HydroSun –
A project funded through the Green Platform Initiative

prediktor
a TGS Company

Ocean Sun

Scatec REIN Hydro

Statkraft Multiconsult

SINTEF NTNU

IFE NIVA Norwegian Institute for Water Research

UNIVERSITY OF OSLO

HydroSun

Project owner: Scatec Period: 2021 – 2024 Total budget: 130 million NOK

Main Goal: First full-scale hybrid power plant based on hydropower and floating PV

Competence Project

Funded by Research Council of Norway

Hybrid hydro-FPV power plants

- **Owner: IFE**
- **PM: Josefine Selj**
- **Partners**: **SINTEF Energy Research**, UiO, NTNU, NIVA, Scatec, TGS-Prediktor, Ocean Sun, Statkraft, Hydro REIN, Multiconsult

Industrial project

Funded by Innovation Norway & Industry Partners

DP0 - Project Management and Communication

DP1 - Hybrid solar and hydro power plant

- **Owner: Scatec**
- **PM: Hanne Nøvik**
- **Partners**: **SINTEF Energy Research**, IFE

DP2 –Digital tools and control systems for hybrid power plants

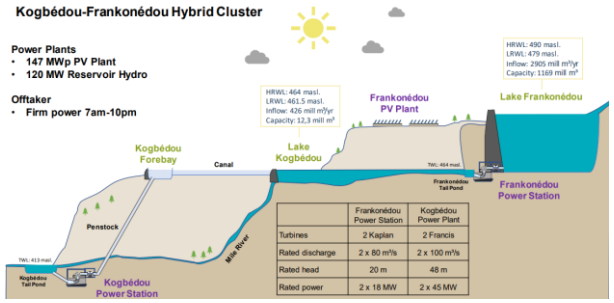
- **Owner: TGS-Prediktor**
- **PM: Espen Krogh**
- **Partners**: **SINTEF Energy Research**, IFE

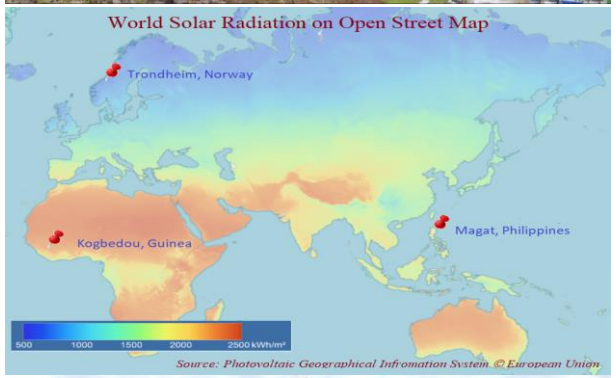
DP3: Technologies for large scale FPV plants

- **Owner: Ocean Sun**
- **PM: Børge Bjørneklett**
- **Partners**: IFE

HydroSun test cases via vLab

SHOP Portal
Short-term Hybrid Optimization Program





Guinea

- Input data preparation
- Test 1: determine maximum baseload
- Test 2: impact of reservoir evaporation
- Test 3: detailed study of pricing regime and evaporation for a given load obligation
- Test 4: impact of turbine partial damage

Magat

- Input data preparation
- Test 1: Quantitative analysis for investment decisions under hybrid scheduling of hydro, solar, and BESS in mean year
- Test 2: Quantitative analysis for investment decisions under hybrid scheduling of hydro, solar, BESS, and pump in dry, mean and wet years for day-ahead and reserve capacity markets

World

- Input data preparation
- Test 1: Impact of the correlation of hydro and solar in Guinea, the Philippines, and Norway

Zembia

- Input data preparation
- Test 1: Quantitative analysis for investment decisions under hybrid scheduling of hydro, solar, pump, and BESS in dry, mean, and wet years

HydroSun Video

SHOP for investment decision on a hybrid power plant in Zambia

Presentation | 29.11.2023 | Vegard Kristiansen

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AGENDA

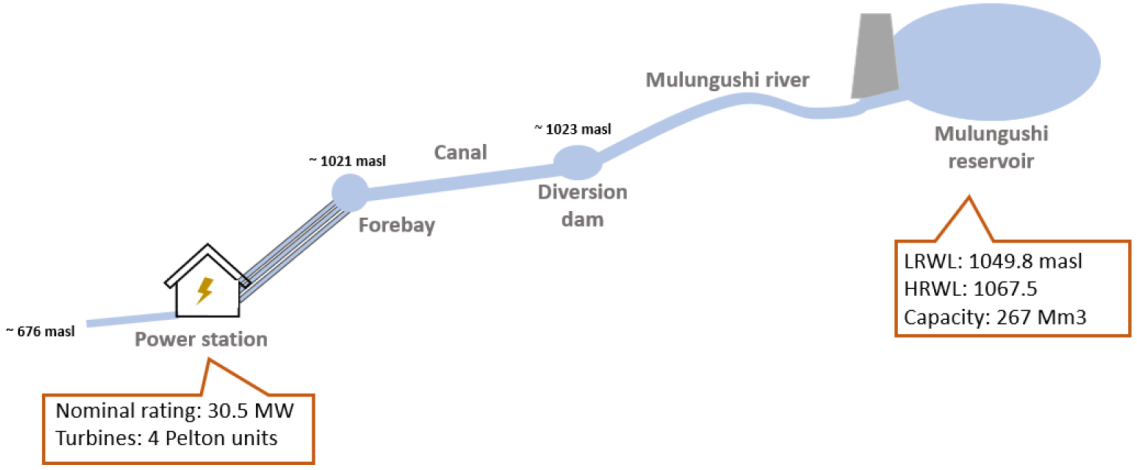
1. **Background**
2. Planned and Possible Upgrades
3. Model & Assumptions
4. Results

