

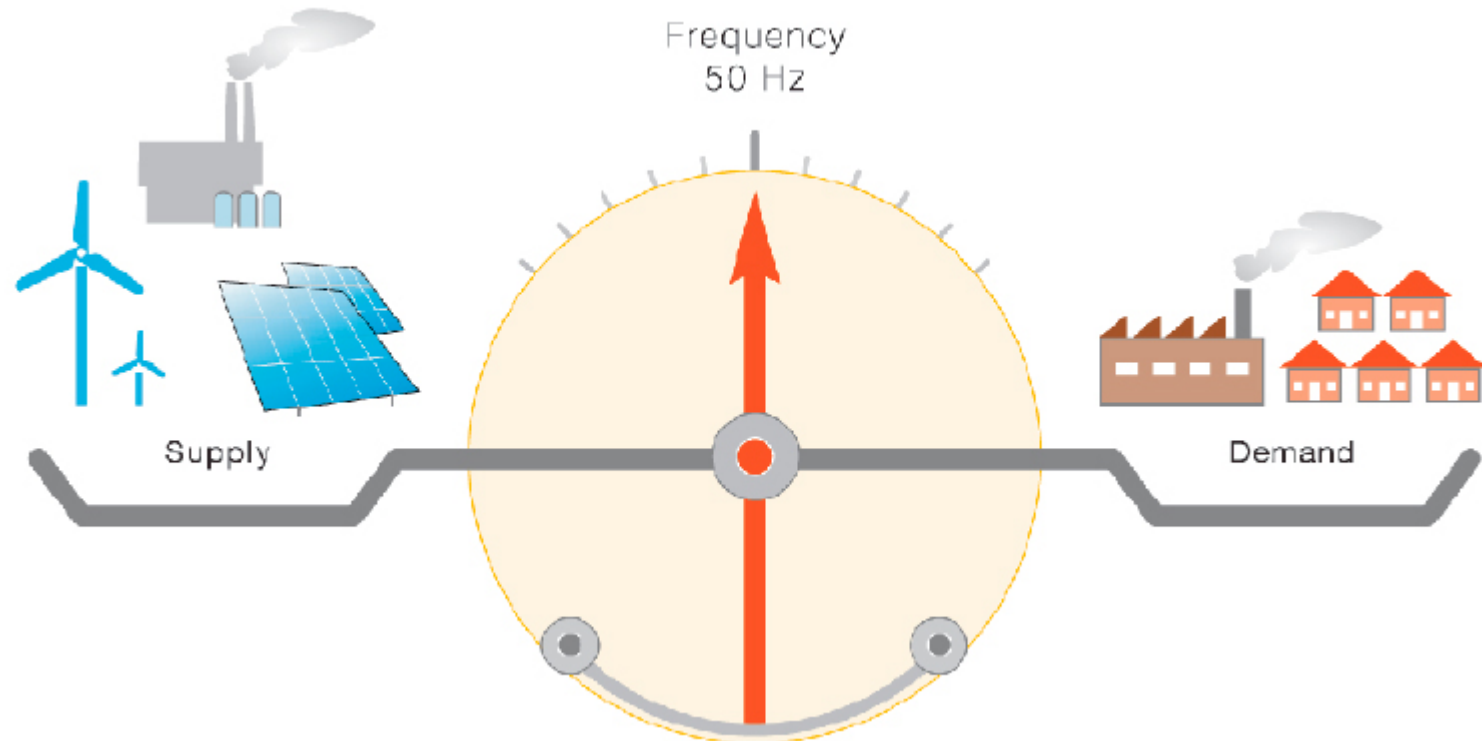


Europa-Universität
Flensburg

Key challenges of energy systems

100 % Renewable energy systems and the concept of residual load

Key challenge: Balance of supply and demand

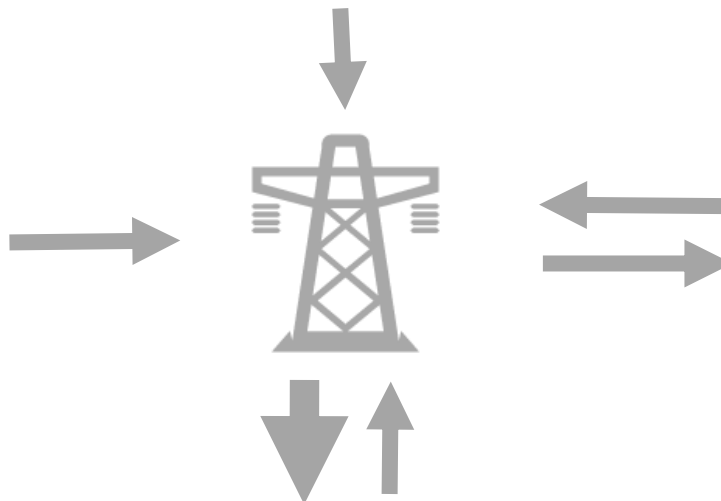
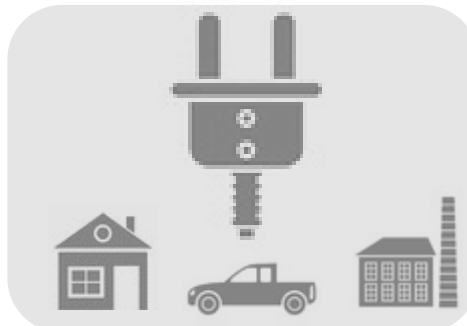
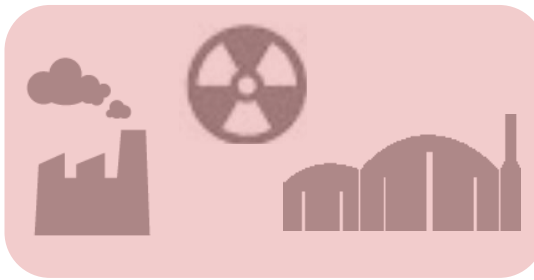


Renewables

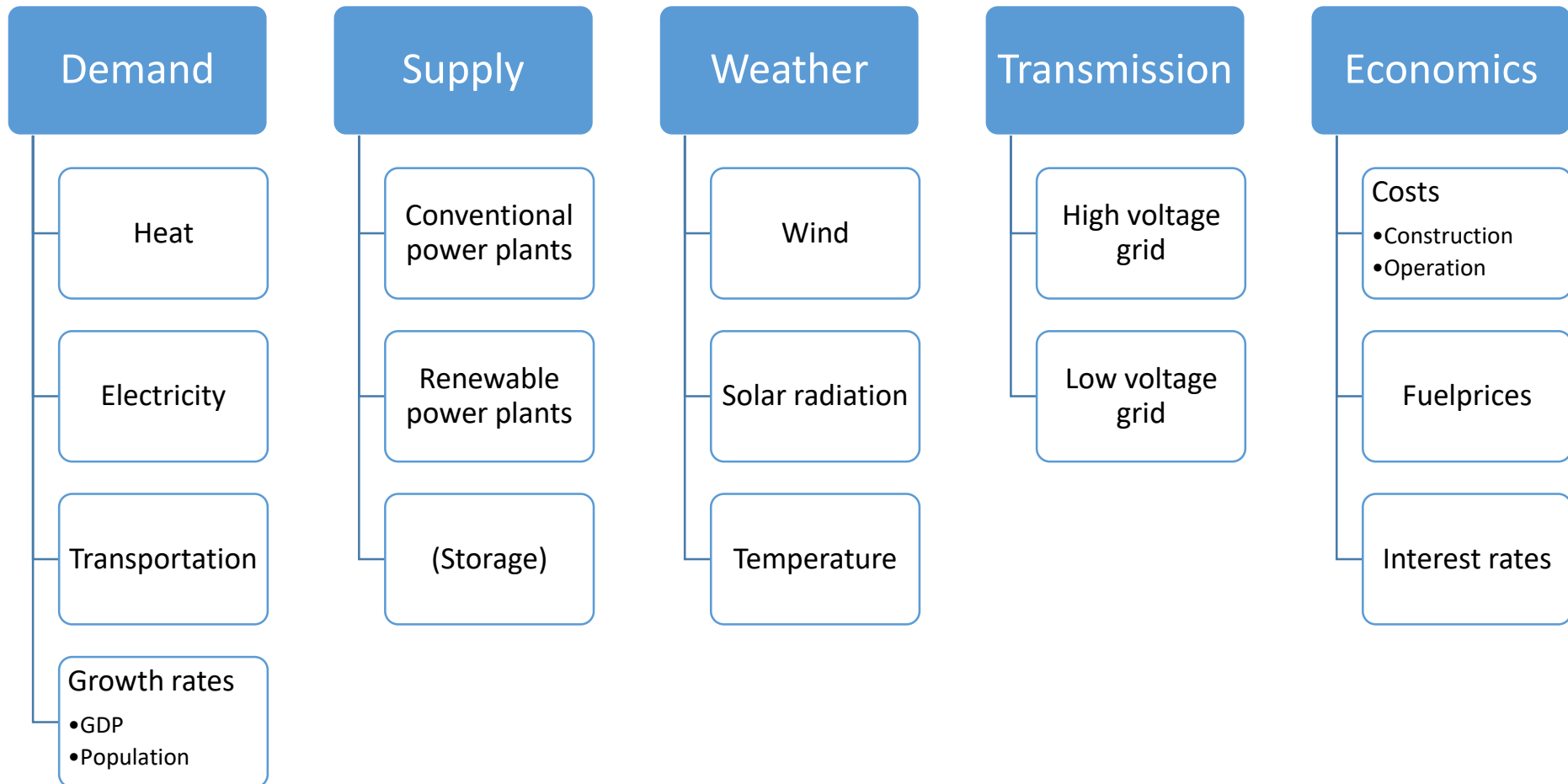
Conventionals

Storage

Consumption

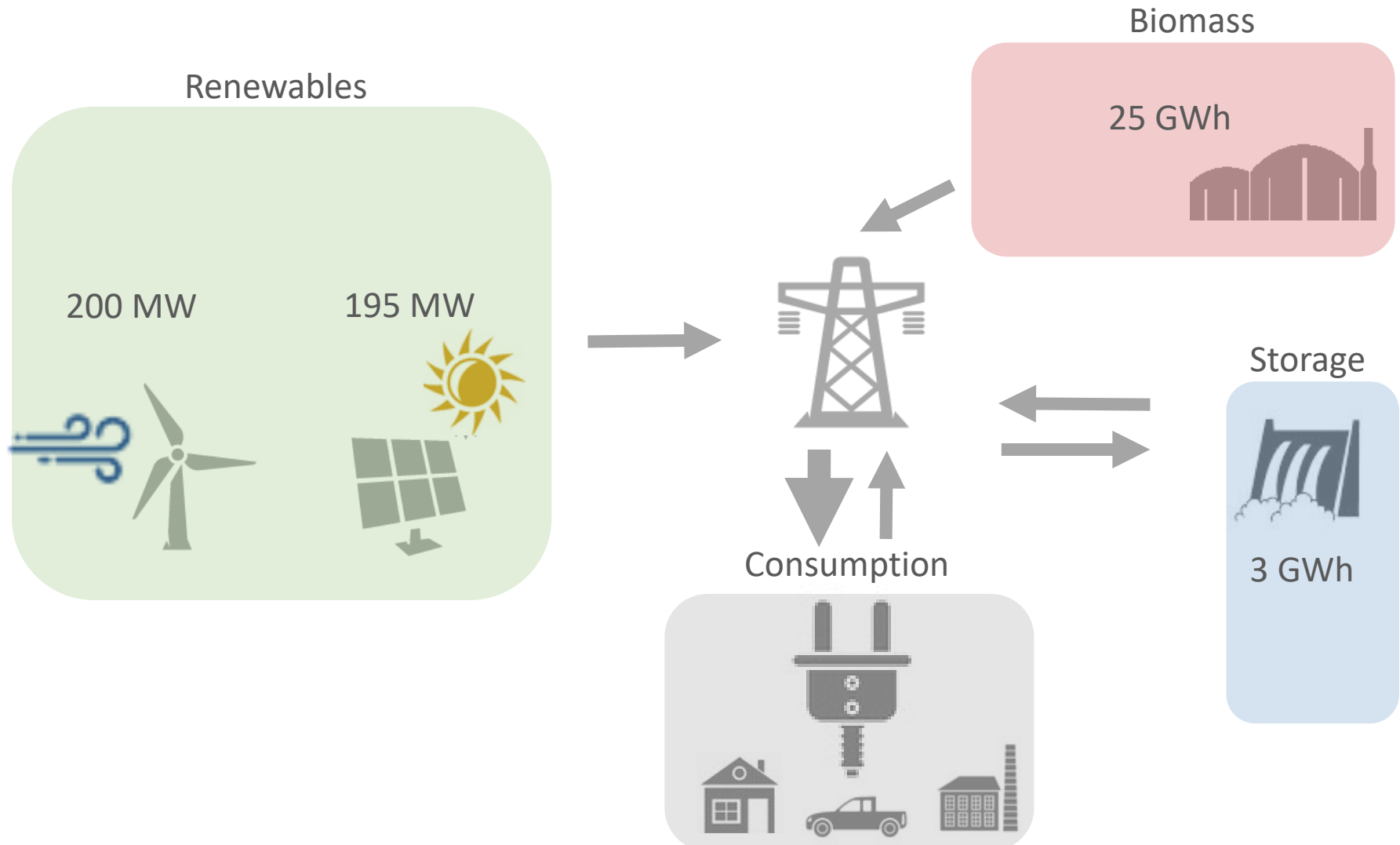


A model can only be as good as it's input data!

