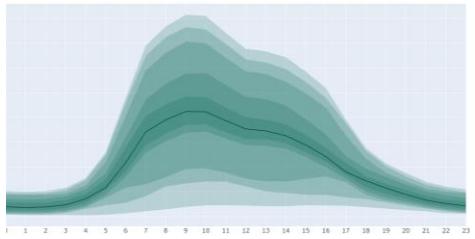
Reaching autarky on AU Viborg campus

Energy system modelling results

Demands

Electricity load profile calculation

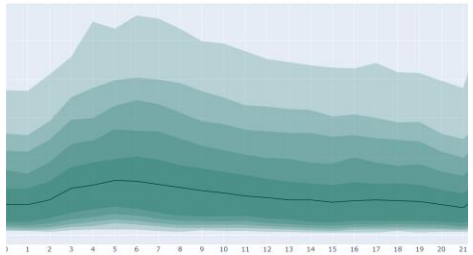
- Total load = el. consumption + 40%* of gas consumption
- Load profiles are calculated using German standard load profiles for businesses, modification s.t. monthly consumption corresponds to given values



Yearly demand: 5.7 GWh
Peak load: 1.6 MW

Heat load profile calculation

- Heat load = 50%* of gas consumption
- Load profiles are calculated using German standard load profiles for businesses, modification s.t. monthly consumption corresponds to given values



Yearly demand: 3.3 GWh
Peak load: 1.2 MW

* *According to electrical and thermal efficiency of CHP*

Data from: Email from Björn Andersen from 15.05.2025

Gas consumption is given in m^3. It is assumed that all gas consumption comes from Biogas CHP.

Electricity demand is given in kWh. It is assumend that the production from the CHP is not included (= imports from grid).

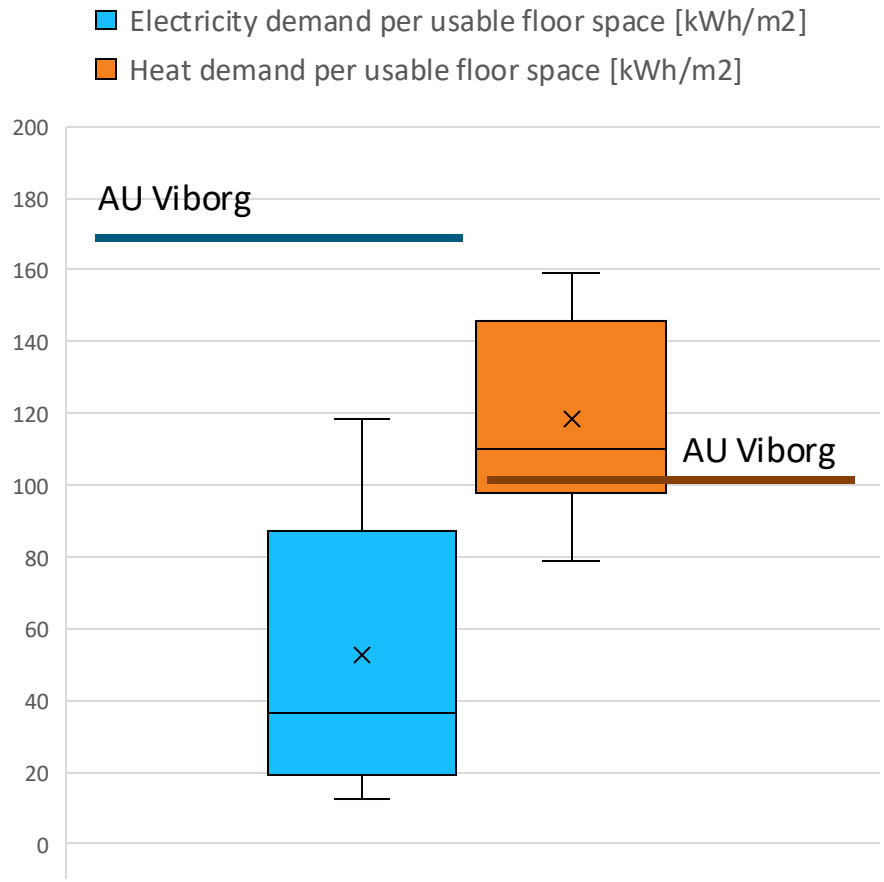
Gas forbrug, Foulum			
	2021	2022	2023
Jan	61,448	49,106	63,148
Feb	51,737	43,218	59,310
Mar	69,470	49,447	65,462
Apr	57,322	58,475	53,444
Maj	66,596	57,007	46,243
Jun	47,376	47,857	31,179
Jul	37,013	38,833	37,615
Aug	46,818	34,271	29,087
Sep	48,929	48,252	35,925
Okt	57,089	51,422	53,638
Nov	45,263	64,606	75,011
Dec	47,203	72,210	76,513
I alt	636,263	614,704	626,573