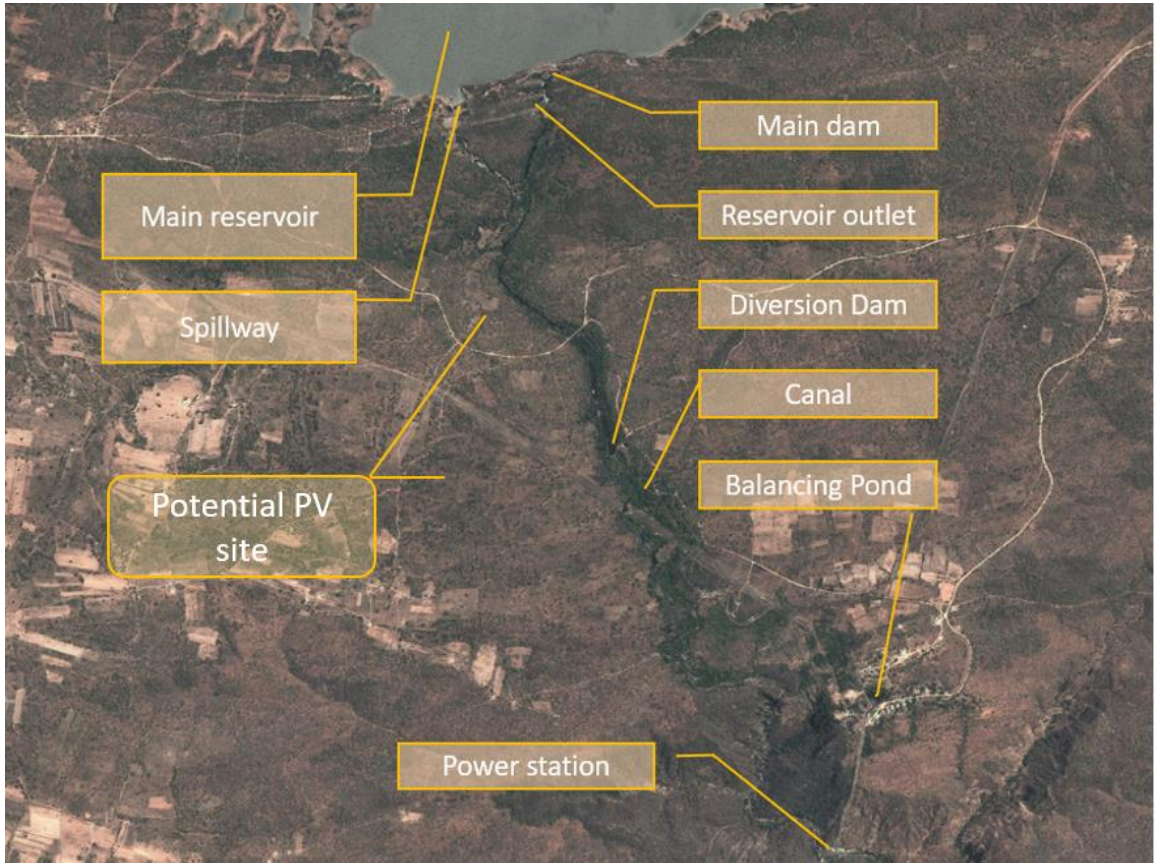
Mulungushi hydropower station

- Located in the Central District of Zambia
- Owned and operated by Lunsemfwa hydro power company (LHPC)
- First unit installed in 1925
- Total installed capacity is 30.5 MW

Existing Generating Assets

Overview of Mulungushi Hydro Power Station

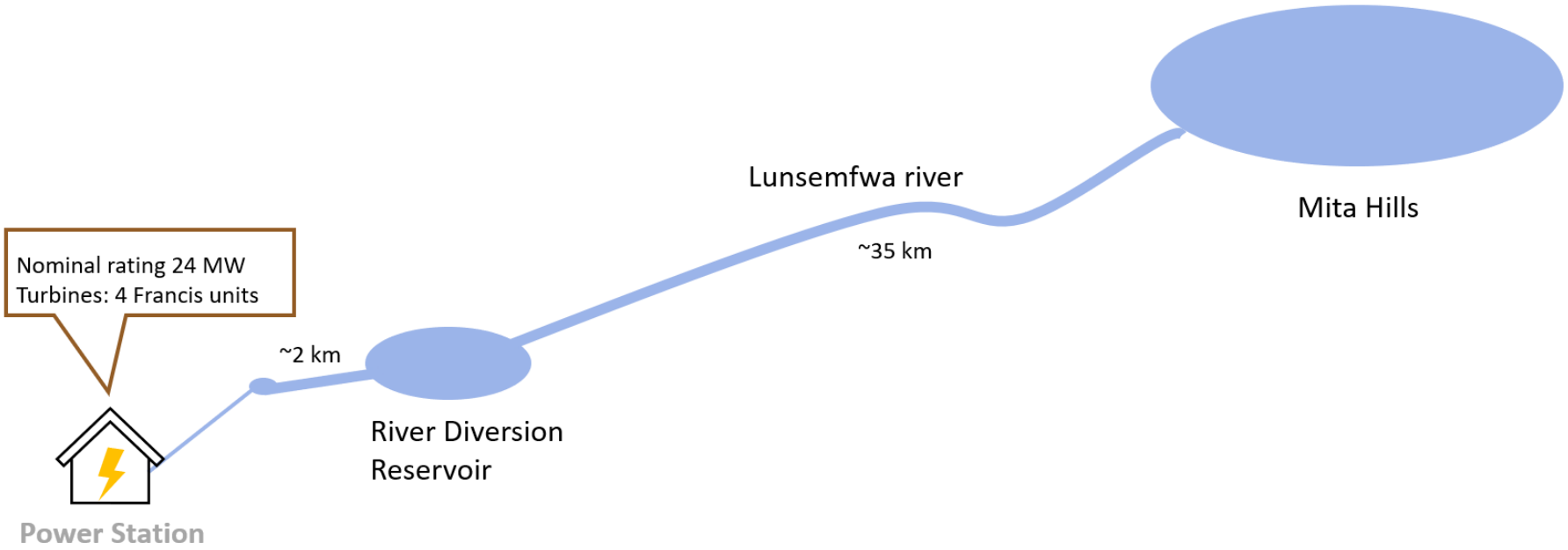




MPS - Mulungushi Power Station

Existing generating assets

Overview of Lunsemfwa Hydro Power Station



LPS - Lunsemfwa Power Station

Existing generating assets

Regulation of Mulungushi waterway

- Characterized by old equipment and machinery
- Challenging to precisely and swiftly regulate discharge

Existing Generating Assets

Water Resources at Mulungushi Reservoir and Mita Hills

- Decreasing inflow due to climate change and new irrigation projects.
- Higher demand of stable hydropower resources to mitigate intermittent power from PV and wind.
- How to be better equipped to face these challenges?