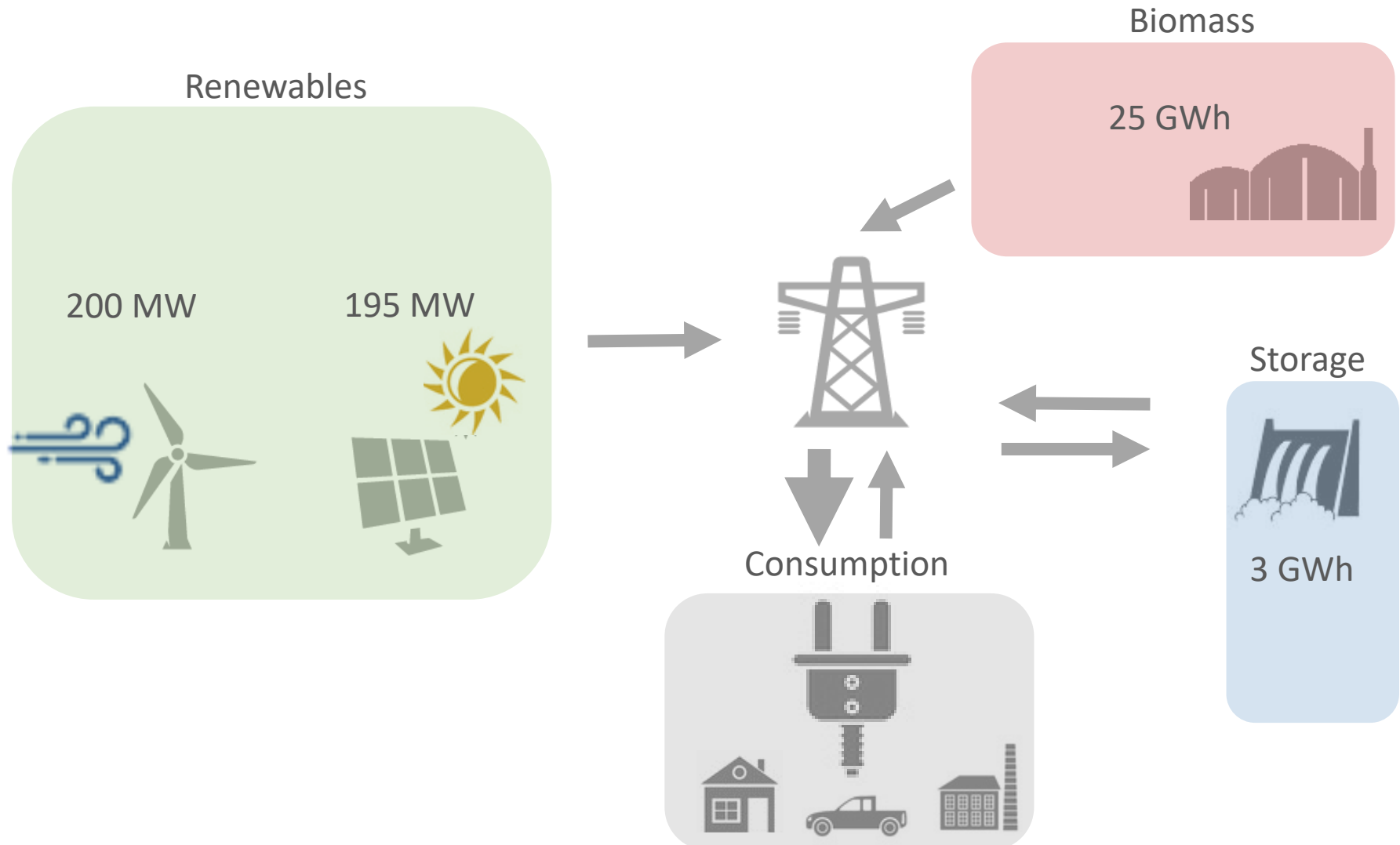


Case study: 100% renewable energy system for Islands

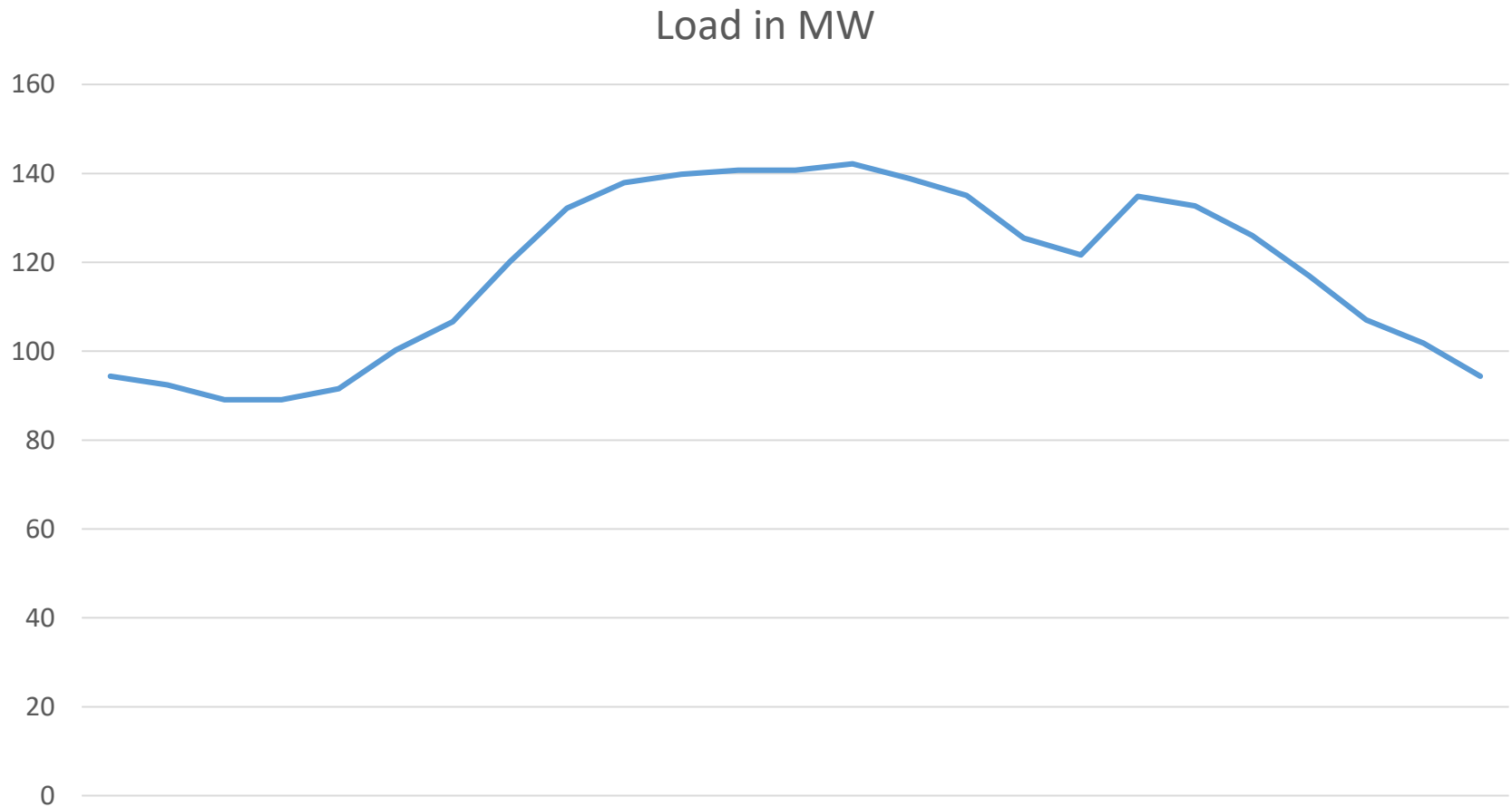
Case study: 100% renewable energy system for Islands



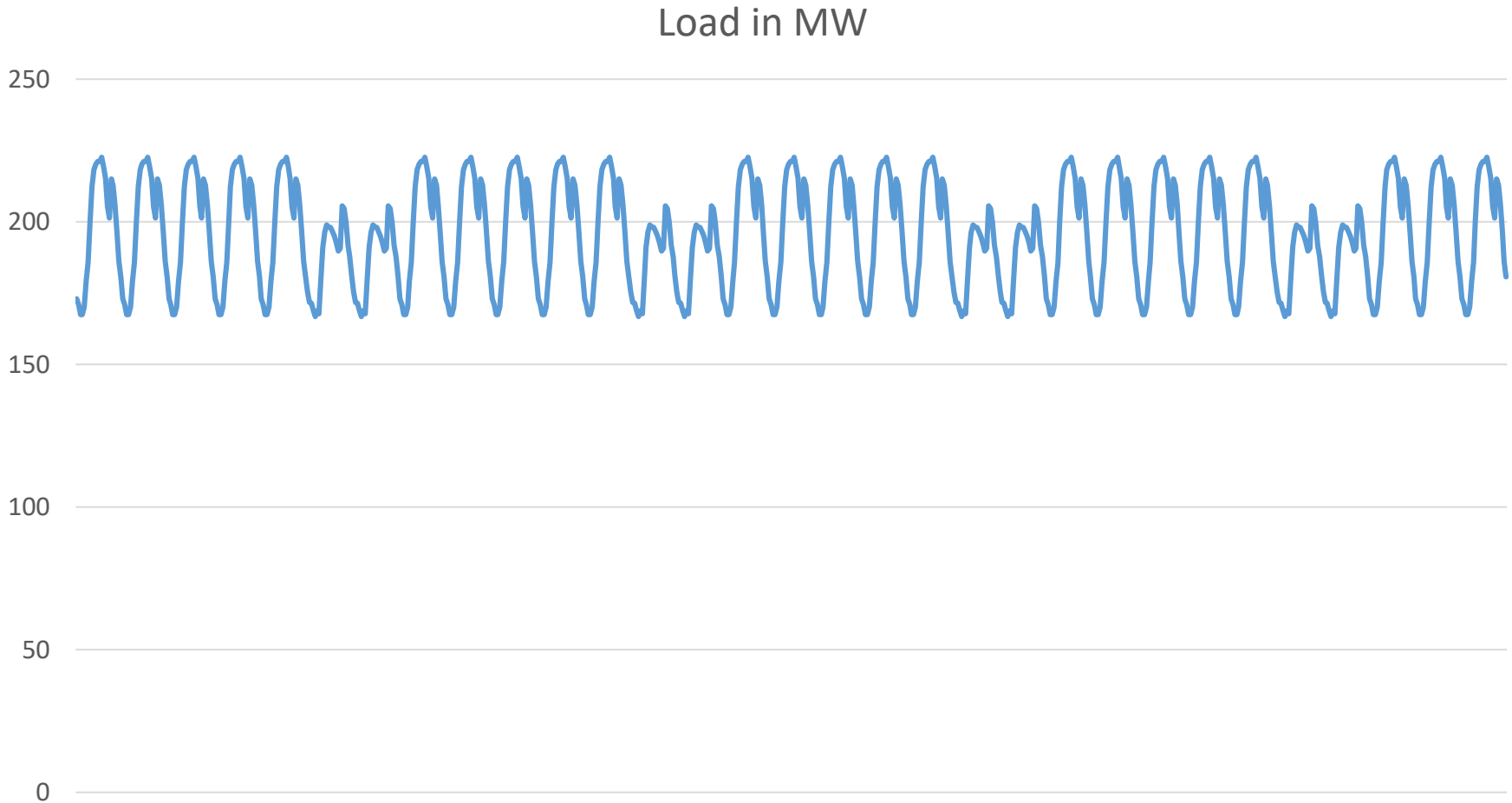
Consumption



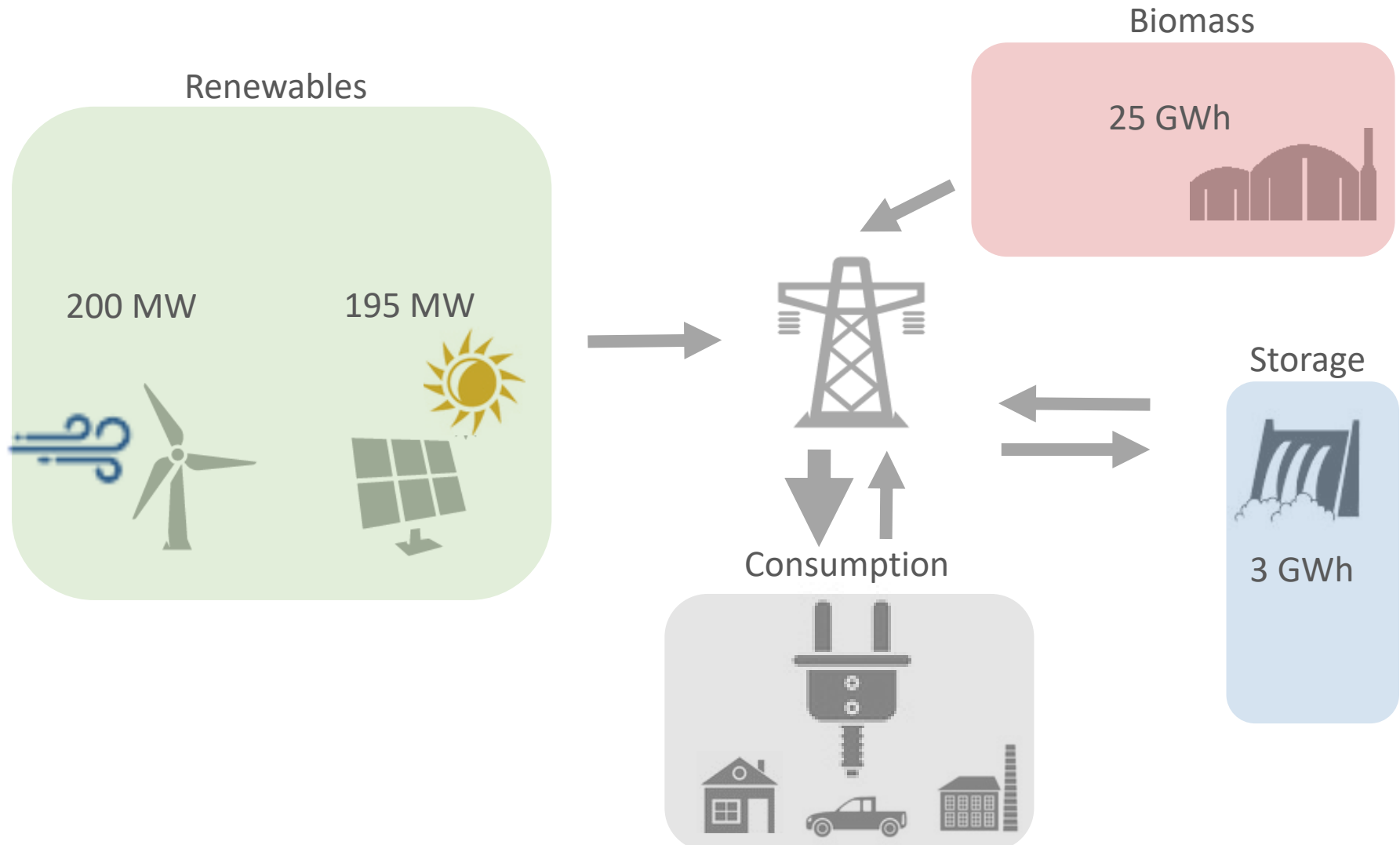
Electrical demand (one day)



Electrical demand (one month)



