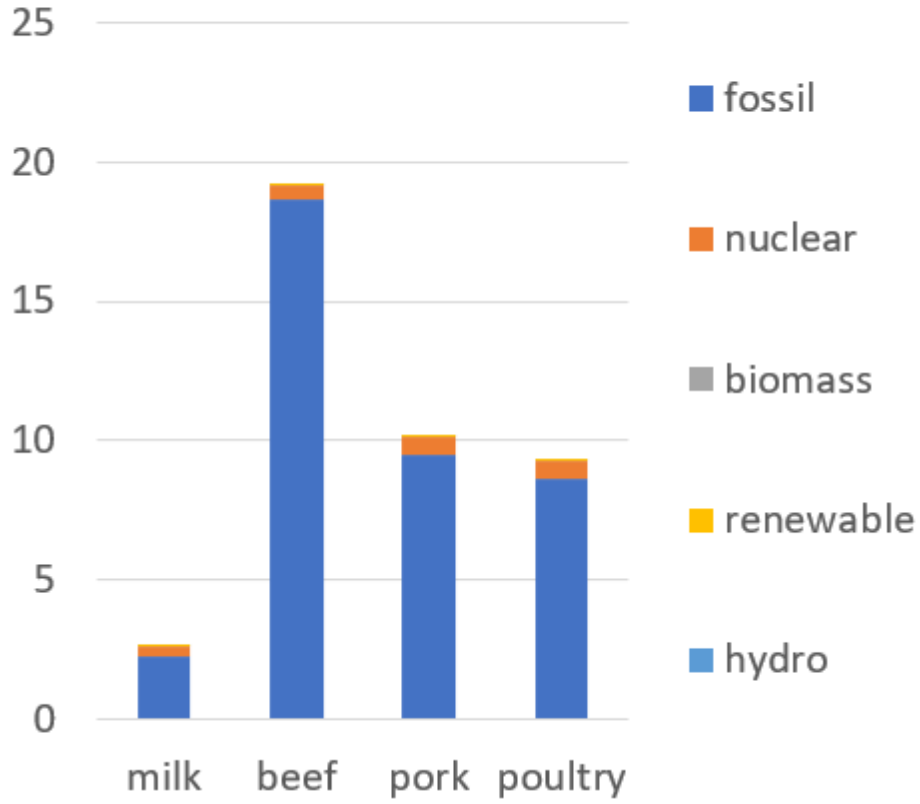
(million tonnes, EU, 2021)

Meat production

(thousand tonnes, EU, 2021)



kWh per kg produced milk or meat



Source: Eurostat

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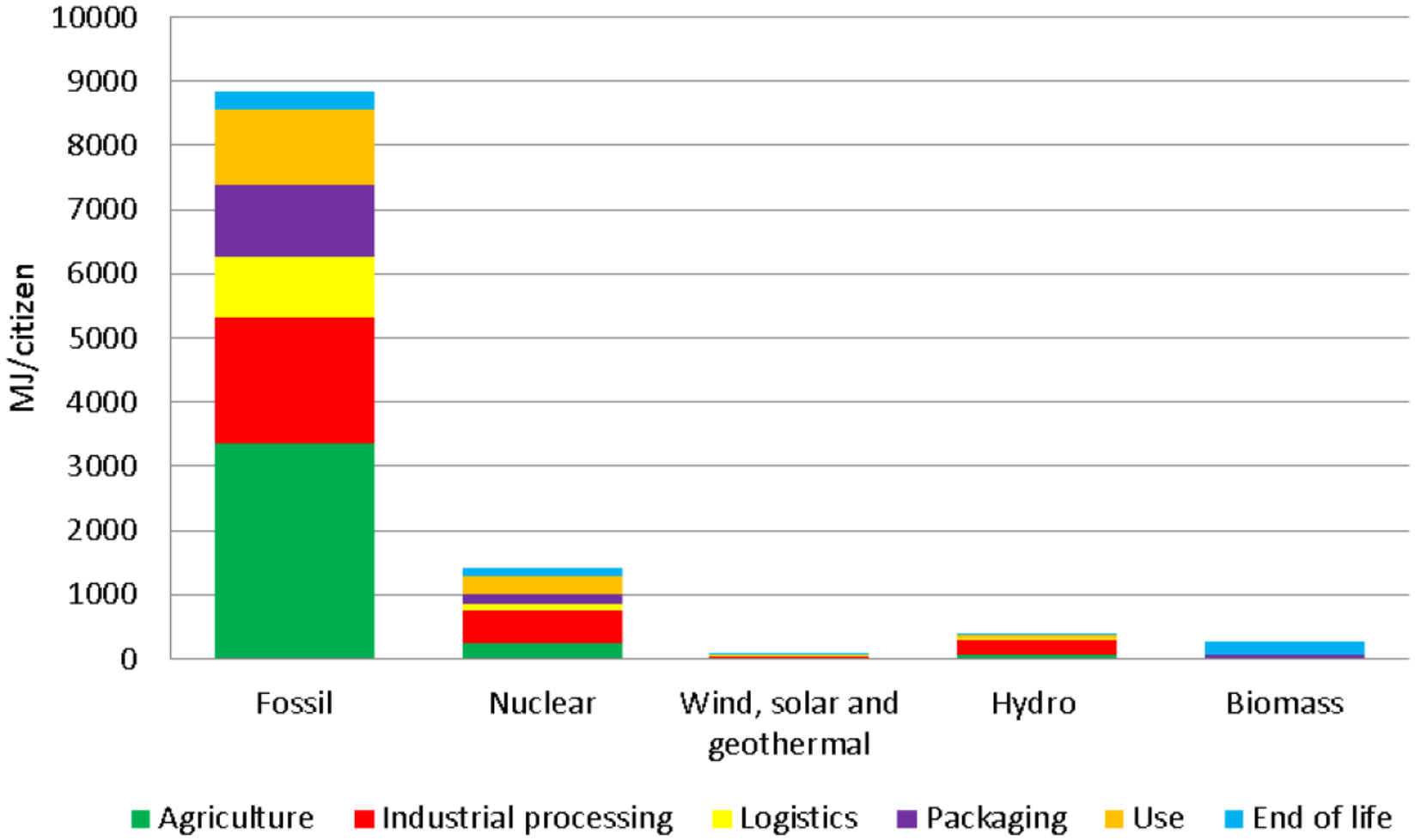
LOCATING ENERGY USAGE



Source: European commision

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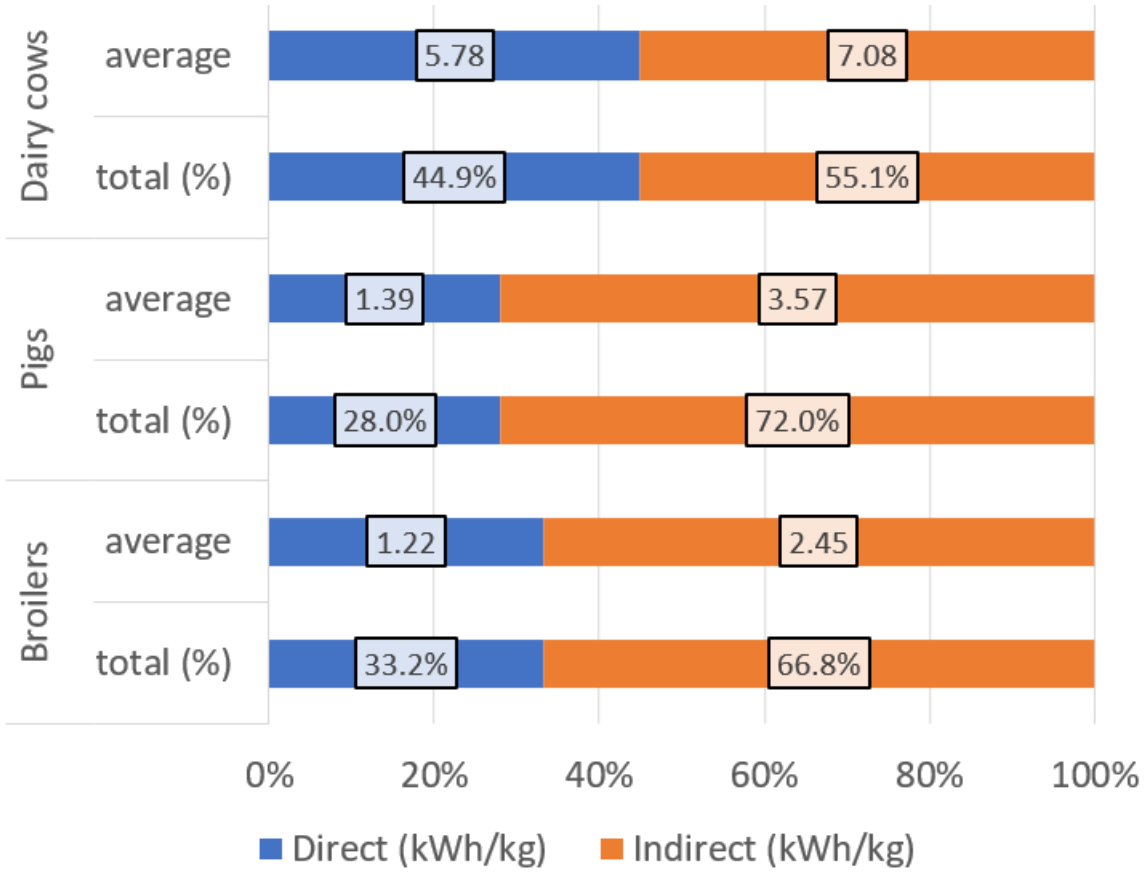
ON-FARM (DIRECT) ENERGY USAGE



Corresponding emissions?