AGENDA

1. Existing generating assets
2. **Planned and possible upgrades**
3. Model & Assumptions
4. Results

Planned and possible upgrades

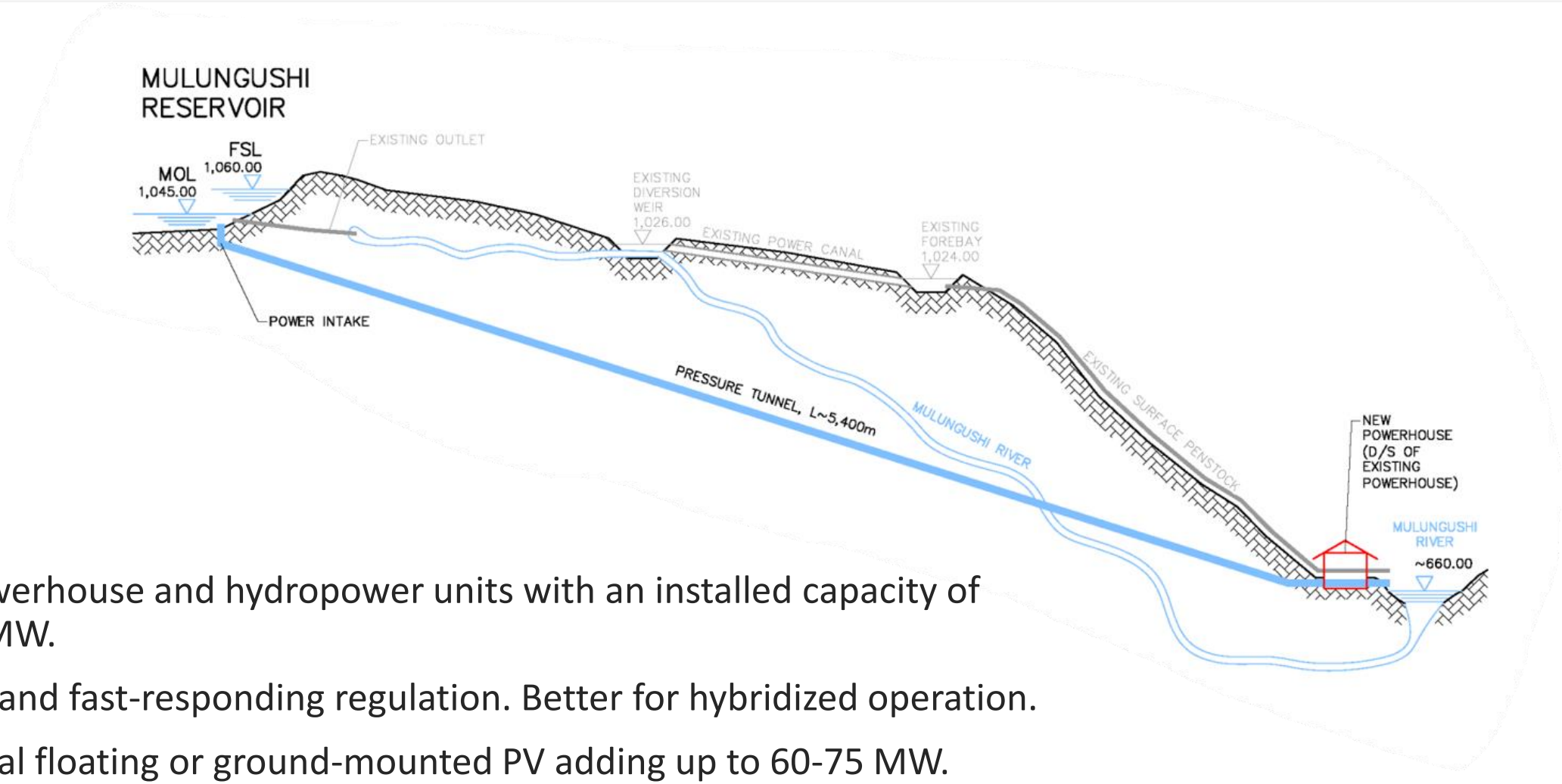
Installation of 10 MW PV

- Relatively cheap way of adding additional energy.
- Ground-mounted PV installation
- Contribute to allocate water, ensuring a more flexible energy system

