eurac research

Towards a renewable energy system: how to integrate power to heat

Wolfram Sparber

IRENA Innovation Week, Bonn, September 2018

Credits: BLS – NOI TechPark Bolzano

Eurac Research - Institute for Renewable Energy

Applied research on renewable energy and energy efficiency

About **100 collaborators,** laboratories in the field of PV, heat pumps, district heating, building envelopes, …


alperia
wir sind südtiroler energie
siamo l'energia dell'alto adige

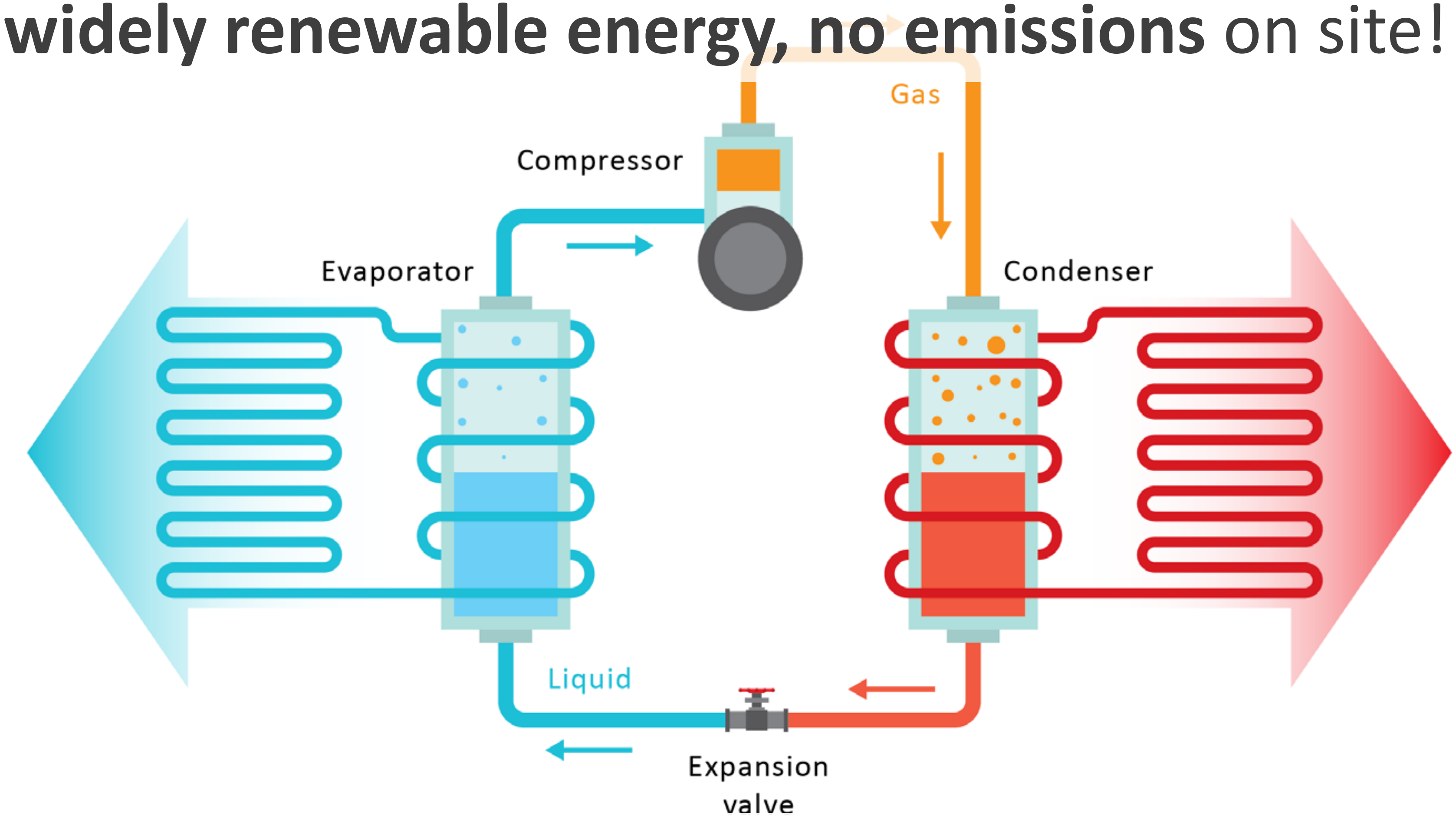

Climate change
Source: Theconversation.com, Bernhard Staehli, shutterstock

Air quality in urban areas

Source: Times.com, Beijing, China, May 4, 2017

Heat pumps for the heating sector

Using **widely renewable energy, no emissions** on site!



So **THE Solution** for all our heating needs?

Source: Vecteezy.com

Modelling of regional energy systems

Eurac Research: W. Sparber, D. Moser, M. Prina, U. F. Oberegger, R. Pernetti, G. Garegnani, R. Vaccaro, M. Cozzini

South Tyrol's Climate plan

Target

1,5 tons of CO_2 emissions
per person/per year

Questions

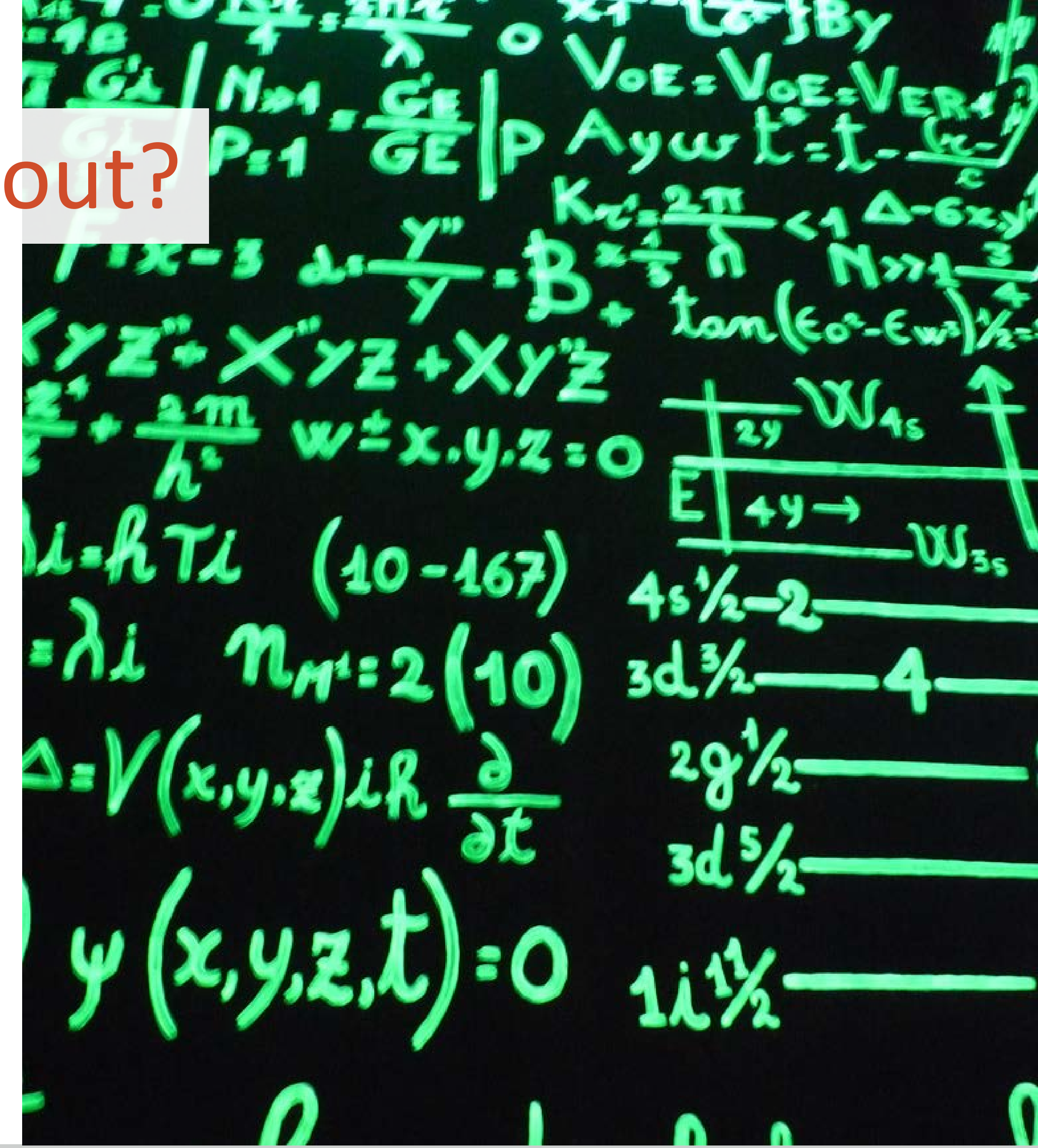
- Is it feasible to reach the target of the climate plan?
  If so, which features should the new energy system have?

- How much will the new energy system cost in comparison to the current one?

- How will the financial structure of the energy system change and which main effects will this have on the energy assets in the upcoming years?

What are we talking about?

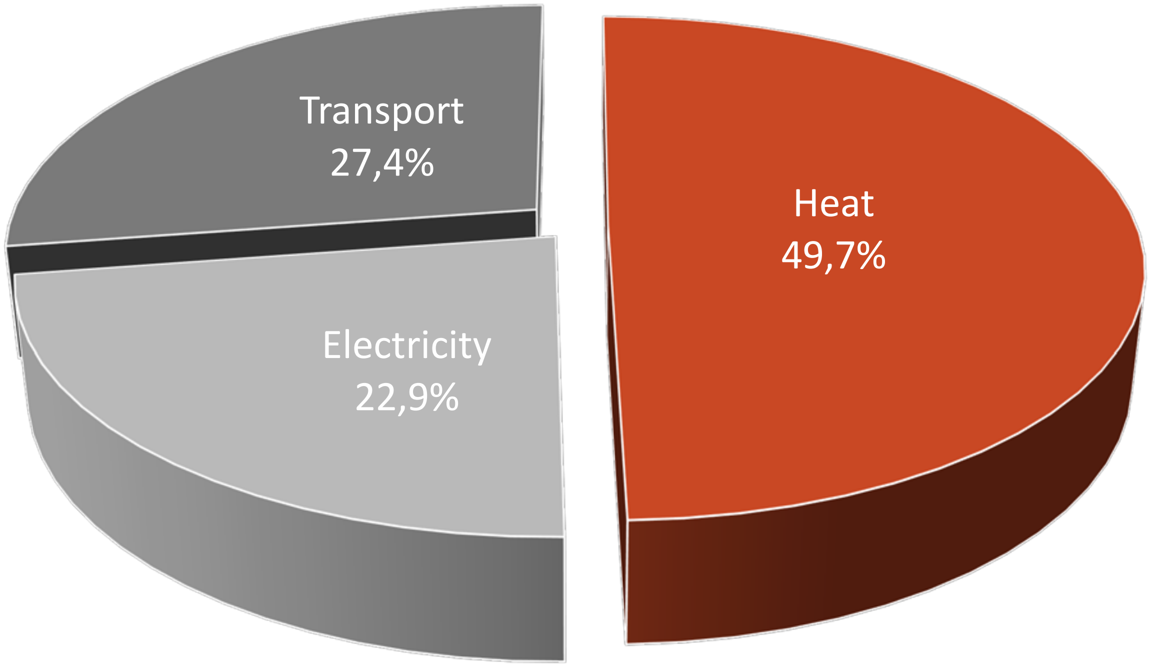
- We are talking about a **dynamic model** that simulates the **hourly** energy production and consumption.
- Starting point is a series of data from different sources, internal calculation and assumptions.
- Data accuracy is sometimes limited. Using more accurate data will improve the model accuracy.
- The model takes into account current technologies and natural resources, and their current costs.



Starting point

Energy consumption in South Tyrol

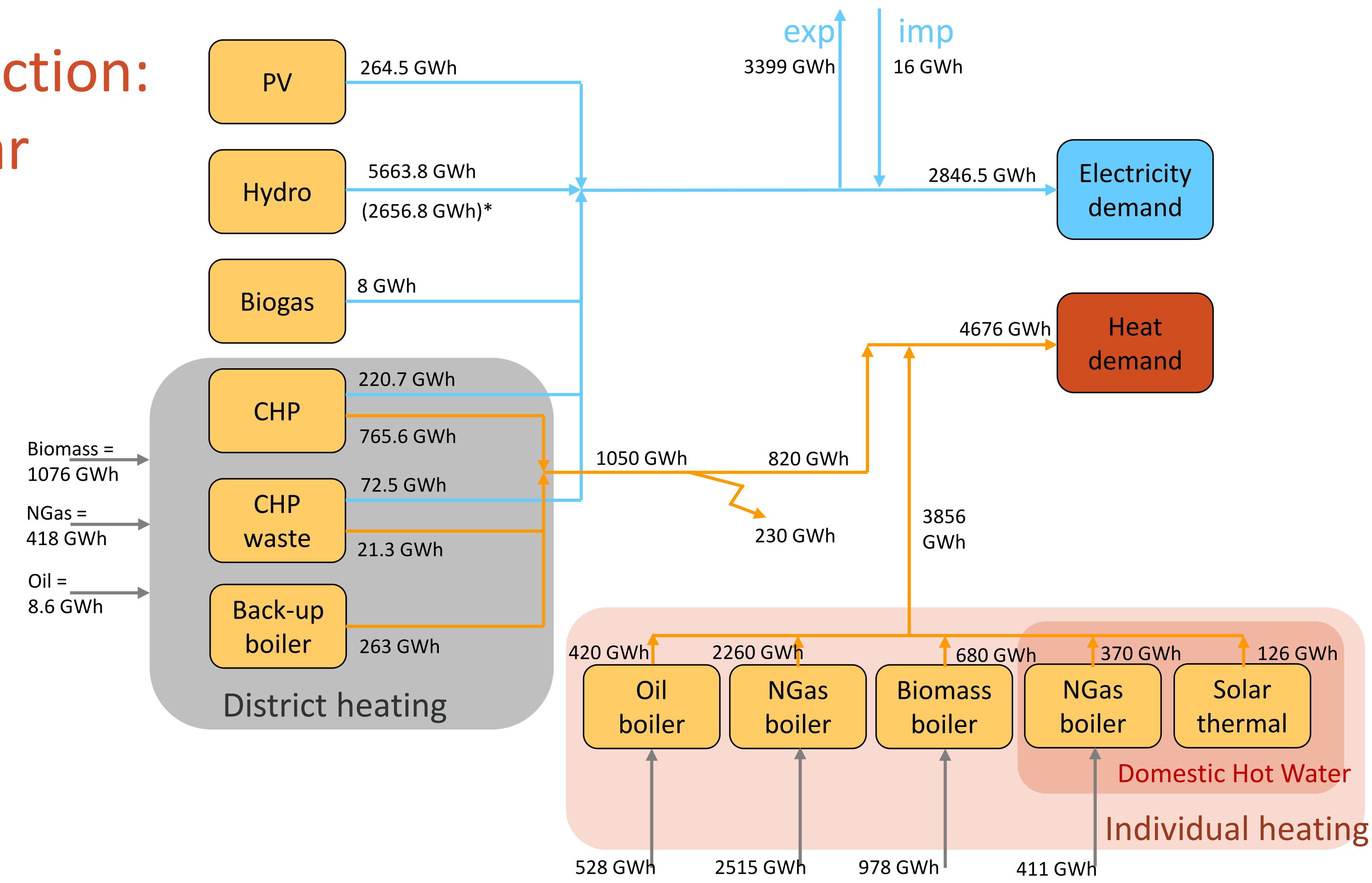
Energy consumption in South Tyrol: 12,4 TWh



- Electricity consumption = 2846.5 GWh
- Heat consumption = 6166.5 GWh
- Transport energy consumption = 3400 GWh

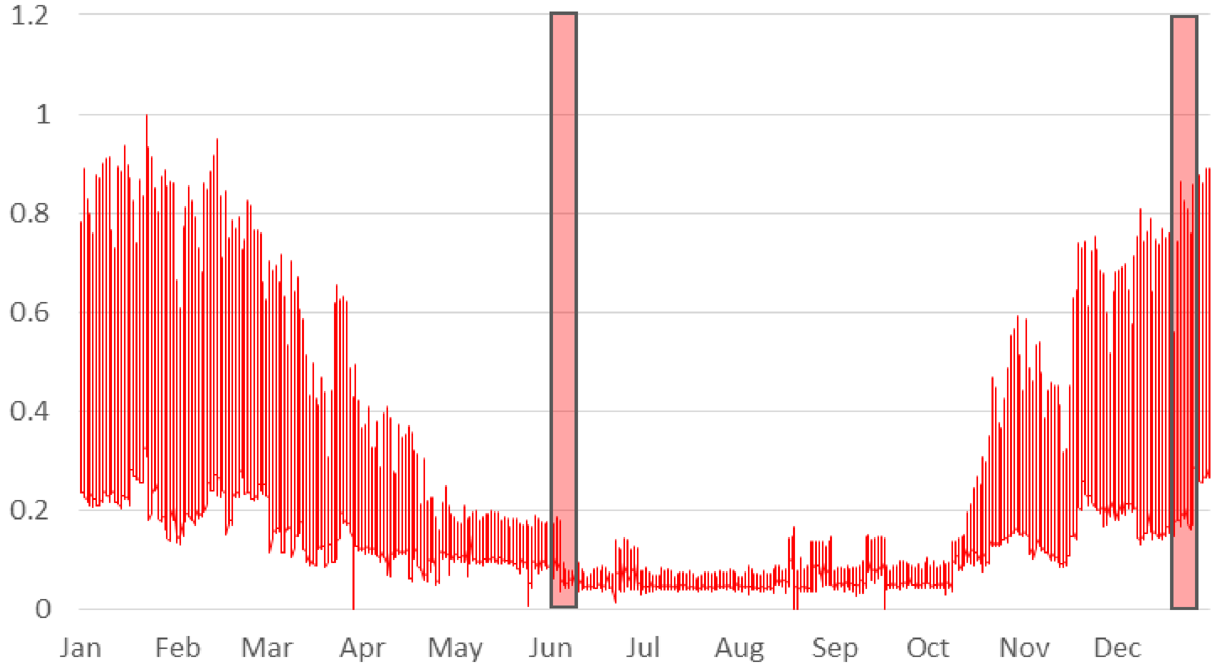
Overall energy consumption in South Tyrol, in the reference year 2014