- Old studies: ~ 20%
- New studies: ~ 4%

Sources: AgrEE and European Commision

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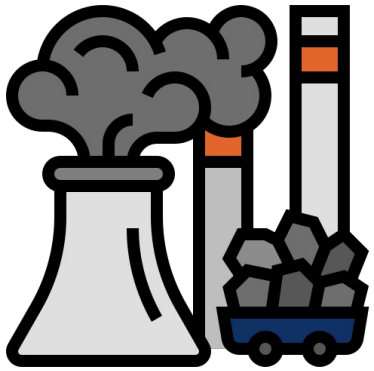
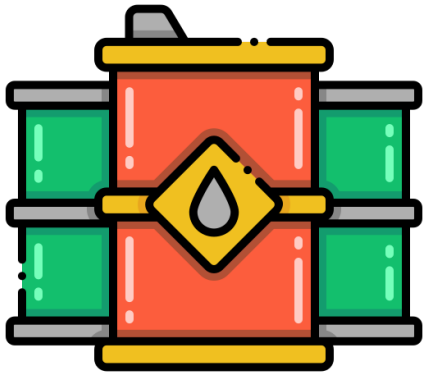
THE CHALLENGE





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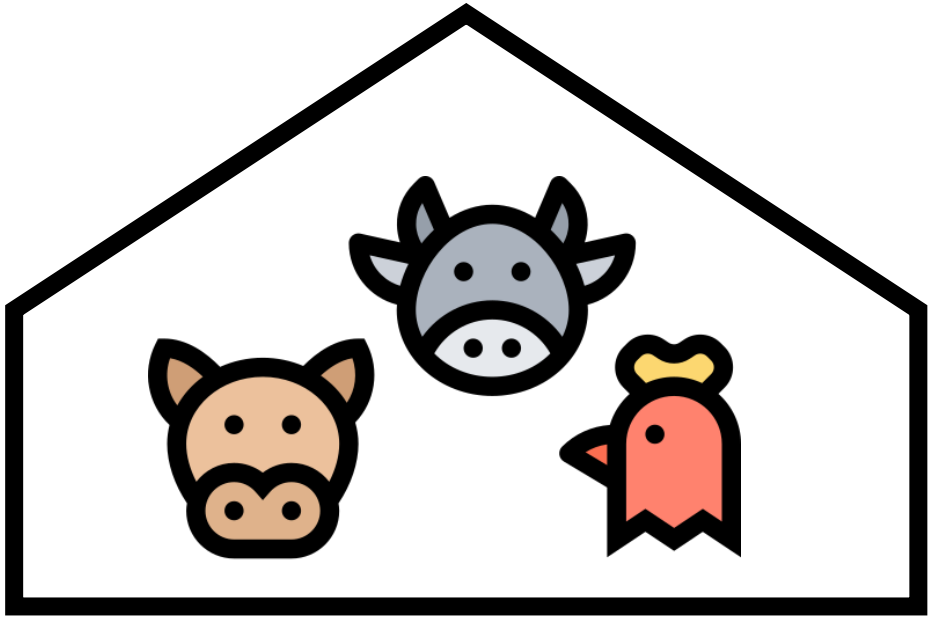
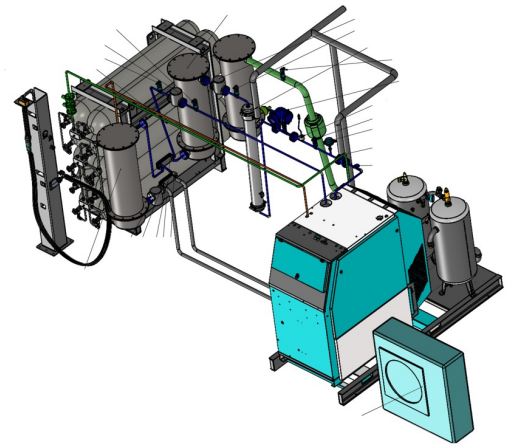
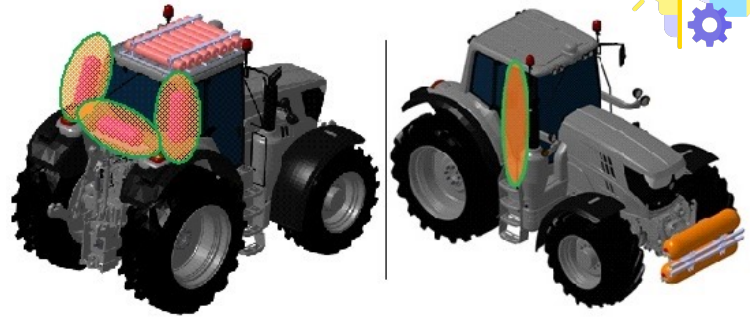
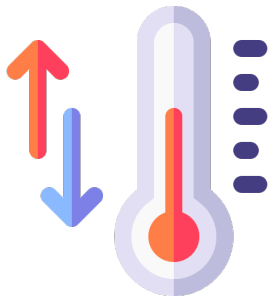
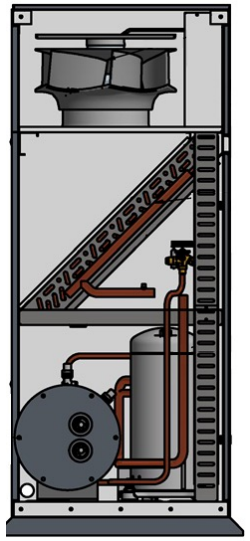
RES4LIVE PROJECT

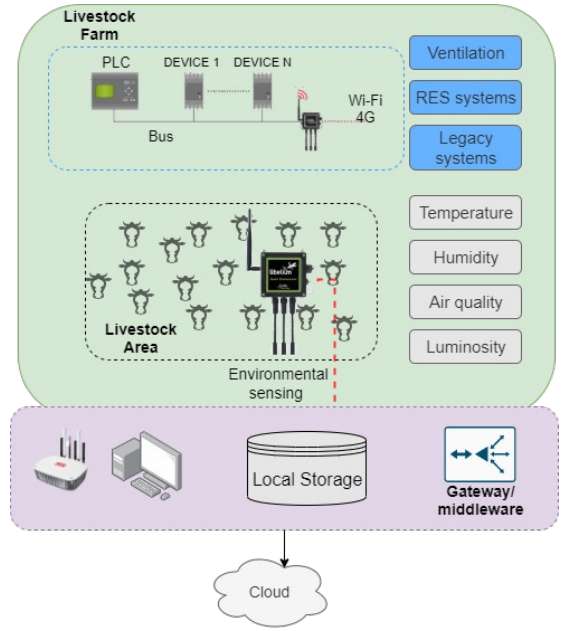












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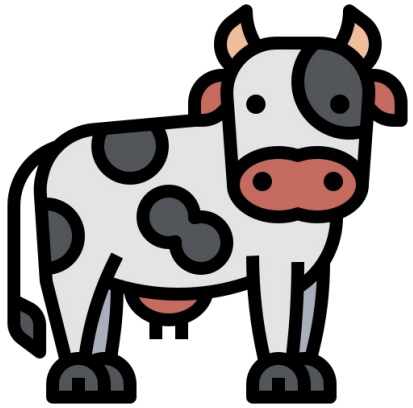
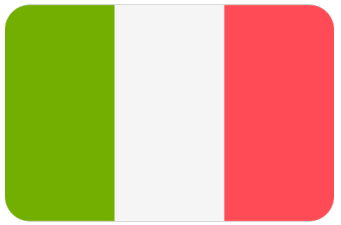
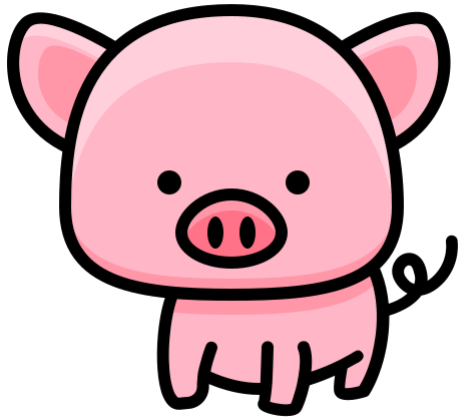
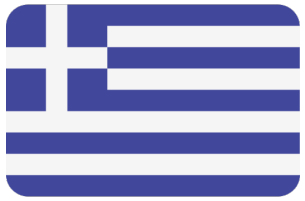
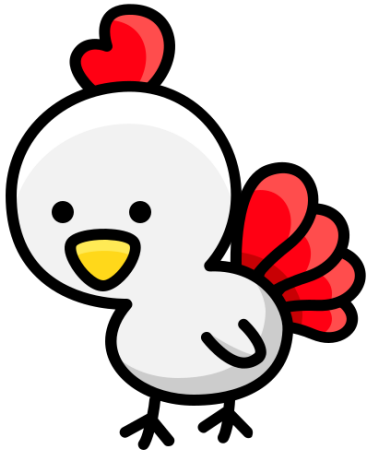
PILOT FARMS











