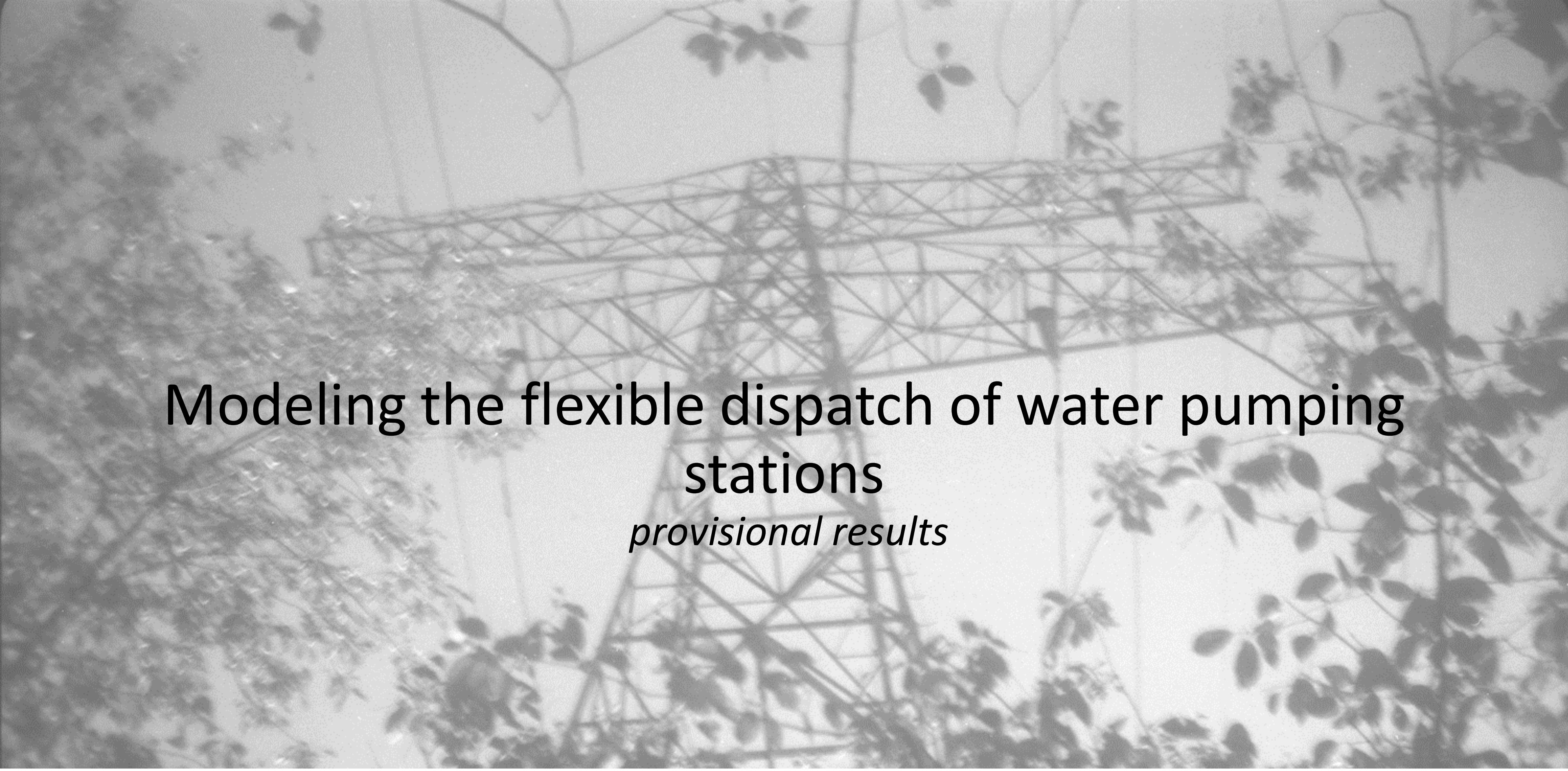


Modeling the flexible dispatch of water pumping stations

provisional results

April 2018

eRisk Group

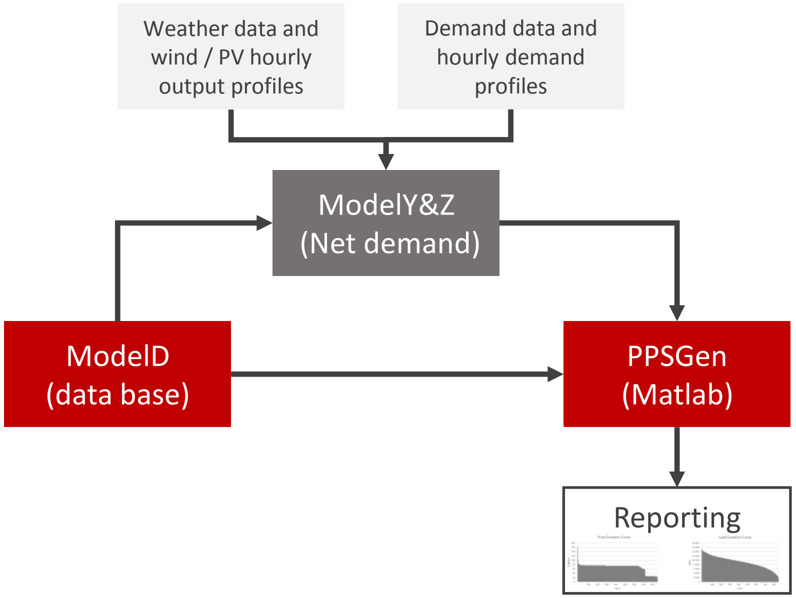
Energy & Finance

Content

PPSGen: The structure of the model

PPSGen: Model components

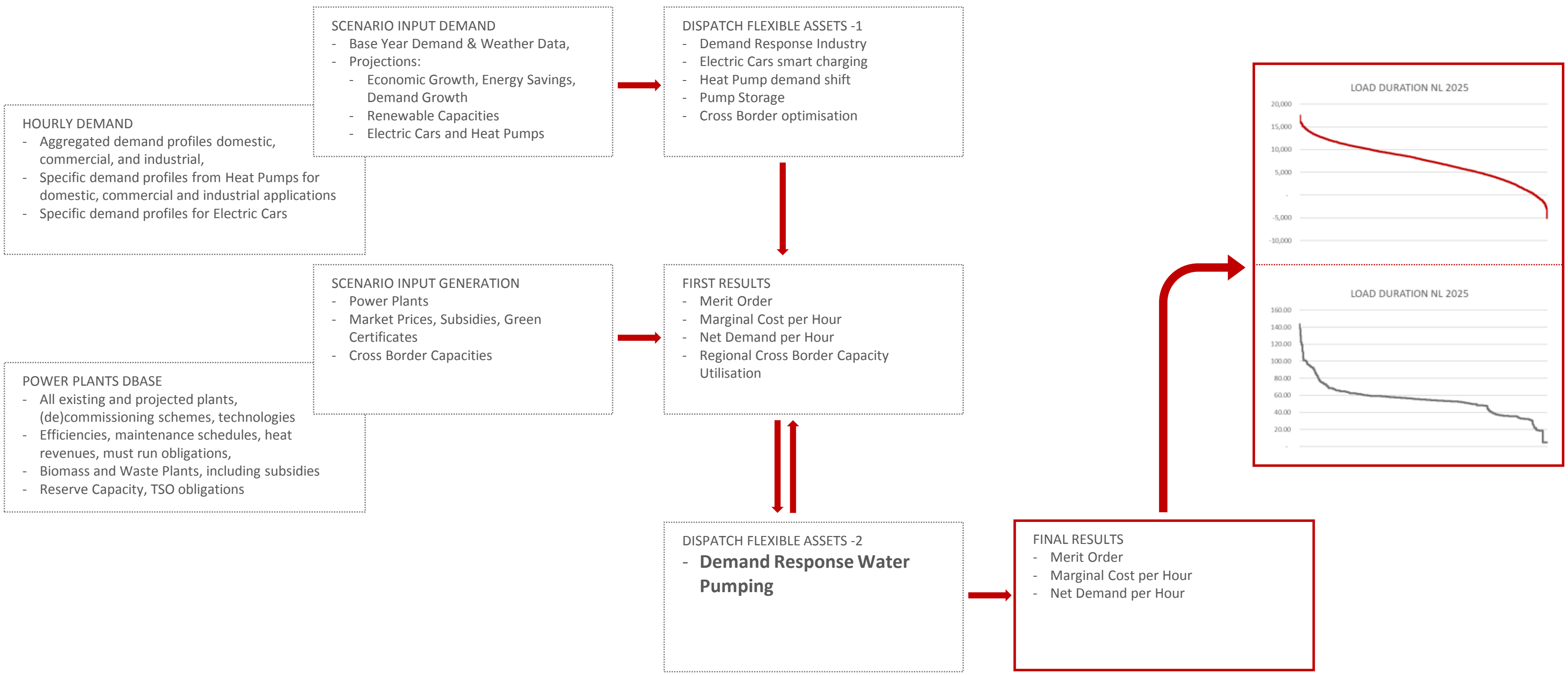
- ModelD is the starting point of the model. ModelD is the database of the model with the following data: all conventional power plants (> 5 MW) per country, the inter-connections capacity, renewable energy capacity, new technology capacity
- In ModelD, six scenarios to 2050 are defined for data inputs about possible future developments, including economic growth, and electricity and heat saving
- Information defined in ModelD and the gross hourly demand and normalised wind and PV generation data is fed in ModelY. ModelY uses the data to calculate the net hourly electricity demands
- In ModelZ, the net hourly electricity demand is adjusted for non-core region cross border optimisation and the dispatch of flexible assets such as demand response, resulting in a final net demand
- The final net demand and the flex constraints and relevant plant and market data of ModelD are collected and used as input in the Matlab core of the model, PPSGen 3.0