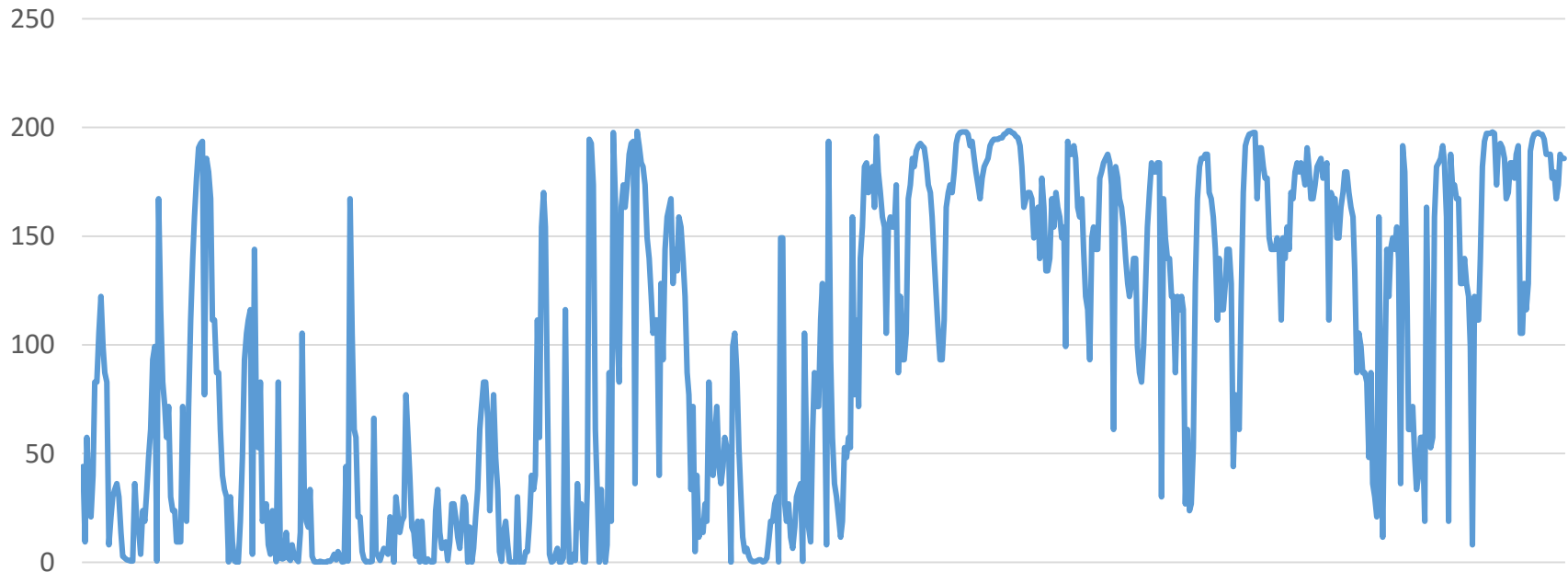
Generation: Renewables



Wind energy generation (one month)

1. Size of the island: 430 km²
2. Theoretical potential on shore: 4.3 GW

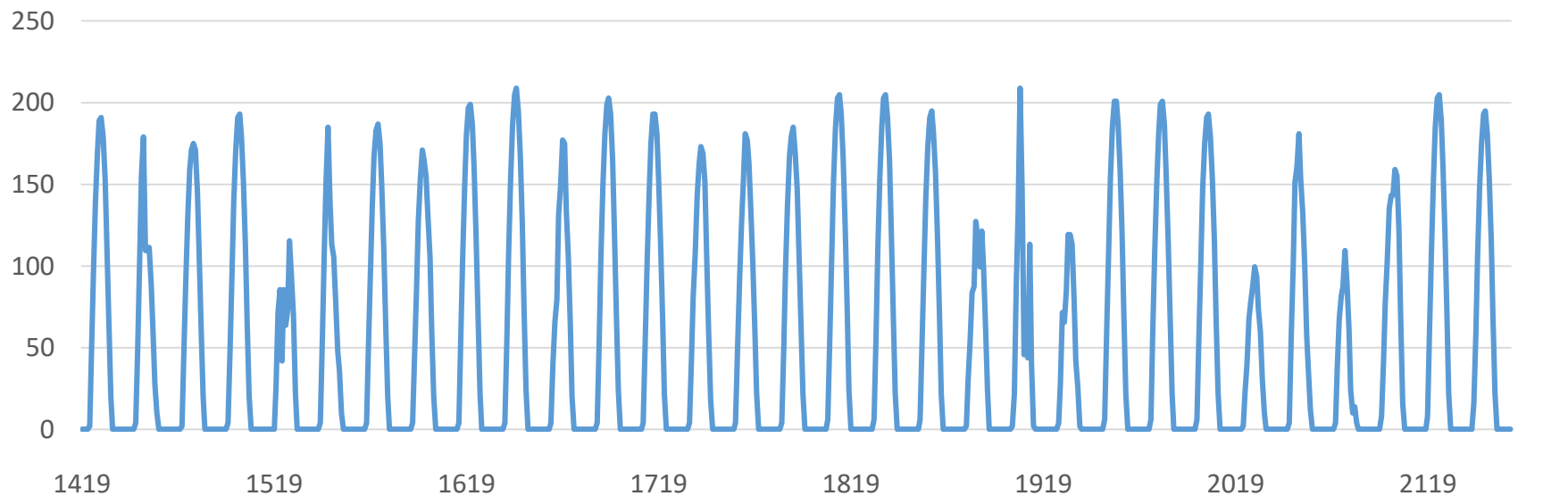
Hourly wind power production in MWh



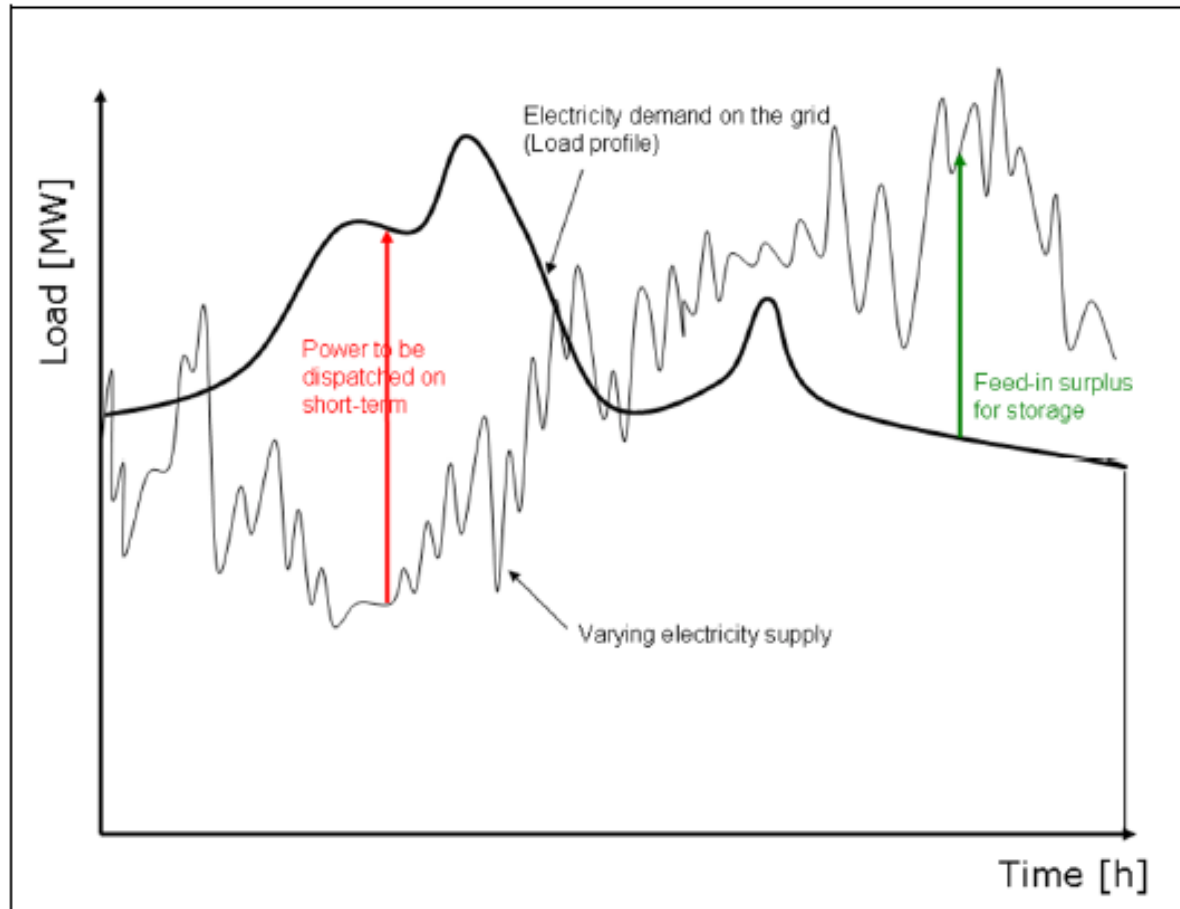
PV generation (one month)

1. Size of the island: 430 km²
2. Theoretical PV potential: 5 375 GW

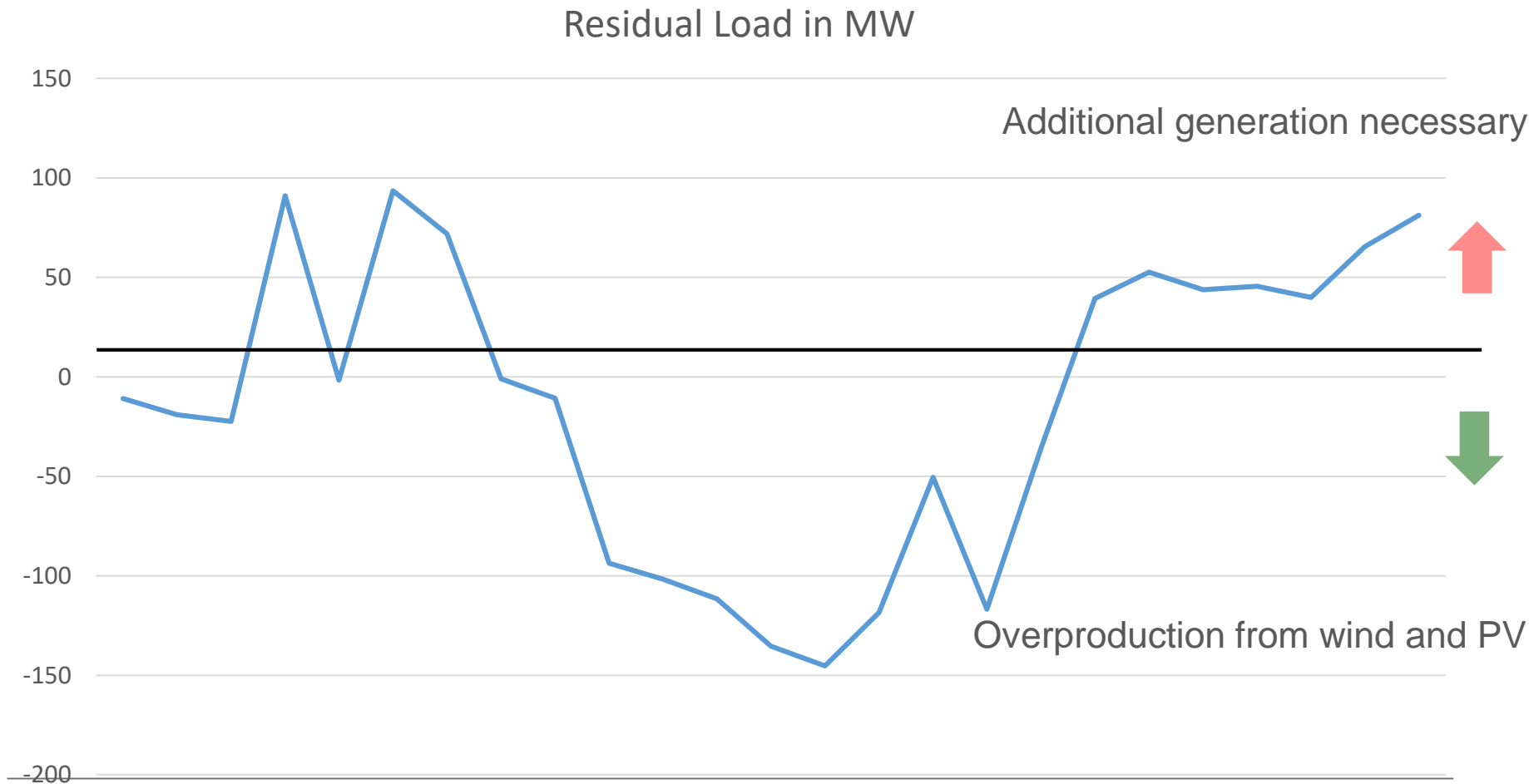
Hourly PV production in MWh



Residual load and the need for flexibility

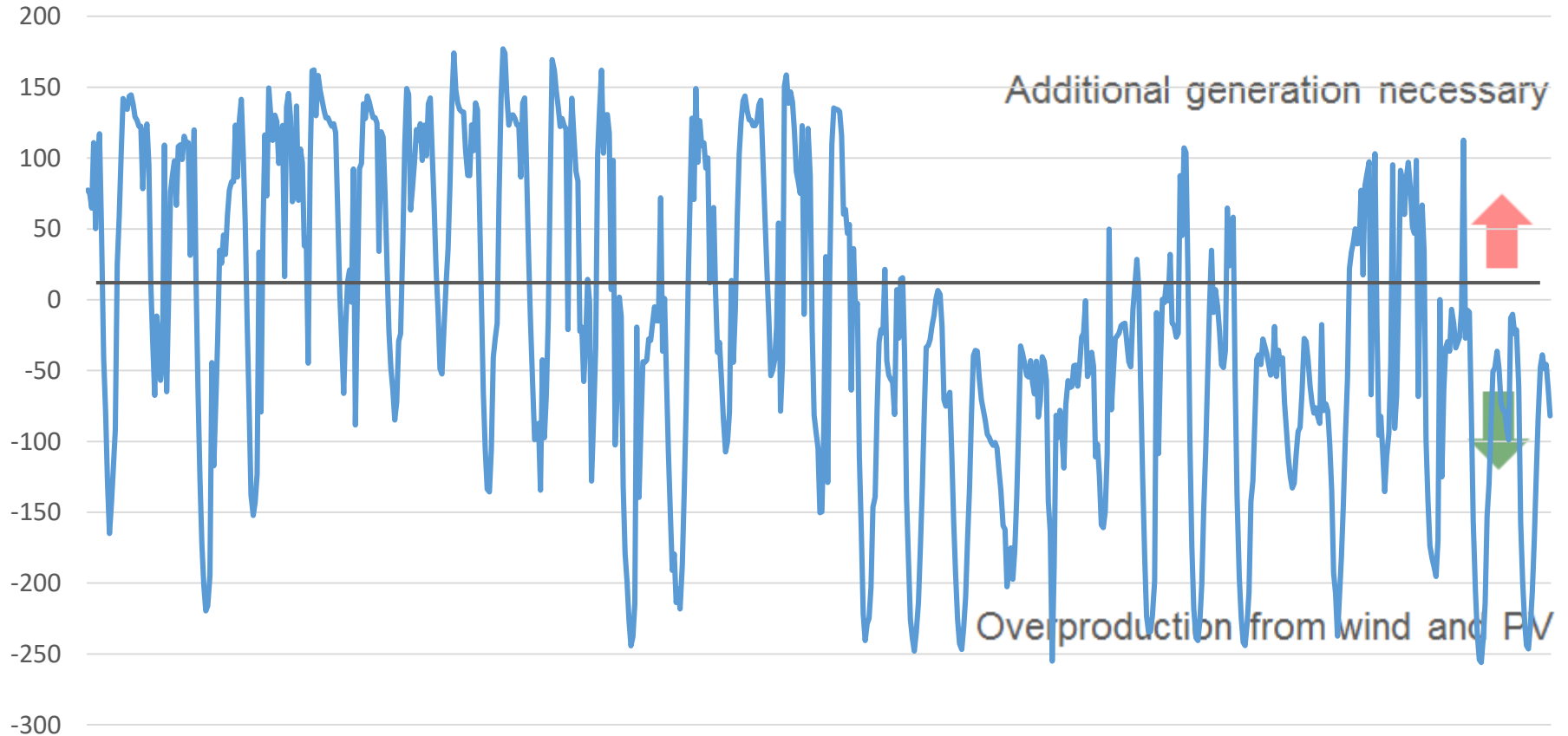


Residual load for 100% Renewables (one day)