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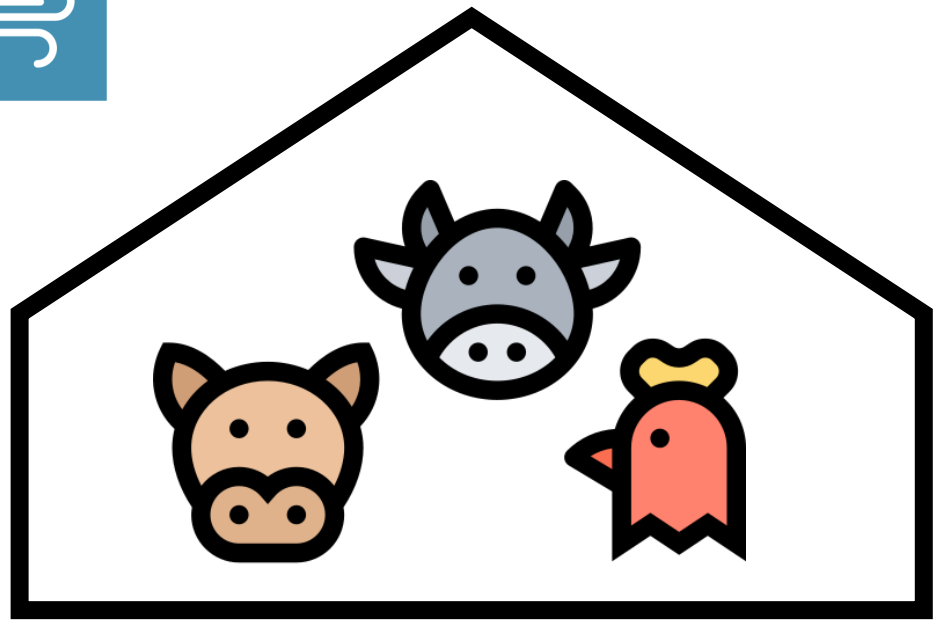
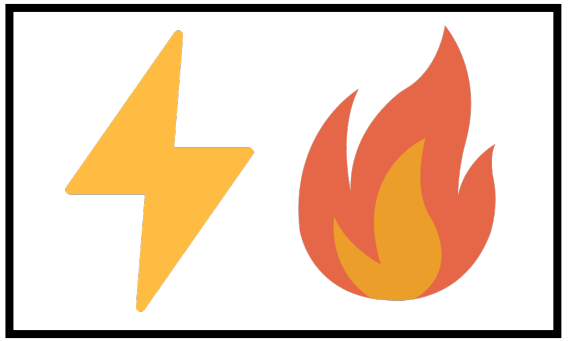
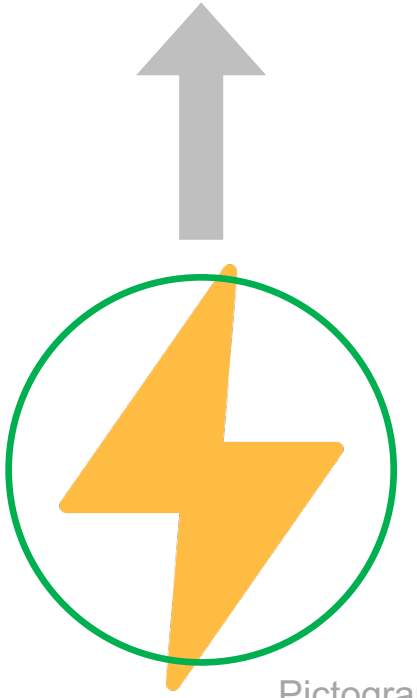
MODEL APPROACH







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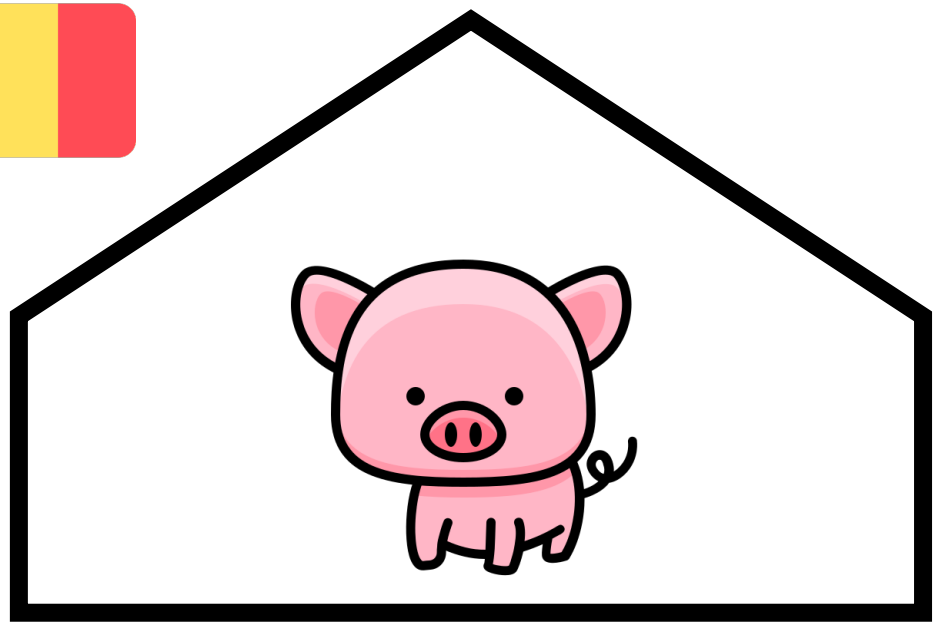
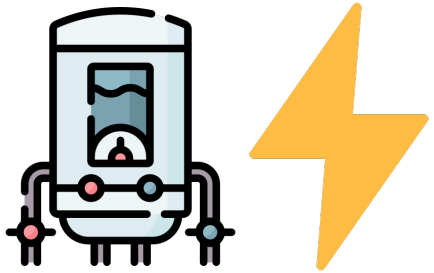
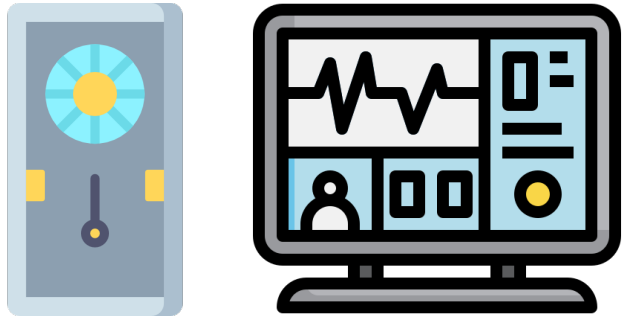
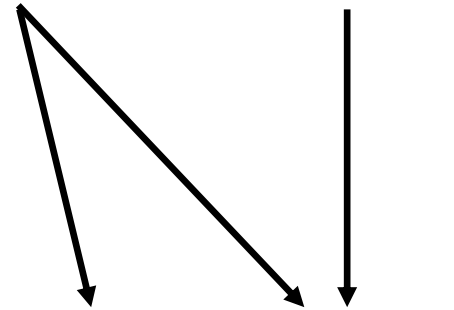
CASE STUDY: VARKENSCAMPUS (GHENT)









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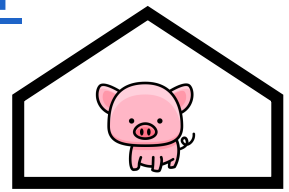
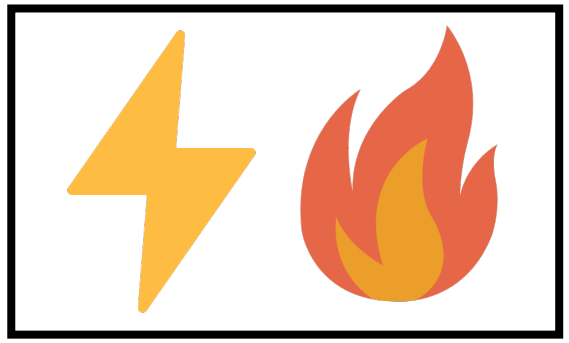
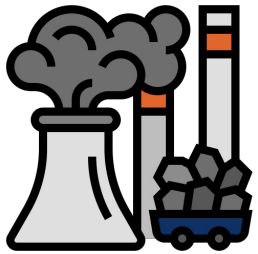
MODEL INPUT

Barn properties

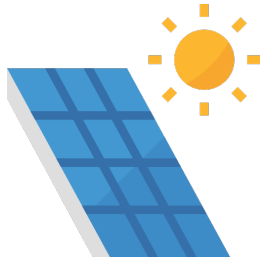


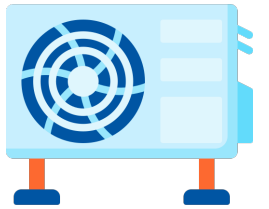


Cost and emissions



Renewables properties





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Pictogrammes from flaticon.com

MODEL OUTPUT

One configuration

e.g. 50m² PV + 1 wind turbine + 2 kWh battery

- Energy balance per hour over 1 year:
  1. Solar
  2. Check for thermal storage
  3. Heat pumps (if any)
  4. Check for batteries
  5. Fill up with remaining demand with electricity from grid and/or heat from a gasboiler

→ How to find optimal combinations?

