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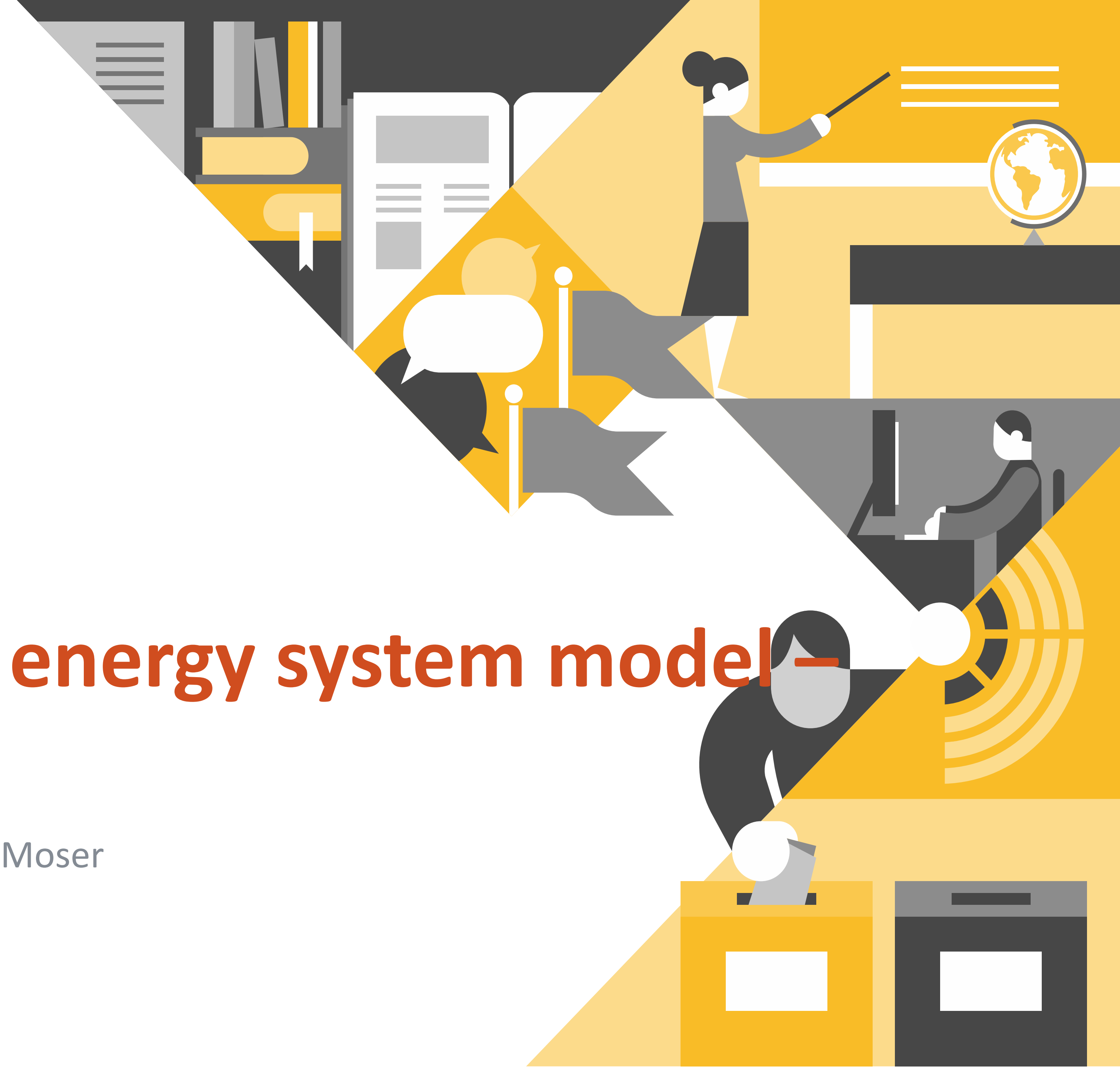


Niederosterreich energy system model – Annex 1

W. Sparber, R. Vaccaro, M. G. Prina, D. Moser

Index:

- Additional assumptions
- Energy flow in Lower Austria
- Profile assumptions
- Energy efficiency assumptions
- Learning curve
- Costs database
- Analysis of the results