- In PPSGen 3.0, the optimal dispatch to minimise dispatch costs of available power plants, flex capacity and cross border capacity versus a given net demand is calculated, resulting in hourly electricity prices and loads per generating technology per year and per country



PPSGen 3.0 uses data which are modelled in Excel/VBA using statistical and linear modelling technologies. The data are generated in three separate Excel files (modelD and ModelY) which are connected via a logical through put of data

PPSGen: Overview

PPSGen is a fundamental merit order model of the North West European electricity markets. The fundamental method is based on basic economic principles of supply and demand describing price dynamics and modelling the impact of the main physical and economic factors determining the market equilibrium price of electricity



Assumptions base case (NEV) scenarios – general characteristics

- This study is based on the NEV scenario 2017 which was prepared by ECN in October 2017 for the yearly published study *Nationale Energie Verkenning* for the Dutch government. The scenario *voorgenomen beleid* has been used, specifically the following data:
  - Natural gas, coal, and CO2 prices
  - Gross electricity demand
  - Interconnection capacity
  - Installed capacity per technology for electricity generation
- The ECN data do not provide detailed information about the projected capacity installed per generation technology for electricity generation and the generation cost per technology. To align with the NEV scenario, eRisk Group has, based on the information available, made assumptions on the projected installed capacity and has used eRisk Group's generation cost assumptions per technology
- The growth of the electricity demand in the NEV scenario is assumed to remain at the 2016 levels. Notably because of the energy savings realized in the domestic sector and own production. To align with the NEV scenario, eRisk Group has, based on the information available about electricity and heat savings and the growth in electrical cars en heat pumps, adjusted demand to align with the demand in the NEV scenario. Because of the missing details about and the way demand is modeled in PPSGen the NEV en PPSGen (i.e. Household electricity production is not included in demand) demand do not match 100%
- eRisk Group has made two scenario variants to the NEV scenario 2017: the NEV High and Low scenario
- NEV High scenario: in this scenario the following assumptions are adjusted: Higher CO2 price based on the CO2 prices as assumed in carbon floor scenario as agreed in the new government policy agreement, higher demand based on 0,3% higher economic growth, 18% higher gas prices and gradual phase out in 2030 of all coal pant capacity