Pictogrammes from flaticon.com

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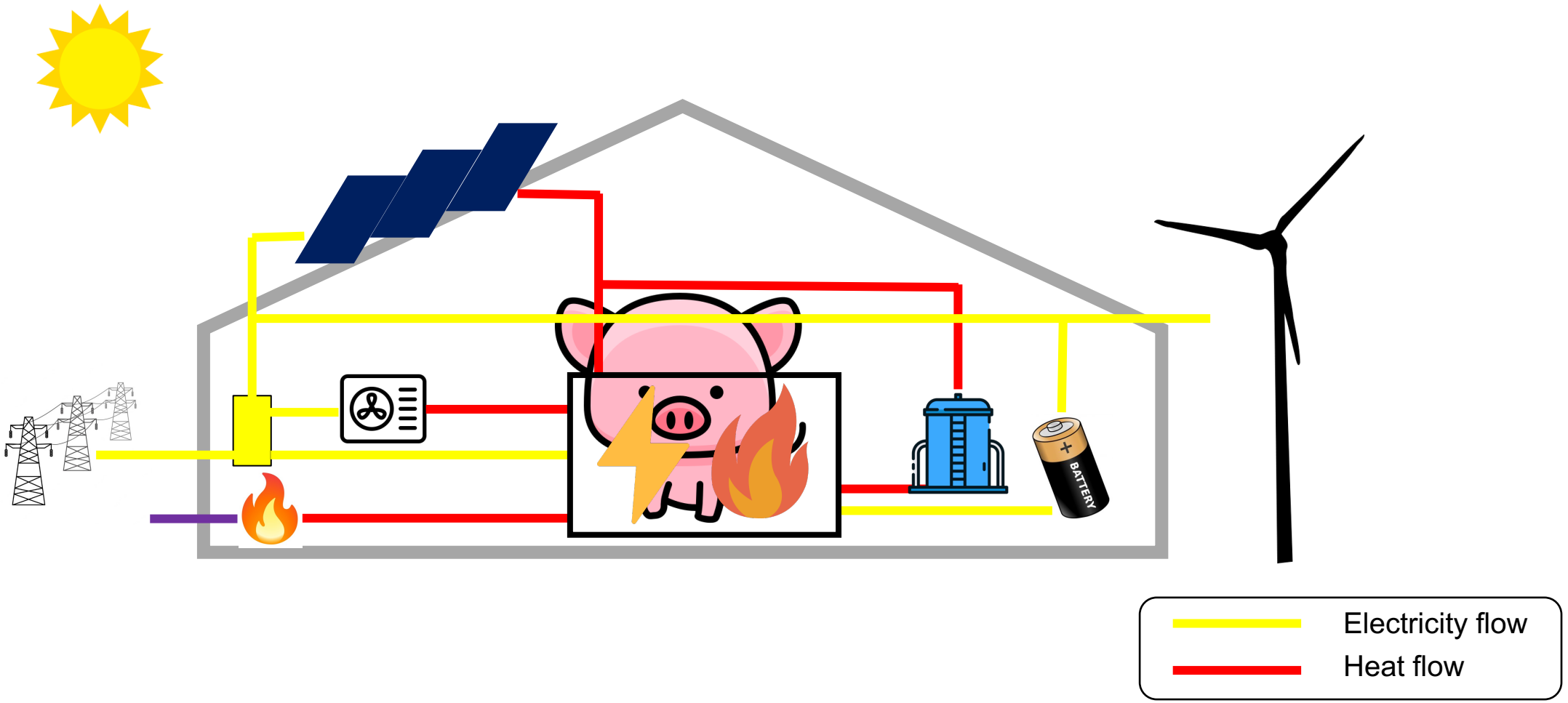
MODEL OUTPUT: VISUALIZED



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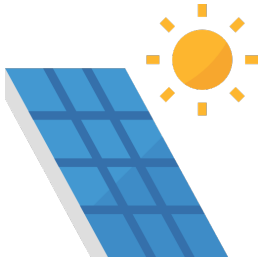
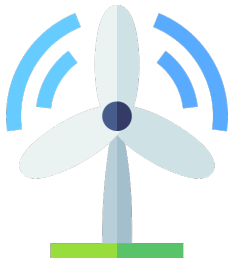
MODEL OUTPUT: OPTIMIZATION

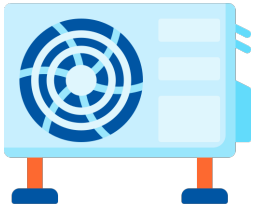


[0, 10, 50, 100, 500, 1000] m²



[0, 1, 2]

[0, 10, 50, 100, 500, 1000] m²



Small: [0, 0, 15, 30] kW

Big: [0, 60, 55, 30] kW

PVT [0, 10, 50, 100, 500, 1000] m²

[0, 250, 800, 1000, 2500, 5000] liter

[0, 2, 5, 10, 100] kWh

Pictogrammes from flaticon.com

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MODEL OUTPUT: OPTIMIZATION

123 480 possible combinations

Exclude options containing storage without renewables

120 788 calculations

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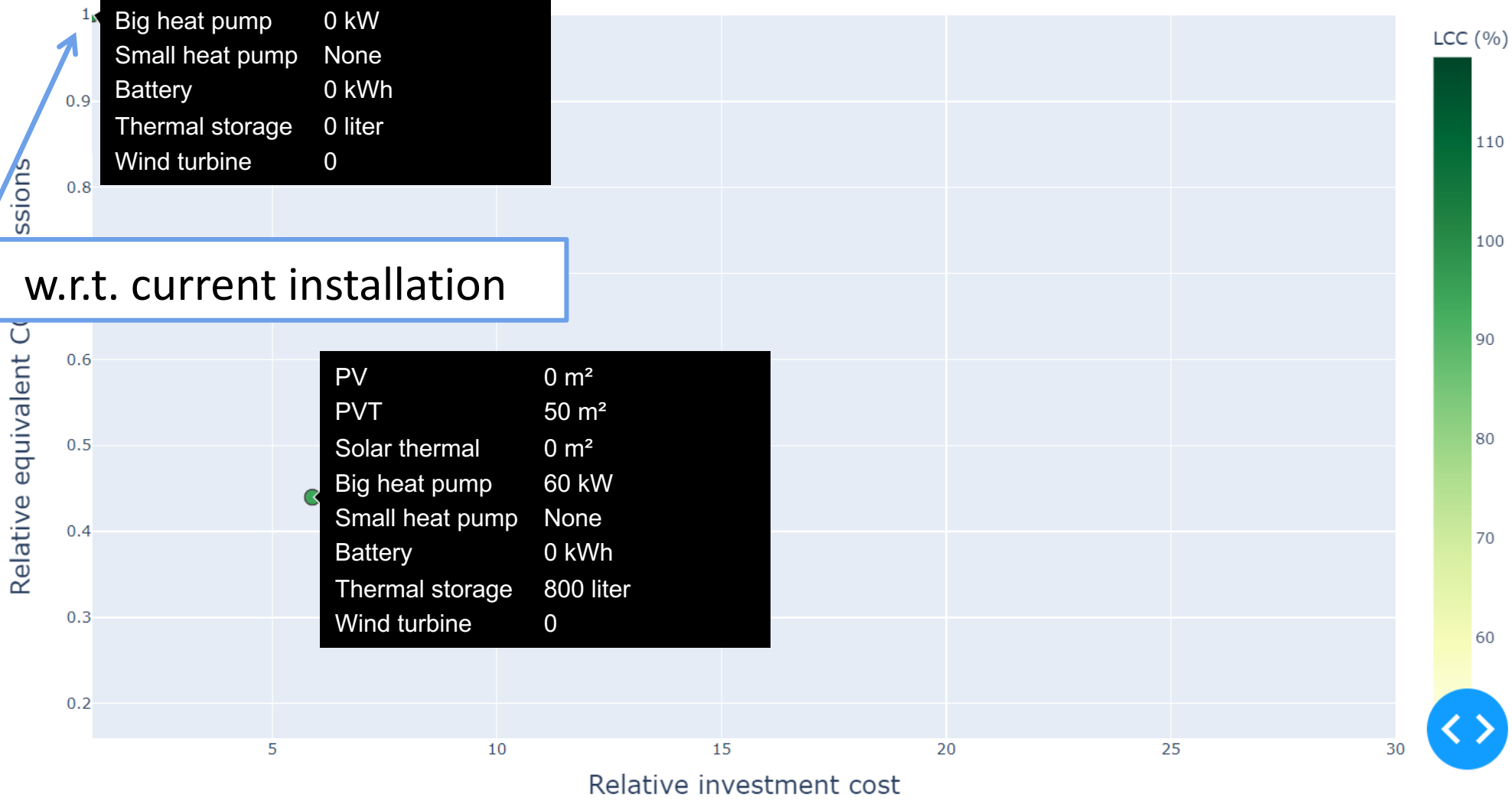
RESULTS