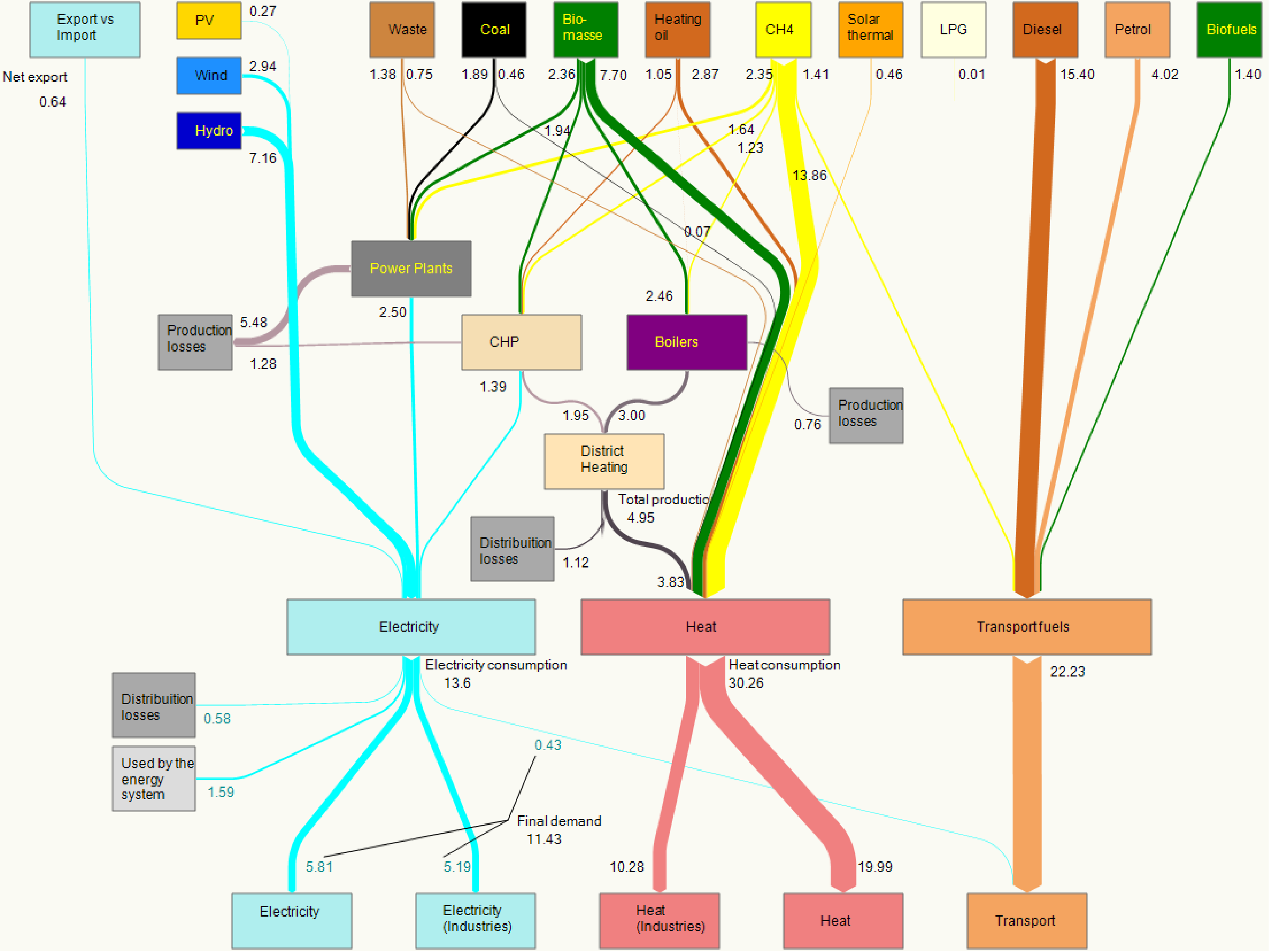
Additional assumptions

- Renewable generation profiles and equivalent hours assumed as constant. Climate change possible impact on insolation, precipitation or wind intensity is therefore not considered.
- Likewise, temperatures are considered constant. Possible temperature fluctuations due to climate change are not considered.
- The future year considered for the optimization analysis is 2050. All cost parameters are updated at 2050 considering technology learning curves. Technology efficiency increase or radical new technologies are not taken into account.
- Costs trends of electricity price are not considered. Electricity price is assumed to remain constant.

Additional assumptions

- Emission factors considered are taken from IPCC (biomass emission factor is equal to 0)
  https://www.ipcc-nggip.iges.or.jp/EFDB/main.php
- Coal phase-out has been considered (and also Oil phase-out within cogeneration units)
- Electricity consumption considers electricity losses of the grid.
  Energiebilanz Niederösterreich 1988 bis 2017 (Detailinformation)
- The demand for electricity is changing due to the gradual introduction of individual technologies. Apart from these simulation-related changes, the consumption of the power sector was assumed to be constant
- Emissions from fermentation processes are not taken into account