-Head start on ground works

Planned and possible upgrades

Possible upgrade of Mulungushi Hydro Power Station

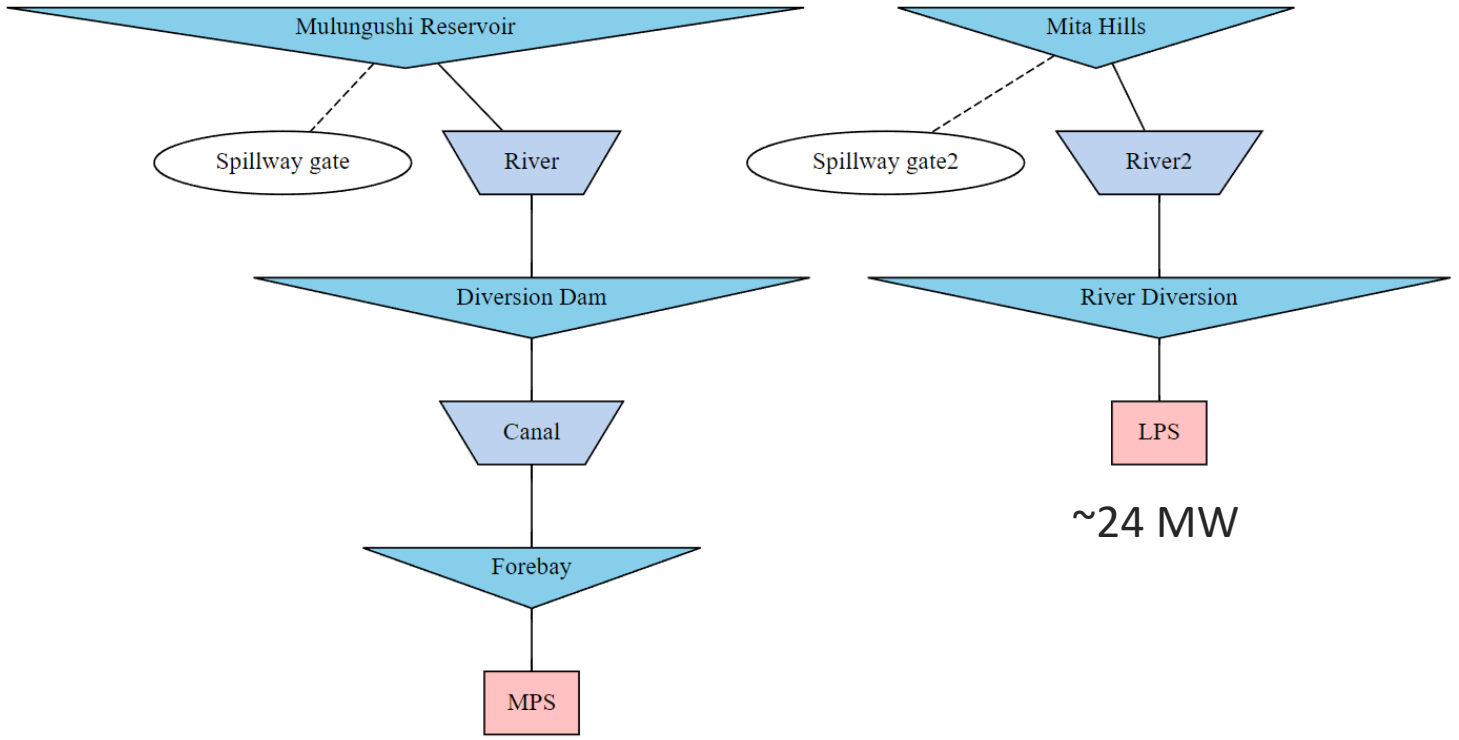


- New powerhouse and hydropower units with an installed capacity of 70-100 MW.
- Modern and fast-responding regulation. Better for hybridized operation.
- Additional floating or ground-mounted PV adding up to 60-75 MW.

AGENDA

1. Existing generating assets
2. Planned and possible upgrades
3. **Model & Assumptions**
4. Results

SHOP Topology Tree



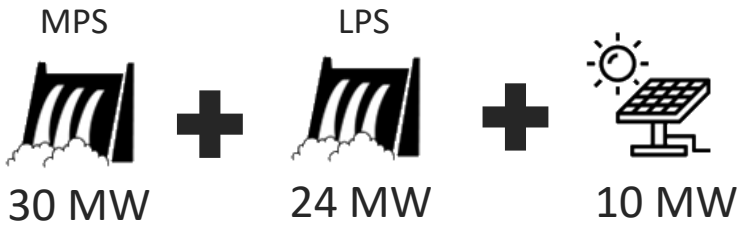
~10 MW

Short-term Assets

1. Existing generating assets

2. Stand-alone operation of 10 MW PV

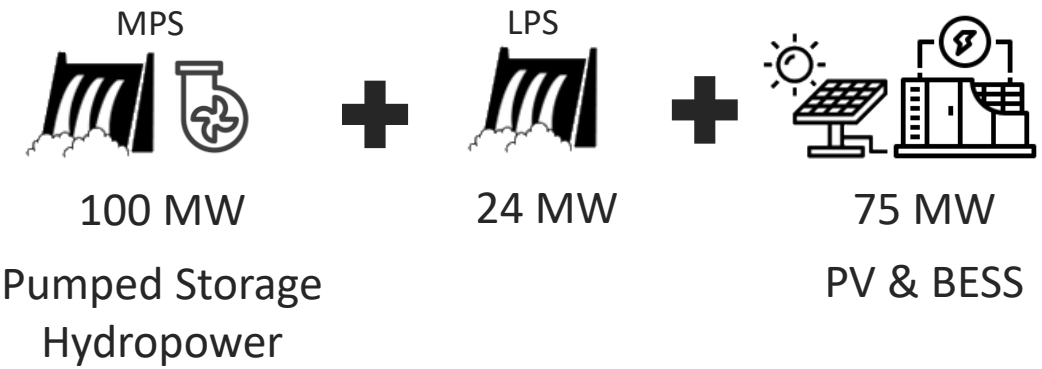
3. Hybridized operation of PV plant and existing hydropower assets



Possible future scenarios

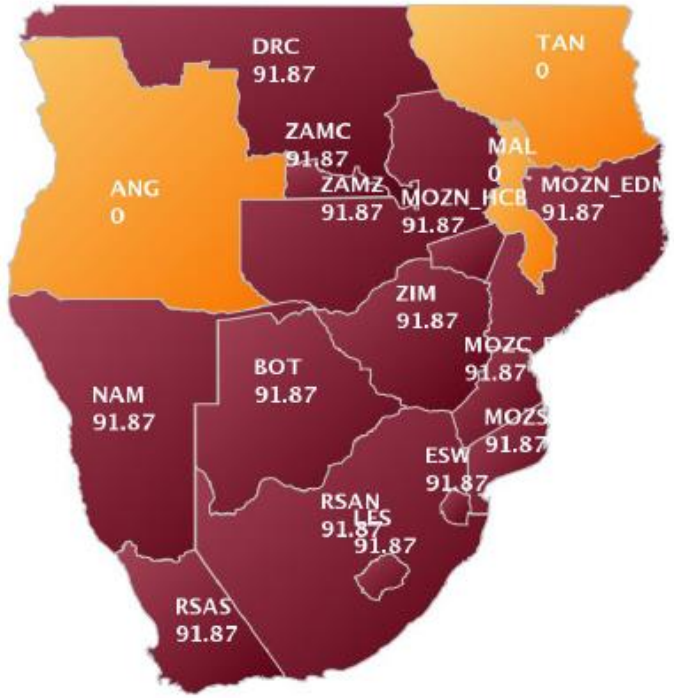
1. Hybridized operation of PV plant and upgraded hydropower assets

2. Hydropower with pumping opportunities and PV + BESS



Southern African Power Pool and Market Data

- ~80% of the energy in the SAPP region is traded through bilateral agreements
- Important power off-takers in Zambia are ZESCO & CEC
- Remaining 20% is traded on the spot market platform