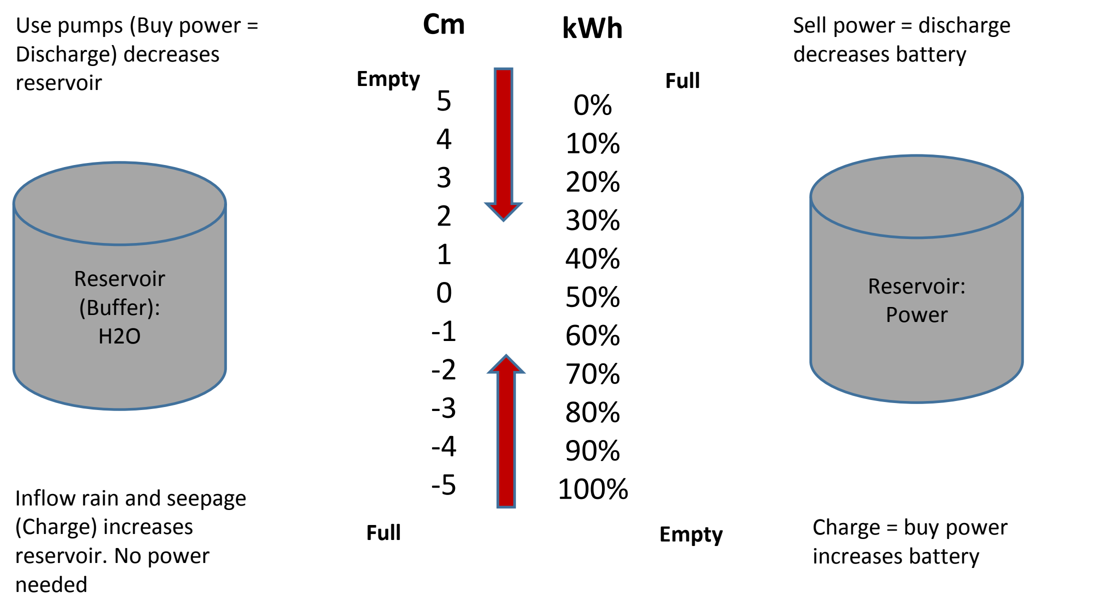
Content

Modeling flexible dispatch water pumping stations

General assumptions

- The dispatch of water pumps is comparable to the dispatch of a battery
- The inflow of water (seepage and rainwater = afvoer) into groundwater is equal to charging a battery
- The inflow of water is a given, has no power use and is only limited by the ground water reservoir (buffer)
- The pumping is equal to the discharge of a battery
- The reservoir capacity is equal to the water volume between the lower and upper limit of the groundwater target level
- The groundwater limits are set at plus and minus 5 cm around the ground water target level
- At minus 5 cm the reservoir is full and at plus 5 cm the reservoir is empty
- The efficiency of the battery is 100% and no operational dispatch cost are assumed