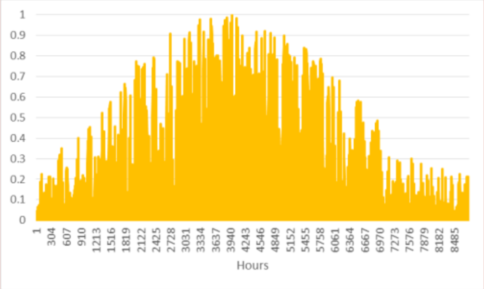
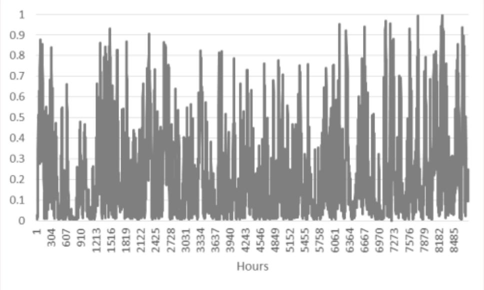
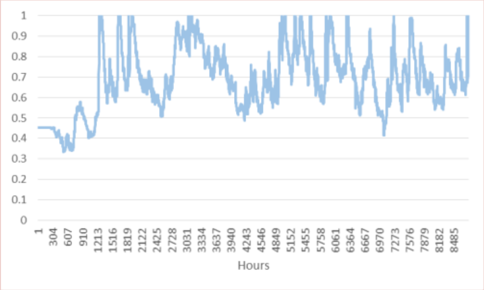
Energy flow in Lower Austria [TWh]



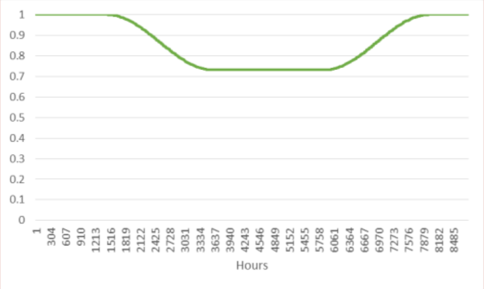
Remarks:

- The database is based on the Energiebilanz NÖ 2016
- Simplifications have been made for the purpose of illustration.
- Electricity consumption for electric heating systems is directly assigned to the final power consumption.
- Consumption or electricity production of the Schwechat refinery is excluded.

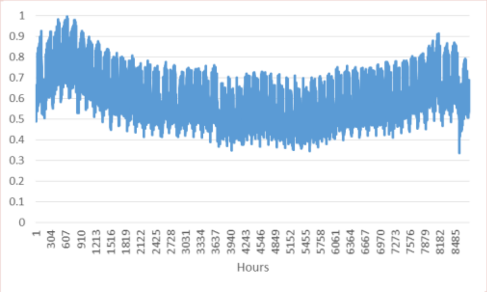
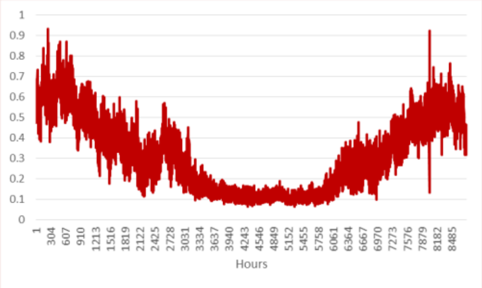
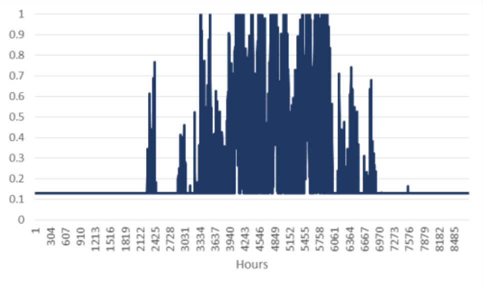
Profile assumptions

Generation	Profile used	Shape
PV electricity generation	PV_Niederosterreich_2017.txt Data provided by Niederosterreich region	
Wind power generation	Wind_Niederosterreich_2017.txt Data provided by Niederosterreich region	
River Hydro generation	River_Hydro_Niederosterreich_2017.txt Data provided by Niederosterreich region	

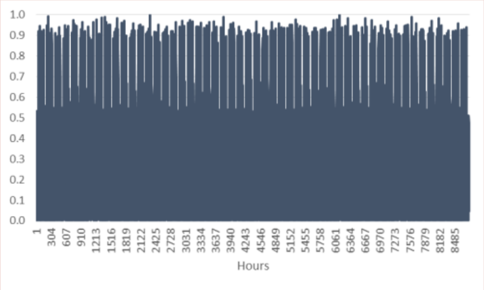
Profile assumptions

Generation	Profile used	Shape
Biomass electricity generation	Biomass_Niederosterreich_2017.txt Data provided by Niederosterreich region	

Profile assumptions

Demand	Profile used	Shape
Electricity demand	Niederosterreich_electricity_demand_2017.txt Data provided by Niederosterreich region	
Heat demand DH and Heat demand individual	DH_Niederosterreich_2017.text Data provided by Niederosterreich region	
Cooling demand	Germany cooling demand 2010.txt The Austrian existing EnergyPLAN country model for the year 2010 uses this profile (http://www.energyplan.eu/useful_resources/existingcountrymodels/)	