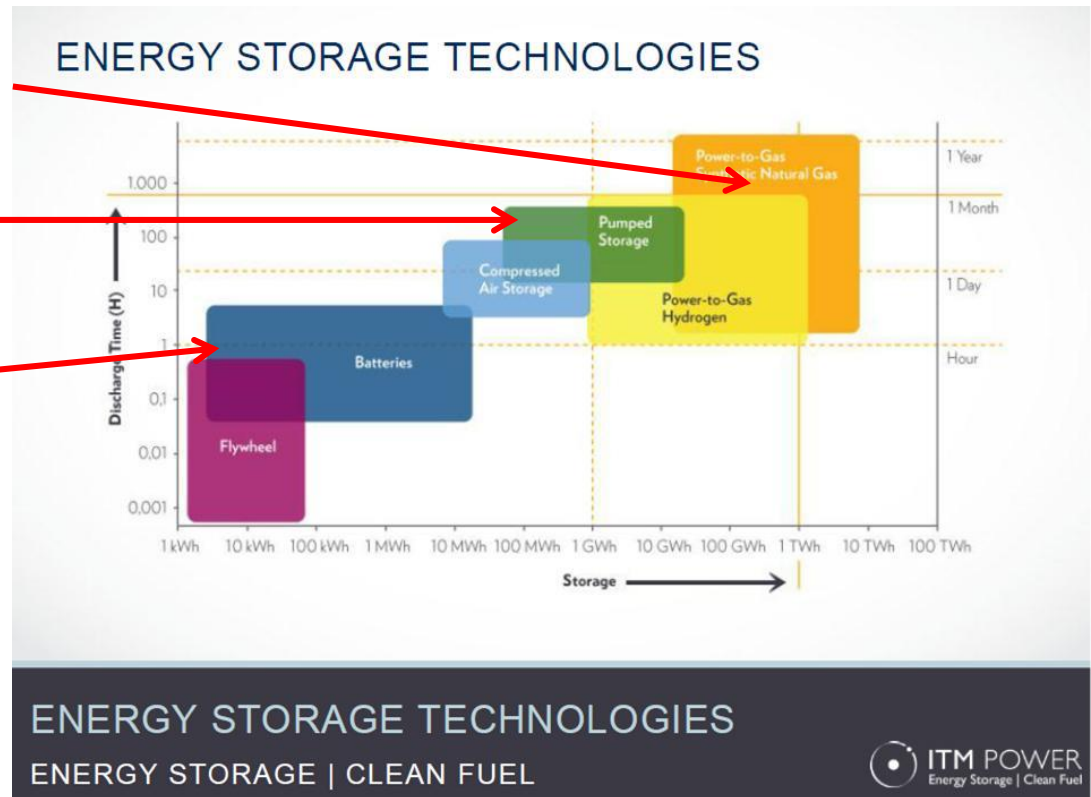
Residual load (one month)

Residual Load in MW

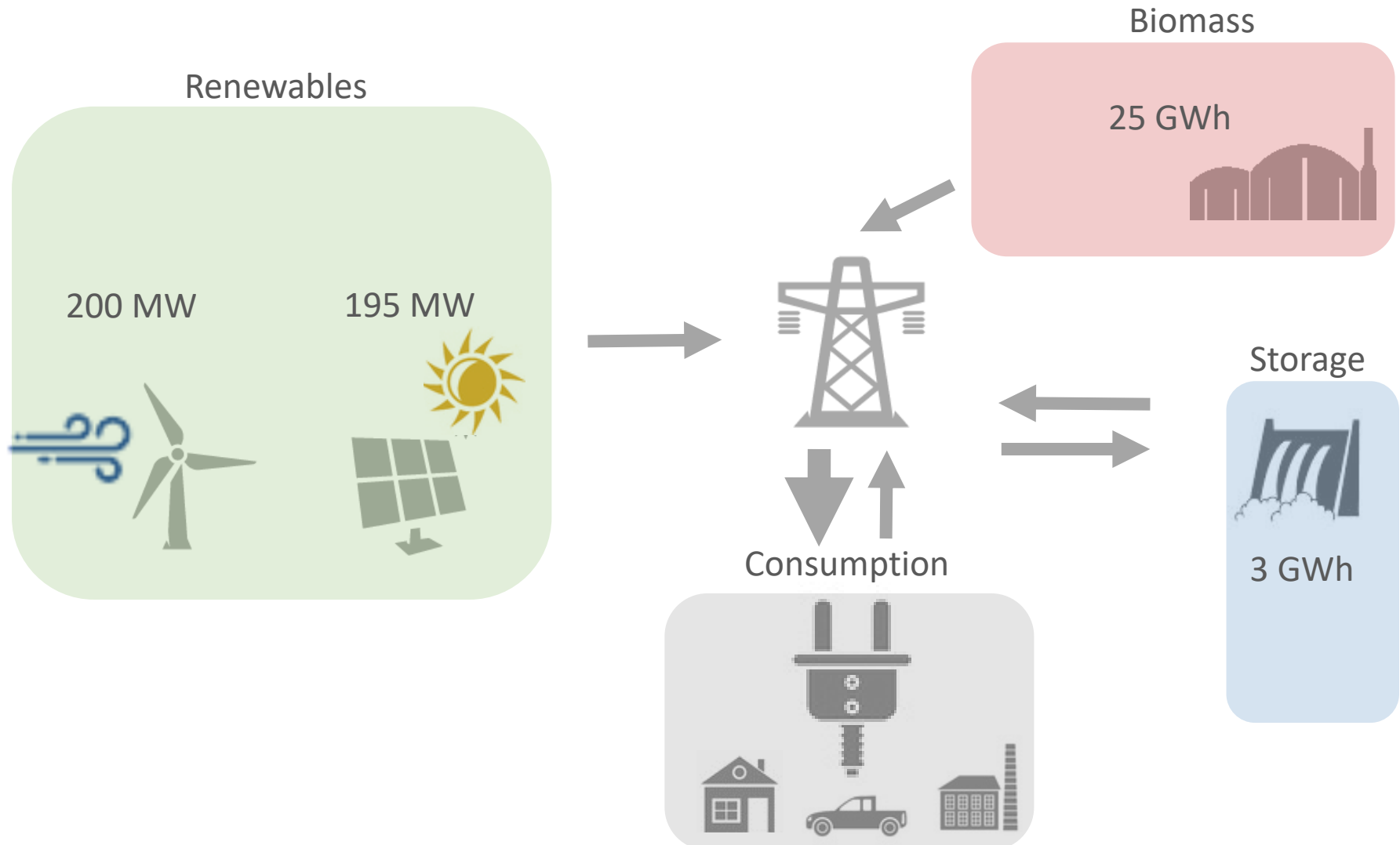


Storage options

- Power to gas (to power)
- Pump storage hydropower
- Battery storage

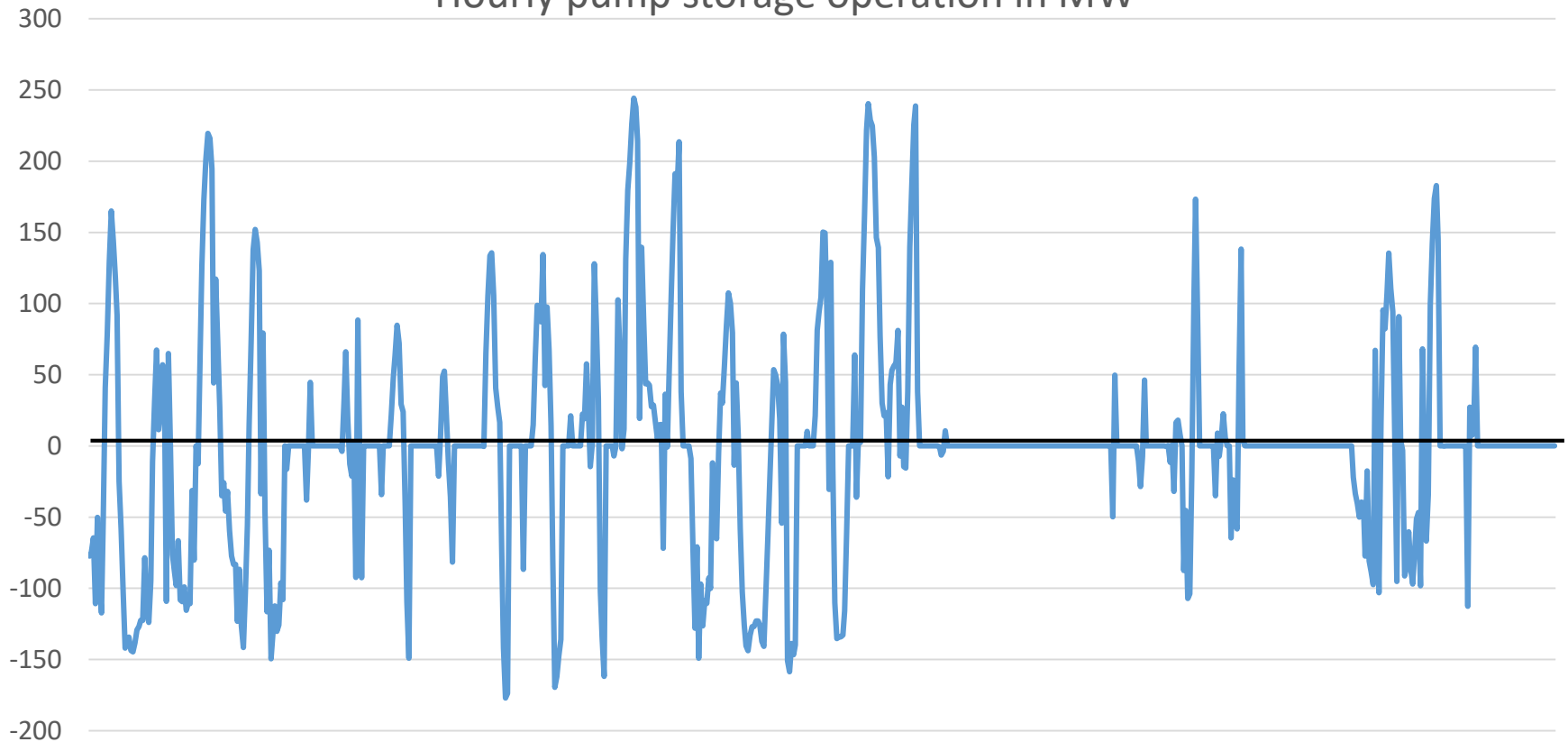


Storage



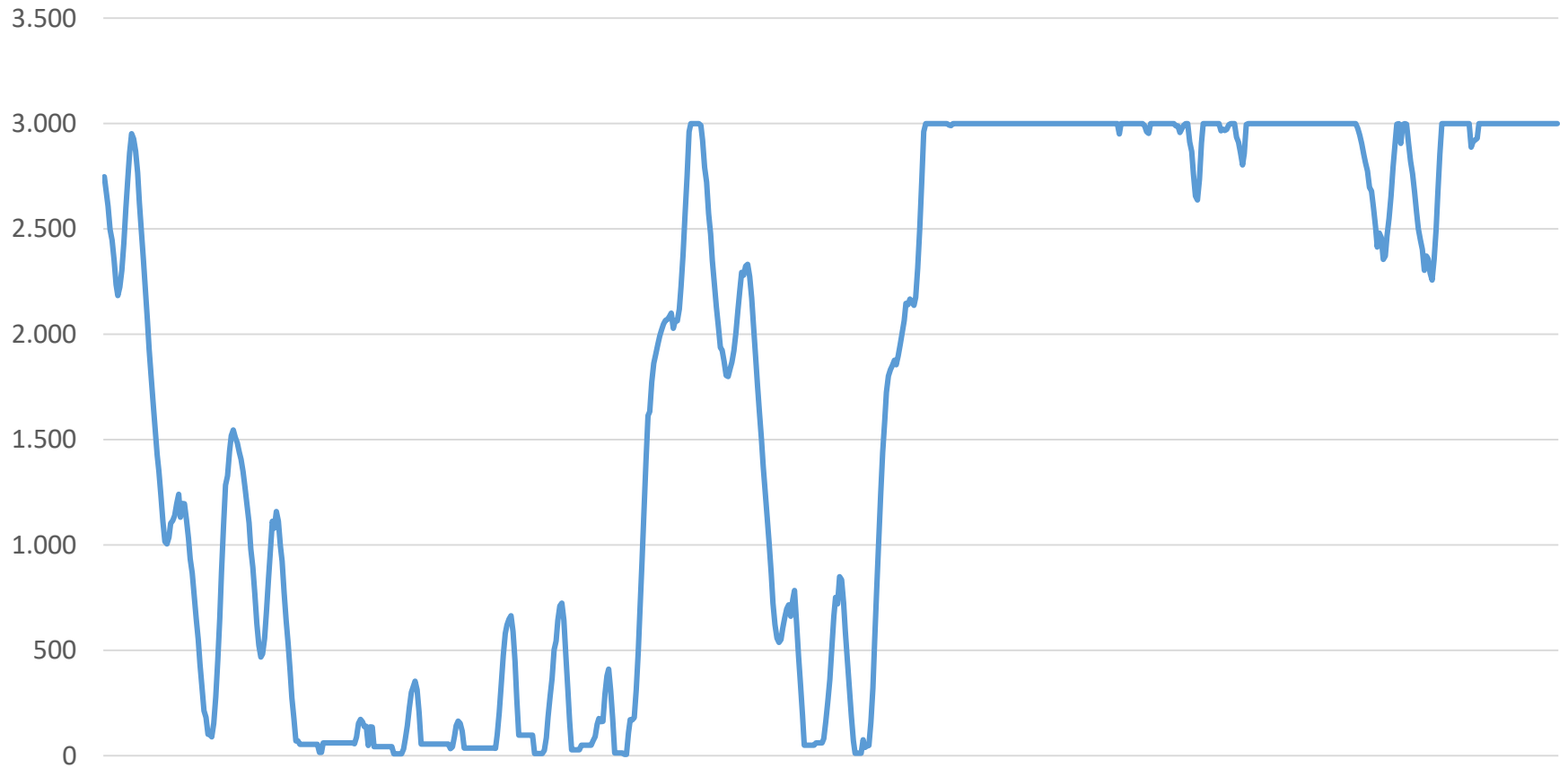
Pump storage (one month)