El forbrug, Foulum			
	2021	2022	2023
Jan		402,440	467,238
Feb		391,477	441,233
Mar		460,097	485,426
Apr		403,409	414,750
Maj		439,557	455,311
Jun		395,685	437,329
Jul		390,348	411,641
Aug		395,228	438,851
Sep		393,440	433,161
Okt		413,590	464,368
Nov		384,554	457,163
Dec		355,084	451,453
KFC (helår)	688,670	688,670	
I alt	5,294,513	5,513,579	5,357,924

Demands

Plausibility check

- Calculated specific demands [kWh/m²] for the campus are compared to ~ 500 neighbordhoods in Berlin
- In comparison the demands for electricity are quite high and for heat average



Scenarios

Scenario	description	Motivation for scenario
base	Heat generation only from CHP (635kW el., 790 kW th.), 840 kWp Freefield-PV	Base for comparison, calculate autarky level without Flow-storage
Flow-storage	Base + 720kWh / 120kW el. Redox-Flow storage	Assess impact of flow-storage on autarky level
Rooftop-PV	Flow-storage + usage of rooftop-PV enabled	Assess impact of using larger share of PV, assess potential of rooftop PV
Autarky	No el. grid connection, PV + storage optimized	Calculate necessary capacities to reach 100% independence from the power grid
Autarky w/ wind	Autarky, but with additional wind power plants	Calculate necessary capacities if also wind power is used (typically very beneficial to RE-systems)

PV rooftop Potential

- No source for 3D building data known
- Potentials are estimated using the buildings ground area
- Approach for estimating Rooftop-PV potentials:
    1. Get building ground area
    2. Select orientation group (SE/NW, S/N, SW/NE, E/W)
    3. Assumption: All roofs have tilt = 40°
    4. Module area = 60% * building area / cos (40°)

orientation	azimuth	kWp
SE	40	2003
S	10	1056
SW	-60	6643
E	80	731
NW	-140	2003
N	-170	1056
NE	120	6643
W	-100	731

Economic assumptions

Technology	CAPEX	OPEX	Life expectancy
PV Freefield	400 €/kWp	10 €/kWp/a	35
PV rooftop	1000 €/kWp	12 €/kWp/a	35
Flow storage	500 €/kWh	10 €/kWh/a	20
Biogas CHP	400 €/kW_{th}	14 €/kW_{th}/a	20
Thermal storage	8 €/l	-	20
Wind power onshore	1100 €/kW	14 €/kW + 50€/MWh add. fees for grid connection etc.	27

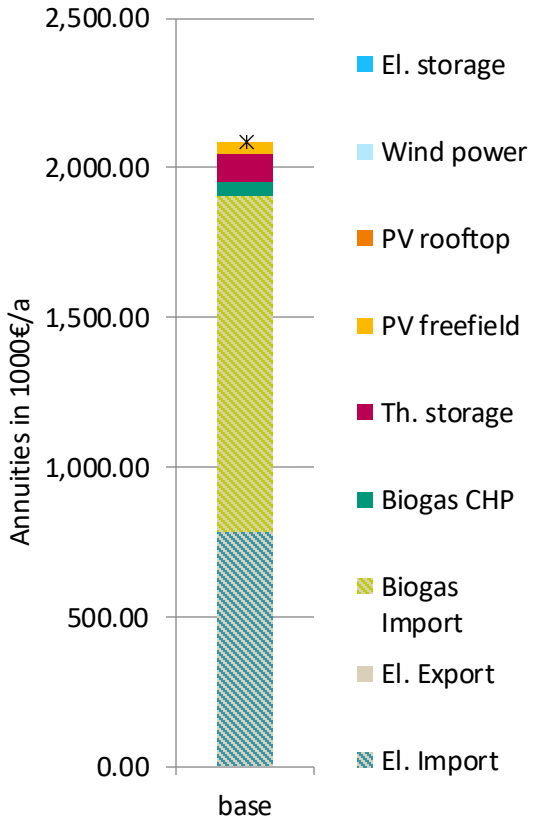
Other cost assumptions:

- Interest rate 7%
- Electricity price: 35ct/kWh + 40€/kW, no feed-in remuneration
- Biogas price: 17 ct/kWh (7ct Gas*, 10ct grid fees, taxes, etc.**)

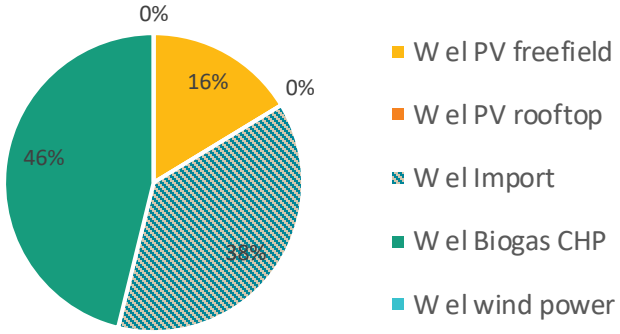
Sources: DAE, KEA

Scenario 1 (base) – 840 kWp Freefield-PV, no storage

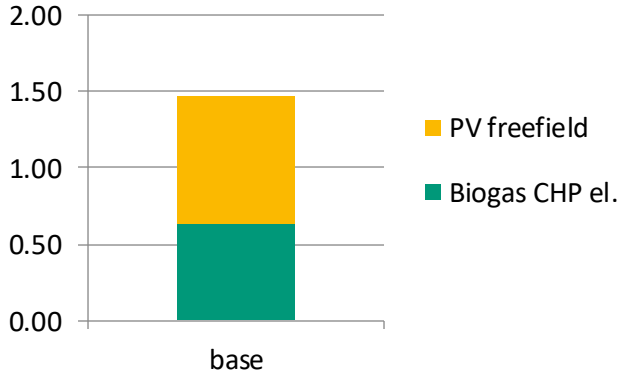
Total yearly energy system costs



Electricity generation mix



Installed el. Generation capacities in MW



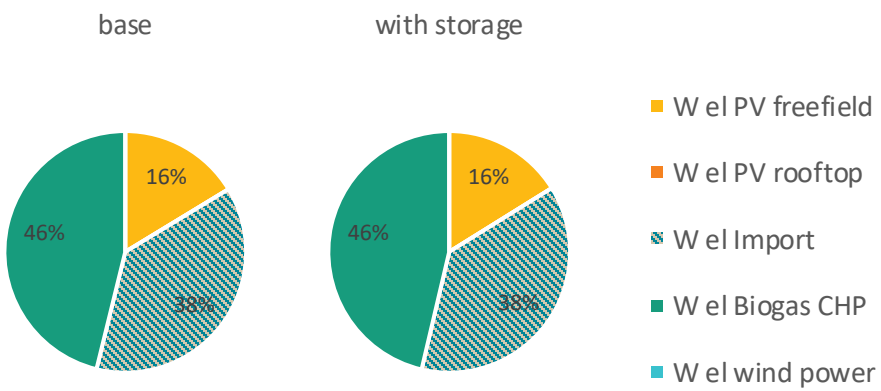
- The base scenario is characterized as
  - Heat demands are fully met by CHP plant with 635 kW_{el} / 790 kW_{th}
  - 840 kWp Freefield PV with 35° south orientation is built
  - Flow-storage is not built
- 16% of the electricity demand can be met by PV (96% of PV-production can be used, 4% needs to be exported/curtailed)
- CHP operation is heat led (runs when heat is needed), provides 46% of the electricity demand