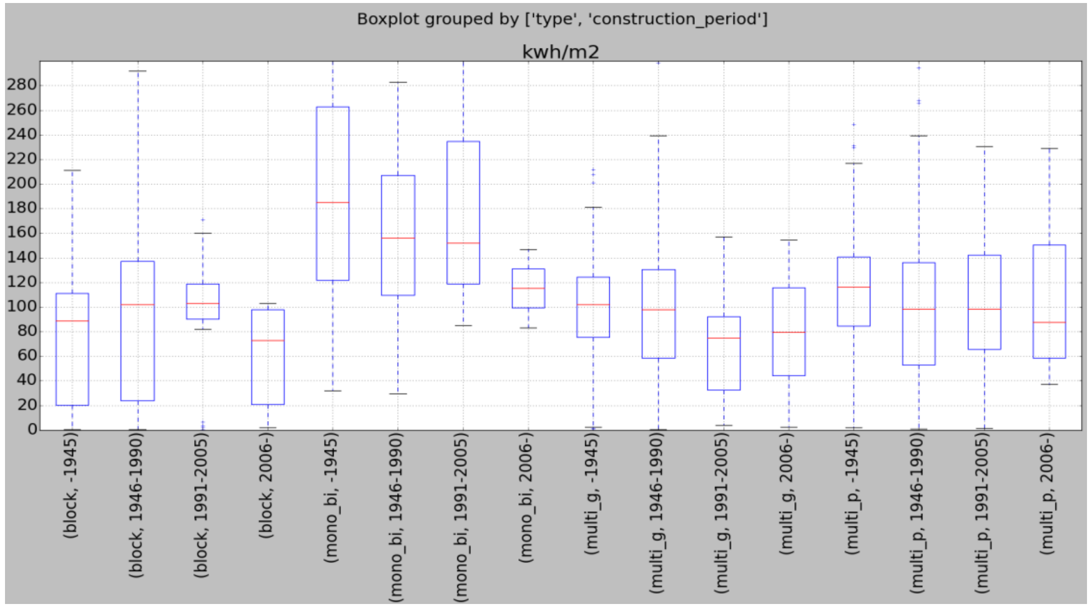
Profile assumptions

Demand	Profile used	Shape
Electric transport demand	IT Transport demand.txt Electric transport demand in Italy in 2015 Approximation through profile curves of neighbouring countries. Charging especially in the evening and overnight	

Energy efficiency assumptions

Building stock analysis and elaboration of the energy efficiency cost curve

1. **Analysis and classification** of the provincial residential **building stock: construction period**, the **types of buildings** (single family house, multi family house, detached, block) and the heating degree days (**HDD**).
2. **Evaluation** of the **specific heat consumption** for each municipality, construction period, and type of buildings.
3. **Assessment of the cost of retrofit** and the **actual energy savings** associated to retrofit measures (through Passive House Planning Package (**PHPP**) **simulations** launched to evaluate the thermal energy consumption in post-retrofit conditions)
4. Possible to calculate the **annual thermal energy savings** for each construction period and type of building and also the value of the **euro per kWh saved**. The results obtained show therefore higher values of energy savings for municipalities with colder climates.

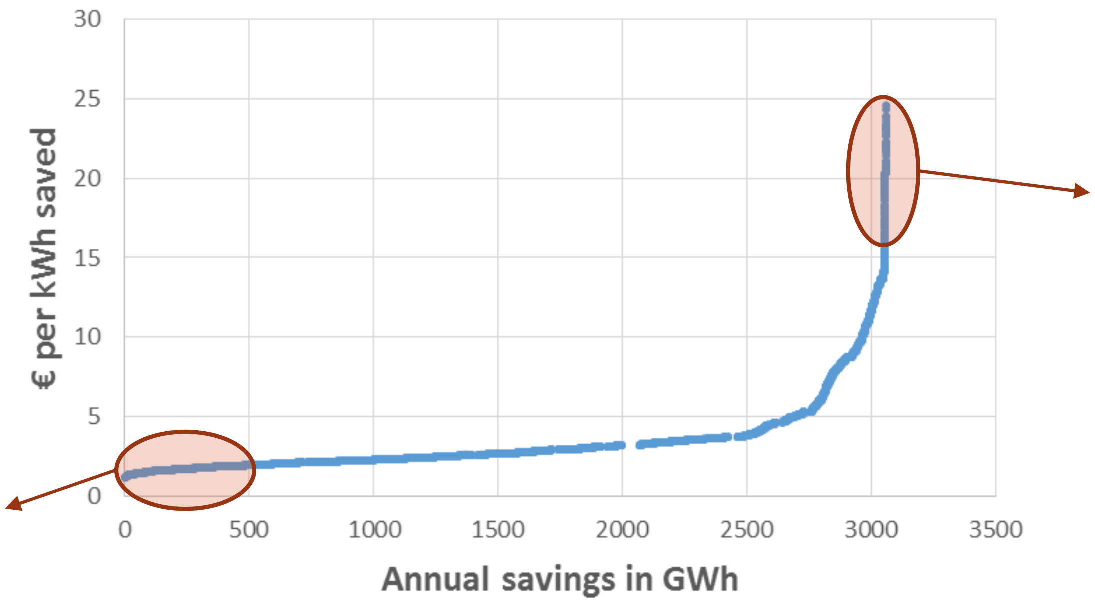


A detailed explanation of the methodology adapted for Lower Austria can be found under: http://www.eurac.edu/en/research/technologies/renewableenergy/newsandmedia/Documents/20170405_EnergyModellingSouthTyrol_appendix2_final.pdf