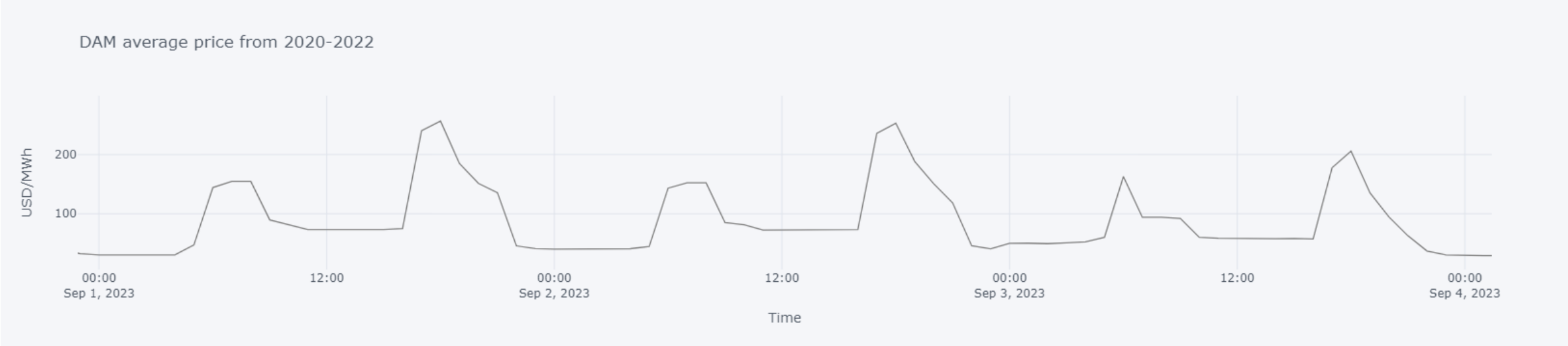


CEC - Copperbelt Energy Corporation

ZEZCO- Power utility owned by the Government of the Republic of Zambia

SAPP Day-Ahead market prices

- Distinct morning and evening price peaks



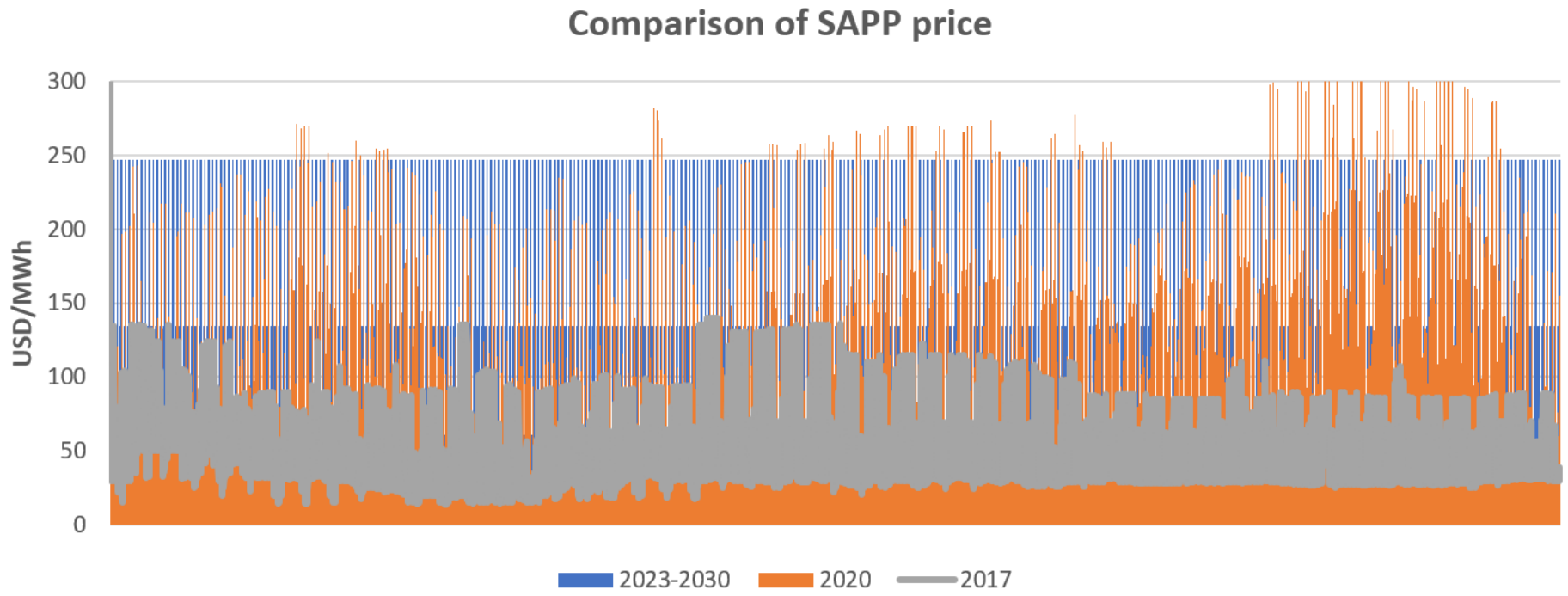
Prices based on hourly price values from 2022

Model & Assumptions

SAPP Day-Ahead market prices

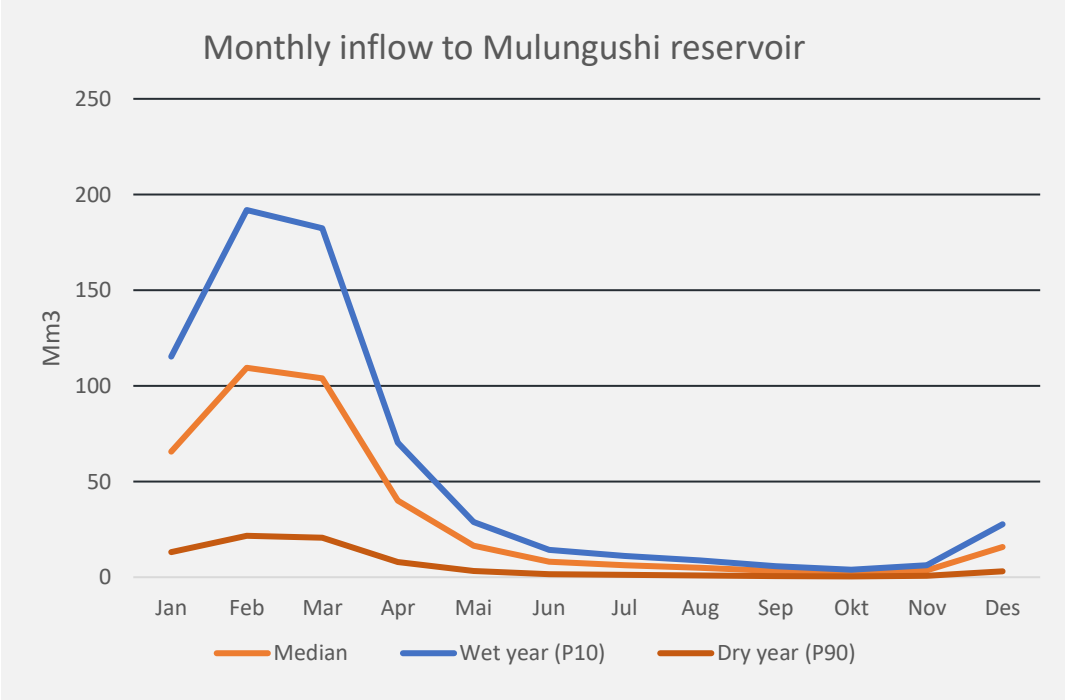
- Studied SAPP prices from different years