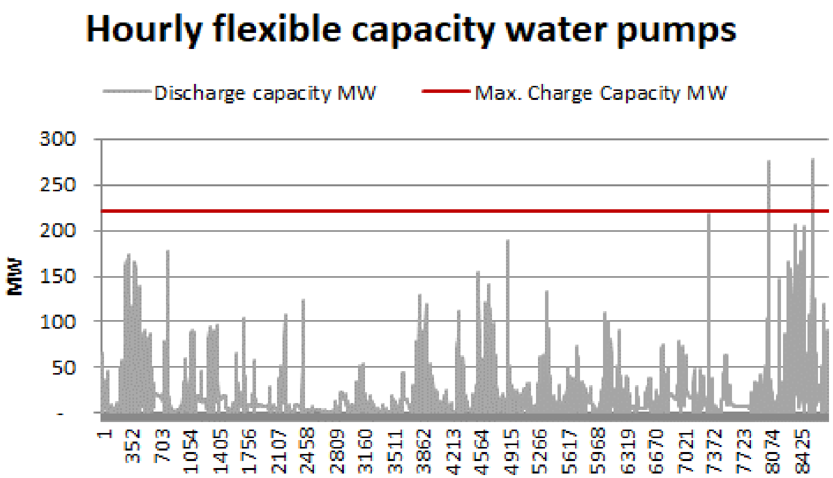
Groundwater reservoir vs. Battery reservoir



Modeling flexible dispatch water pumping stations

Flexible capacity of water pumps

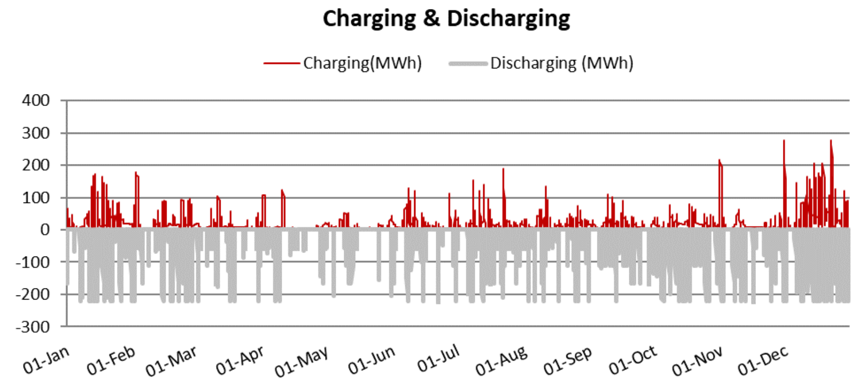
- The total reservoir / dispatch and maximal pump capacity are derived from the NHI data
- The start level of the reservoir is equal to the target level (half full)
- Total available reservoir capacity = 1724 MWh
- The reservoir capacity is the available flexible capacity enabling a delay in the dispatch of the water pumps
- Total available maximal discharge (pump) capacity per hour = 221 MW)
- The maximal allowed discharge gradient (ramping up and down) is limited to 50 MW per hour
- Total available discharge capacity per hour (dispatch profile) = total hourly interpolated and rainfall corrected daily inflow of water (seepage and rainwater) of 18 water boards (hourly charging capacity)
- Total electricity consumption is MWh 139.602 (Peak 43,68% / off peak 56,32%)



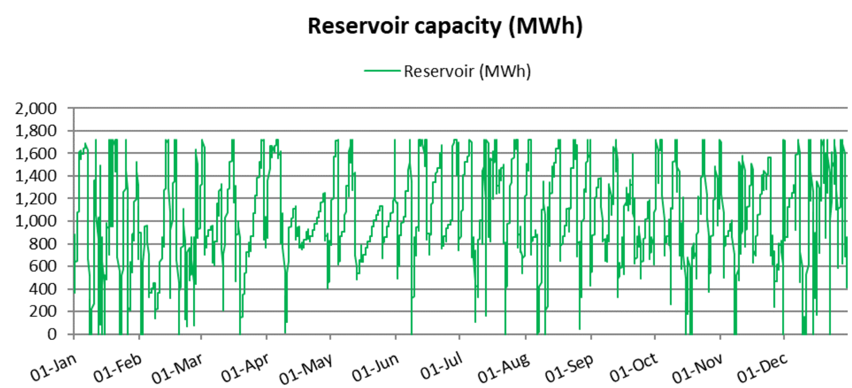
Modeling flexible dispatch water pumping stations