Example: e.g. 50m² PVT + 60kW heat pump + 800l buffertank

PV	0 m²
PVT	0 m²
Solar thermal	0 m²
Big heat pump	0 kW
Small heat pump	None
Battery	0 kWh
Thermal storage	0 liter
Wind turbine	0

w.r.t. current installation

PV	0 m²
PVT	50 m²
Solar thermal	0 m²
Big heat pump	60 kW
Small heat pump	None
Battery	0 kWh
Thermal storage	800 liter
Wind turbine	0



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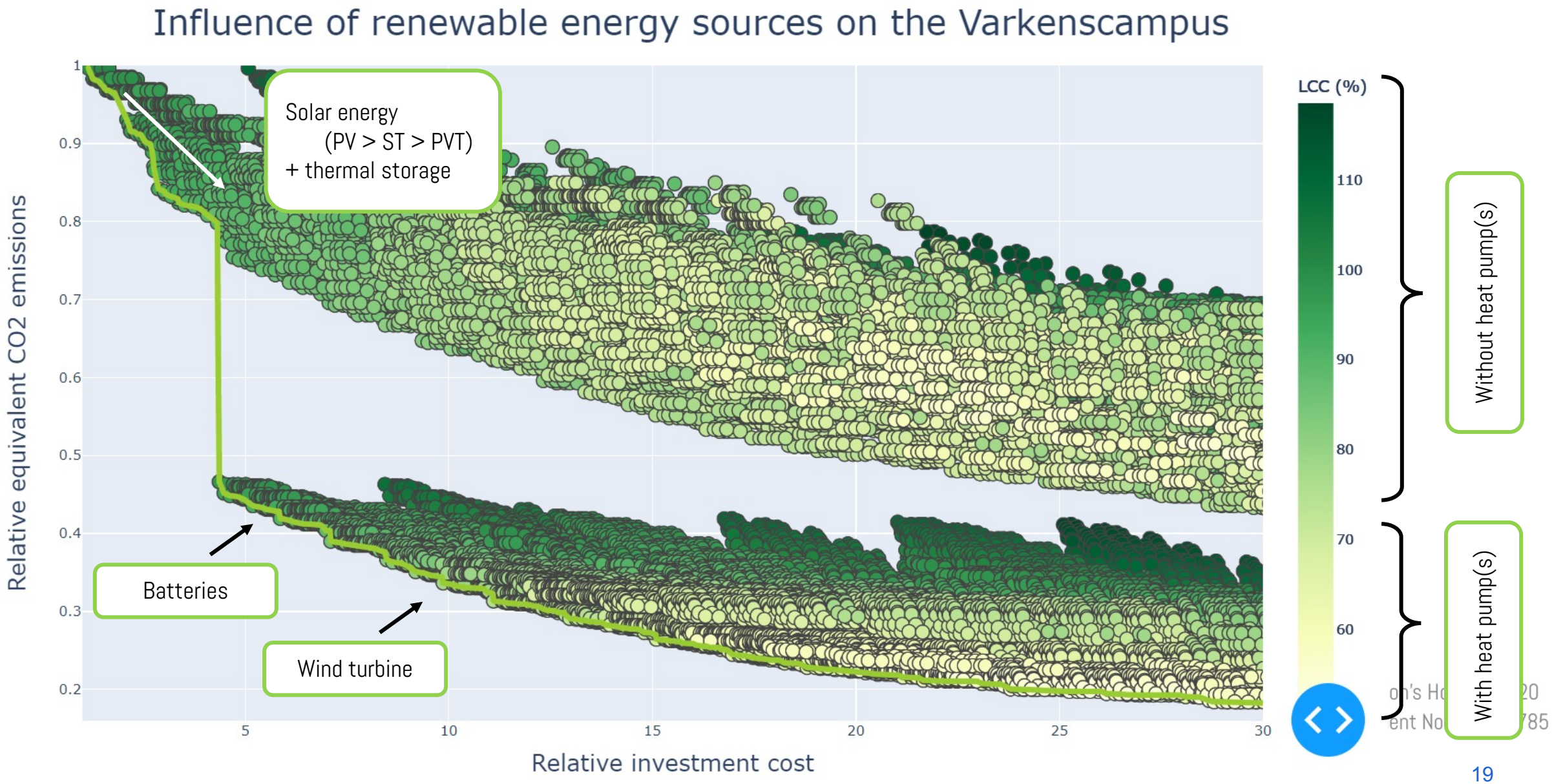
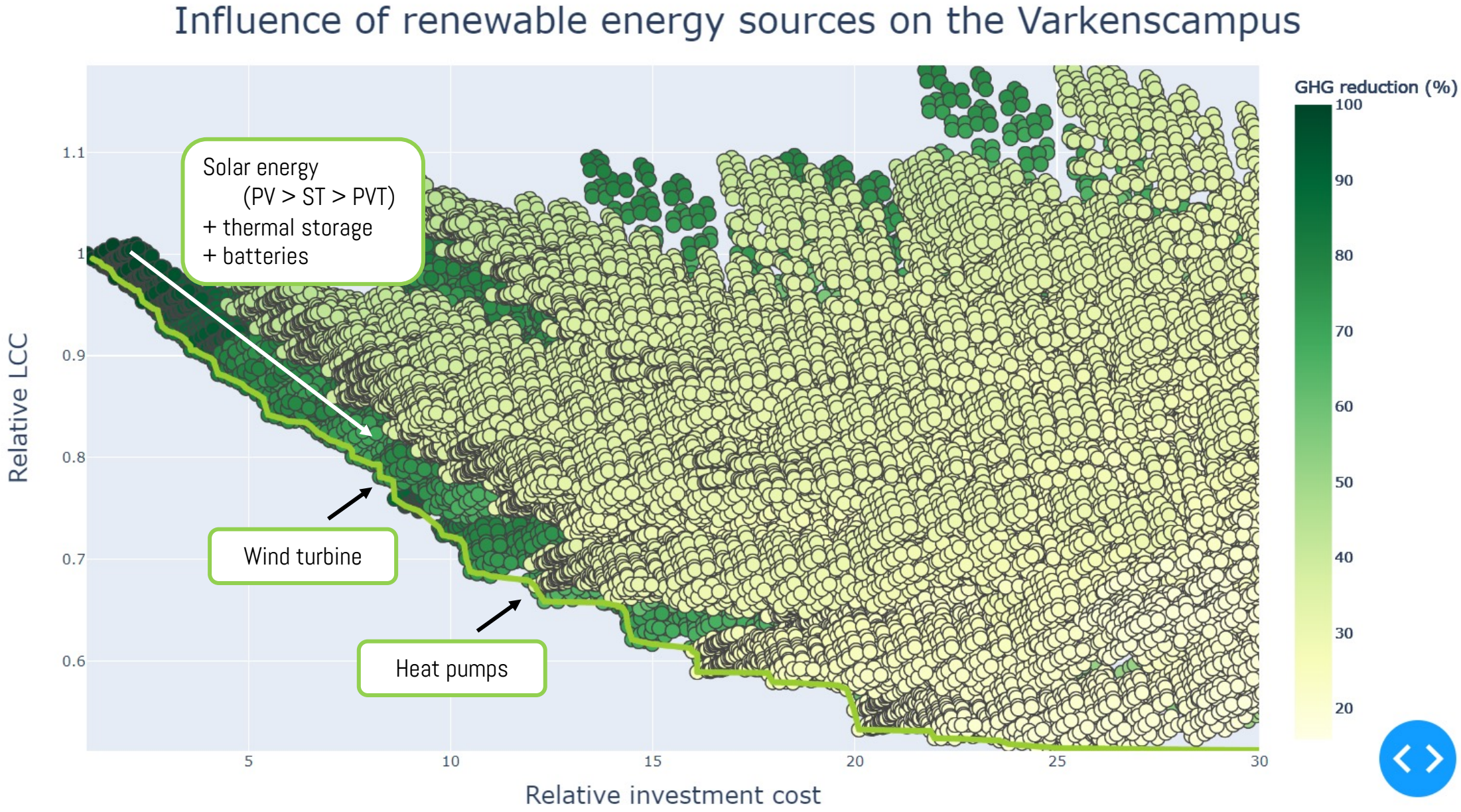
RESULTS