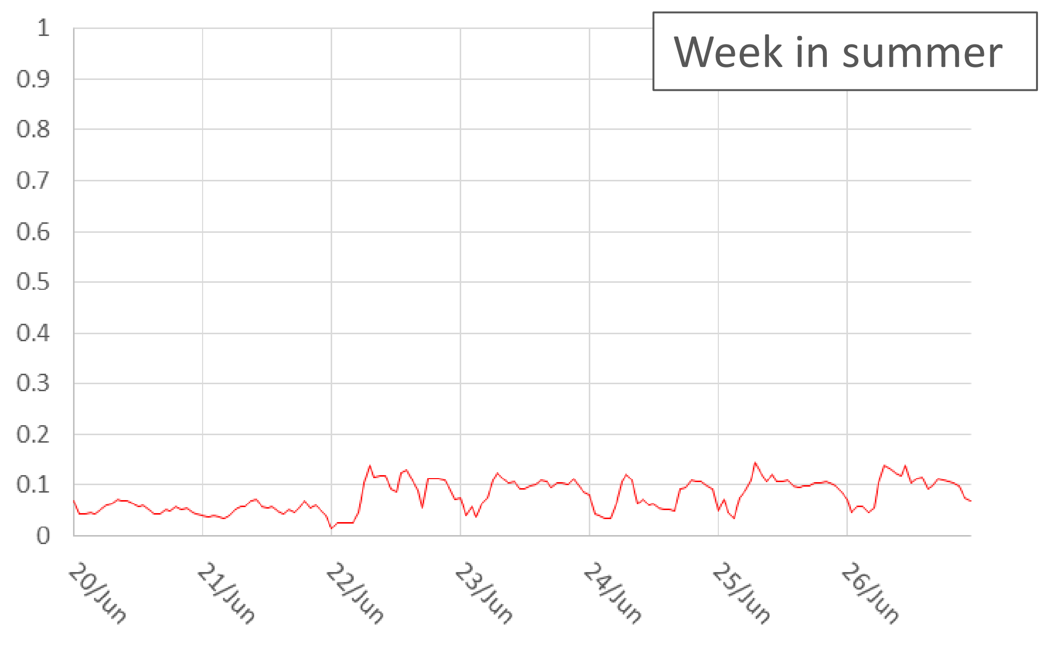
Energy Production: reference year

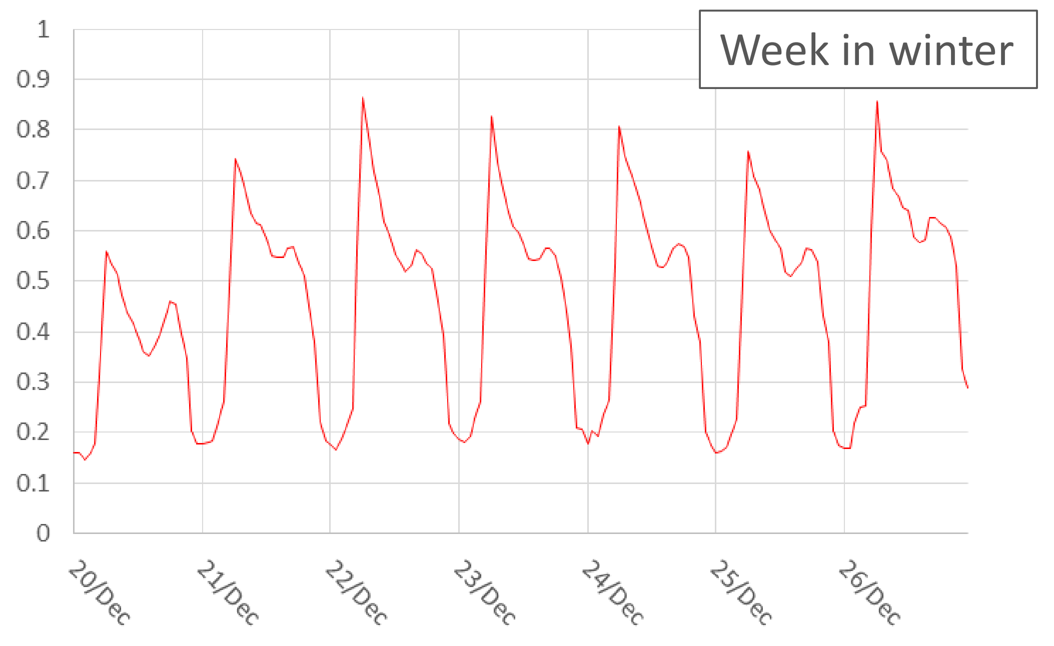


*if only River hydro electricity production is considered within the model

Year profile: heating

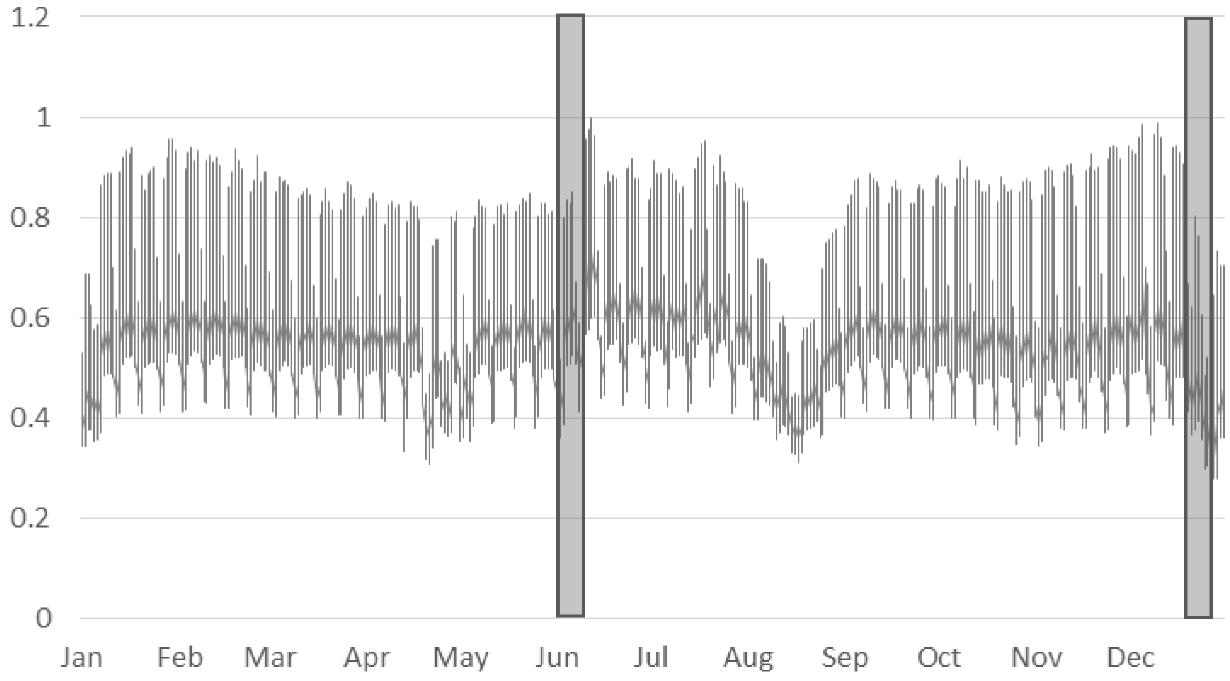


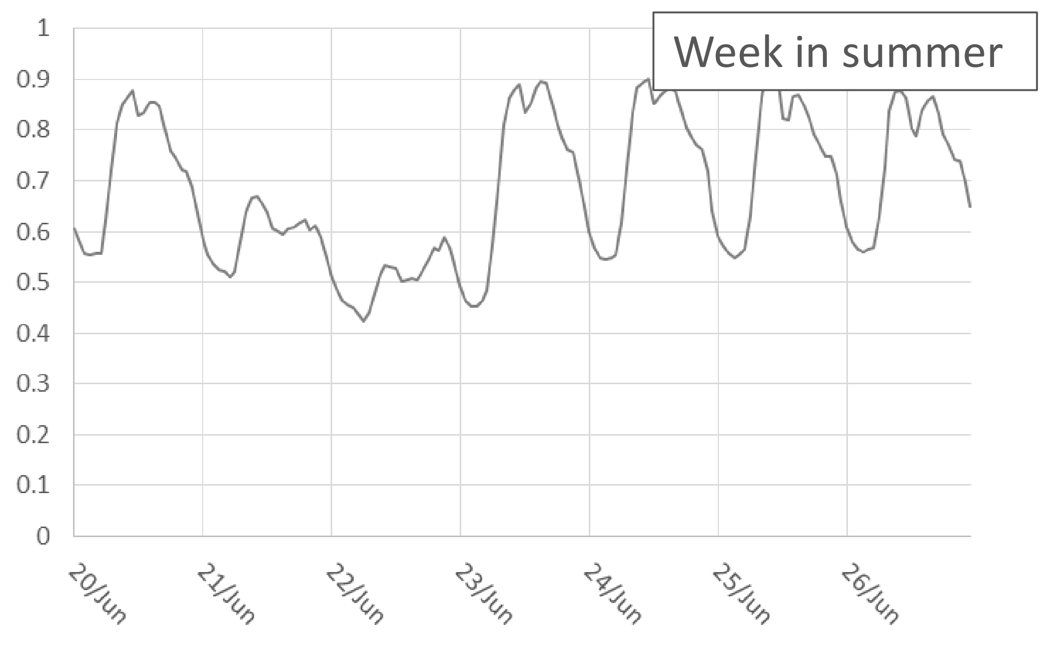


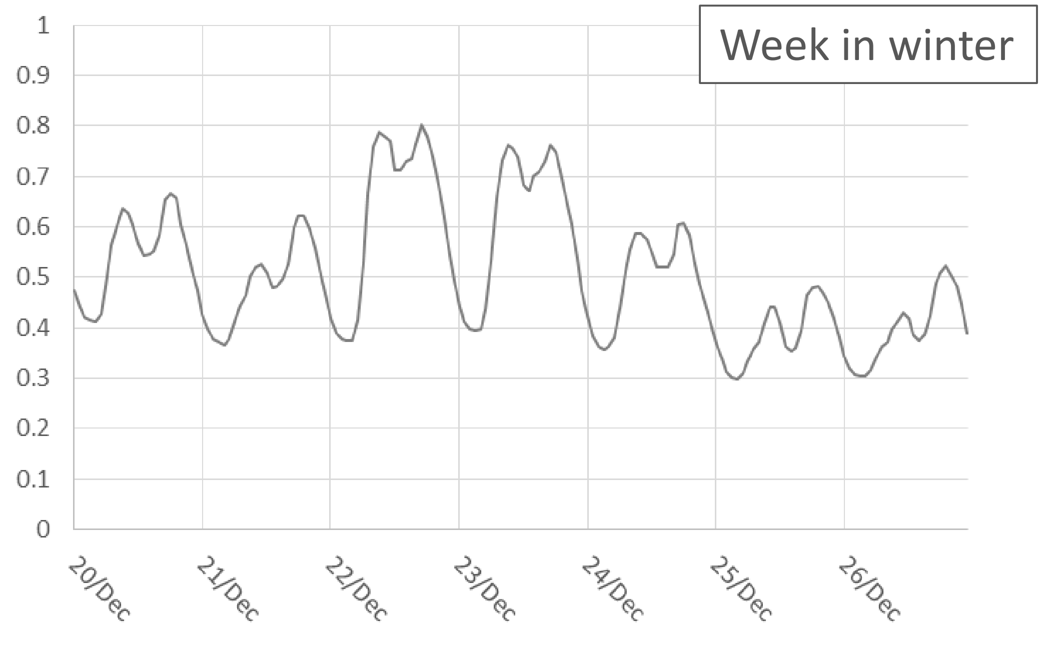


Year profile of the heat consumption from district heating, Bolzano 2014. Source: Alperia Ecoplus