Energy efficiency assumptions

Building stock analysis and elaboration of the energy efficiency cost curve

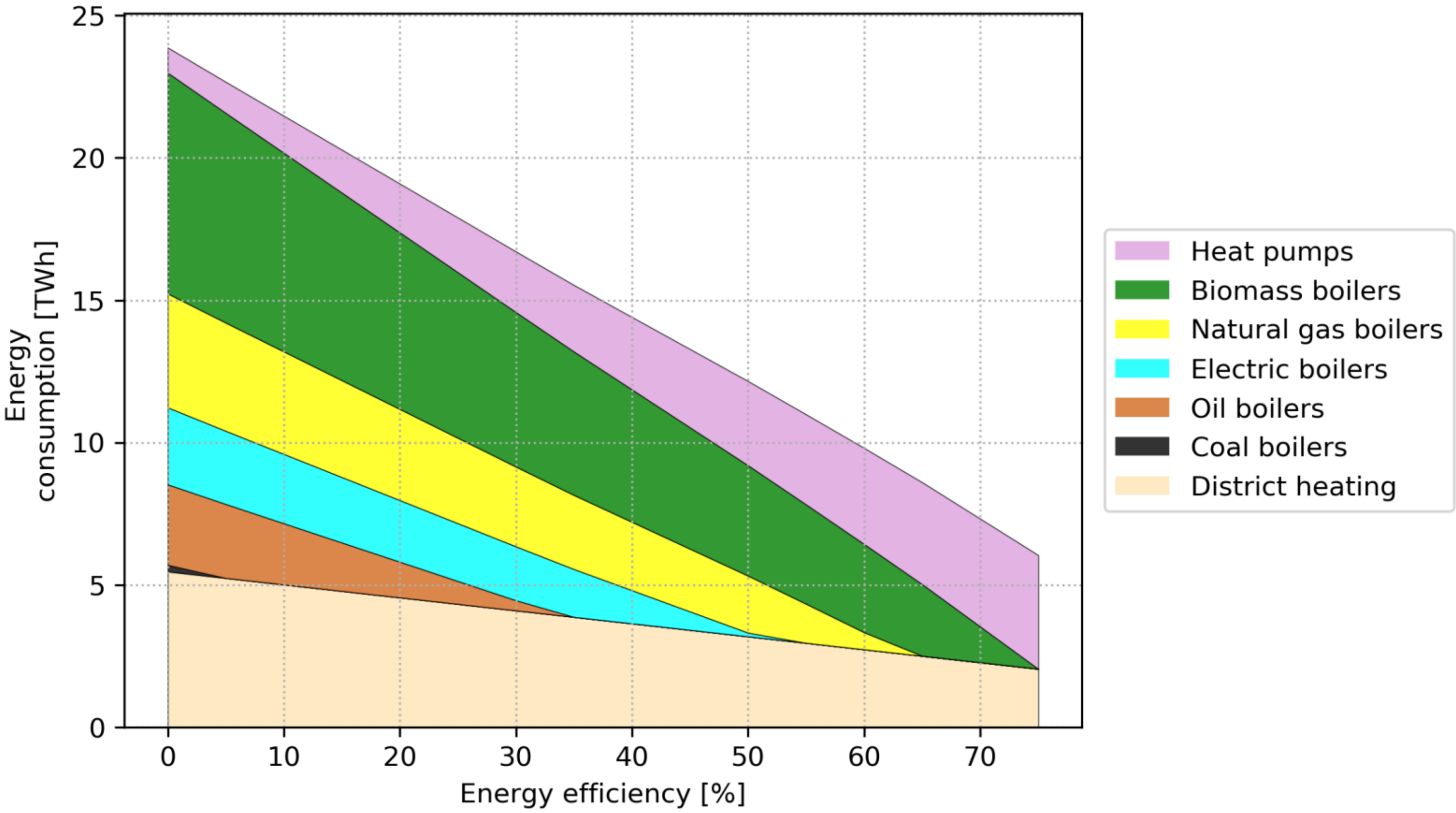
Measures that produce high energy savings compared to the costs (roof insulation for old SFH built before 1946, façade insulation and basement insulation)



Measures that result in lower energy savings in comparison to the cost (window replacement in new buildings), but which are implemented in addition to the energy aspects for various other reasons (comfort, safety, ...)