Description of water pump flex algorithm process

- Flexible capacity data are fed in PPSGen
- Algorithm optimises the dispatch of the water pumps like a battery
- Algorithm executes the following: collect hourly prices for a week and collect associated discharges according to the unoptimised dispatch profile
- These data including the dispatch conditions are used in a Linear Solver to minimise the dispatch cost and generate an optimised dispatch profile
- The following dispatch conditions are applied:
  - Optimisation horizon is one week
  - Reservoir capacity (buffer) of the battery is between 0 and 1724 MWh. Start/End year capacity 862 MWh
  - Discharging capacity (outflow water) is between 0 and 221 MWh. Hourly gradient is max. 50 MW per hour
  - Charging capacity is equal to the charging profile (hourly inflow water)
  - Battery is half full in the beginning and at the end
- Weekly calculations until all 8760 hours in a year are optimised
- The result is an optimised (minimised costs) discharge profile



Base case scenario 2020 with other flex



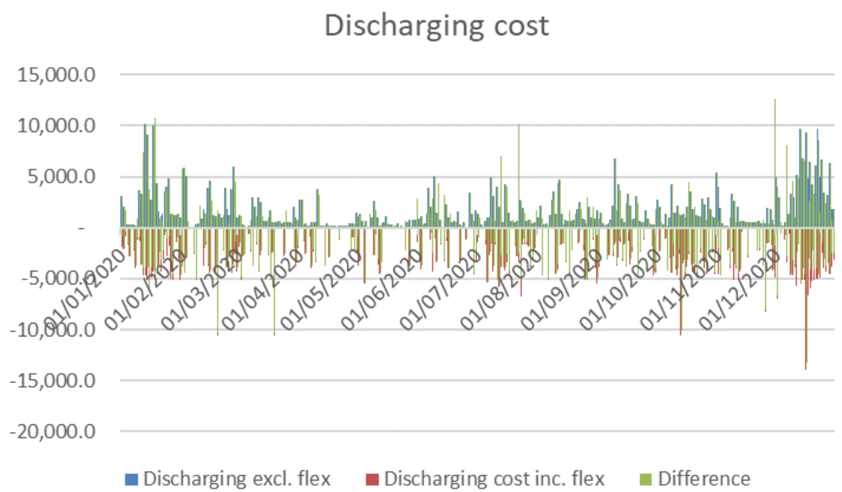
Content

1. PPSGen 3.0
2. Modelling flexible dispatch water pump stations
    1. General assumptions
    2. Dispatch capacity
    3. Algorithm
3. **Provisional results**
4. Next steps

Provisional results

Financial results base case scenario 2020 without other flexible sources

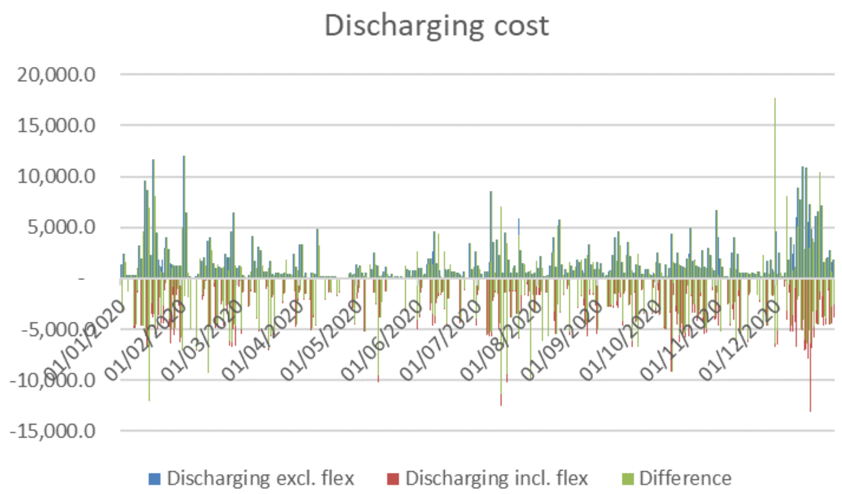
- Cost excl. flex € 5.131.942
- Average price: € 37,3 MWh
- Cost incl. flex € 3.226.984
- Average price: € 37,4 MWh
- Difference € 1.904.957