Influence of renewable energy sources on the Varkenscampus
Relative equivalent CO2 emissions
Relative investment cost
LCC (%)
Solar energy
(PV > ST > PVT)
+ thermal storage
Batteries
Wind turbine
Without heat pump(s)
With heat pump(s)

RESULTS (3)



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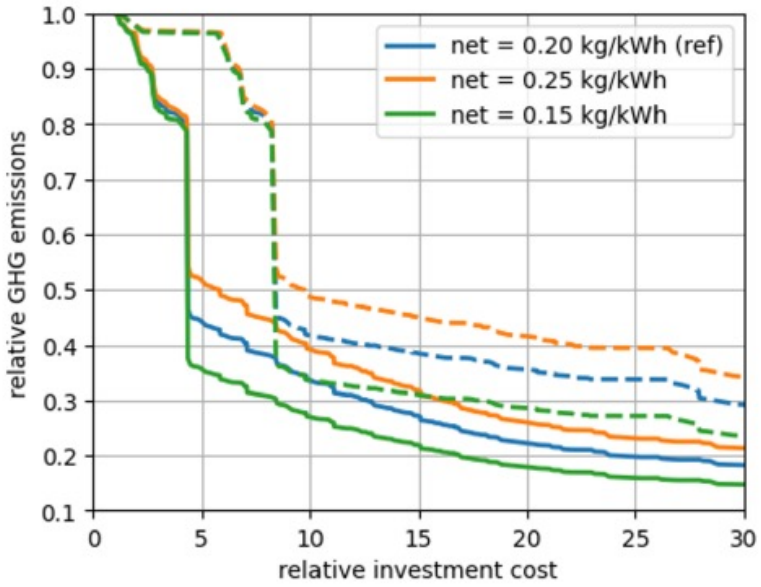
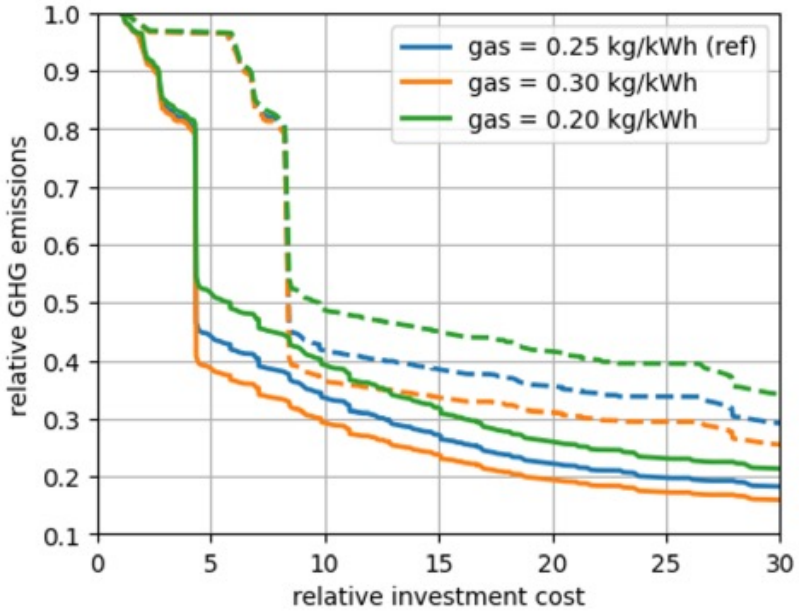
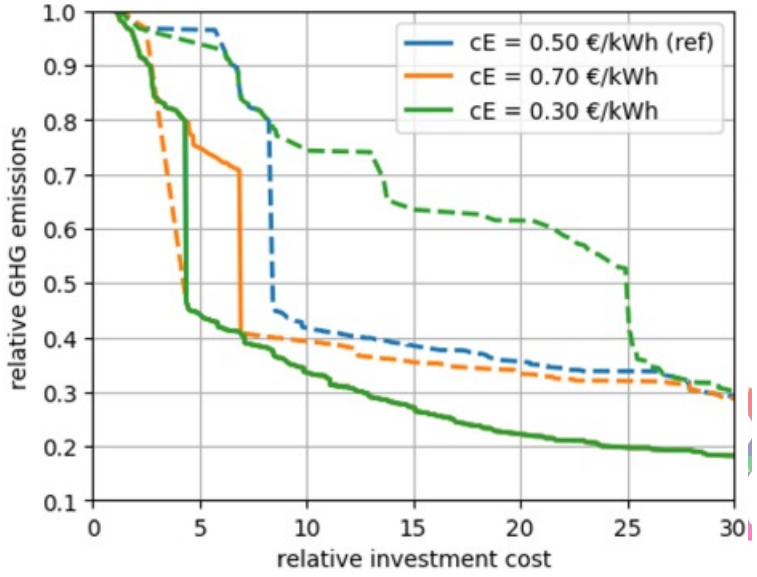
SENSITIVITY ANALYSIS

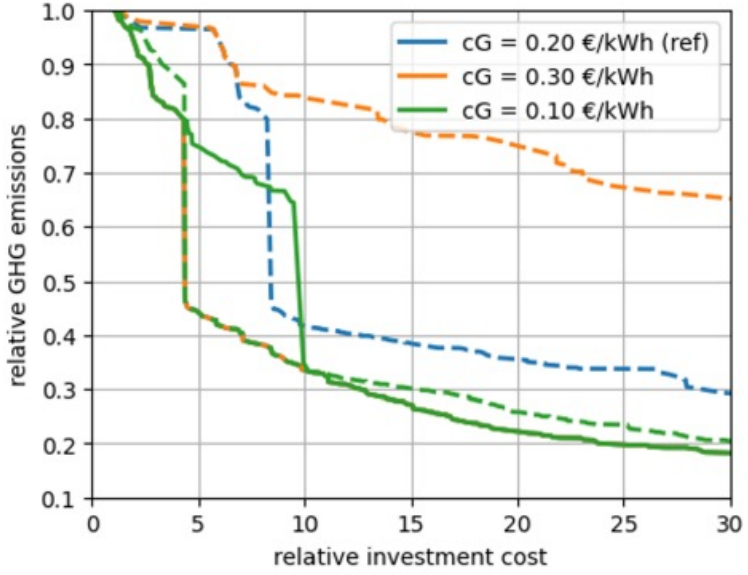


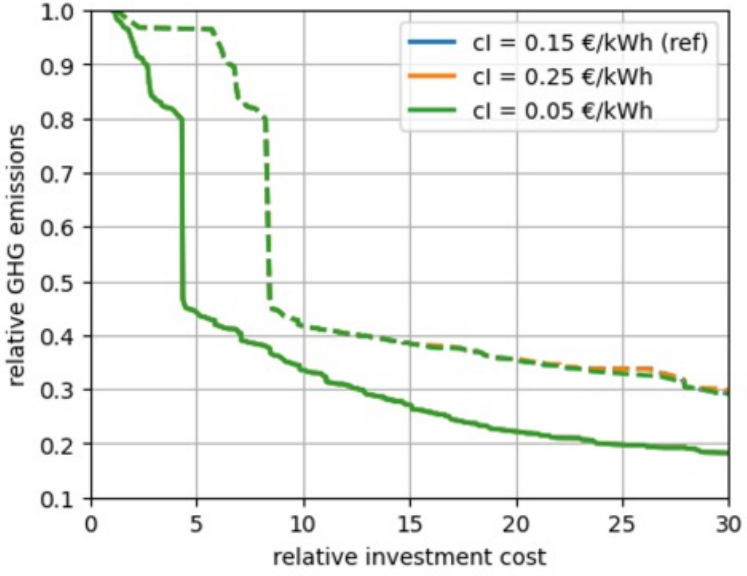


Changing

- Emitted GHG from the grid
- Emitted GHG from the grid
- Electricity cost
- Gas price
- Injection cost







lorizon 2020
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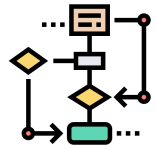
CONCLUSION



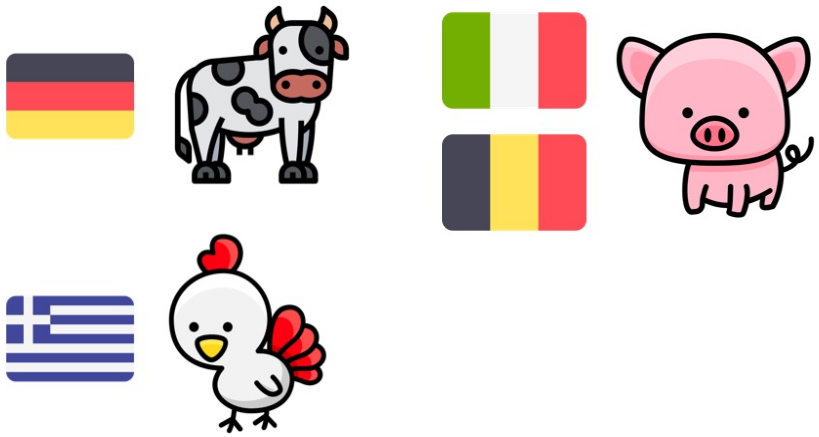
- Solar is winner for this type of demand profile
- Thermal storage comes next
- Solutions with wind turbines have the lowest LCC values
- Heat pumps reduce the most amount of greenhouse gas emissions