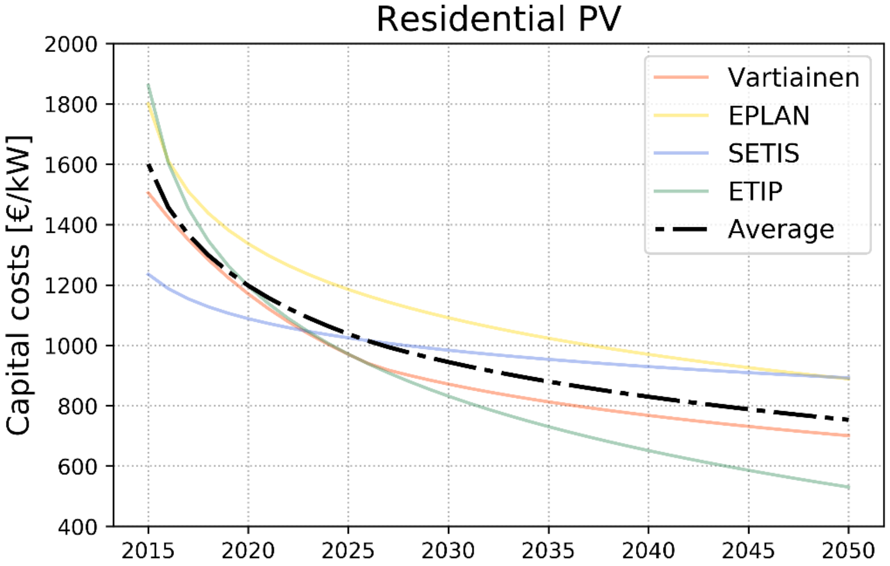
Energy efficiency assumptions

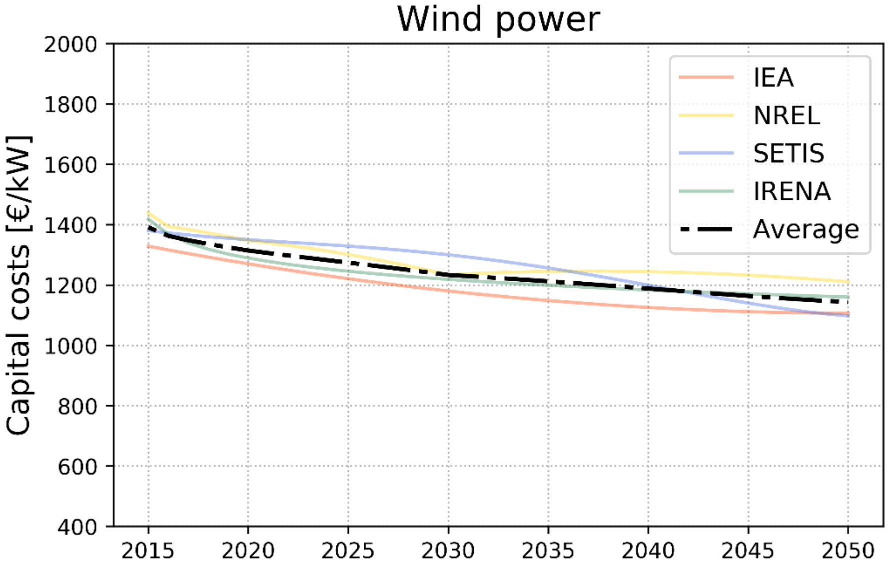
Assumptions on energy efficiency and heat pumps