SAPP Price year	Average price [USD/MWh]
2017	50.5
Avg. 2020-2022	86.2
Estimate for 2023-2030	124.2



Hydrology data

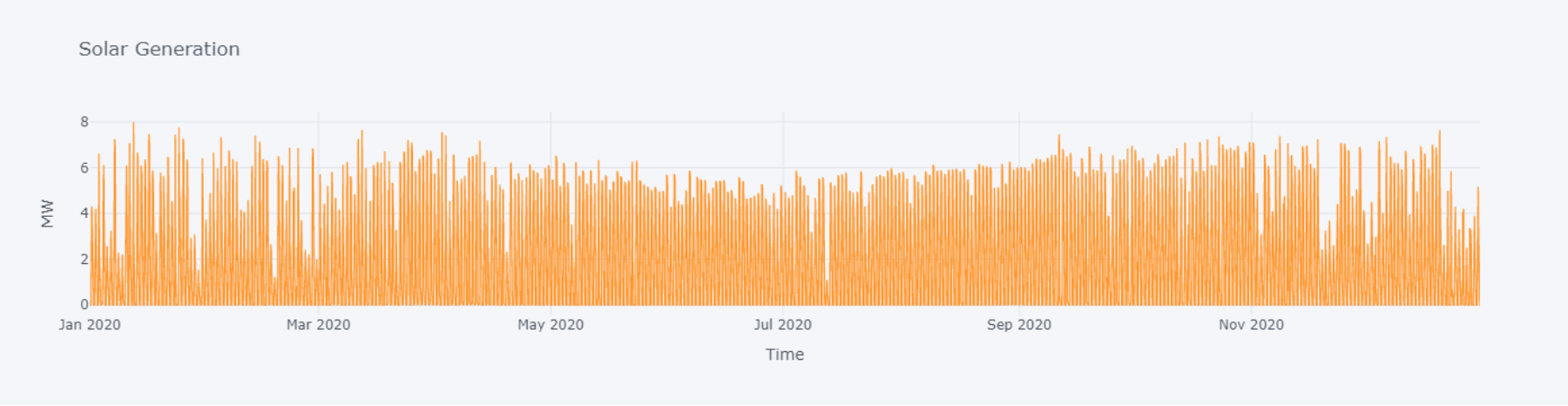
- Impact of inflow
- Reservoir volume/head curves