Hourly pump storage operation in MW

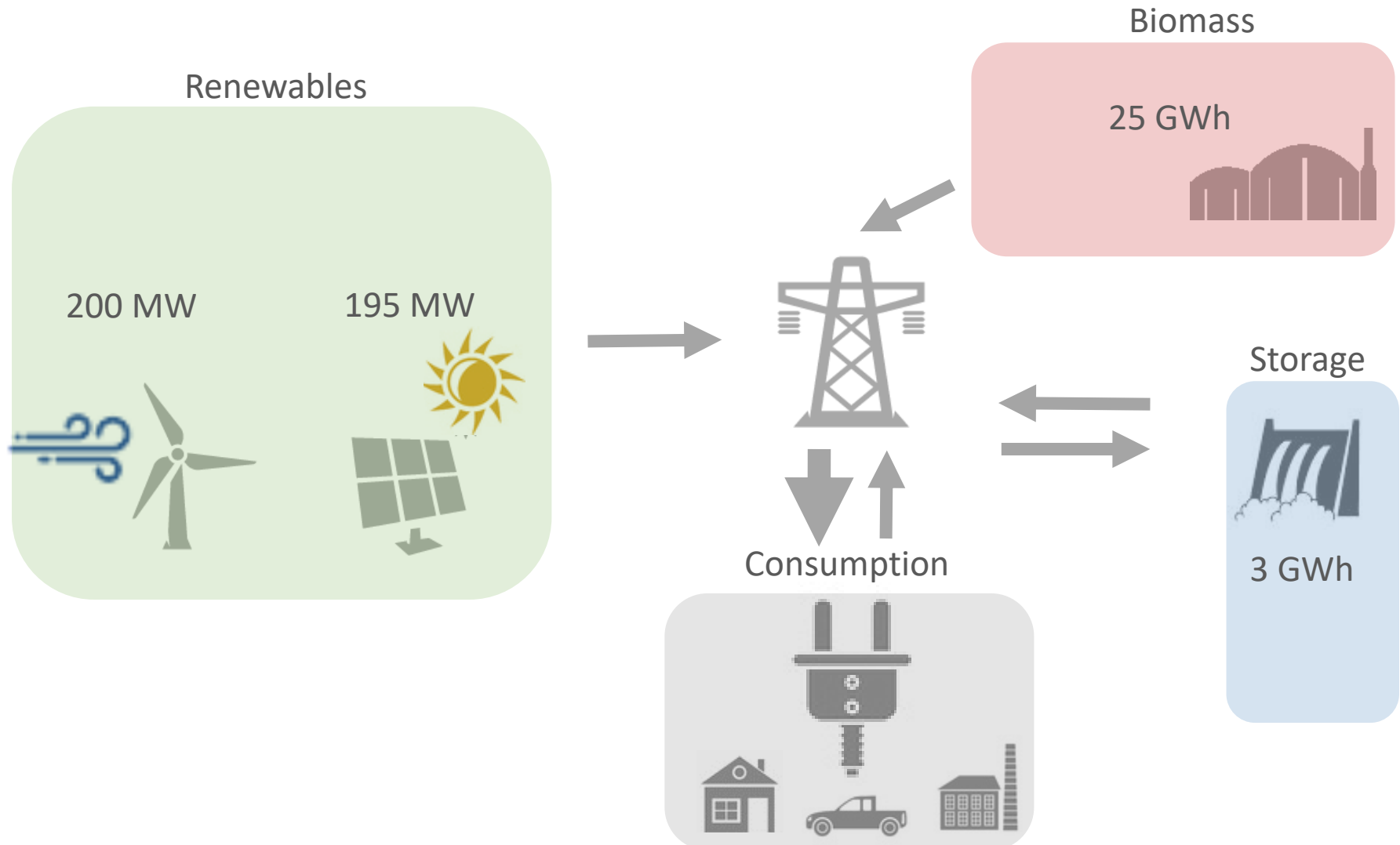


Storage filling level (one month)

Storage Balance [MWh]