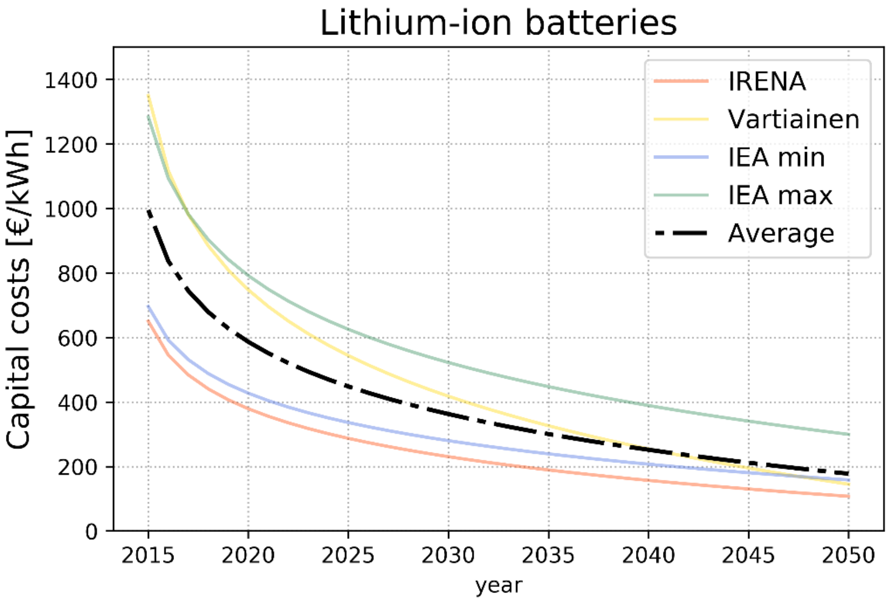


- The **installation of heat pumps** is allowed in the model only after deep energy refurbishment of buildings.
- **Domestic Hot Water (DHW)** in buildings reached by district heating network is supplied by district heating itself. For the other individual buildings there are two different demands: DHW and heating demand. The heating demand can be reduced through energy efficiency refurbishment. The DHW share instead is not influenced by energy efficiency.
- The optimization decides which share of renovated buildings should install heat pumps (the graph on the left shows the theoretical decrease of energy consumption due to energy efficiency with the assumption of 100% installation of heat pumps in renovated buildings)
- In the individual sector, at the increase of the energy efficiency share, heat pumps substitutes different type of boilers with the following priorities:
  1. Coal boilers
  2. Oil boilers
  3. Electric boilers
  4. Natural gas boilers
  5. Biomass boilers

Learning curves







On the top left, cost trends for residential PV (2015-2050) from different sources: Vartiainen et al. [1], EnergyPLAN [2], SETIS [3] and ETIP-PV [4]. On the top right, cost trends for wind turbines (2015-2050) from different sources: IEA [5], NREL [6], SETIS [3], IRENA [7]. On the bottom left, cost trends for lithium-ion batteries (2015-2050) from different sources: IRENA [8], Vartiainen et al. [1], IEA [9].

Learning curves

[1] Moser D, Breyer C, Masson G, Vartiainen E. Improving the Competitiveness of Solar PV with Electricity Storage. 33rd Eur Photovolt Sol Energy Conf Exhib 2017:2783–9. doi:10.629/EUPVSEC20172017-7DO.8.4.

[2] Cost Database | EnergyPLAN n.d. http://www.energyplan.eu/useful_resources/costdatabase/ (accessed April 10, 2018).

[3] Carlsson J, Perez Fortes M del M, Marco G de., Giuntoli J, Jakubcionis M, Jäger-Waldau A, et al. Energy Technology Reference Indicator (ETRI) projections for 2010-2050. Publications Office; 2014.

[4] Breyer C, Vartiainen E, Masson G. The True Competitiveness of Solar PV. A European Case Study. n.d.

[5] Wiser RH, Jenni K, Seel J, Baker E, Hand MM, Lantz E, et al. Forecasting Wind Energy Costs and Cost Drivers: The Views of the World's Leading Experts | Electricity Markets and Policy Group n.d. https://emp.lbl.gov/publications/forecasting-wind-energy-costs-and (accessed April 10, 2018).

[6] Tidball R, Bluestein J, Rodriguez N, Knoke S. Cost and Performance Assumptions for Modeling Electricity Generation Technologies. Golden, CO (United States): 2010. doi:10.2172/993653.

[7] IRENA. The Power to Change: Solar and Wind Cost Reduction Potential to 2025. /Publications/2016/Jun/The-Power-to-Change-Solar-and-Wind-Cost-Reduction-Potential-to-2025 n.d.

[8] IRENA. Electricity storage and renewables: Costs and markets to 2030. /Publications/2017/Oct/Electricity-Storage-and-Renewables-Costs-and-Markets n.d.

[9] Leuthold M. Energy Storage Technologies Battery Storage for Grid Stabilization IEA EGRD Conference on Energy Storage 2014.

Costs database

Technology costs at 2050
(Investment, fixed operation and maintenance and lifetime)

Prod. type	Investment		Period	O. and M.
	Unit	MEUR pr. Unit	Years	% of Inv.
Small CHP units	164 MW-e	1.2	25	2
Large CHP units	0 MW-e	0.79	25	2
Heat Storage CHP	0 GWh	3	25	3.8
Waste CHP	1.38 TWh/year	215.6	20	4.7
Absorp. HP (Waste)	0 MW-th	0.4	30	1
Heat Pump gr. 2	0 MW-e	2.9	20	0.7
Heat Pump gr. 3	0 MW-e	2.9	30	0.15
DHP Boiler group 1	0 MW-th	0.1	20	1.5
Boilers gr. 2 and 3	1200 MW-th	0.075	27	3.26
Electr Boiler Gr 2+3	0 MW-e	0.1	20	1.47
Large Power Plants	950 MW-e	0.95	30	3.2
Nuclear	0 MW-e	3.02	20	3.5
Interconnection	0 MW	1.2	40	1
Pump	99999 MW-e	0	50	1.5
Turbine	99999 MW-e	0	50	1.5
Pump Storage	0 GWh	177.6	10	0
Indust. CHP Electr.	0.00 TWh/year	68.3	25	7.3
Indust. CHP Heat	0.00 TWh/year	68.3	25	7.3

Technology costs at 2050
(Investment, fixed operation and maintenance and lifetime)