Year profile: electricity

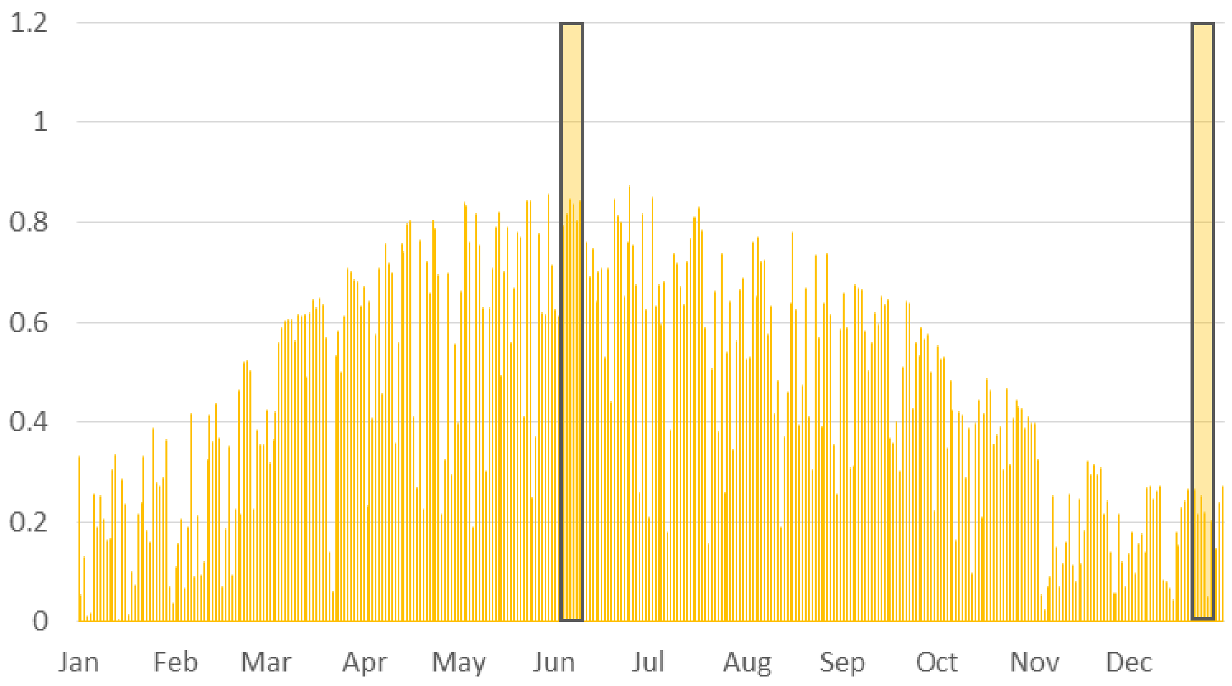


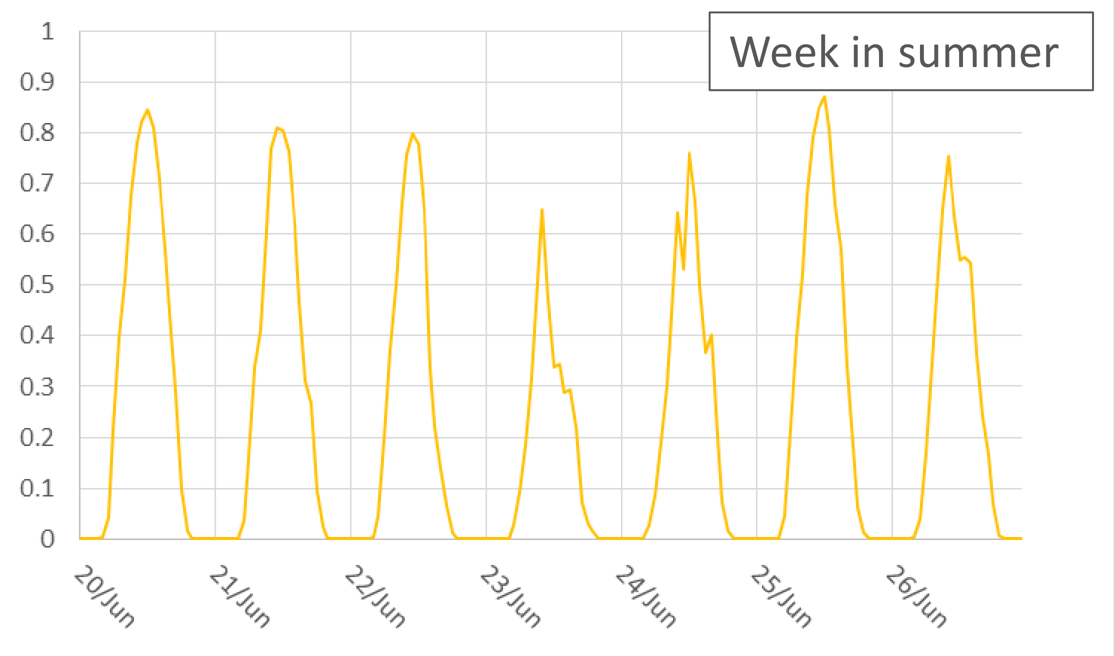


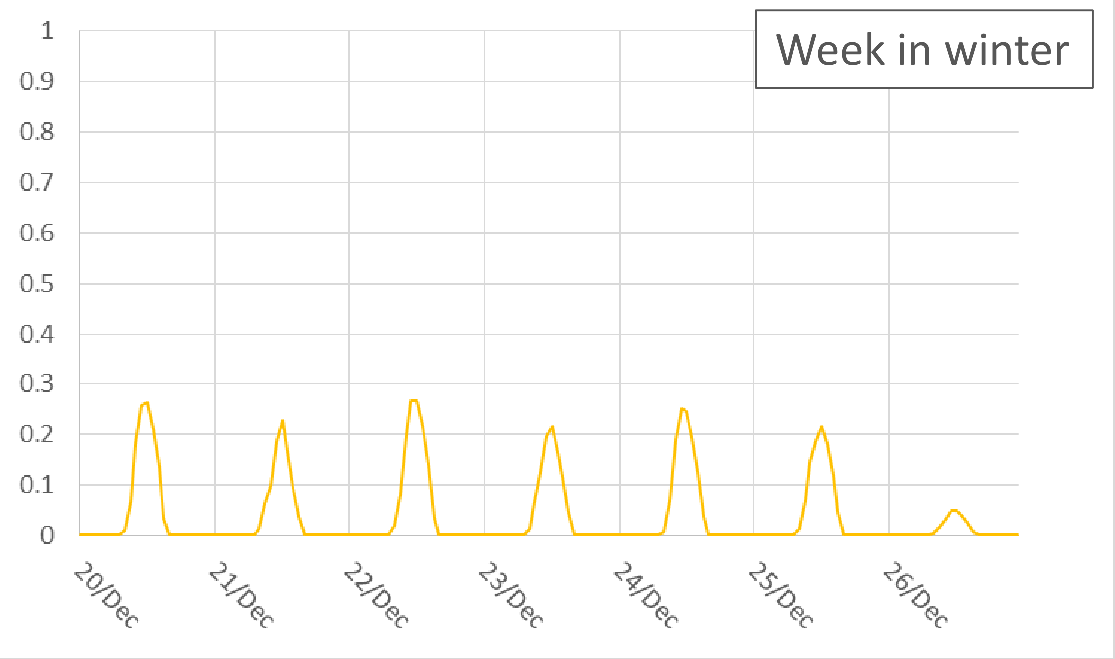


Year profile of the electricity consumption, Northern Italy.
Source: Terna
Assumption / simplification: the energy consumption in South Tyrol follows this profile

Example: PV production







Profile of solar radiation – average hourly data from 13 different locations in South Tyrol. Source: Province of Bolzano/Bozen

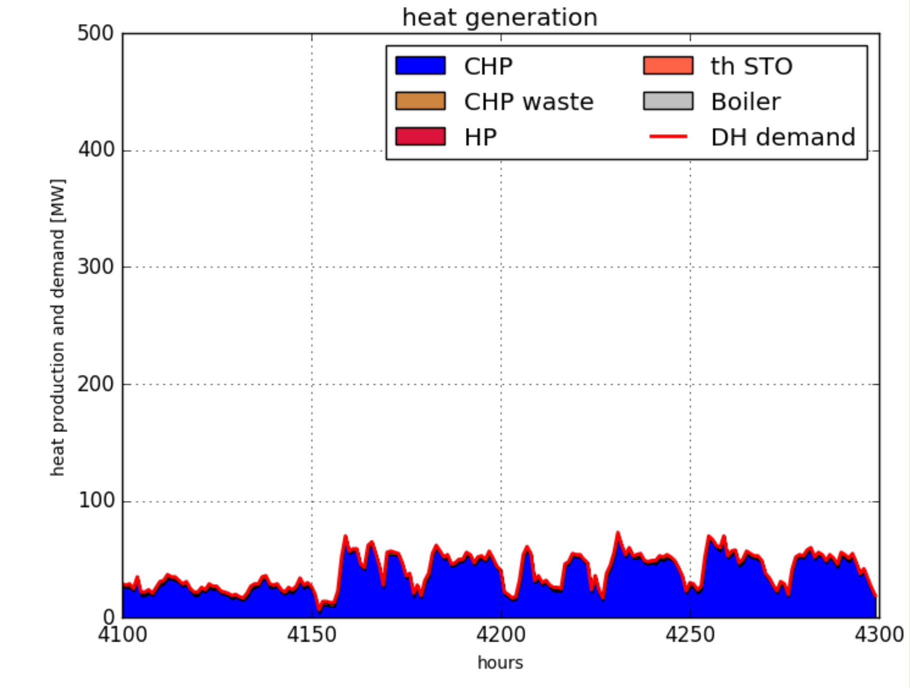
The model

Starting data and assumptions

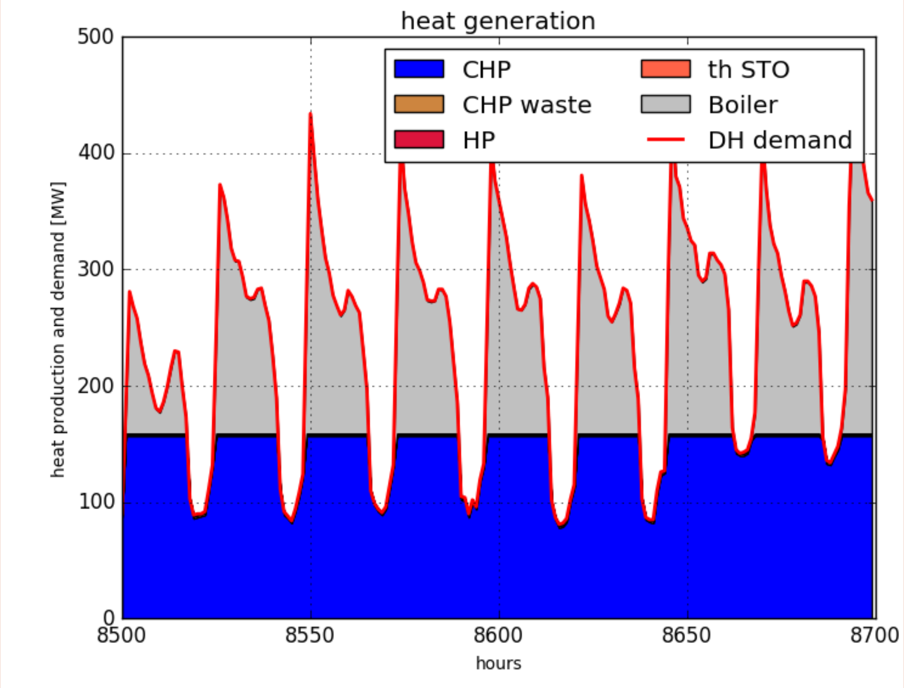
Modelling of the reference scenario: District heating use

District heating

Week in summer



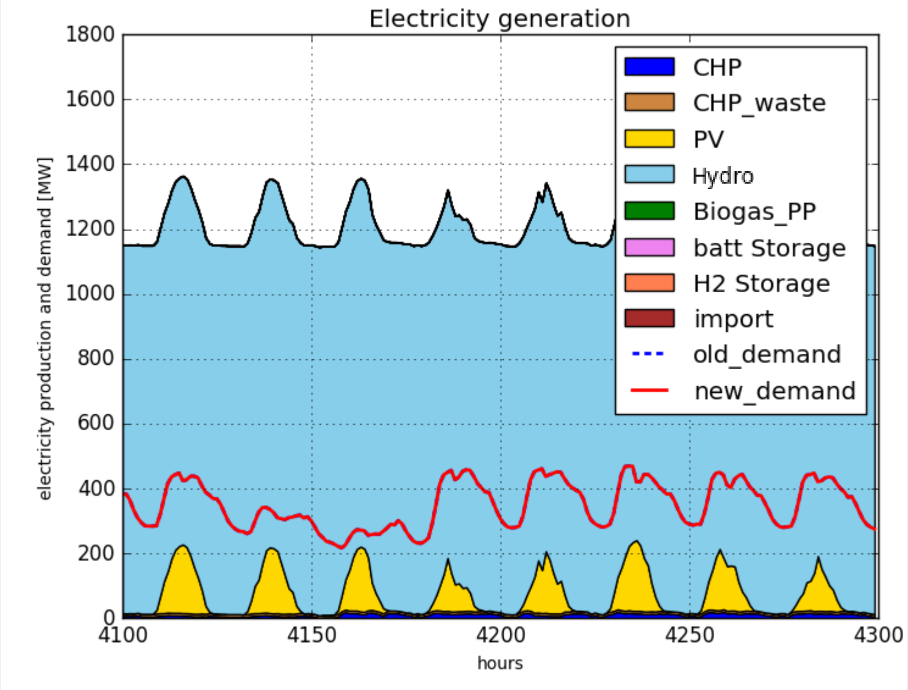
Week in winter



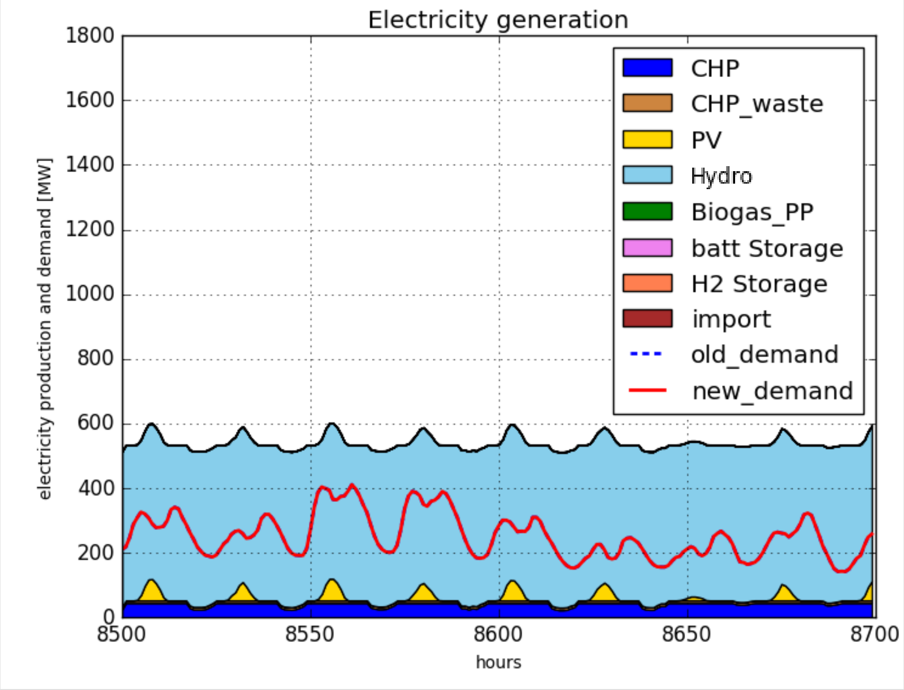
Modelling of the reference scenario: Electricity consumption

Electricity

Week in summer



Week in winter



Optimization model of the energy system

Optimization of the costs compared to CO_2 emissions, varying different parameters.

Model n objectives – Eurac Research

Simulation model

Energy PLAN
Advanced energy system analysis computer model

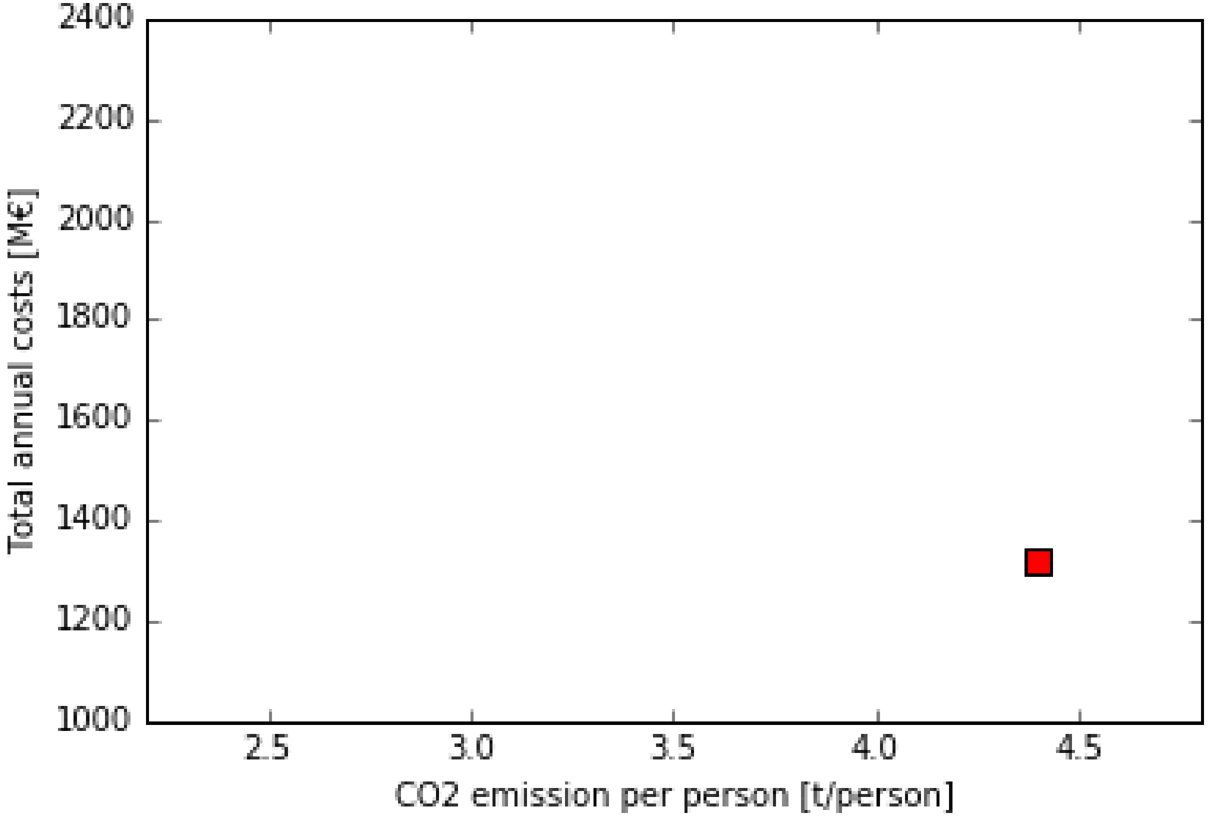
EnergyPLAN (Aalborg University)

+

Optimization model

python

Multi objective evolutionary algorithm MOEA



Each point on the chart shows total costs and CO2 emissions per each energy system.
For each energy system, hourly energy production and consumption have been simulated.

Hydroelectric

Assumption: constant hydroelectric use

PV


Credits: Quale Energia

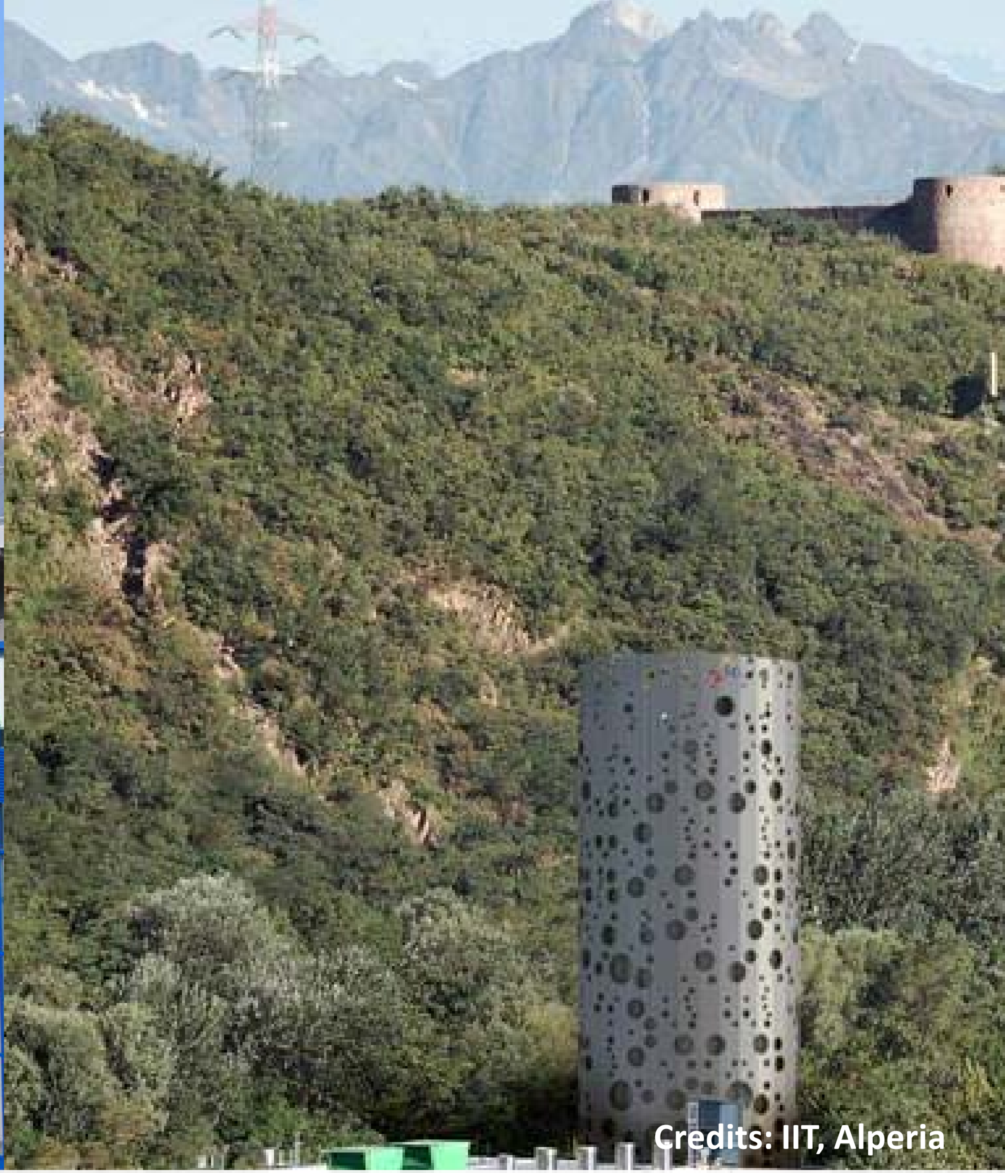
Assumption: possible installation of the building rooftops, except in historical centers. No ground use (max. potential 1250 MW, as calculated in the SolarTirol project)

Wind power

Credits: Commons Wikimedia

Assumption: no use of large wind farms in South Tyrol

Storage technologies



Assumption: possible use of energy storage systems such as thermal energy storages, batteries and hydrogen production

Biomass / Biomas

Assumption: constant use of biomass, no increase in biomass import. Slight possible increase in biogas use.