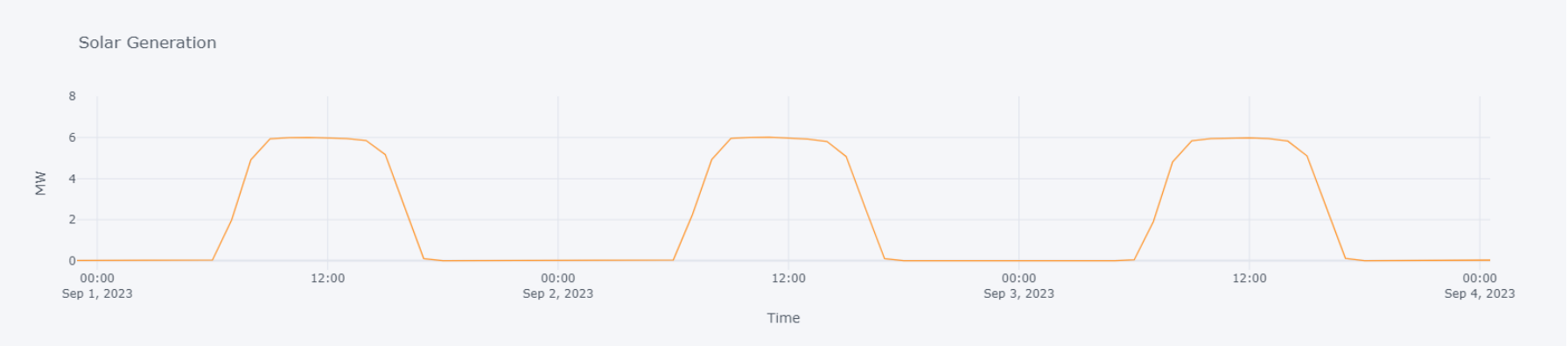


Dry: 71.3 Mm3	Median: 380.0 Mm3	Wet: 645.3 Mm3

Solar generation data

- Solar generation data which represent a 10/100 MW PV plant



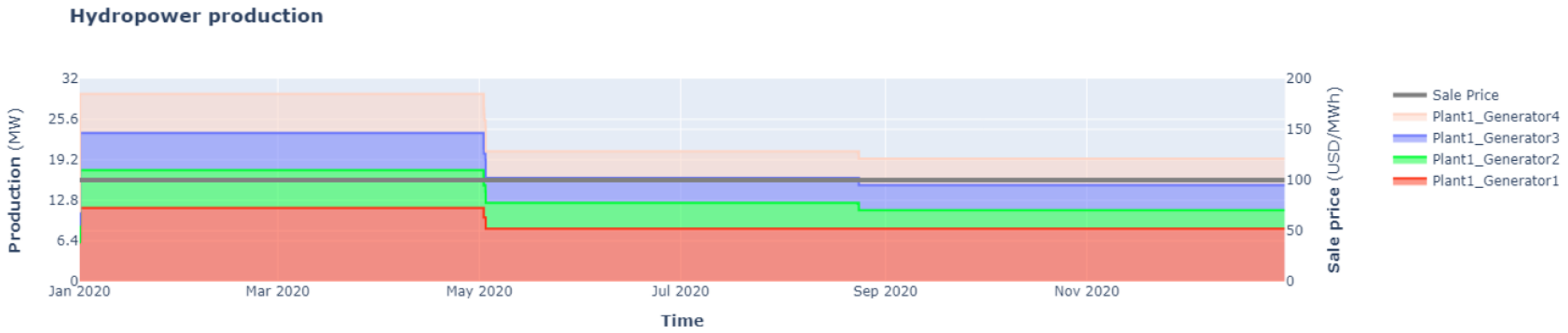


AGENDA

1. Existing generating assets
2. Planned and possible upgrades
3. Model & Assumptions
4. **Results**

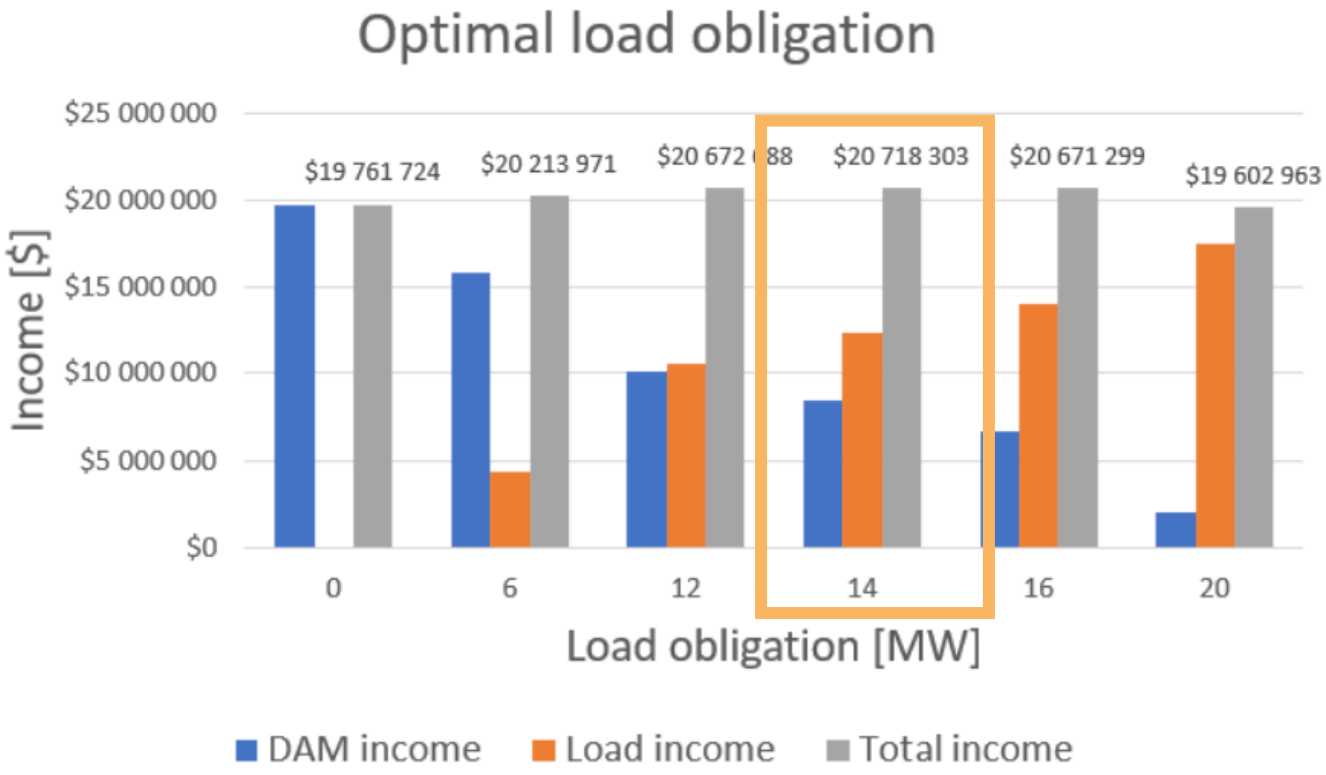
Historical operation of Mulungushi Power Plant

- Sold power through firm PPAs as long as hydropower resources were available.
- PPA tariff: 10 cent/kWh.
- Annual revenue in a median inflow year: ~ $20 000 000



Shared market operation, firm load obligation and spot market

- Optimal firm load is 14 MW. Tariff: 10 cent/kWh
- Remaining power is sold on SAPP, with historical prices from 2022