Prod. type	Investment		Period	O. and M.
	Unit	MEUR pr. Unit	Years	% of Inv.
Wind	1491 MW-e	1.1436	25	3.21
Wind offshore	0 MW-e	2.1	40	1.15
Photo Voltaic	259 MW-e	0.753	25	2
Wave power	0 MW-e	1.6	50	2
Tidal Power	76 MW	5.33	25	8.21
CSP Solar Power	0 MW	5.98	20	7.7
River of hydro	1178 MW-e	3.3	50	2
Hydro Power	48 MW-e	3.3	50	1.5
Hydro Storage	0 GWh	7.5	50	1.5
Hydro Pump	0 MW-e	0.6	30	1.96
Geothermal Electr.	0 MW-e	4.03	20	3.48
Geothermal Heat	0 TWh/year	0	0	0
Solar thermal	0 TWh/year	307	25	3.75
Heat Storage Solar	0 GWh	3	35	3.7
Indust. Excess Heat	0 TWh/year	40	30	1

All the costs come from the EnergyPLAN database with the only exceptions of the values obtained from the learning curve analysis of key technologies (PV, Wind power and Lithium-ion batteries)

Costs database

Technology costs at 2050 heat sector (Investment, fixed operation and maintenance and lifetime)

Prod. type	Investment		Period	O. and M.
	Unit	MEUR pr. Unit	Years	% of Inv.
Indv. boilers	776 1000-Units	6.1	21	1.8
Indv. CHP	197 1000-Units	12	10	0
Indv. Heat Pump	59 1000-Units	14	20	1
Indv. Electric heat	180 1000-Units	8	30	1
Indv. Solar thermal	0 TWh/year	1233	25	7

Technology costs at 2050 (variable operation and maintenance costs)

District Heating and CHP systems		
Boiler	0.15	EUR/MWh-th
CHP	2.7	EUR/MWh-e
Heat Pump	0.27	EUR/MWh-e
Electric heating	0.5	EUR/MWh-e
Power Plants		
Hydro Power	1.19	EUR/MWh-e
Condensing	2.636	EUR/MWh-e
Geothermal	15	EUR/MWh-e
GTL M1	1.8	EUR/MWh-fuel-input
GTL M2	1	EUR/MWh-fuel-input
Storage		
Electrolyser	0	EUR/MWh-e
Pump	1.19	EUR/MWh-e
Turbine	1.19	EUR/MWh-e
V2G Discharge *)	0	EUR/MWh-e
Hydro Power Pump	1.19	EUR/MWh-e

Fuel costs at 2050

Fuel price alternative : Basic	Coal	FuelOil	Diesel Gasoil	Petrol/JP	Ngas	LPG	Waste	Biomass	Dry Biomass	Wet Biomass	Nuclear/Uranium Incl. handling etc.
Fuel Price (world market prices) (EUR/GJ)	3.4	16.1	20	20.6	12.2	22.1	+ 0	8.1	6.3	0	1.75

Analysis of the results

	PV [MW]	Wind power [MW]	Batteries [GWh]	Hydrogen [TWh]	Electrolyser [MW]	Solar Thermal [TWh]	Heat pumps [%]	Energy efficiency [%]
RS	250	1500	0	0	0	0.45	0	0
P1	850	1500	0	0	0	0.45	100	10
P2	1100	3700	0	2	500	0.45	100	30
P3	1200	3800	0	2.5	500	0.45	100	60
P4	4750	4000	20	2.5	750	0.8	70	75
P-25	2850	3950	1	2.25	500	0.45	100	45
P-50	4750	4000	5	2	750	0.45	100	60
P-75	4750	4000	14	2.5	1000	0.7	100	65
P-100	4750	4000	20	2.5	2500	0.8	90	70
P3-25	2850	3950	2	2.5	500	0.45	100	60
P3-50	4750	4000	6	2.5	750	0.45	100	60
P3-75	4600	4000	7	1	250	0.45	100	65
P3-100	4750	4000	8	0	0	0.45	100	65

Literaturhinweis: Daten und methodischer Ansatz

EEV 1993 bis 2017 nach ET und Nutzenergiekategorien für Niederösterreich (Detailinformation)
https://www.statistik.at/web_de/statistiken/energie_umwelt_innovation_mobilitaet/energie_und_umwelt/energie/nutzenergieanalyse/index.html
Energiebilanz Niederösterreich 1988 bis 2017 (Detailinformation)
https://www.statistik.at/web_de/statistiken/energie_umwelt_innovation_mobilitaet/energie_und_umwelt/energie/energiebilanzen/index.html

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
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

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
M. G. Prina, M. Lionetti, G. Manzolini, W. Sparber, D. Moser “***Transition pathways optimization methodology through EnergyPLAN software for long-term energy planning***” at the SDEWES conference – Palermo 30th September - 4th October 2018.
M. G. Prina, M. Lionetti, G. Manzolini, W. Sparber, D. Moser “***Creating optimal transition pathways from 2015 to 2050 towards low carbon energy systems using the EnergyPLAN software: methodology and application to South Tyrol***” at Smart Energy System and 4th generation district heating – Aalborg 13th - 14th November 2018

Thanks for your attention

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