→ Autarky level is 62%

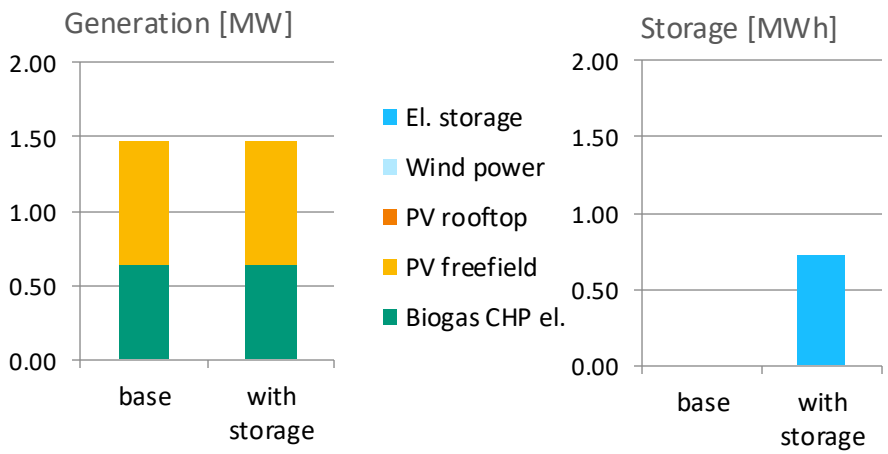
Scenario 2 – with flow battery

- Flow battery cannot increase autarky level because of low solar generation in comparison to electricity demands (share of PV production used increases only slightly from 96% to 98%), the battery is only partially used (~140 cycles per year vs. 250 – 300 for typical PV-storage combinations)
- System costs increase slightly (+2%) due to investment in storage

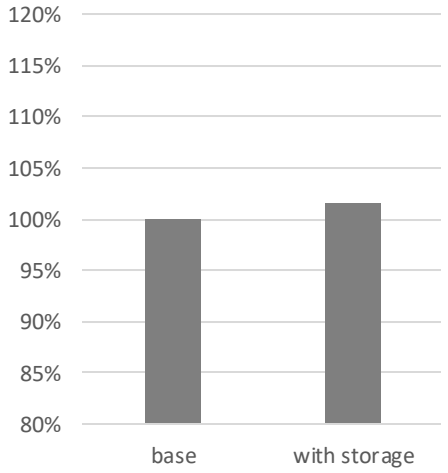
Electricity generation mix



Installed capacities



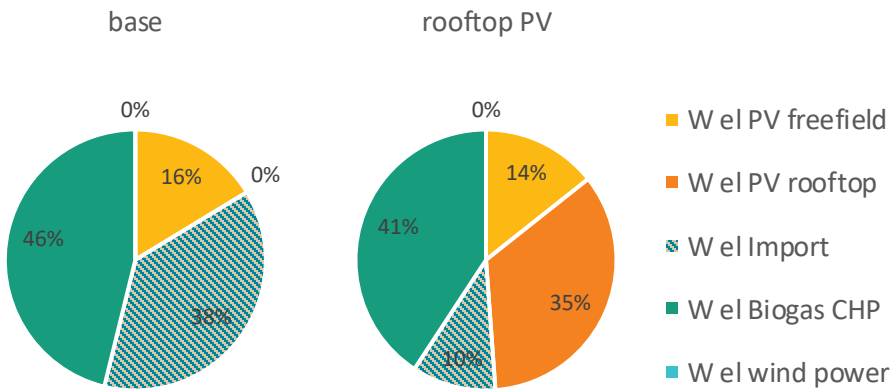
Total costs in % base



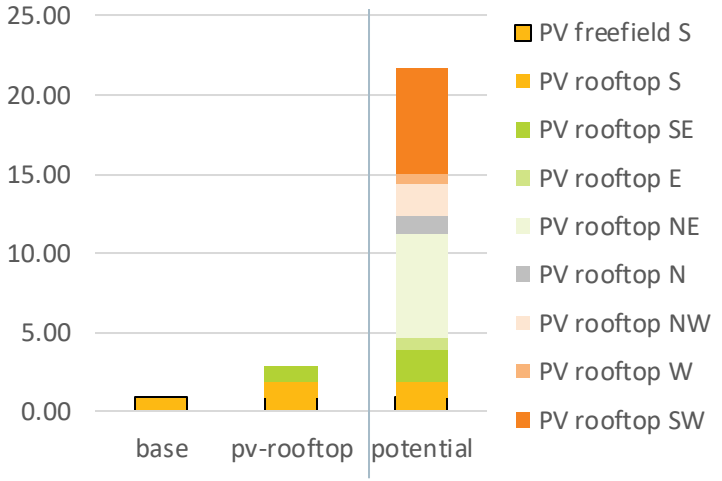
Scenario 3 – rooftop PV

- The total rooftop-PV potential is assessed to be ~ 20 MW, around 10 MW of which with economically attractive south (S), south-west (SW) or (south-east) orientation
- Around 2 MW of rooftop-PV potential is used, a solar generation share of 49% can be reached using the flow-storage. Good utilization of storage, 290 cycles per year are reached.
- Autarky level reaches 90%, costs can be reduced by ~12%