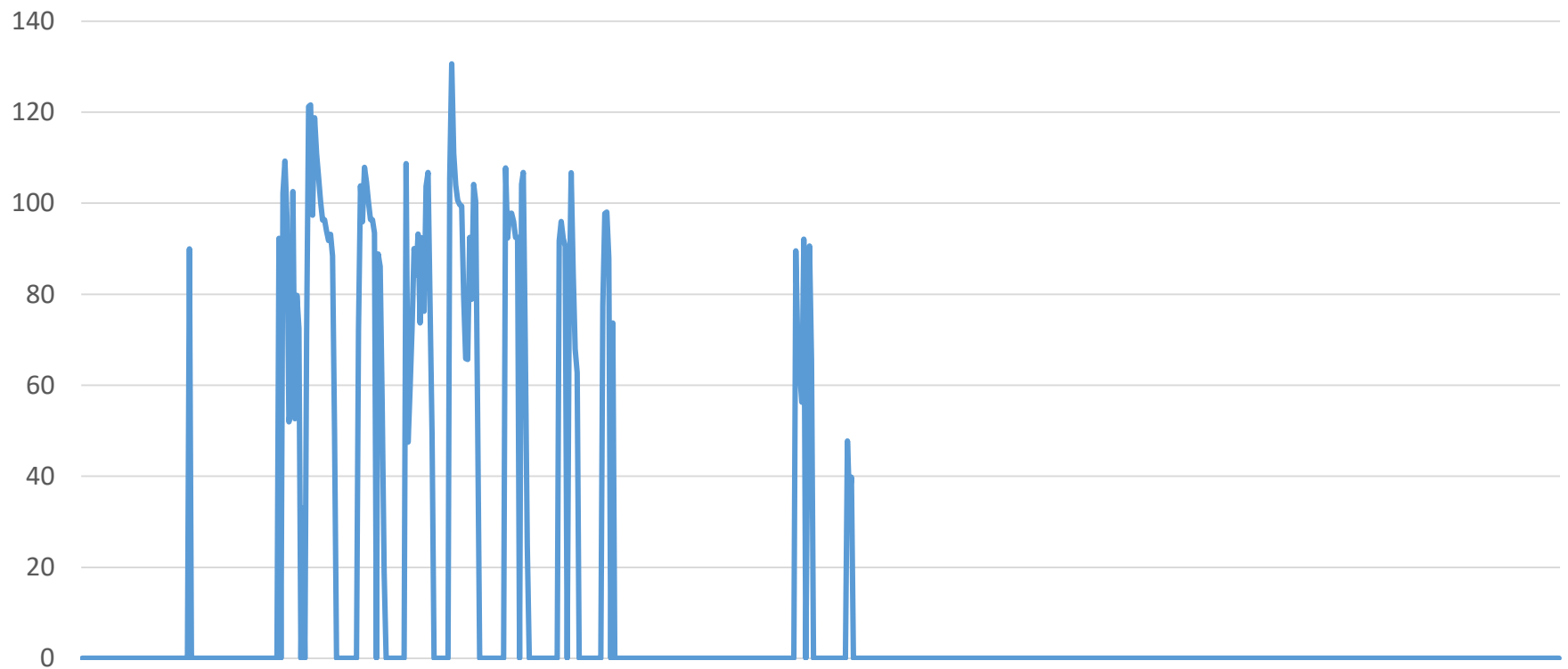


Generation: Biomass



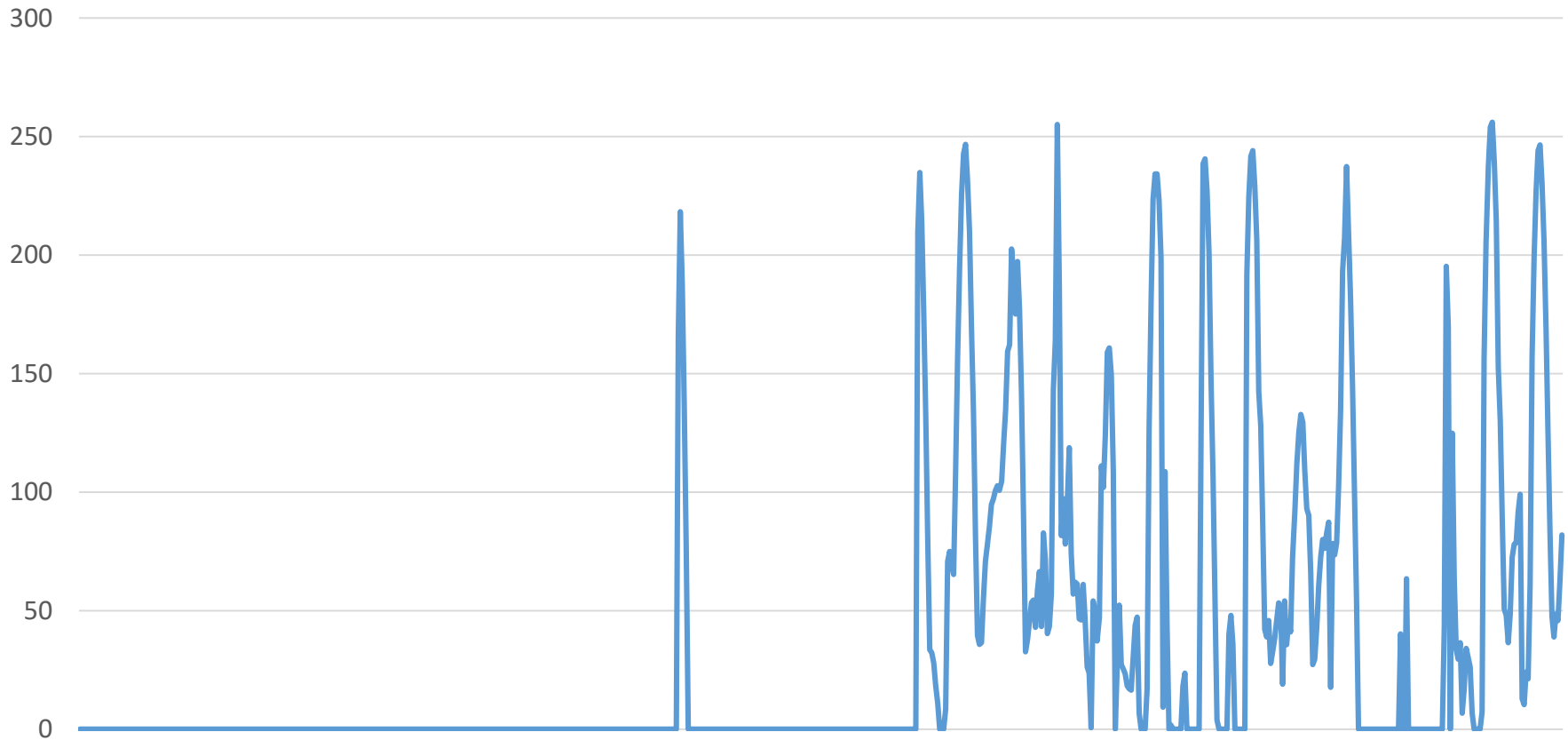
Use of biomass

Hourly production from Biomass in MWh



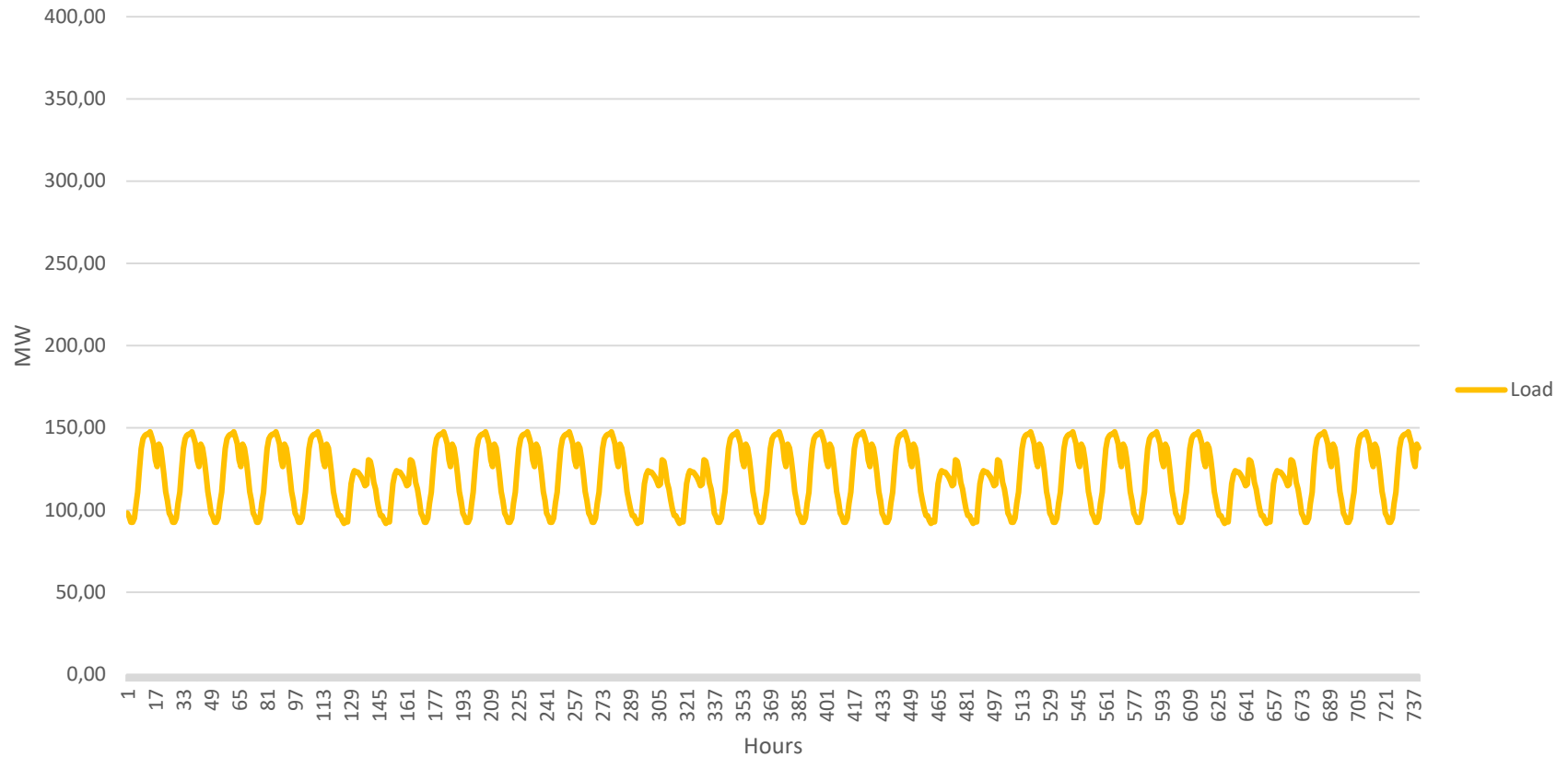
Power overproduction from wind and PV

Excess electricity production in MWh]

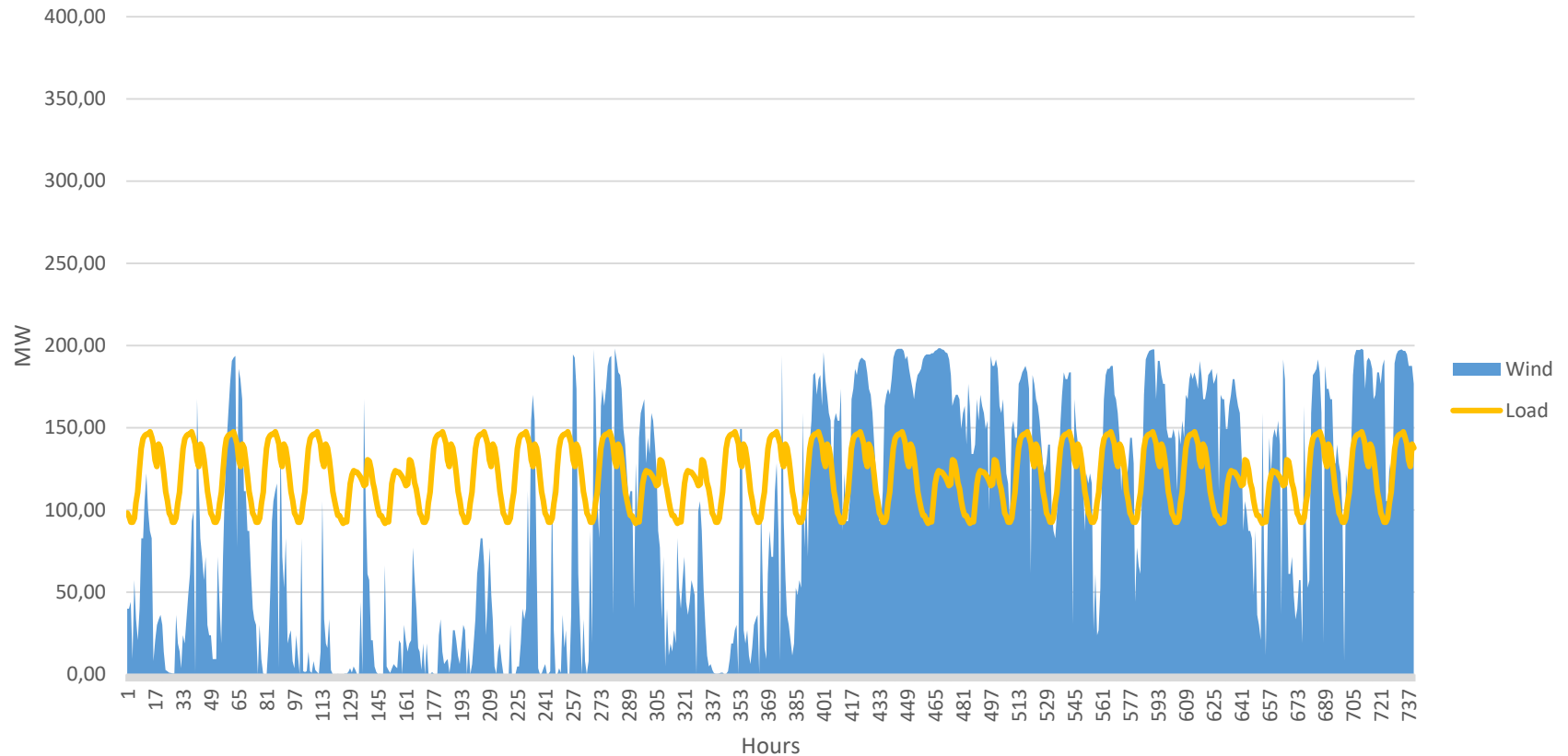


All together...

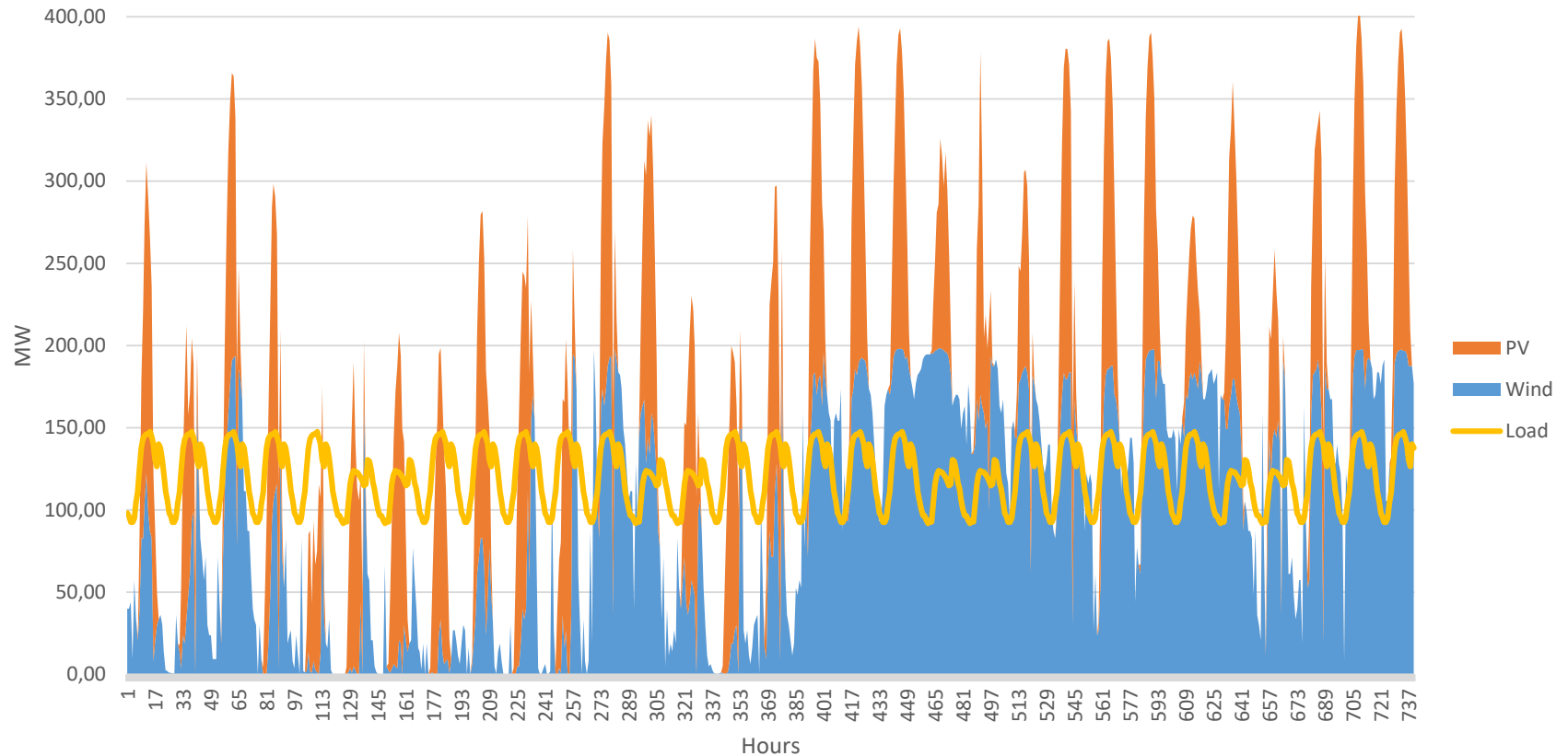
Simulation of 100% RE (one month)



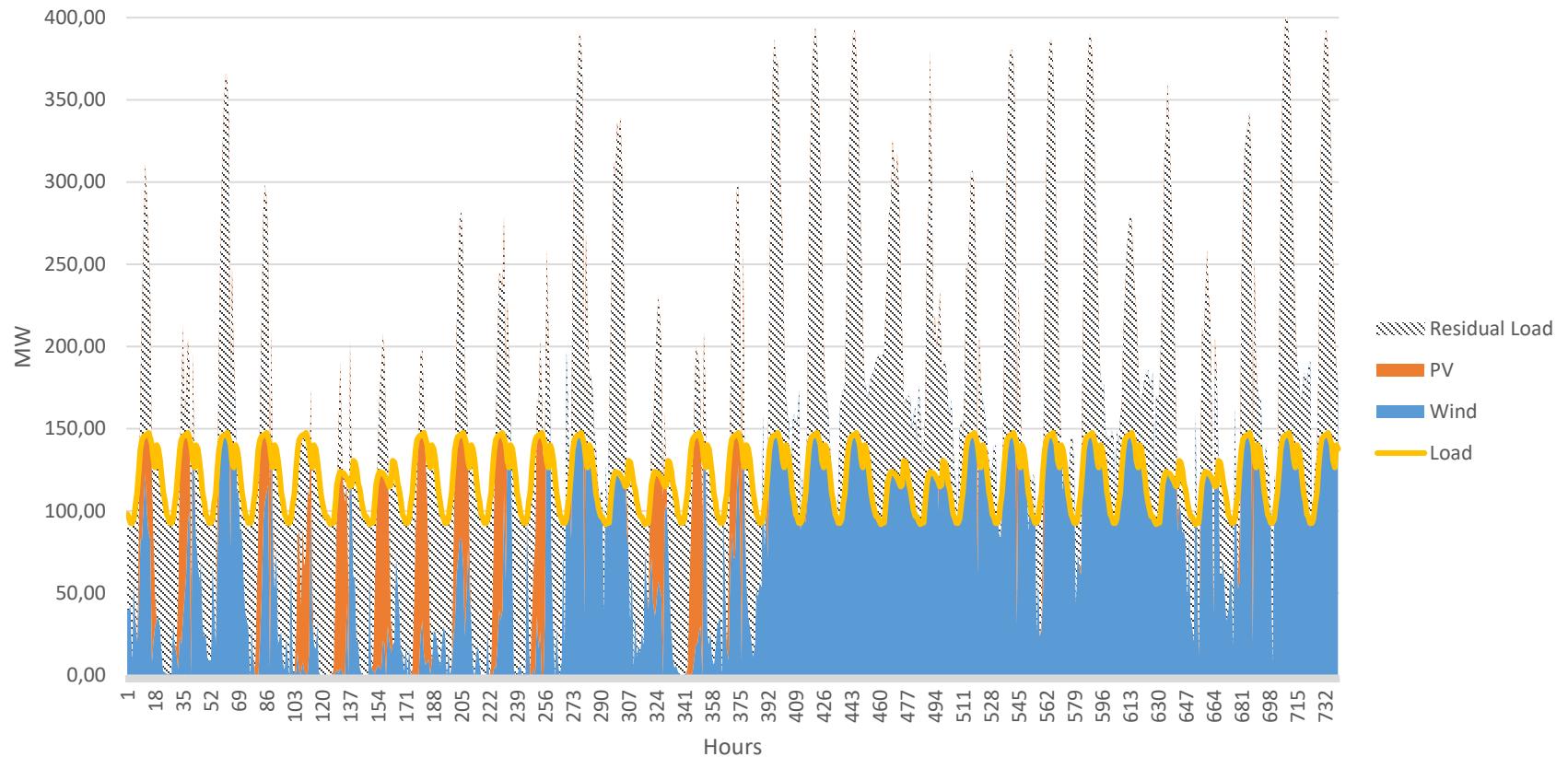
Simulation of 100% RE (one month)