Provisional results

Financial results base case scenario 2020 with other flexible sources

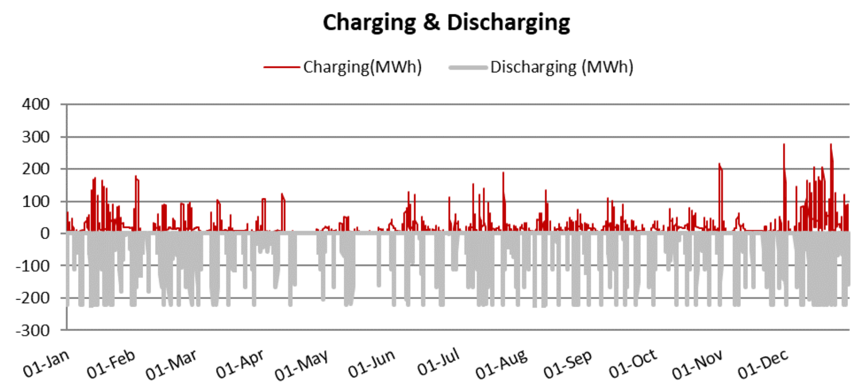
- Cost excl. flex € 5.088.792
- Average price: € 36,9 MWh
- Cost incl. flex € 3.655.372
- Average price: € 37,0 MWh
- Difference € 1.433.420

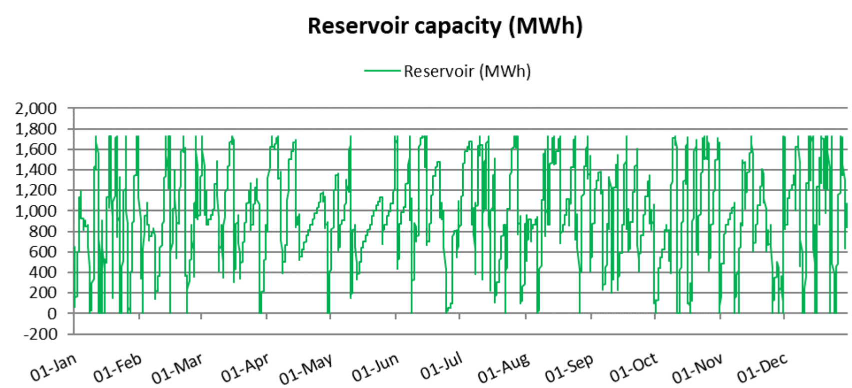


Provisional results

Capacity results base case scenario 2030 with other flex

- The following dispatch conditions are applied:
    - Optimisation horizon is one week
    - Reservoir capacity (Buffer) of the battery is between 0 and 1724 MWh. Start/End year capacity 862 MWh
    - Discharging capacity (outflow water) is between 0 and 221 MWh. Hourly gradient is max. 50 MW per hour
    - Charging capacity is equal to the charging profile (hourly inflow water)
    - Battery is half full in the beginning and at the end
- Weekly calculations until all 8760 hours in a year are optimised
- The result is an optimised (minimised costs) discharge profile