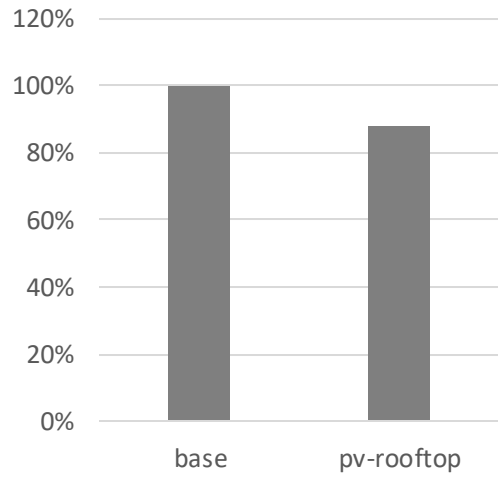
Electricity generation mix



Usage of PV-potential



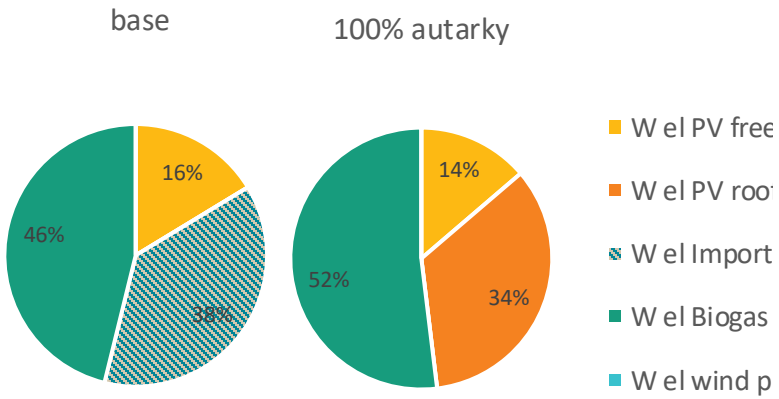
Total costs in % base



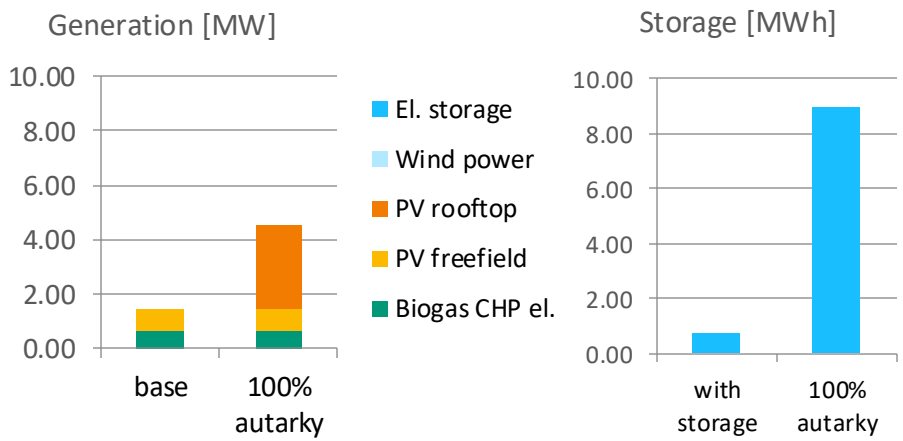
Scenario 4 – autarky

- In order to reach full autonomy from the power grid ~ MWp PV are needed and the size of the electrical storage needs to be increased drastically from 720 kWh to ~8900kWh. Storage needs to be over-dimensioned and is not fully utilized, only 106 cycles per year are reached.
- The share of electricity generation from the CHP plant increases from 46% to 52%, a small part of the produced heat cannot be used, biogas consumption increases by ~11% compared to other scenarios.
- Total energy system costs increase by ~ 8%