Pictogrammes from flaticon.com

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.101000785

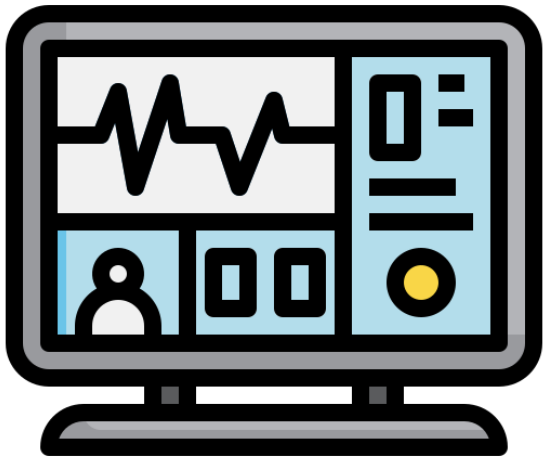
FUTURE WORK: ENERGY DEMAND PROFILES?

RES4LIVE pilot barns



Surveys

Simulation



Also testing and validating the model!

Pictogrammes from flaticon.com

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THANKS FOR THE ATTENTION!

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Picture from Kris Brabants

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RES4LIVE
ENERGY SMART LIVESTOCK FARMING TOWARDS ZERO FOSSIL FUEL CONSUMPTION

RES4LIVE PARTNERS

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AGRICULTURAL UNIVERSITY OF ATHENS

AARHUS UNIVERSITY

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

ATB

CERTH
CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

CETRI
Center for Technology Research & Innovation

CRMT
Powertrain R&D

EAAP
European Federation of Animal Science

EUREC
The Association of European Renewable Energy Research Centres

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MGsustainable

Pleg.ma
Labs

Psyctotherm

TerraEnergy
The Alternative Solution

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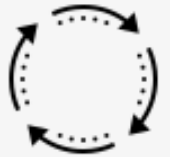
APPENDIX: RES4LIVE PROJECT

- Horizon 2020 project: 2020-2024
- 17 partners from 8 countries



Adaption of renewable energy sources + existing commercial solutions	Design, install and test solutions in 4 pilot farms	Measure impact on technological, economical en ecological levels	Make solutions reproducable

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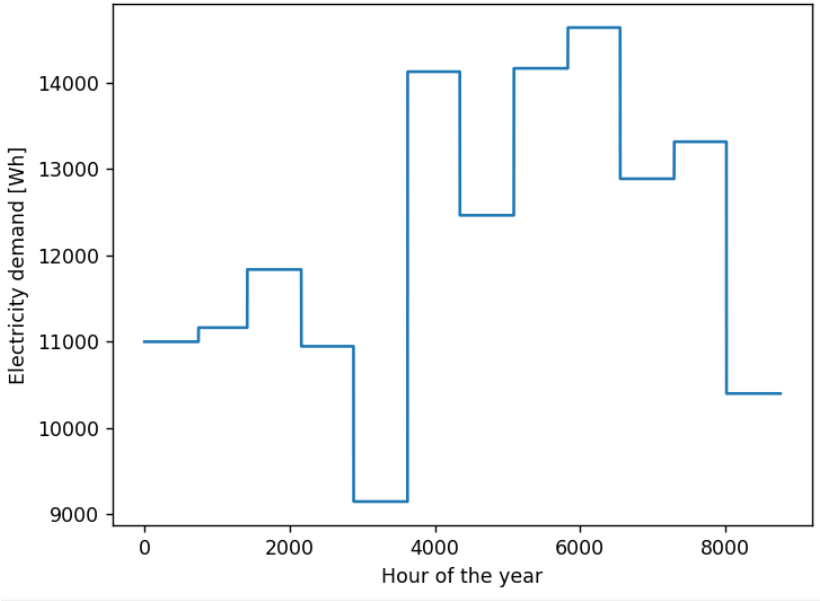
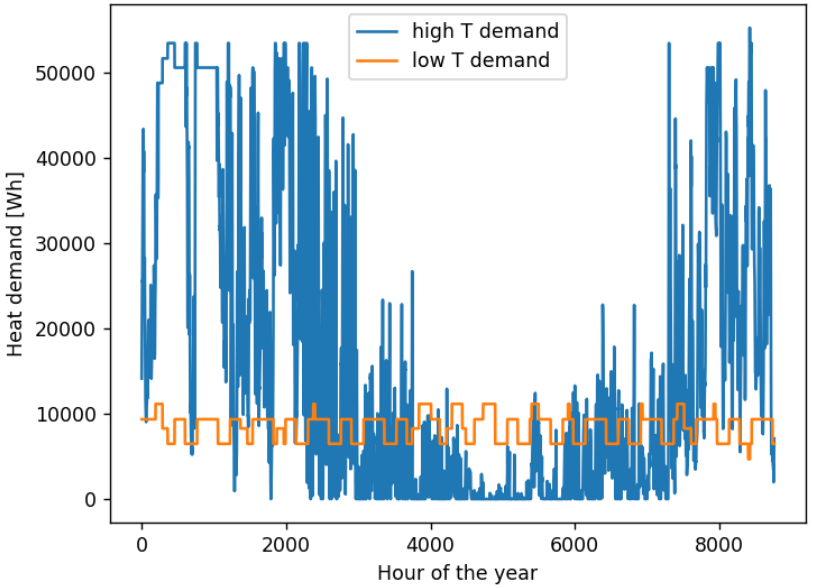
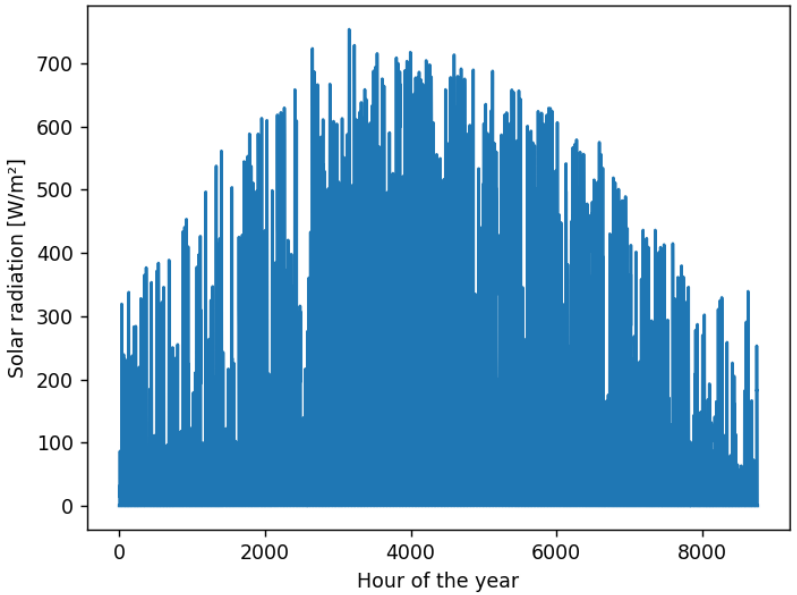
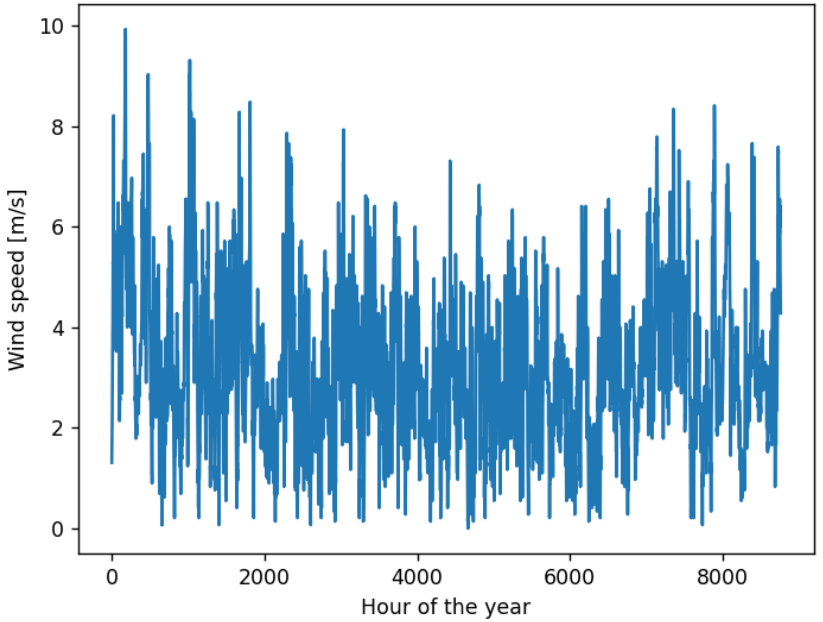
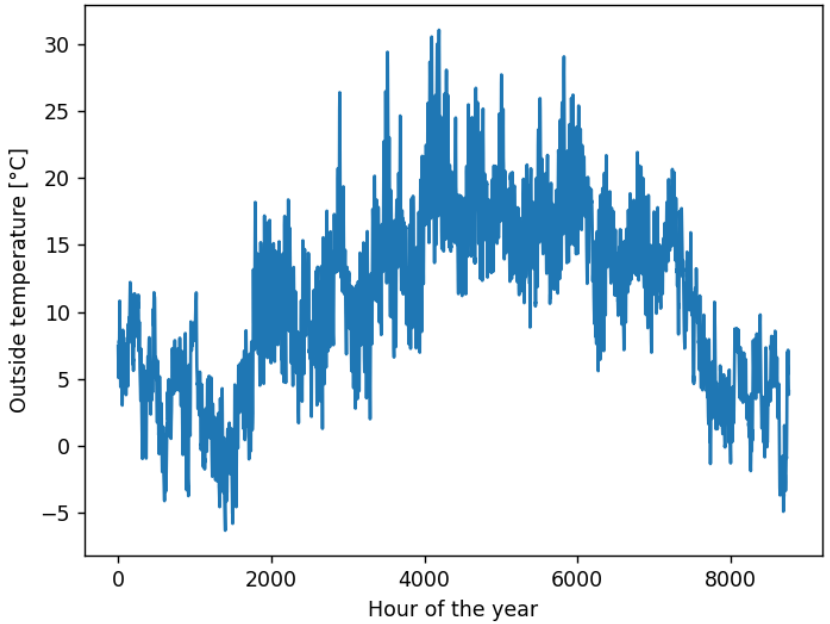
APPENDIX: INPUT PROFILES