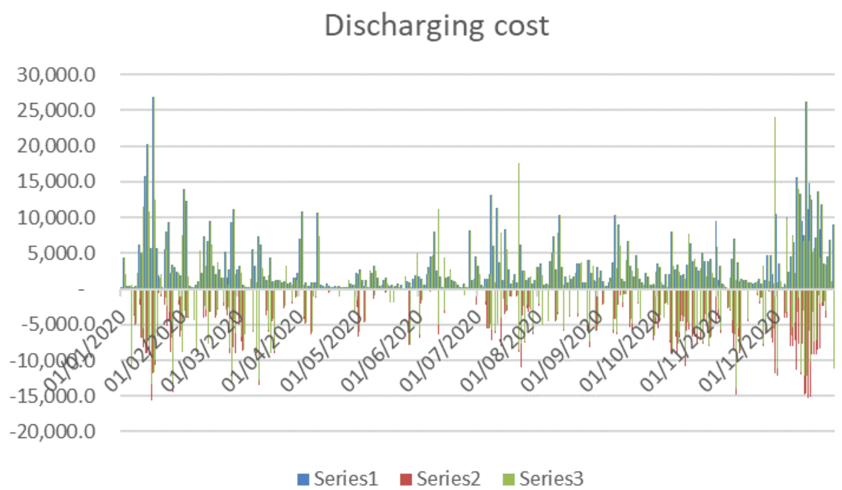




Provisional results

Results base case scenario 2030 without other flexible sources

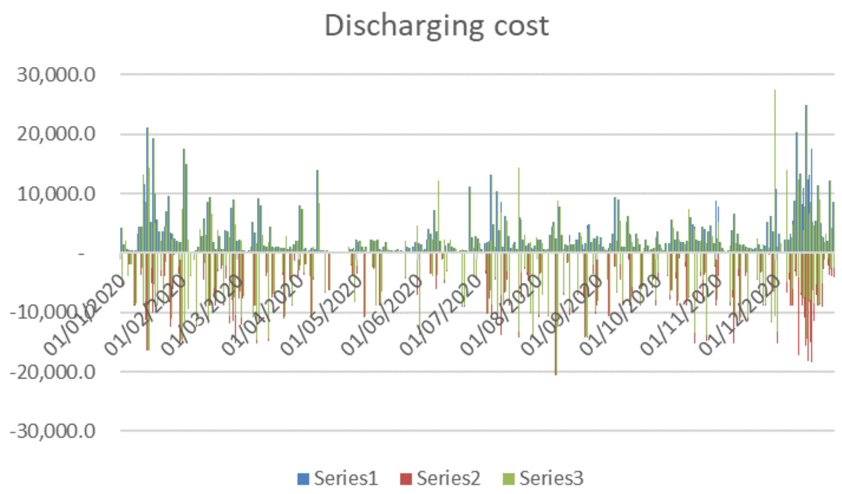
- Cost excl. flex € 9.541.642
- Average price: € 69,8 MWh
- Cost incl. flex € 4.175.628
- Average price: € 69,8 MWh
- Difference € 5.366.013



Provisional results

Results base case scenario 2030 with other flexible sources

- Cost excl. flex € 9.757.284
- Average price: € 70,8 MWh
- Cost incl. flex € 6.985.676
- Average price: € 70,8 MWh
- Difference € 2.771.608



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Next steps

Deliverable

- Financial optimisation dispatch water pump flexibility (2020 /2025/2030 base case (NEV 2017) / Base case (NEV 2017 high)
  - Model output dispatch water pumps with and without flexible capacity
  - Explanation of results of financial optimisation dispatch of water pumps with and without flexible capacity
  - Break down of total optimisation result (electricity cost reduction) per waterboard (18 waterboards from the NHI data)
- CO_2 reduction water pump flexibility (2020 /2025/2030)
  - Model output dispatch water pumps with and without flexible capacity
  - Explanation of results of CO_2 emissions dispatch of water pumps with and without flexible capacity

Contact

eRisk Group
Energy & Finance

- MAARTEN MEIJBURG
  - mobile: +31 643053281
  - maarten.meijburg@eriskgroup.com

- RUUT SCHALIJ
  - mobile: +31 620437109
  - ruut.schalij@eriskgroup.com

- Website
  - www.eriskgroup.com