Solar thermal / heat pumps

Credits: Eurac Research, canale energia

Assumption: Possible use of solar thermal on rooftops for domestic hot water. Possible use of heat pumps as part of the building‘s heating system.

Energy efficiency

Assumption: Detailed analysis of the building stock in South Tyrol and evaluation of building refurbishment and costs – see appendix 2.

Transport

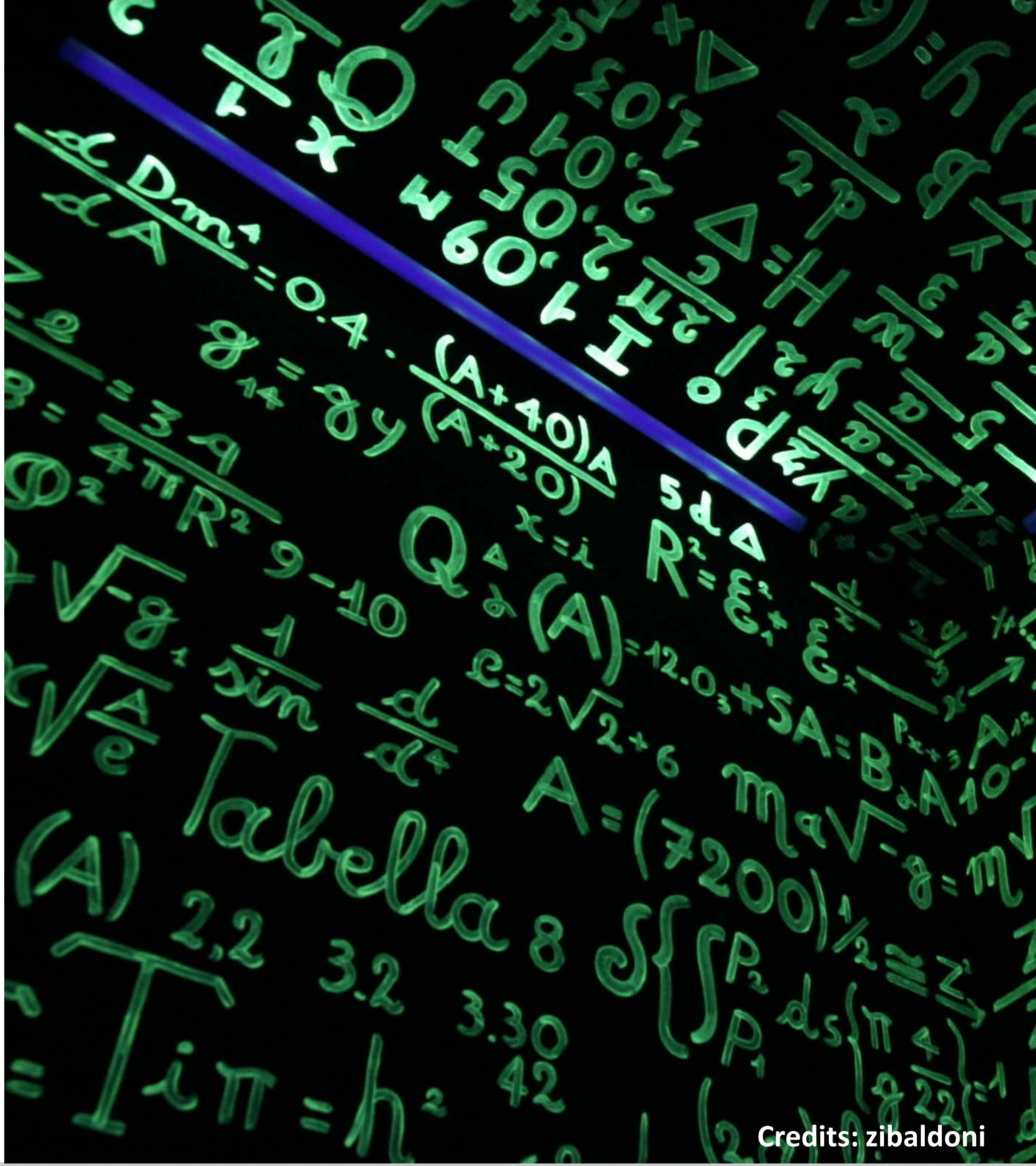
Credits: radio NBC

Evaluation of the total energy consumption and CO_2 emissions of the transport sector.
Analysis of the needed reduction to reach the target.

25,000

different combinations

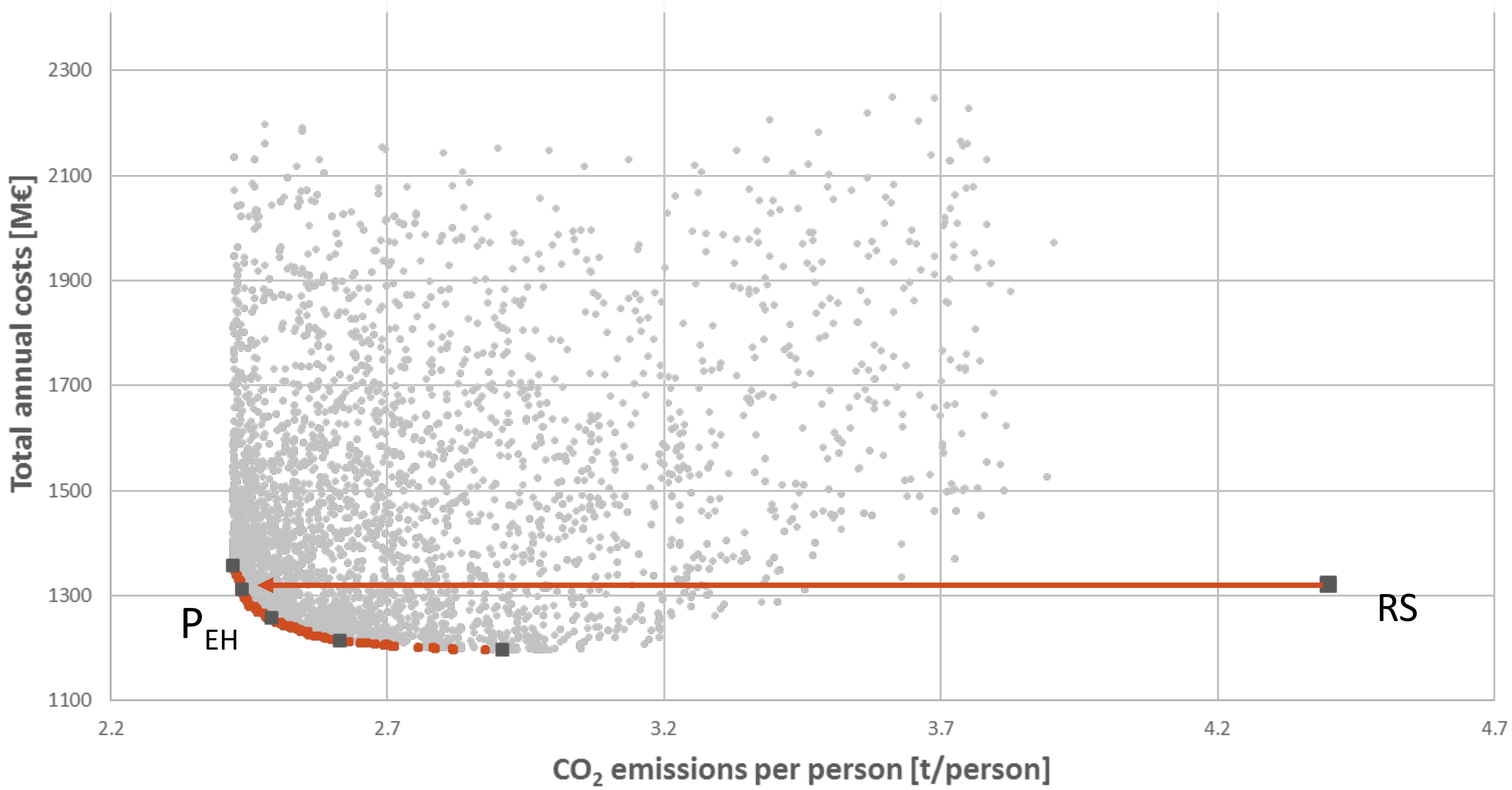
have been simulated to understand which energy systems could have the better features within the given conditions



Credits: zibaldoni

Results

Simulation results– electric and thermal energy

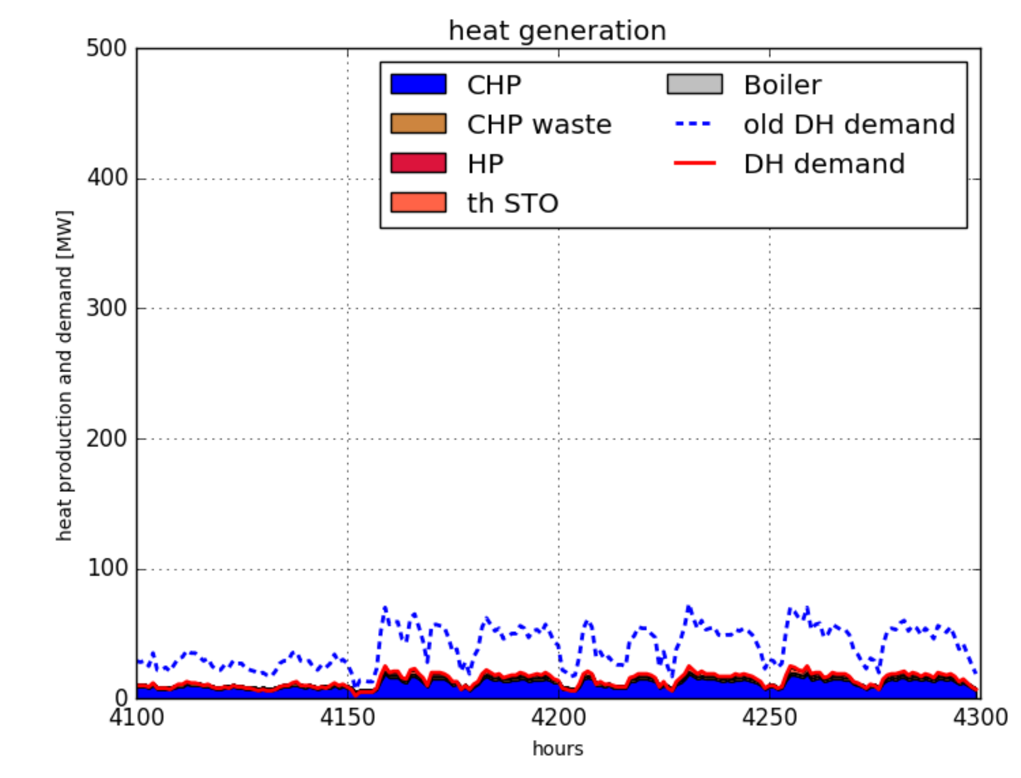


Each point of the cloud represents a specific combination of technologies in the year 2050 with related costs and CO_2 emissions. The P_{EH} scenario represents a combination of technologies with annual costs similar to the reference scenario (current combination of technologies), but with heavily reduced emissions.

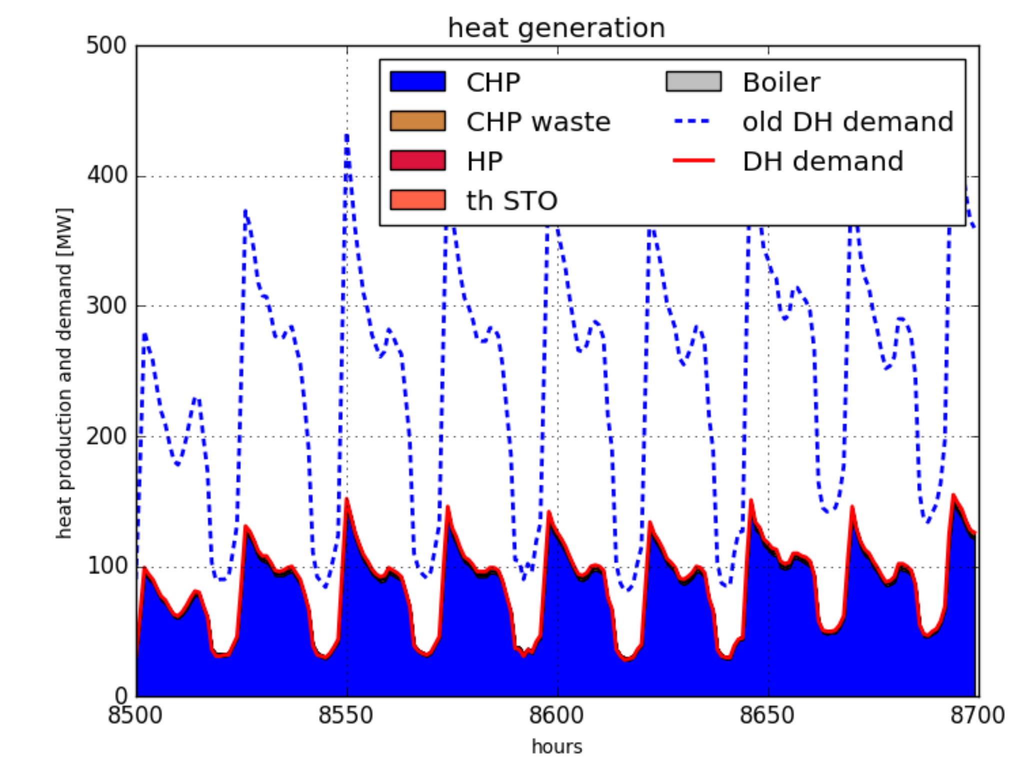
P_{EH} scenario – example district heating