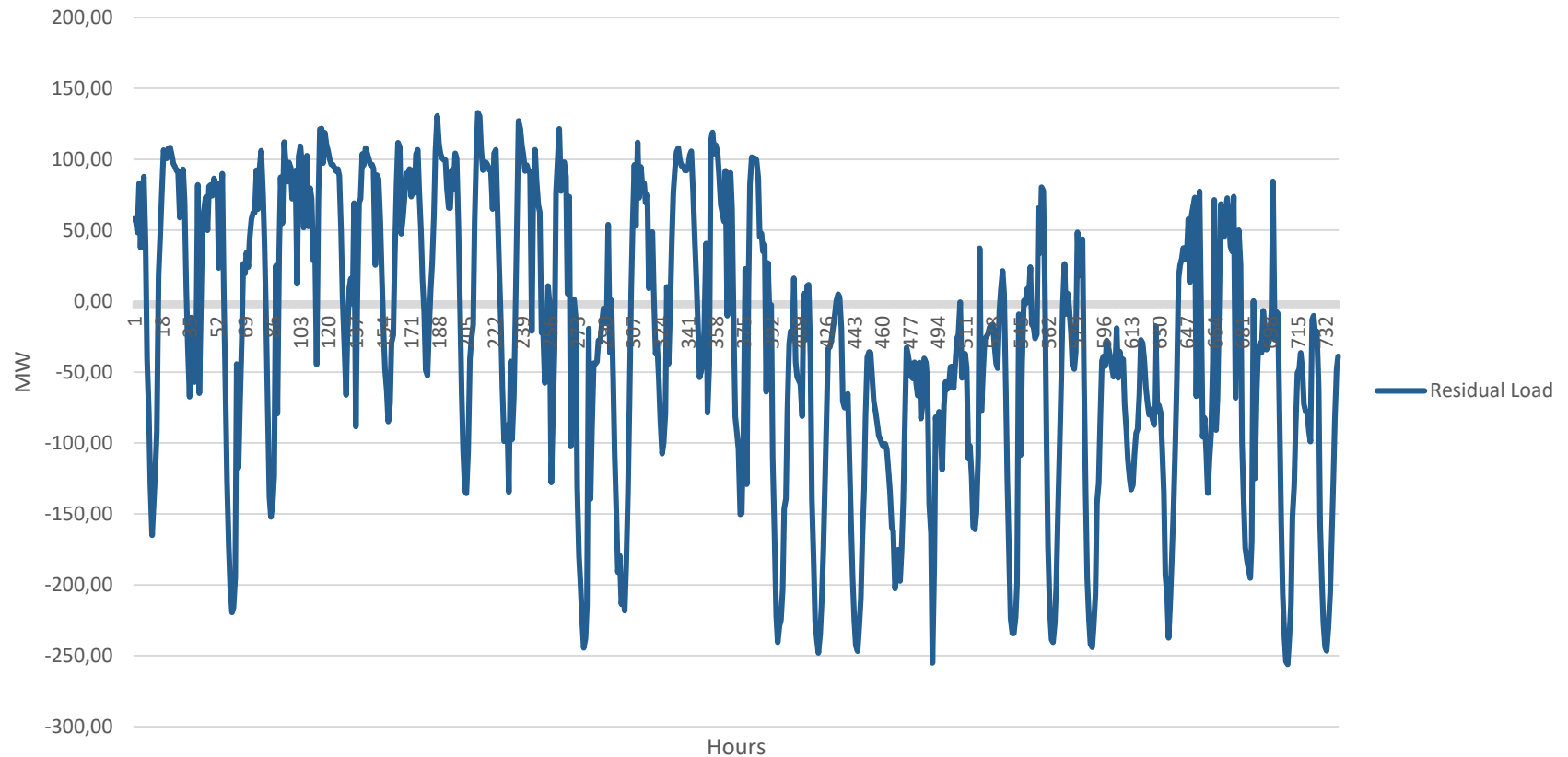
Simulation of 100% RE (one month)



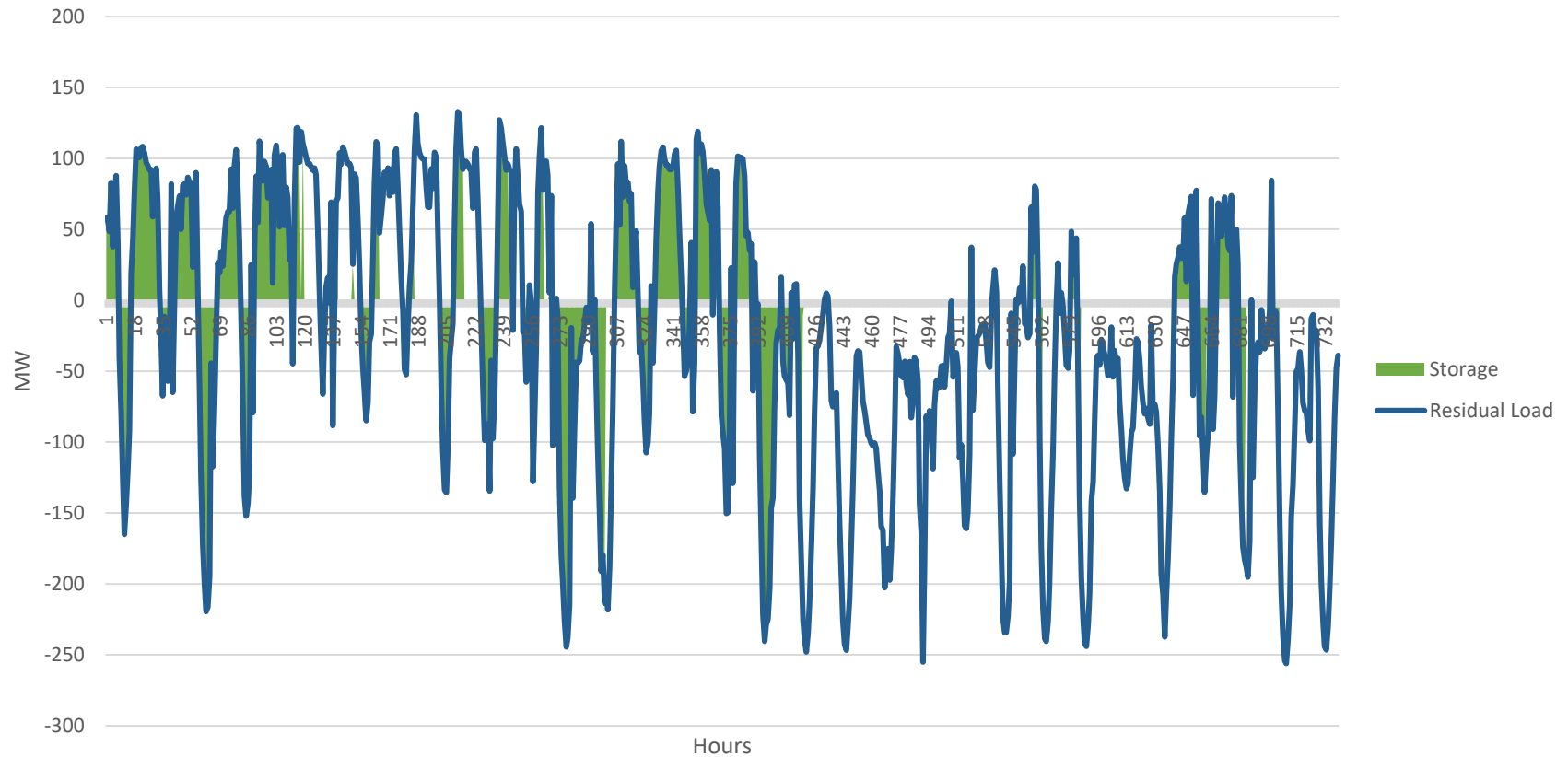
Simulation of 100% RE (one month)



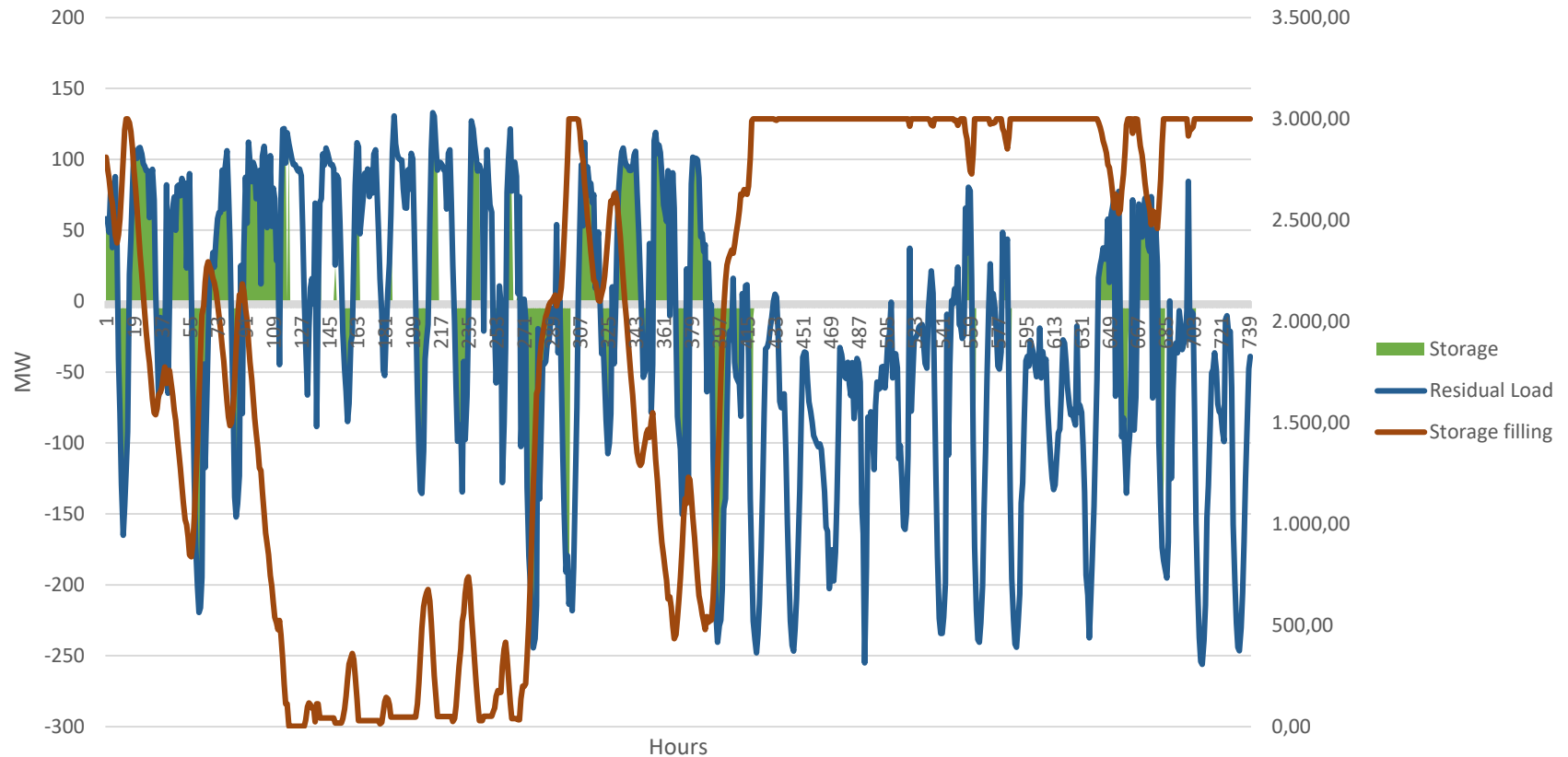
Simulation of 100% RE (one month)



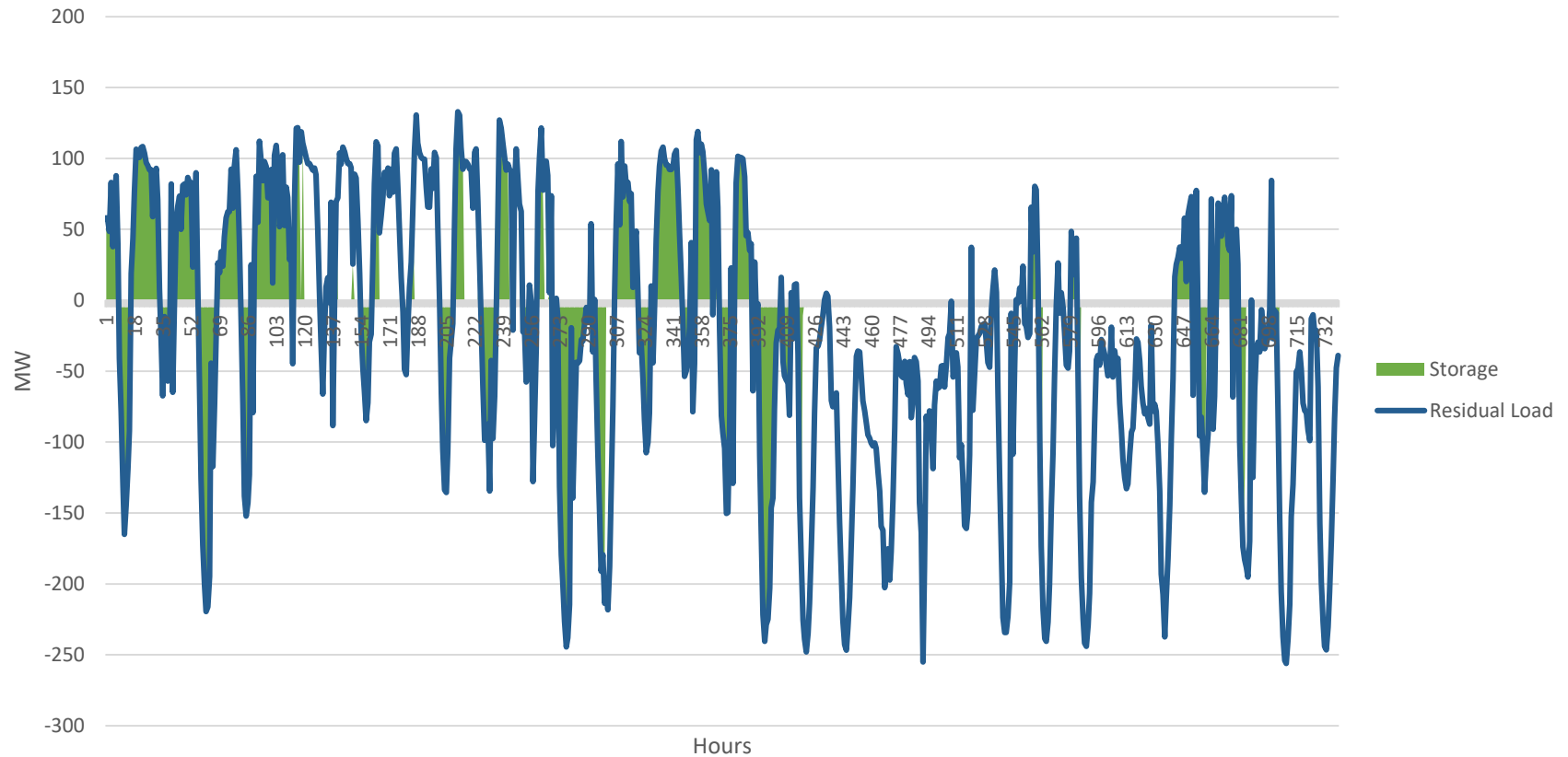
Simulation of 100% RE (one month)