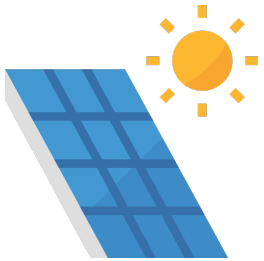








APPENDIX: ENERGY GENERATION FUNCTIONS



$$P_{gen}[W] = \text{GenSun}\left[\frac{W}{m^2}\right] * A_{PV}\,[m^2] * \frac{1000}{7}$$

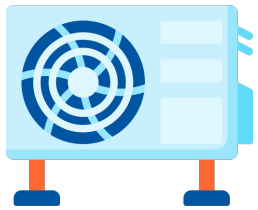
$$P[W] = n * 15kW * \left(\frac{v[\frac{m}{s}]}{7.8\frac{m}{s}}\right)^3$$

$$Q_{gen}[W] = GenSun\left[\frac{W}{m^2}\right] * A_{PV}\,[m^2] * \frac{1000}{7} * 4$$

PVT

Electricity: 0.8 P_{PV}

Heat: 0.7 Q_{ST}



$$COP = COPN\ \frac{\frac{273.15+Tdem+2}{Tdem+2-T_{air}}}{\frac{273.15+Tdem+2}{Tdem+2-T_{nom}}}$$

$$P_{required} = \frac{added\ heat}{COP}$$

$$Q[Wh] = V[kg] * cp\,[\frac{J}{kg\ K}] * \Delta T[K] * \frac{1}{3600\ J/Wh}$$

Battery capacity (Wh)

Maximum power = B_Cap/2 (W)

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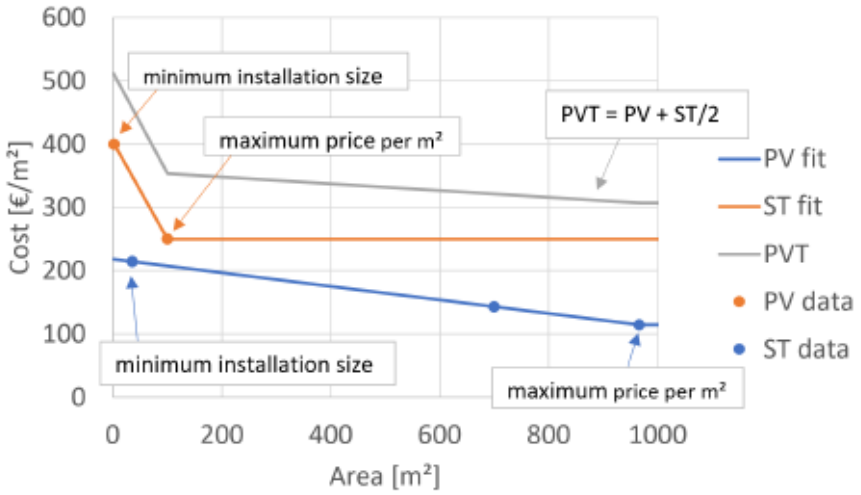
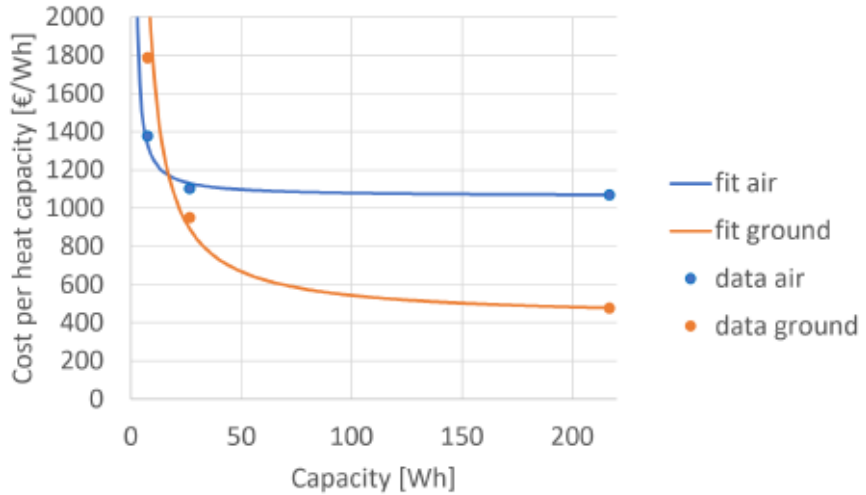
APPENDIX: RES COST FUNCTIONS

- Gas boiler: €15k
- Wind turbine: €60k



(a)



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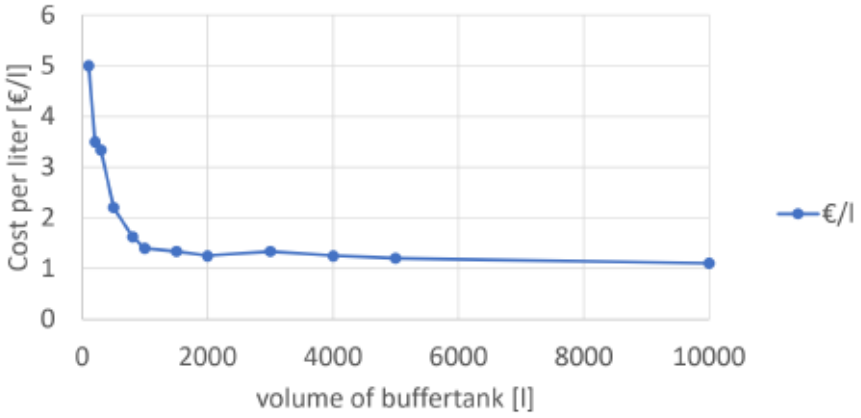

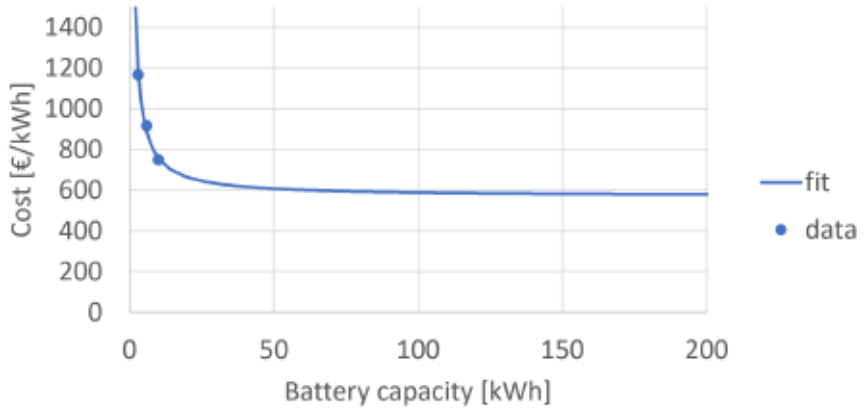

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