District heating

Week in summer



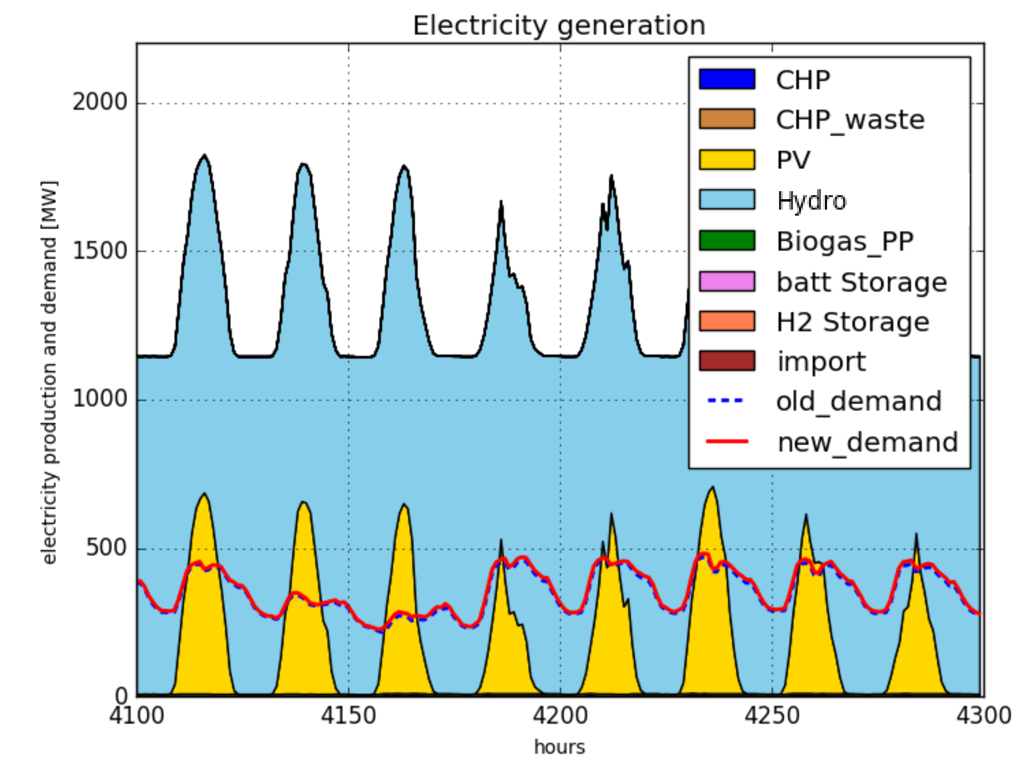
Week in winter



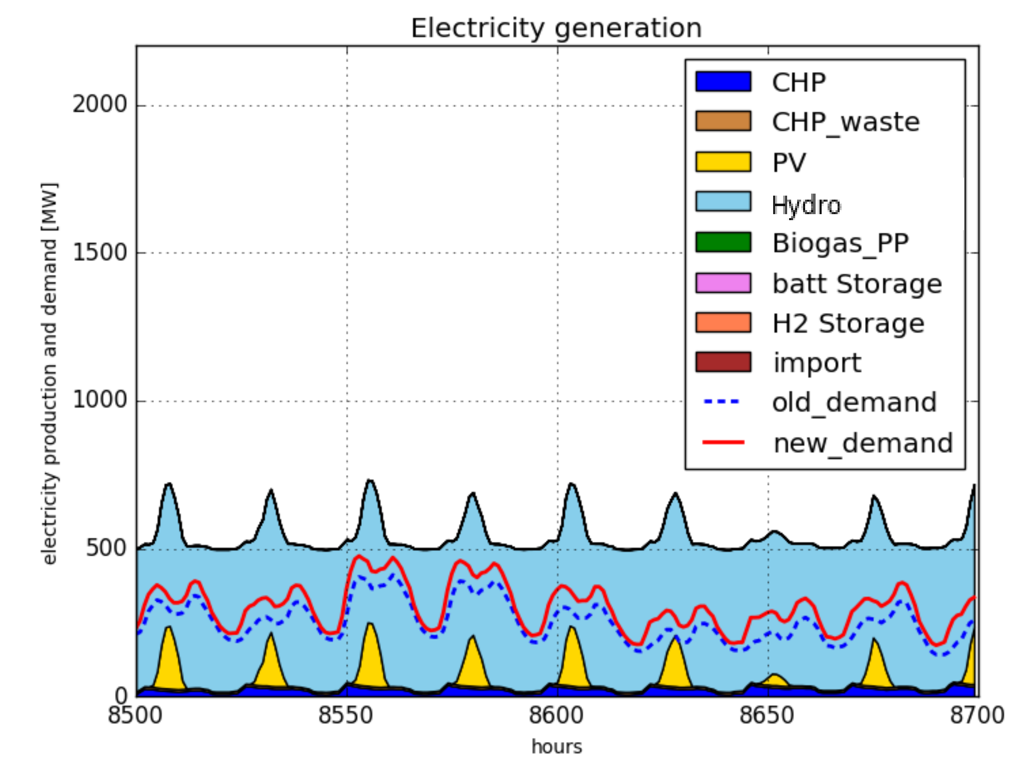
P_{EH} scenario – example electricity

Electricity

Week in summer

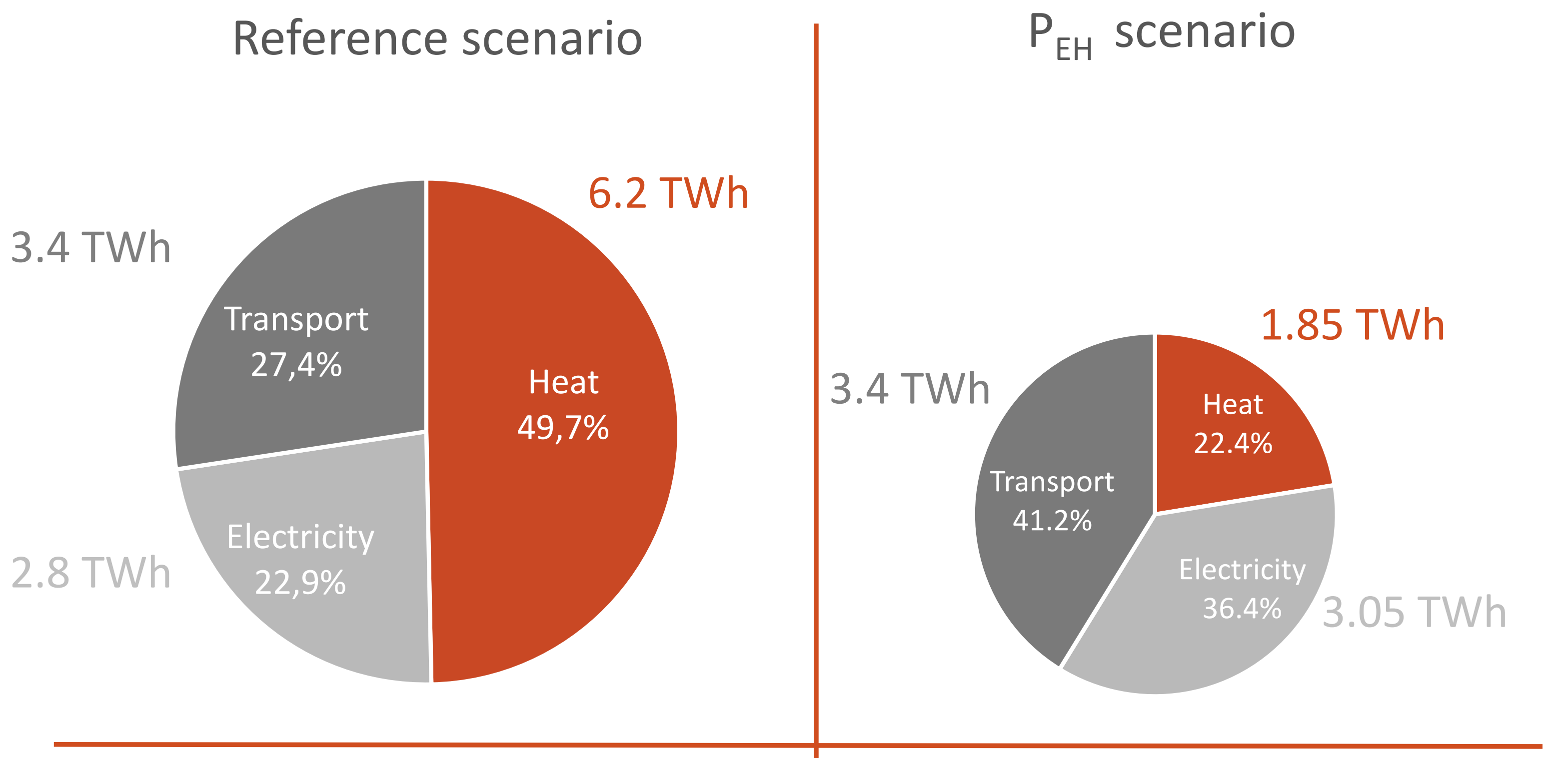


Week in winter



The electricity consumption increases and the profiles changes due to the use of heat pumps

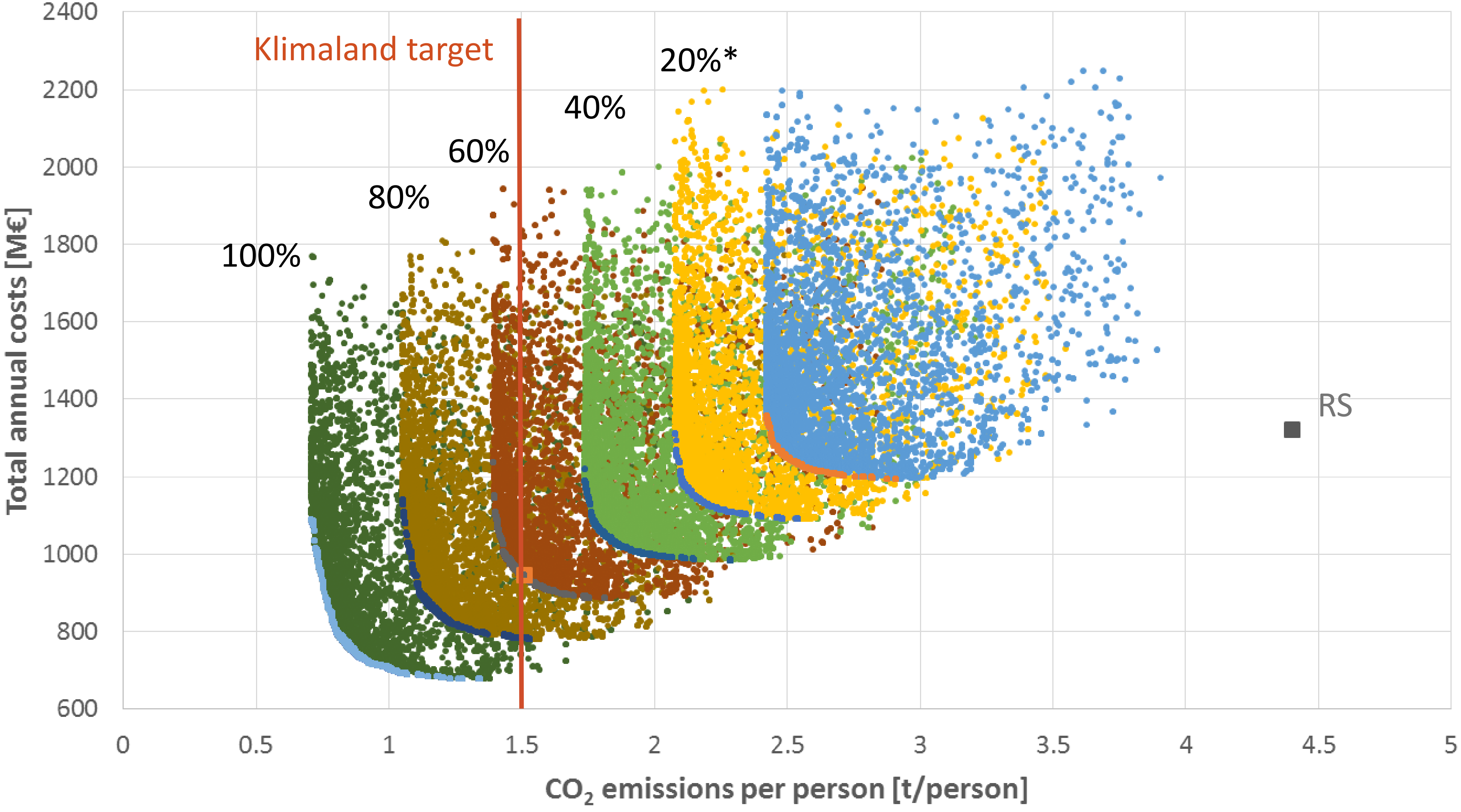
Comparison of the overall energy consumption



Overall energy consumption: 12.4 TWh 8.3 TWh

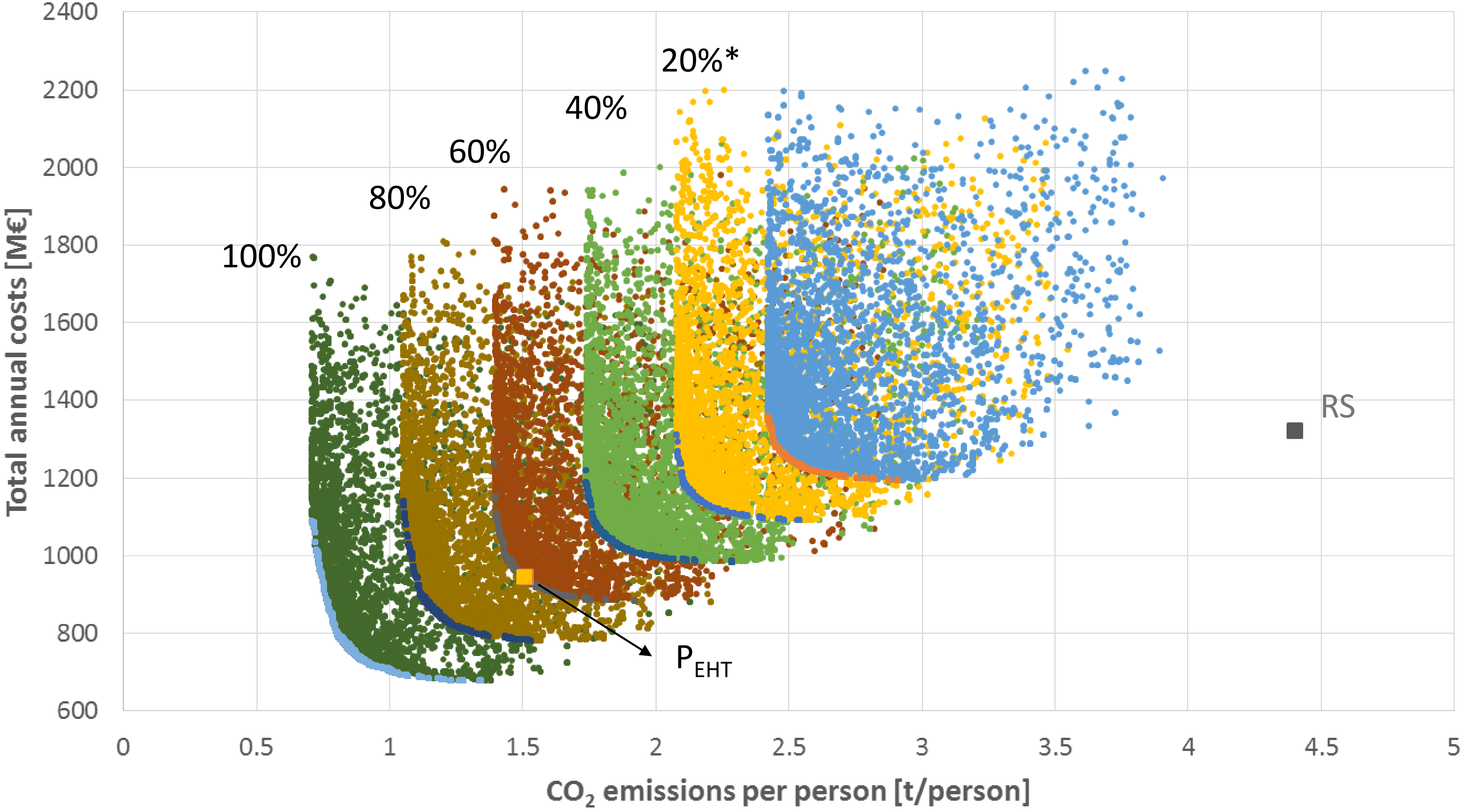
Considering zero emission mobility

% of zero emission mobility



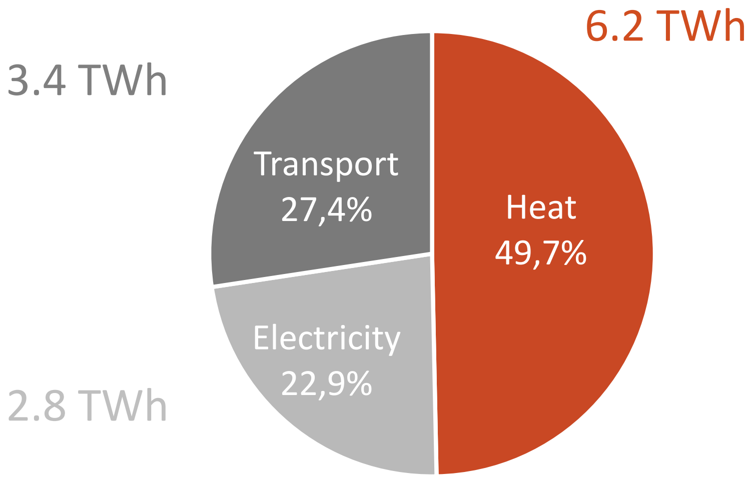
* Penetration percentage of zero emission transport on the overall kilometres covered in the transportation sector