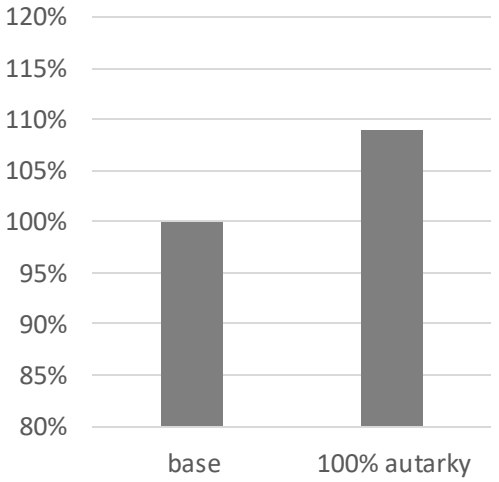
Electricity generation mix



Installed capacities



Total costs in % base

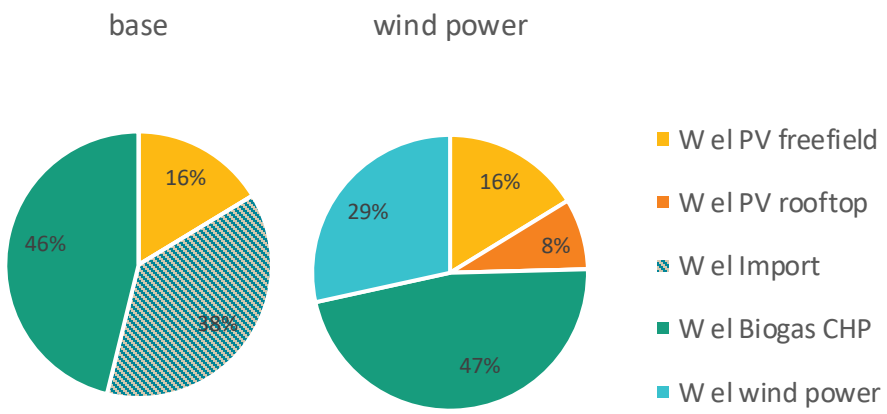


Scenario 5 – autarky w/ wind power

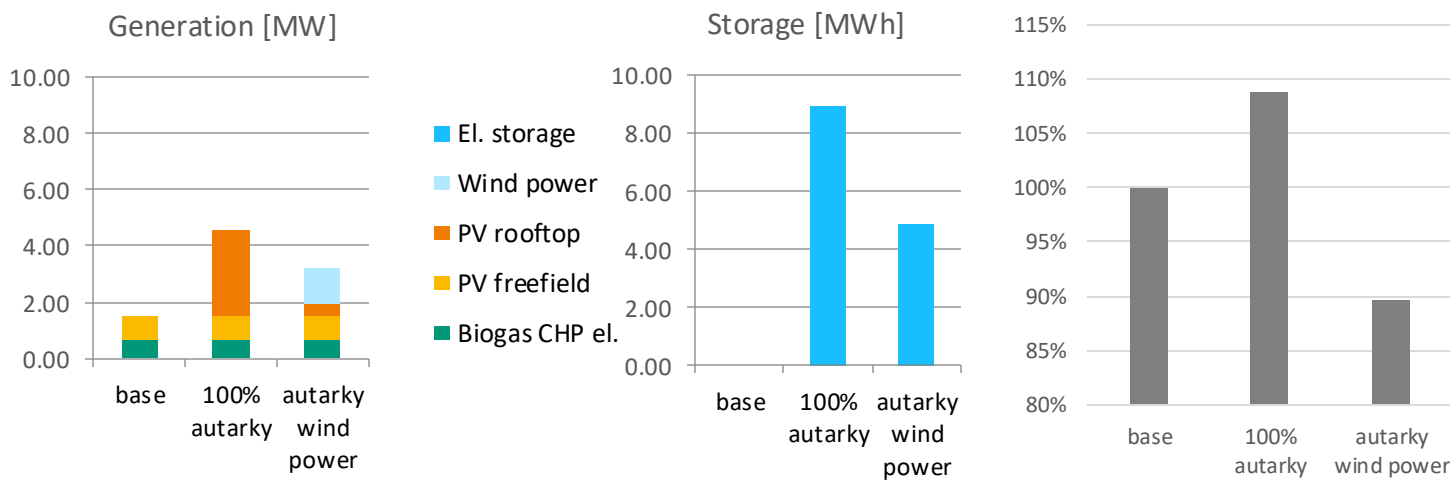
- Denmark has a large share of electricity generation from wind power. As wind power yields are high during winter, when solar generation is low, the combination of both is highly beneficial. In this scenario including locally sourced wind power (@1100€/MW investment costs + 50€/MWh additional fees in operation representing grid fees or other) ~ 19% of energy system costs can be saved compared to the autarky scenario.