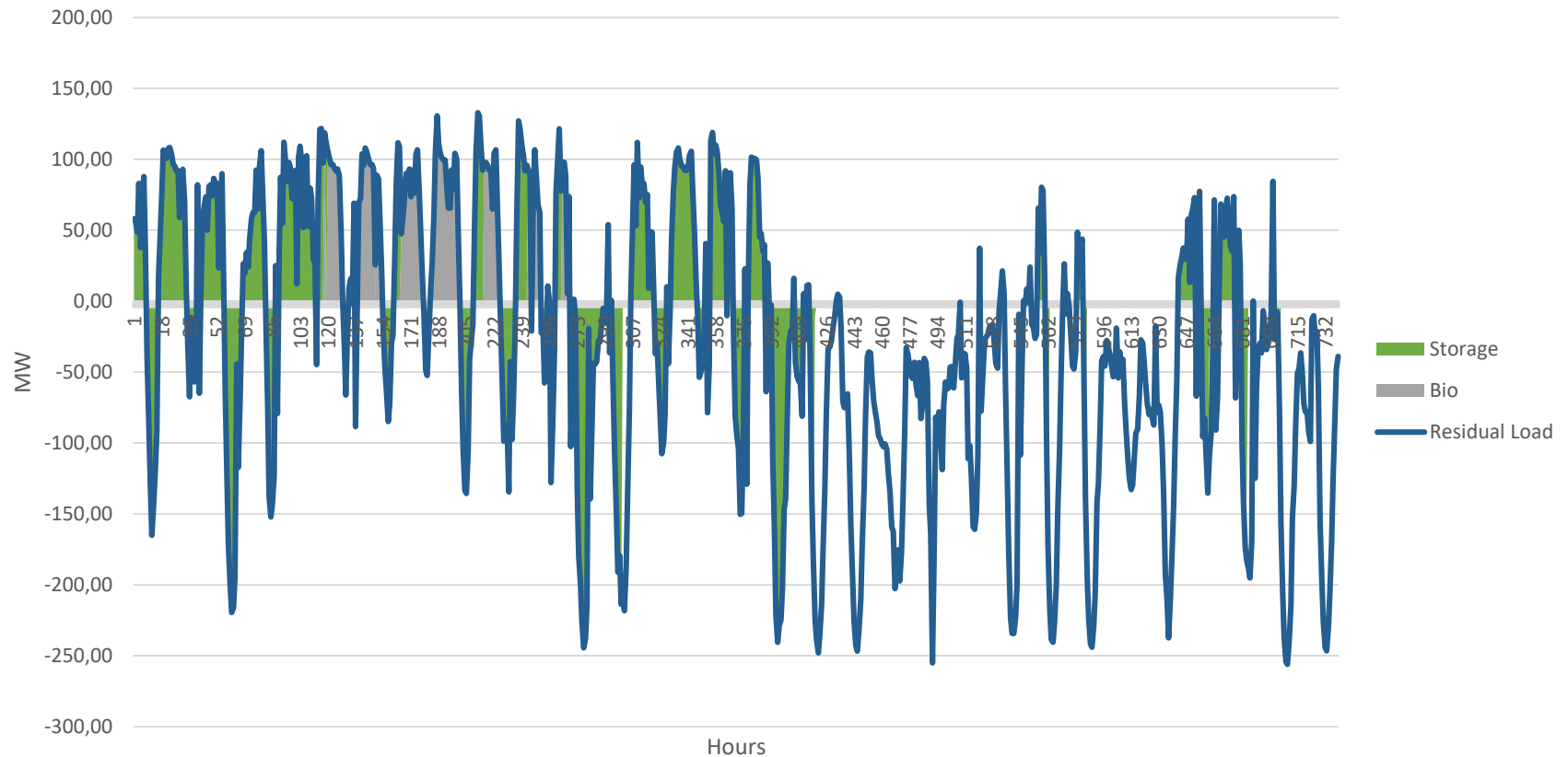
Simulation of 100% RE (one month)



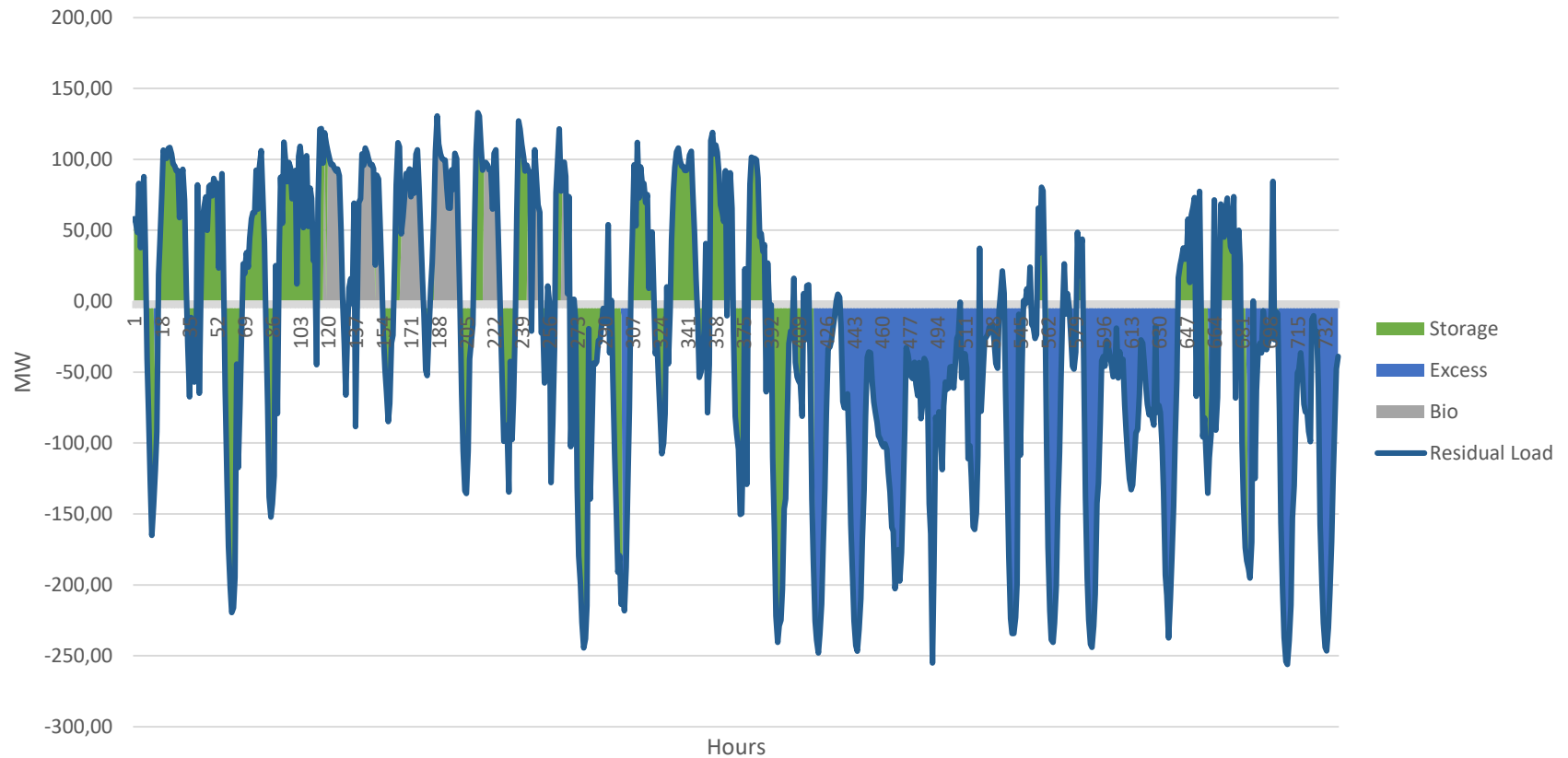
Simulation of 100% RE (one month)



Simulation of 100% RE (one month)

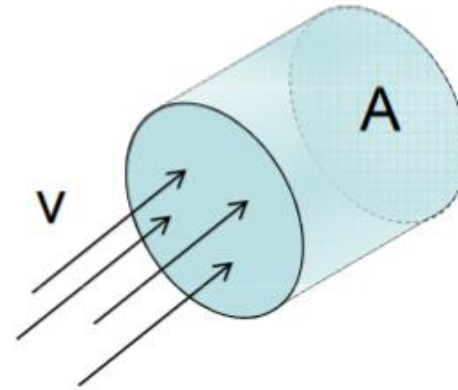


Simulation of 100% RE (one month)



Fundamental Equation of Wind Power

- Wind power depends on:
 - Rotor area (area)
 - Speed of air (velocity)
 - Mass of air (density)



- $KE = \frac{1}{2} * m * v^2$
- $P = \frac{1}{2} * \dot{m} * v^2$
 - $\dot{m} = \rho * A * v$
- $P = \frac{1}{2} * \rho * A * v^3$

with:

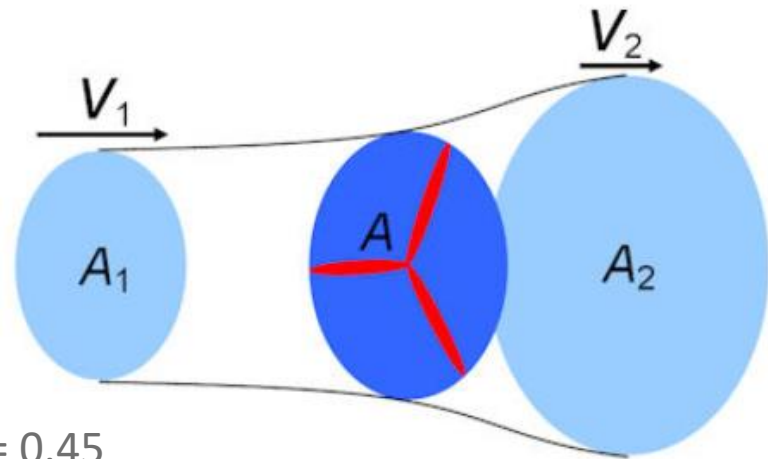
- ρ : density of air [g/m^3]
- A: Rotor area [m^2]
- v: velocity [m/s]

Power coefficient (Betz limit)

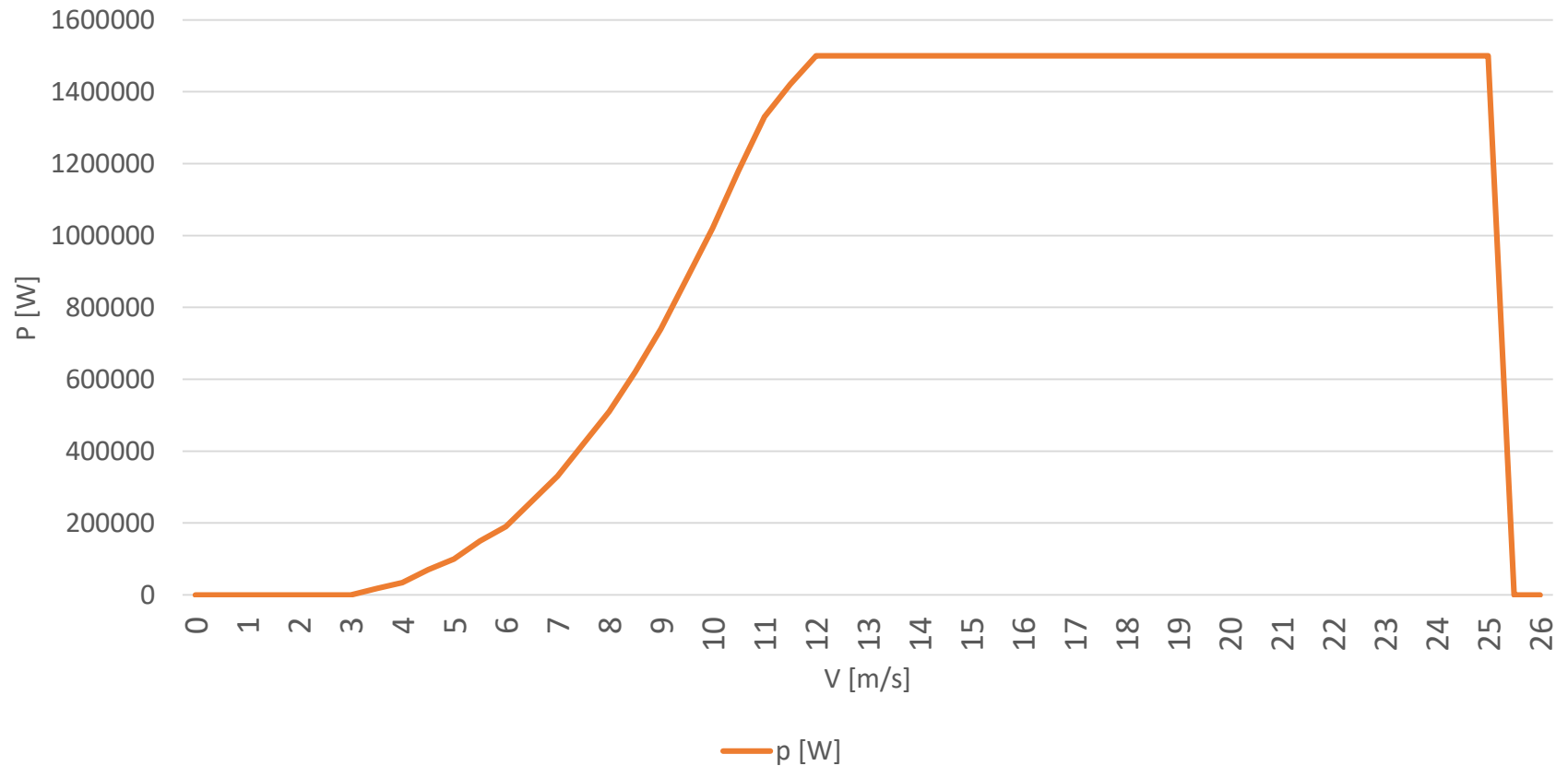
- The technically extractable power from wind is limited by the fact that the air speed behind the rotor can not be zero. Thus, the technical available power is limited by the power coefficient of 0.59 known as the Betz coefficient.

- $P = \frac{1}{2} * C_p * \rho * A * v^3$

- With Betz Factor $C_p = 0.59$
- Including wind turbine efficiency $C_p = 0.45$



Wind Power Curve Characteristics



Thanks for your attention!

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