% of zero emission mobility

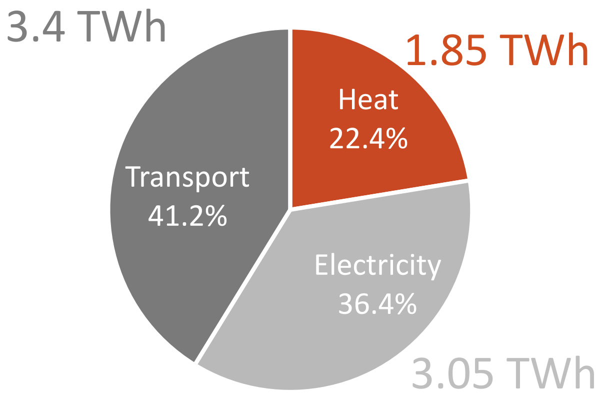


Comparison of the overall energy consumption

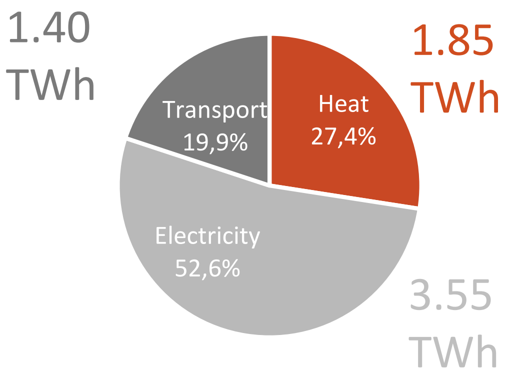
Reference scenario



P_{EH} scenario



P_{EHT} scenario

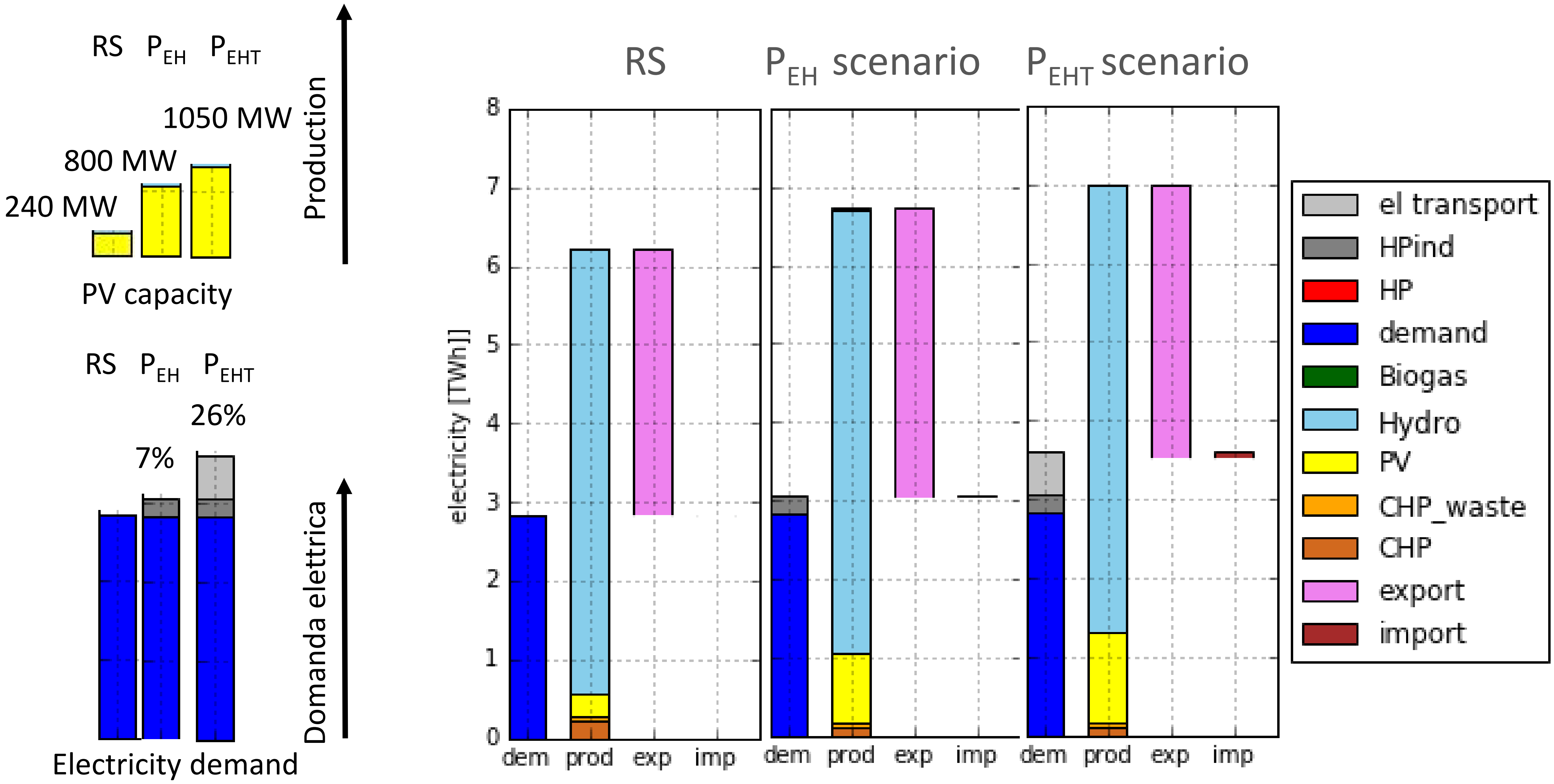


Overall energy consumption: 12.4 TWh

-33% → 8.3 TWh

-45% → 6.8 TWh

Comparison - electricity



Conclusion - modelling

Regional energy modelling - shows:

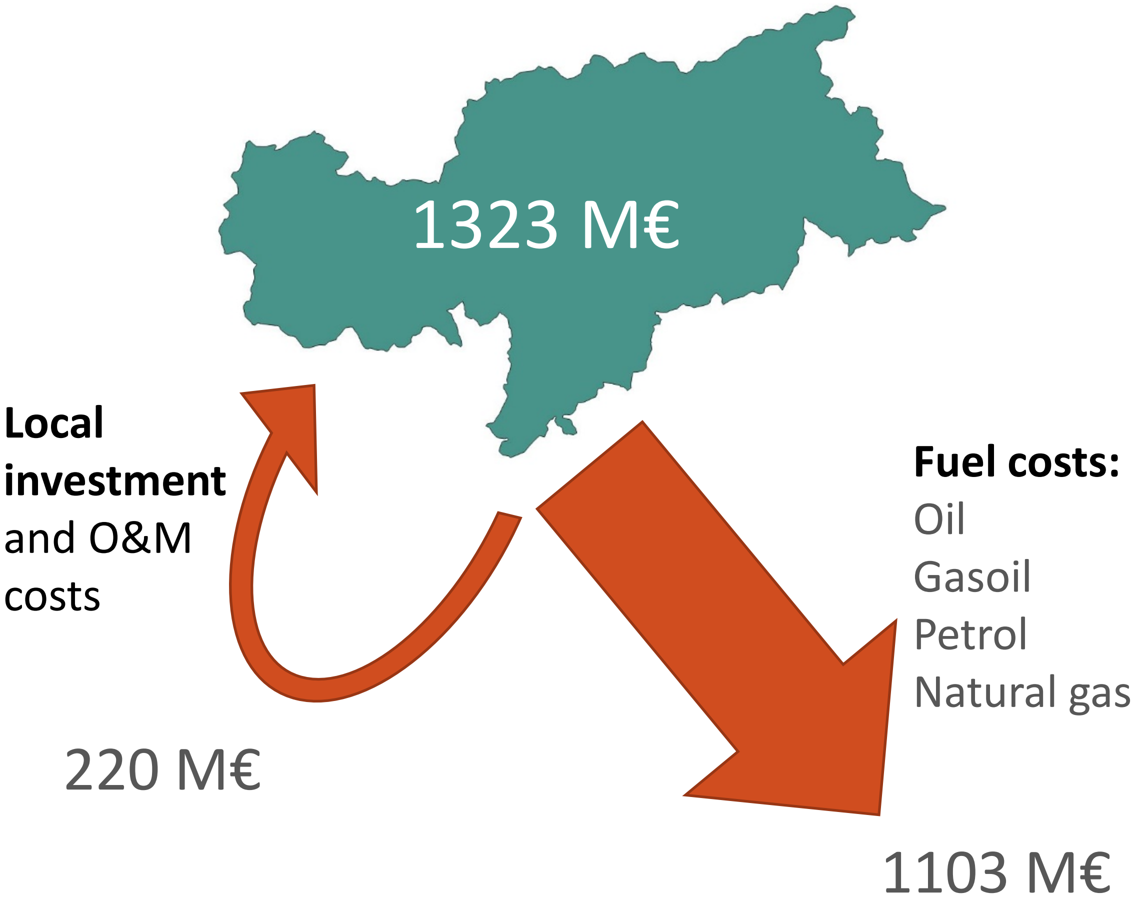
- Yes, there are different energy systems that allow to reach the set regional climate targets

- For the South Tyrol case – the modell leads to a strong reduction of the heating needs, and a strong reduction of fossil fuels for transport, but to an increase of electricity consumption for electrifaction of transport and of heat

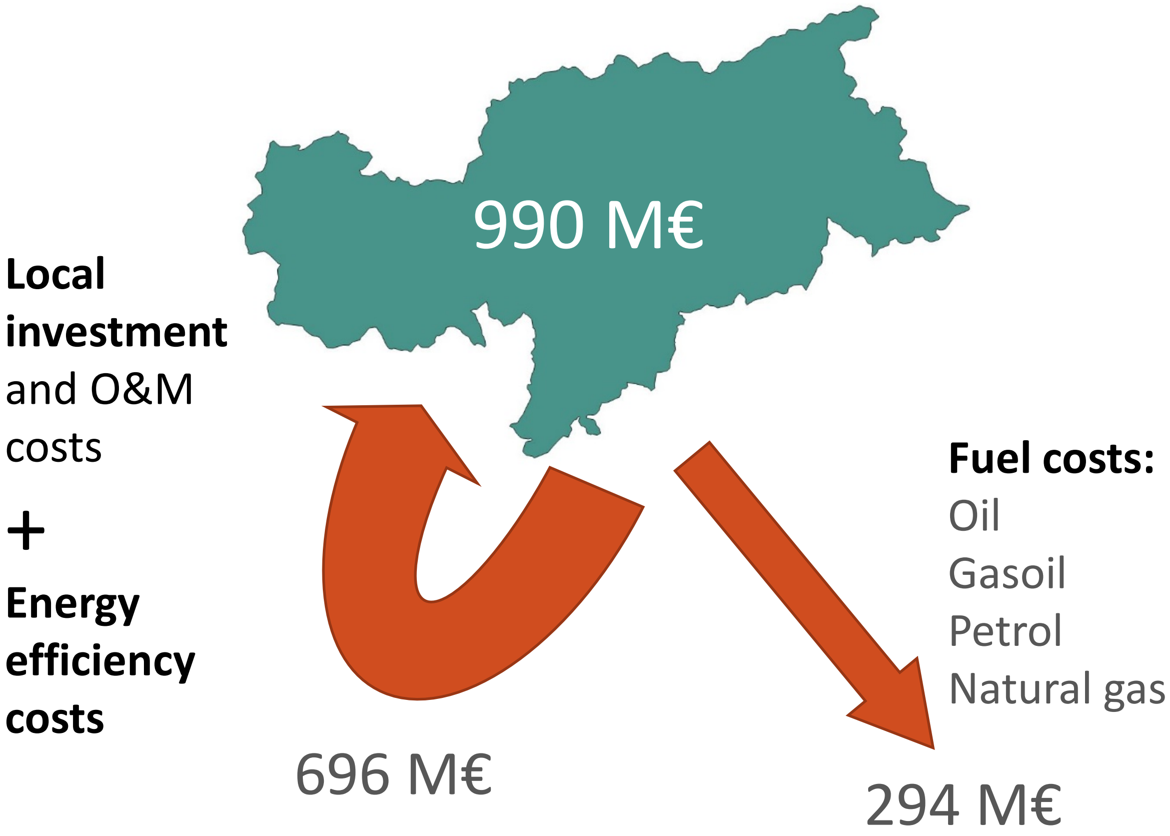
- The financial data show similar overall cost but a big difference in local value …