- Only 55% of the storage capacities of the autarky-scenario only with PV + Biogas are needed, only 1.3 MW of PV is installed (33% of autarky scenario), also 1.3 MW of wind power is installed. Biogas consumption decreases by ~20%. For reaching 100% autarky however, storage needs to be over-dimensioned and is not fully utilized, only 91 cycles per year are reached.

Electricity generation mix

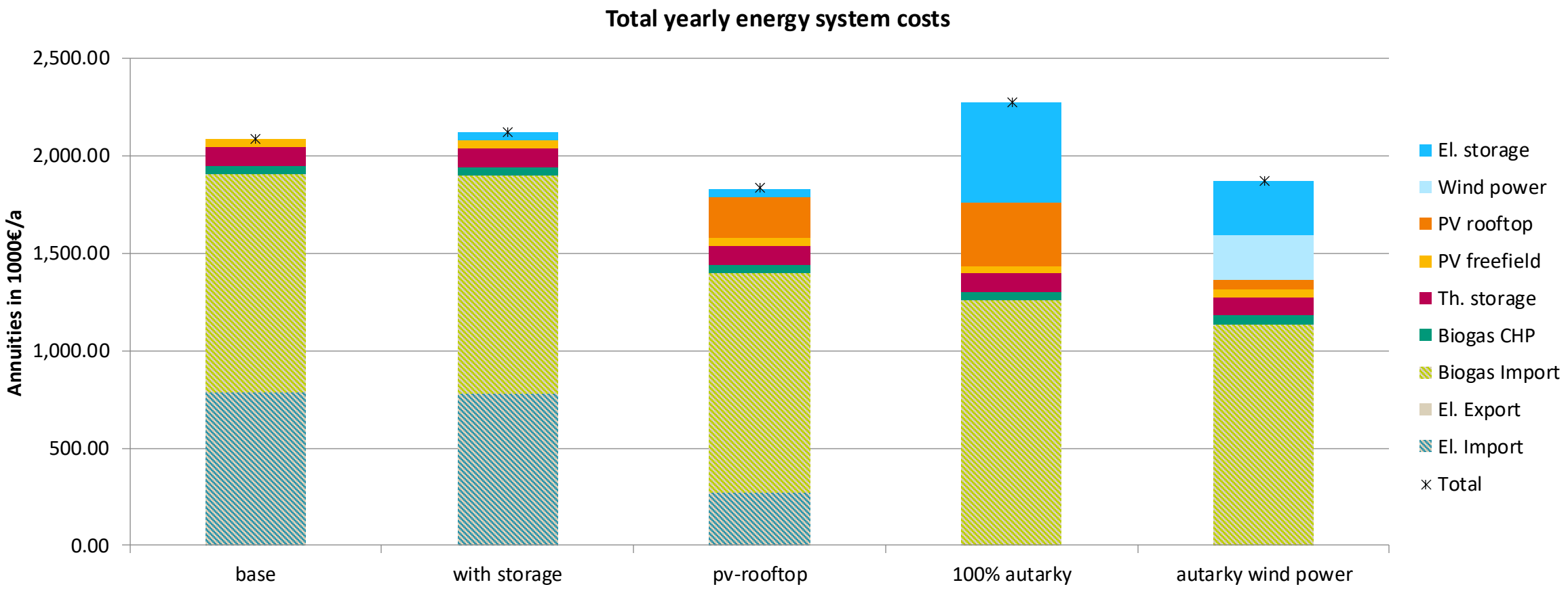


Installed capacities



Total costs in % base

Appendix



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