Financial data

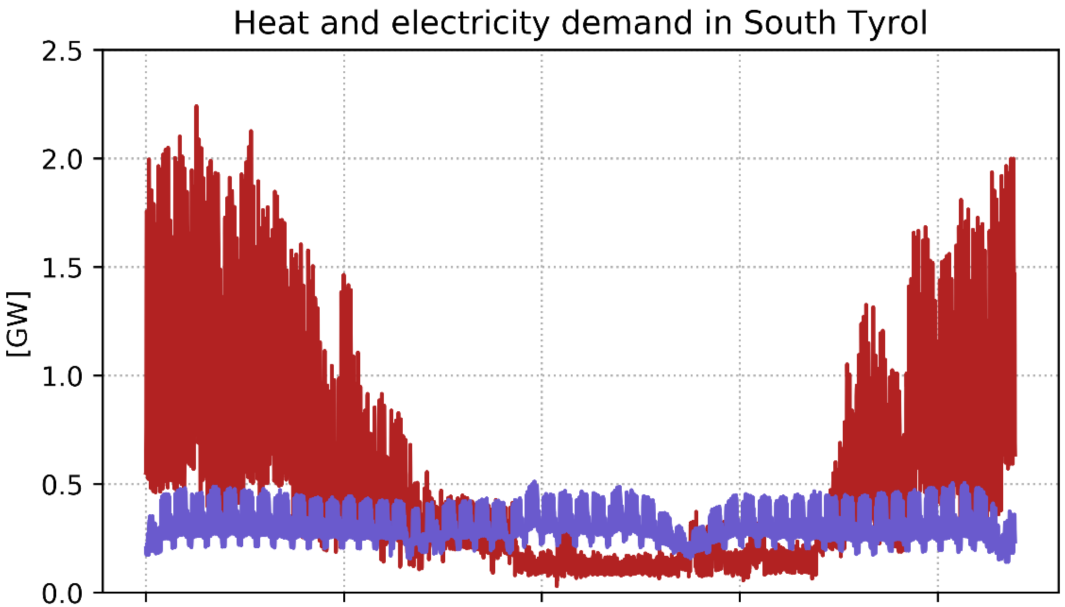
Reference scenario

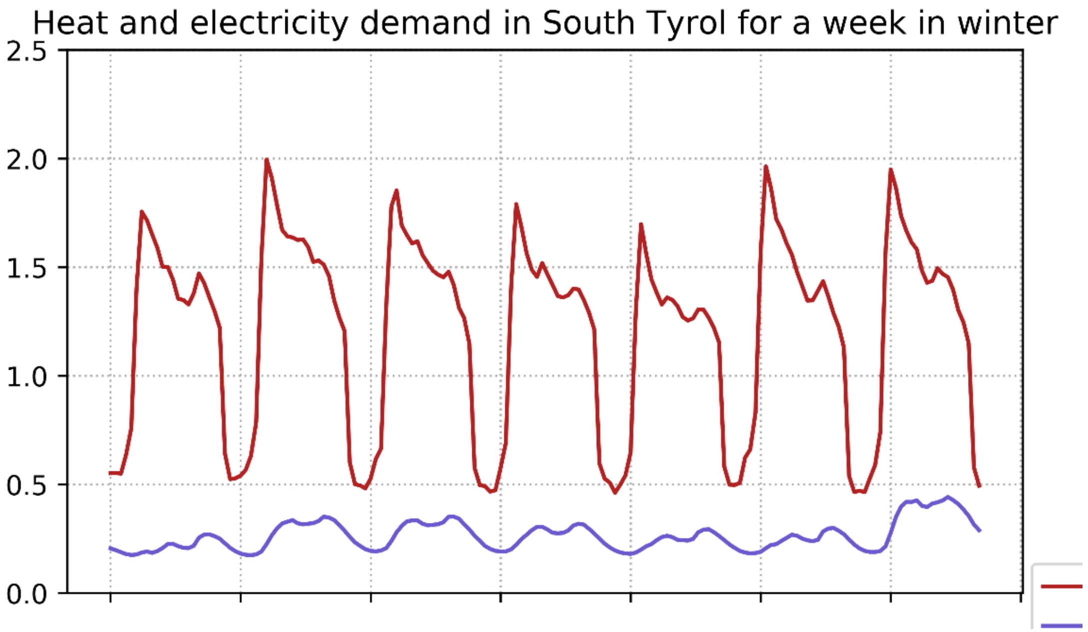


PEHT scenario



Heat and electricity demand: example South Tyrol



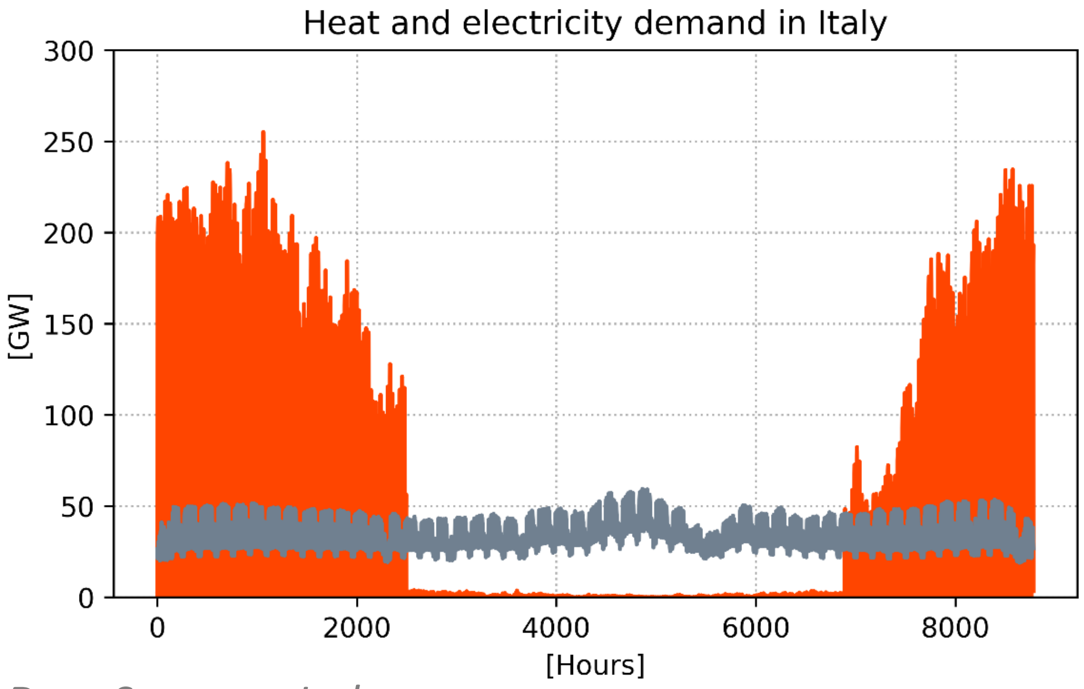


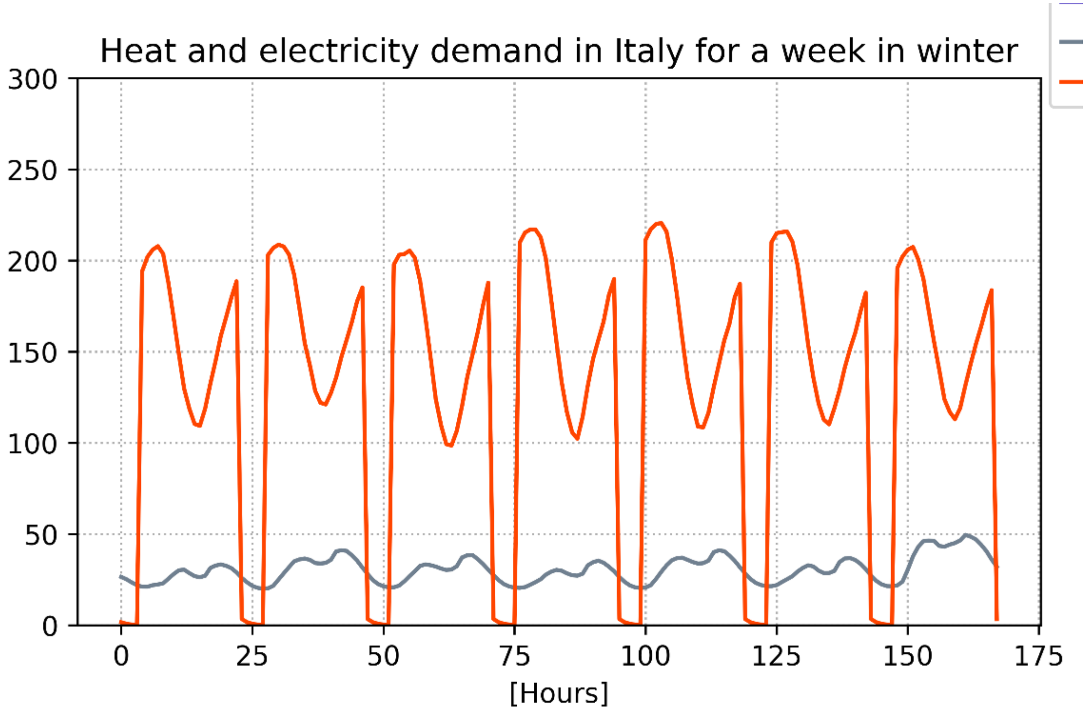
Data Sources - South Tyrol:

- Electricity demand: Terna, Italian TSO. Distribution of the North zone. 2014
- Heat demand: Overall heating demand + profile of district heating of Bolzano, 2014. (Alperia)
- Heat for indstrial applications is not included

Credits and further information Matteo Prina et. all, publications listed below

Heat and electricity demand: example Italy



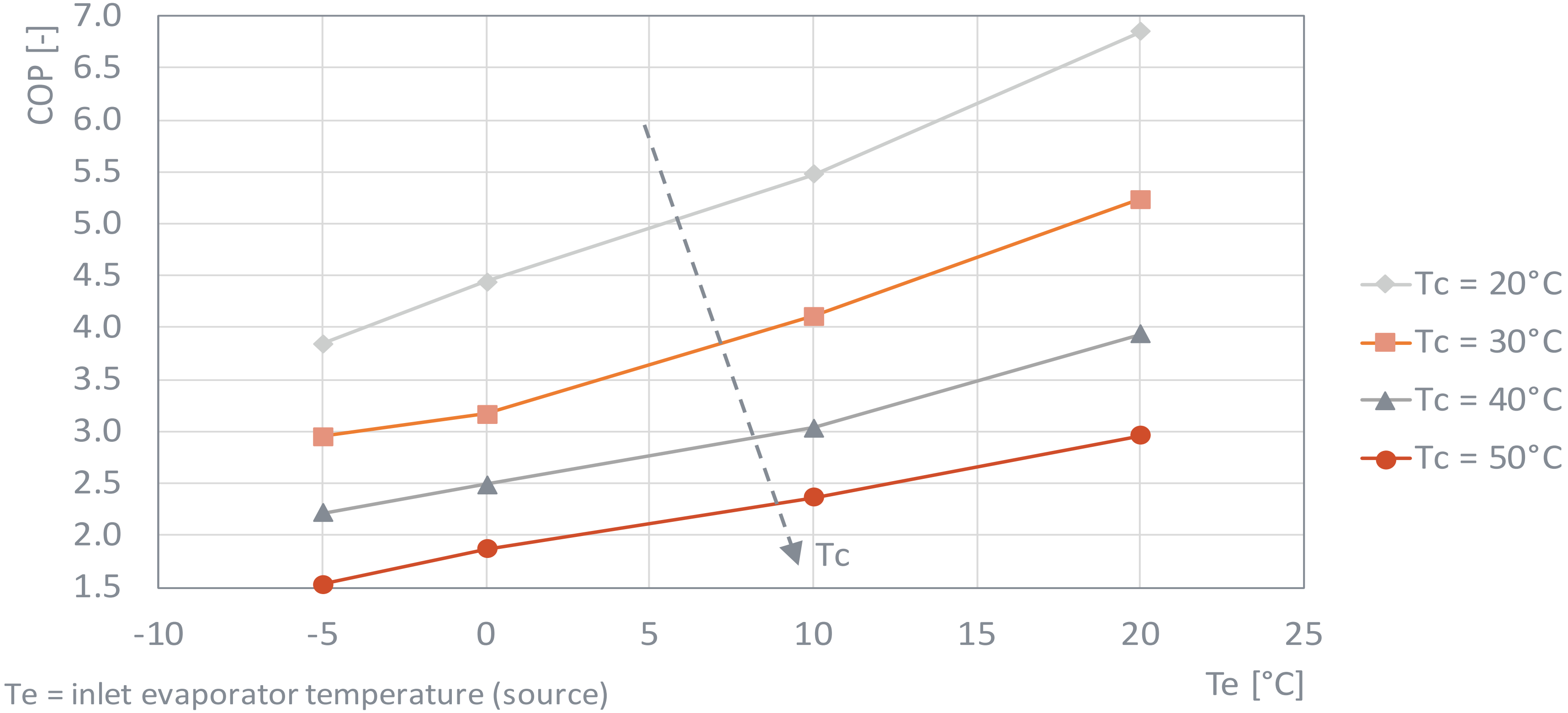


Data Sources - Italy:

- Electricity demand: Terna, Italian TSO. Distribution of the whole Italy. 2015
- Heat demand: Elaboration of Hotmaps (http://www.hotmaps-project.eu/) time-series for residential and tertiary sectors. 2015, considering hourly average temperatures and degree days
- Heat for industrial applications is not included

Credits and further information Matteo Prina et. all, publications listed below

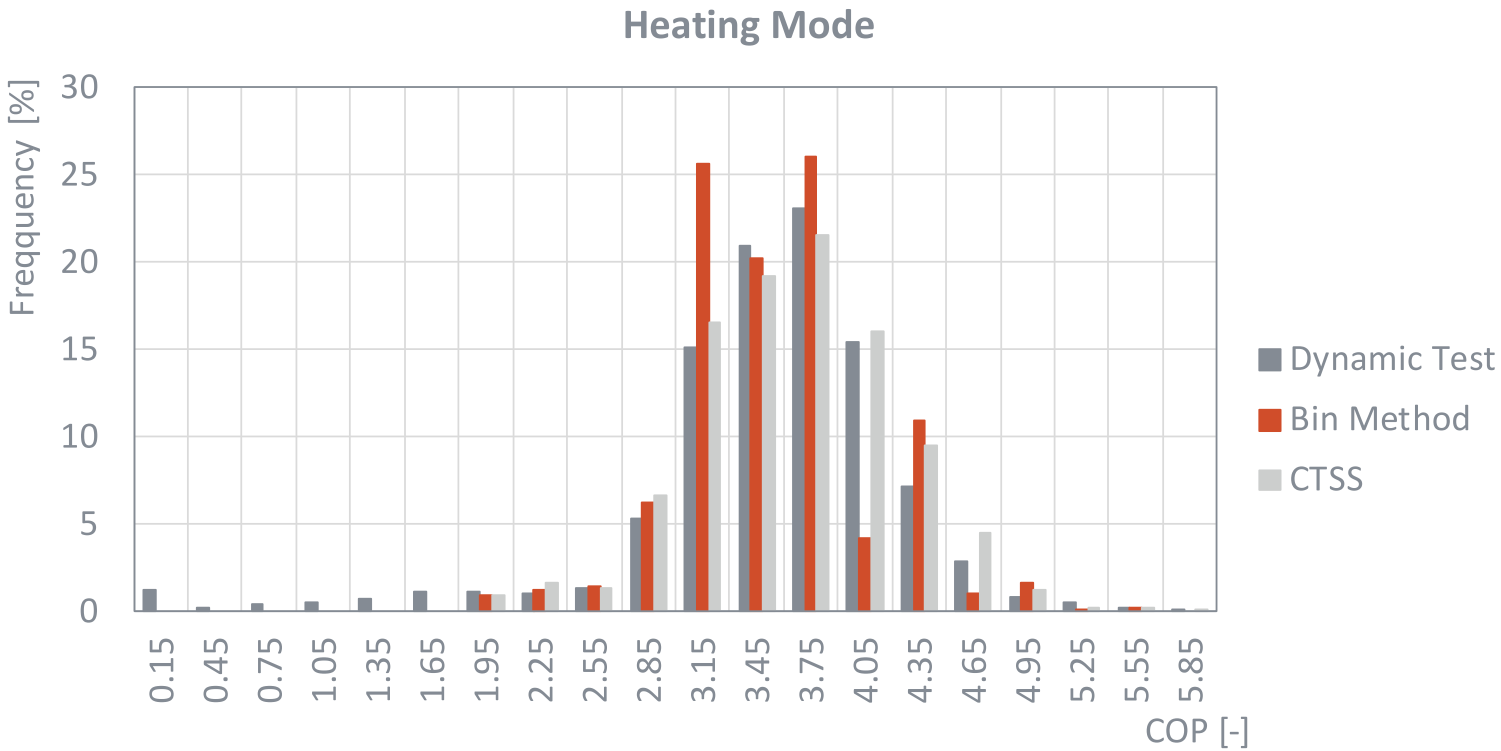
From heat to electricity: temperature



Te = inlet evaporator temperature (source)
Tc = inlet condenser temperature (load)

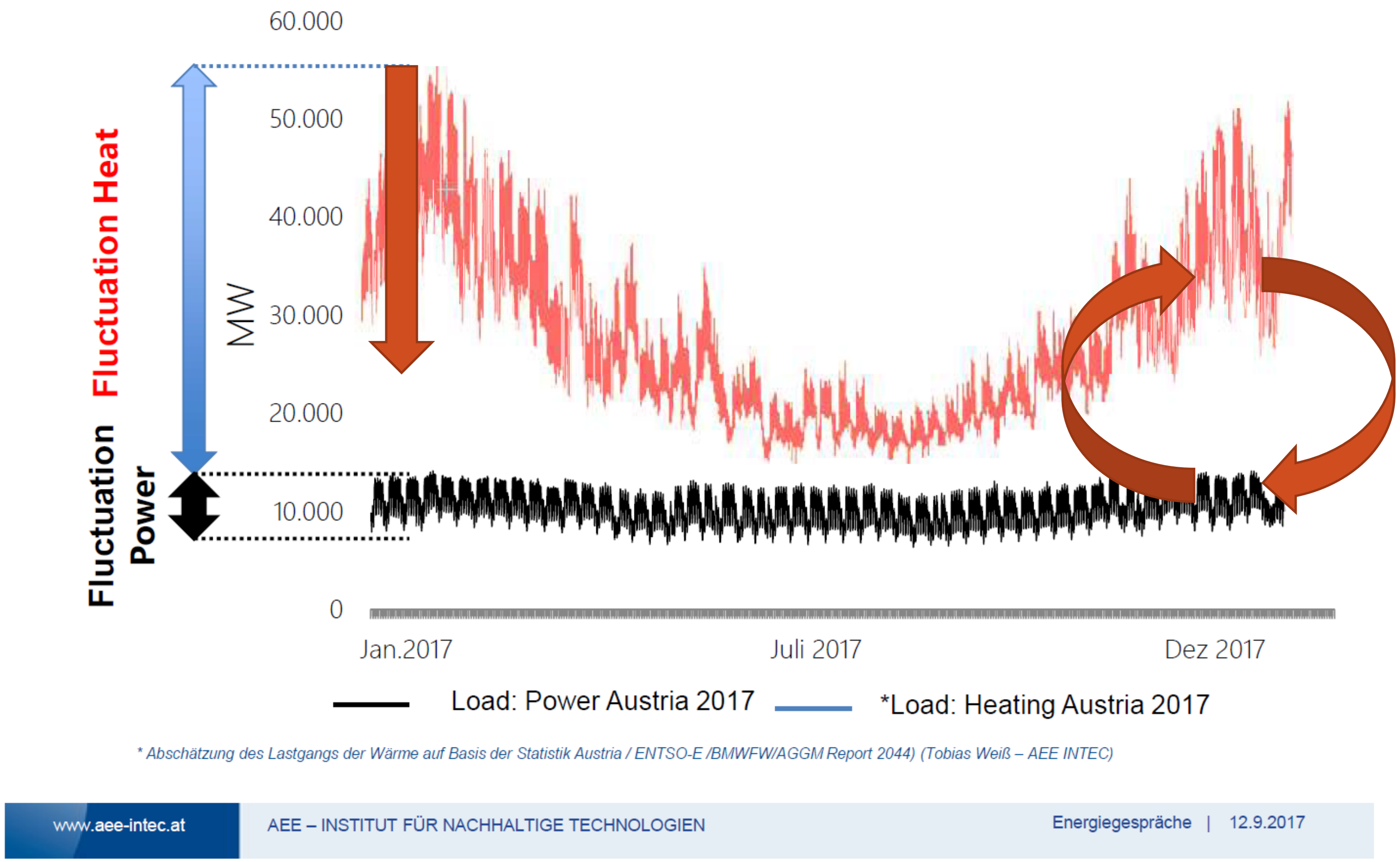
Example of COP variation of a heat pump in dependence of the inlet evaporator temperature. Shrinking temperatures lead to a shrinking COP. Eurac Research laboratory tests of a water / water heat pump with a nominal power 9.4 kW. Credits and further information Diego Menegon et. all, publications listed below

From heat to electricity: frequency



Frequency of presence of single COP values at the utilization of a heat pump over a full year.
External climate data from Bolzano. Eurac Research laboratory test.
Dynamic characterization compared with stationary characterization (i.e. Bin method and CTSS) of heat pumps.
Credits and further information Diego Menegon et. all, publications listed below

Heat and electricity demand: example Austria



Credits: Werner Weiss, AEE Intec

Reduction of heat demand through large scale refurbishment

Città di Bolzano
Stadt Bozen

BEFORE

264* kWh/m^2 year

AFTER

26 kWh/m^2 year

Credits: AREA architetti

Example building in Bolzano part of the FP7 smart city project SINFONIA

Utilization of locally available renewable resources

Alperia – district heating Sesto, utilization of (local) biomass

Sector coupling through co-generation

Alperia – district heating Chiusa, combined heat and power

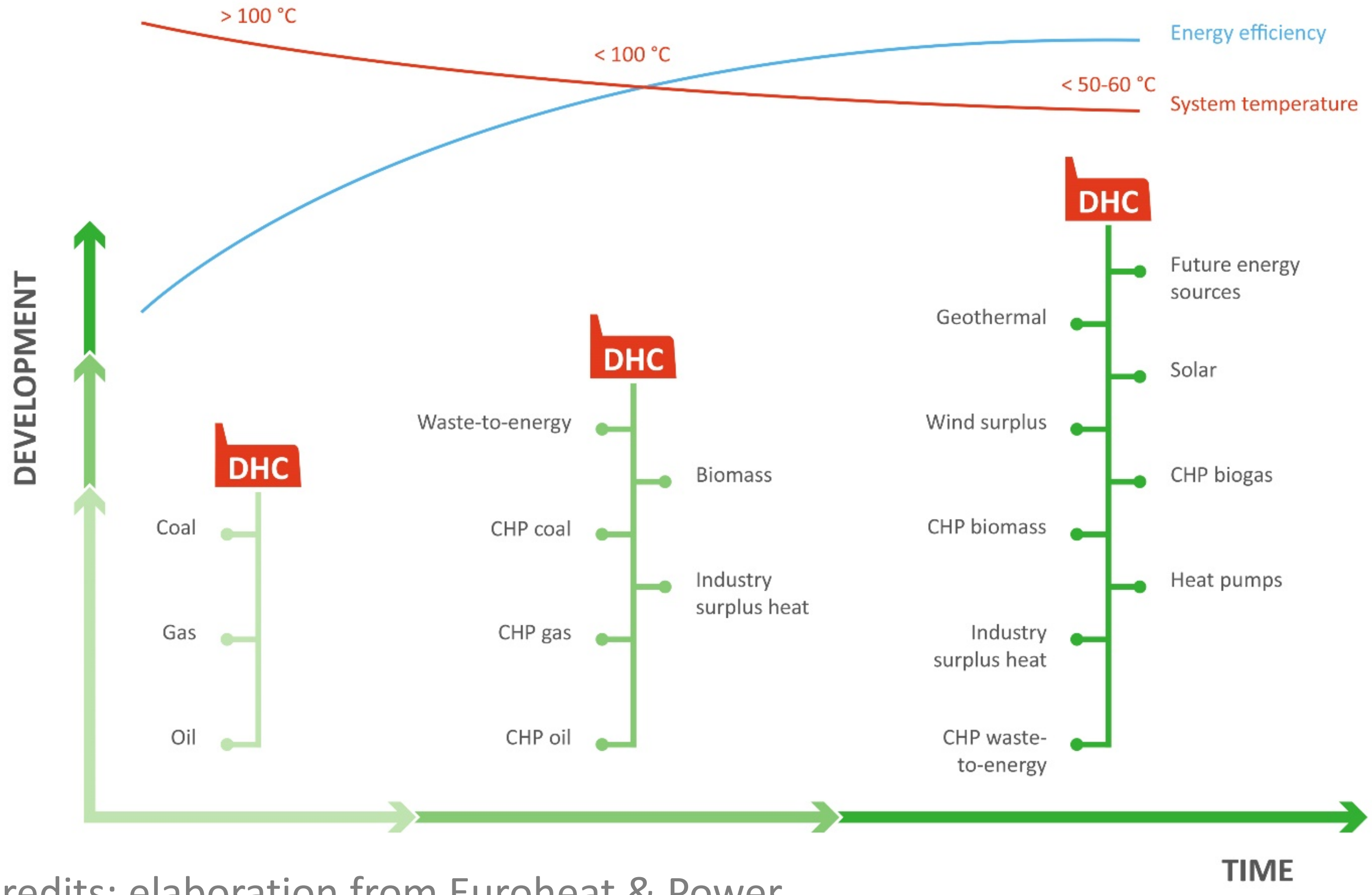
… and storage

Alperia – district heating Bolzano, energy tower and co-generation

… and heat pumps and other integrated technologies

a2a - district heating MIlan, Canavese plant including heat pumps

Evolution of district heating systems



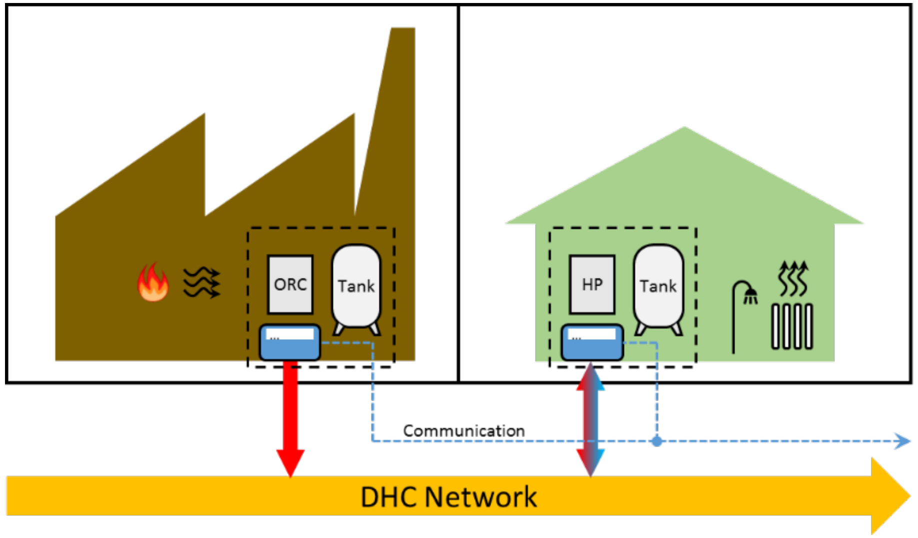
Credits: elaboration from Euroheat & Power

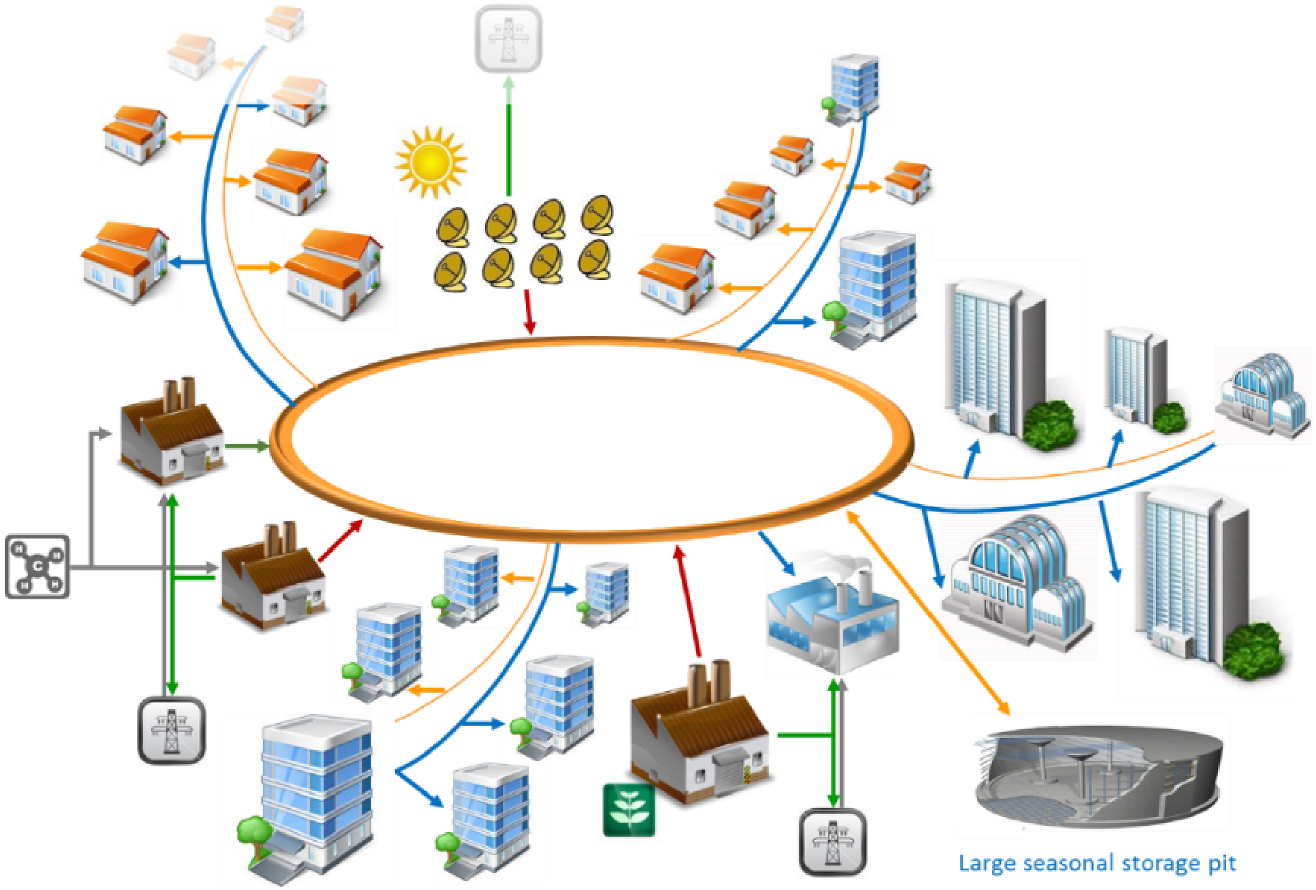
From fossil fuel based heating systems, to renewable based systems producing heat and power. Including thermal storage.

Allowing to take an active role for the electricity grid by producing electricity when needed, transforming oversupply electricity into heat, storing heat.

Further step: low temperature rings with heat pumps

Elaboration of substations for connection to DHC network through *reversible heat pumps*





A decentralised low-temperature DHC network at *15-25 °C for new city quarters or grid expansion*

Example FLEXYNETS concept allowing large scale waste heat integration

The traditional substations of district heating systems are replaced with heat pumps. End-users become prosumers in dependence of their energy needs. The heating network serves as well as low temperature storage.

Closing remarks

- Considering actual heat and electricity demand curves in Europe a full shift to electrification of heat is critical

- For a transformation to a low carbon energy system allowing a high degree of independence actions in many fields are needed. Including renewable energy sources for heat and electricity and large scale refurbishment of buildings

- Heat pumps, co-generation, thermal storage, district heating and low temperature rings allow the coupling of the electric and thermal energy systems and an active grid management

- In such a context heat pumps can give an important contribution to reduce on site emissions and enhance the application of renewables

Additional information about regional energy systems modelling:

Development of the model for regional energy systems:
M. G. Prina, M. Cozzini, G. Garegnani, G. Manzolini, D. Moser, U. F. Oberegger, R. Pernetti, R. Vaccaro, W. Sparber "
Multi-objective optimization algorithm coupled to EnergyPLAN software: The EPLANopt model"
Energy, Vol. 149, pp. 213-221, February 2018, DOI: https://doi.org/10.1016/j.energy.2018.02.050

Elaboration of the case study – South Tyrol
M. G. Prina, G. Manzolini, D. Moser, W. Sparber "Renewable energy high penetration scenarios using multi-node approach: analysis for the Italian case" 33rd European Photovoltaic Solar Energy Conference and Exhibition 25-29 Sep 2017 Amsterdam

Full presentation including technical background, free for download:
http://www.eurac.edu/en/research/technologies/renewableenergy/publications/Pages/Strategic-documents,-books-and-general-publications.aspx -> Energy model South Tyrol, 2017

Simulations on the Italian Energy Systems
MG Prina, L. Fanali, G. Manzolini, D. Moser, W. Sparber, "Incorporating combined cycle gas turbine flexibility constraints and additional costs into the EPLANopt model: The Italian case study“, Energy, Vol. 160, pp. 33-43, October 2018
DOI: https://doi.org/10.1016/j.energy.2018.07.007

Further publication under review at present.

Additional information about dynamic heat pump performance:

Test method:
D. Menegon, A. Vittoriosi, R. Fedrizzi, A new test procedure for the dynamic laboratory characterization of thermal systems and their components, Energy Build. 84 (2014) 182–192. doi:10.1016/j.enbuild.2014.07.085.

Heat pump performance:
A. Vittoriosi, R. Fedrizzi, D. Menegon, Evaluation of Dynamic Operation Effects for a Heat Pump in a Solar Combi-plus System, in: International Solar Energy Society, 2015: pp. 1–10. doi:10.18086/eurosun.2014.03.28.

Dynamic performance:
D. Menegon, Development of a Dynamic Test Procedure for the Laboratory Characterization of HVAC systems, PhD Thesis, University of Udine, 2016. https://air.uniud.it/retrieve/handle/11390/1132918/251012/10990_745_PhDthesis_DiegoMenegon.pdf

Component test method:
D. Menegon, A. Vittoriosi, R. Fedrizzi, A new test procedure for the dynamic laboratory characterization of thermal systems and their components, Energy Build. 84 (2014) 182–192. doi:10.1016/j.enbuild.2014.07.085.

Heat pump performance:
A. Vittoriosi, R. Fedrizzi, D. Menegon, Evaluation of Dynamic Operation Effects for a Heat Pump in a Solar Combi-plus System, in: International Solar Energy Society, 2015: pp. 1–10. doi:10.18086/eurosun.2014.03.28.

System performance:
D. Menegon, A. Soppelsa, R. Fedrizzi, Development of a new dynamic test procedure for the laboratory characterization of a whole heating and cooling system, Appl. Energy. 205 (2017) 976–990. doi:10.1016/j.apenergy.2017.08.120.

Additional information connected projects:

FLEXYNETS

STARDUST TRENTO

Sinfonia

Low temperature district heating systems

Smart city projects with large scale building refurbishment

HOTMAPS

iNSPiRe Systemic energy renovation of buildings

BuildHeat

4RinEU

Open source information on heating in EU

Building refurbishment concepts including heat pumps

Full list of projects and including links is available under:
http://www.eurac.edu/en/research/technologies/renewableenergy/projects/Pages/default.aspx

Urban Energy Transition: Renewable Strategies for Cities and Regions, second edition is the definitive science and practice compendium of energy transformations in the global urban system. This volume is a timely and rich resource as citizens, companies and their communities, from remote villages to megacities and metropolitan regions, rapidly move away from fossil fuel and nuclear power, to renewable energy as civic infrastructure investment, source of revenue and prosperity, and existential resilience strategy.

This book and its chapters present an entirely new edition throughout, in content, structure and science. Structured into four sections on design, technology, planning and finance, they feature:

- **advanced urban planning and design, infrastructure, landscape, mapping and modelling, and governance issues** related to urban renewable energy transformations
- **community and user enabling aspects:** energy access, prosperity and democracy, and urban renewable energy legislation, programs and incentives
- **individual and mass transport innovations** in the context of mobility related energy trends
- **city-wide solar strategies and urban thermal performance** planning, energy sector coupling, and distributed renewable energy and storage systems
- **practical innovations in renewable energy finance,** blockchain technology enabled peer-to-peer renewable energy trading, and the case for regional monetary systems and sustainable lifestyles.
- **analytic case insights into successful practices** from cities and regions around the globe that provide local, regional and country-specific governance and organizational perspectives

Urban Energy Transition, second edition is a cross-disciplinary handbook that enables an immediate, principled and systems-based understanding of essential policy frameworks and action for a sustainable, climate stable world.

Cover image: Degrees of self-sufficiency in locally generated renewable electricity reached by 2050 under a best-practice scenario, mapped for each of the local government areas across Europe's Lake Constance region.

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Edited by Peter Droege

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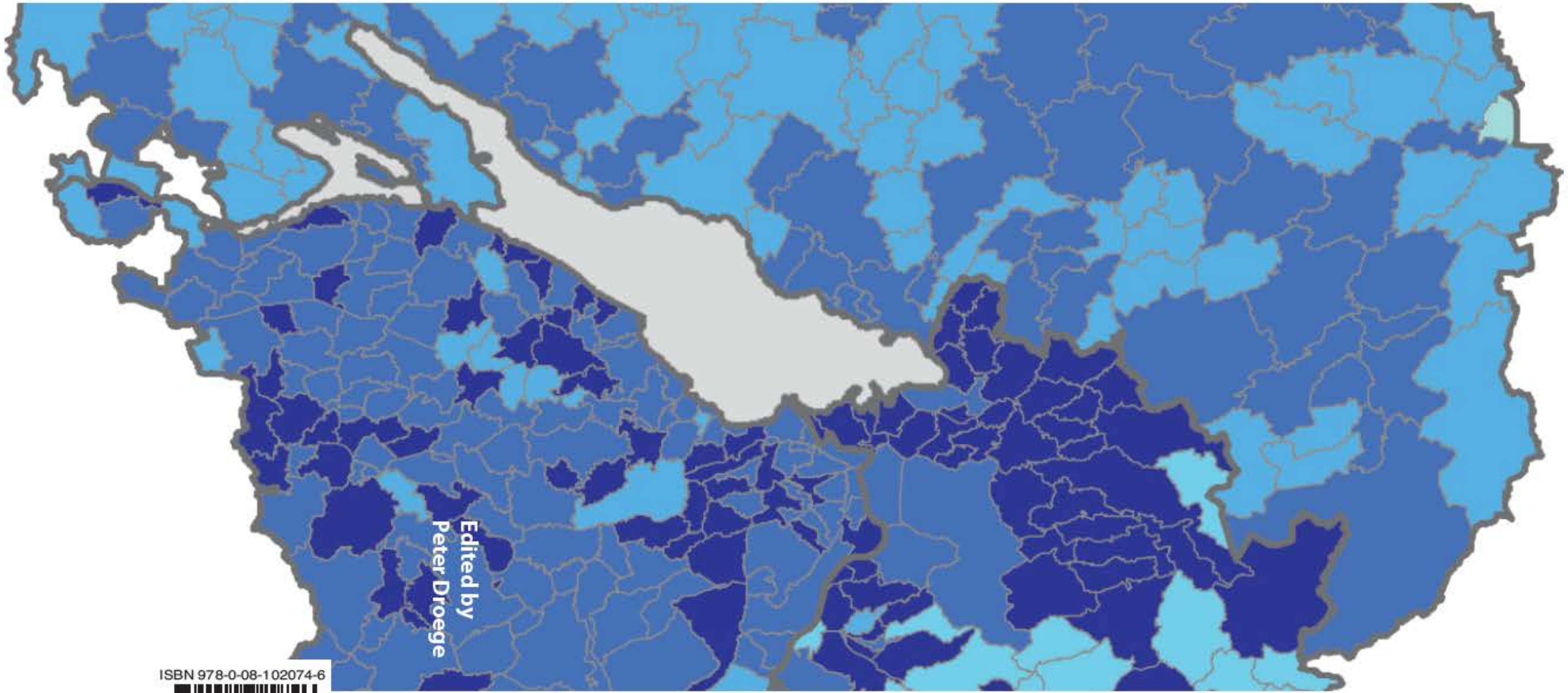

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Thank you for your attention

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