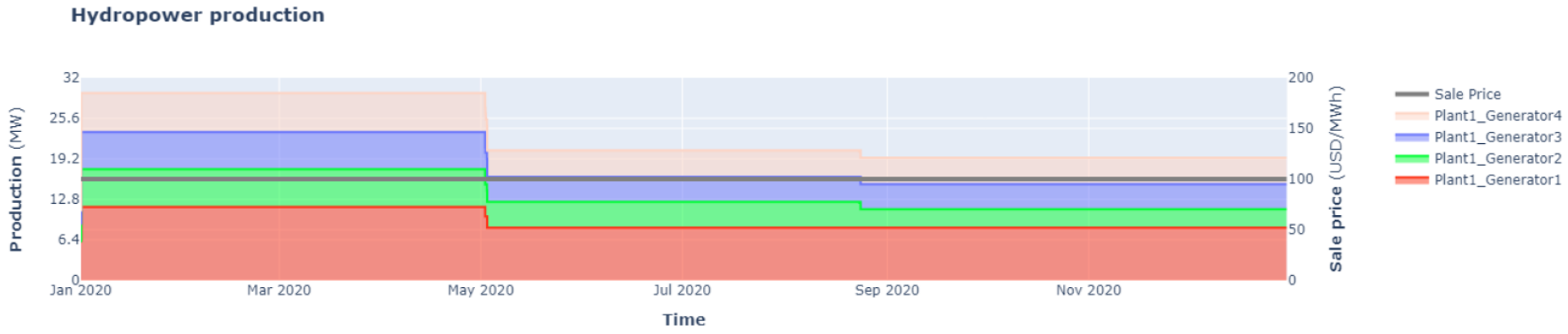
Results

Historical Operation vs. Hybridized Operation with 10 MW PV

30,5 MW hydropower

Firm PPA only

$20 000 000



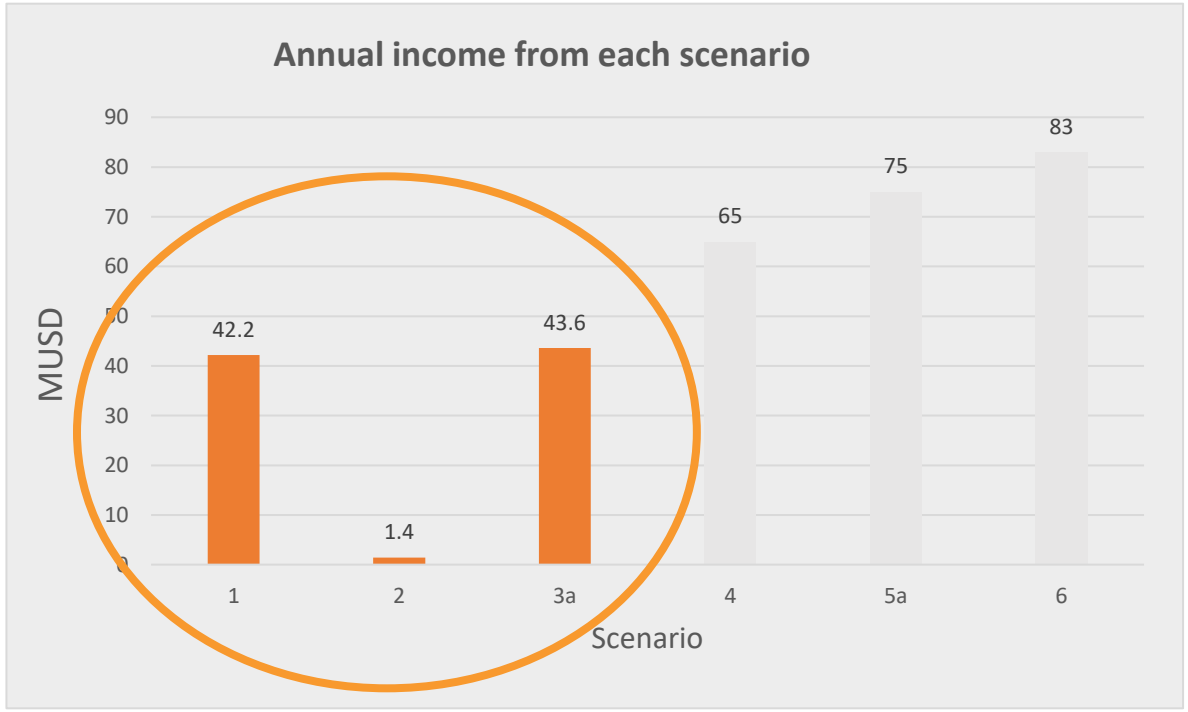
30,5 MW hydropower

10 MW PV

Firm PPA & SAPP

$22 000 000 ↑10%

Annual revenue from each scenario during a median inflow year



1. Existing generating assets of MPS and LPS — MPS 30 MW + LPS 24 MW

2. Stand-alone operation of 10 MW PV — 10 MW

3a. Hybridized operation of PV plant and existing hydropower assets without possibility to buy power from SAPP. — MPS 30 MW + LPS 24 MW + 10 MW

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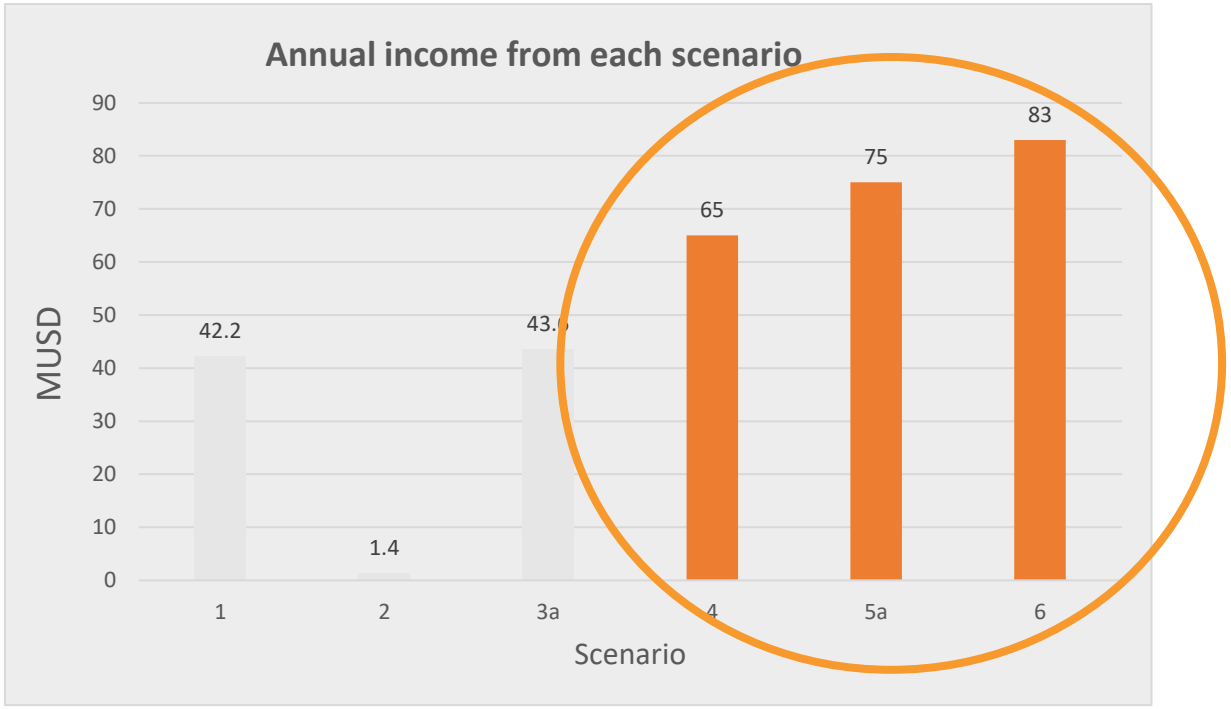
Annual revenue from each scenario during a median inflow year



4. Upgraded MPS and LPS operating without PV.

MPS 100 MW + LPS 24 MW

5a. Hybridized operation of PV plant and upgraded hydropower assets without possibility to buy power from SAPP.

MPS 100 MW + LPS 24 MW + 75 MW

6. Hybridized operation of PV plant and pumped storage hydropower with possibility to buy power from SAPP.

MPS 100 MW Pumped Storage Hydropower + LPS 24 MW + 75 MW + SAPP $

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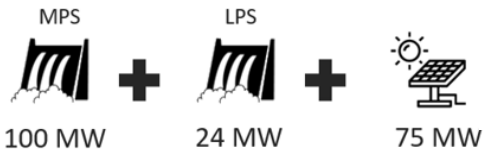
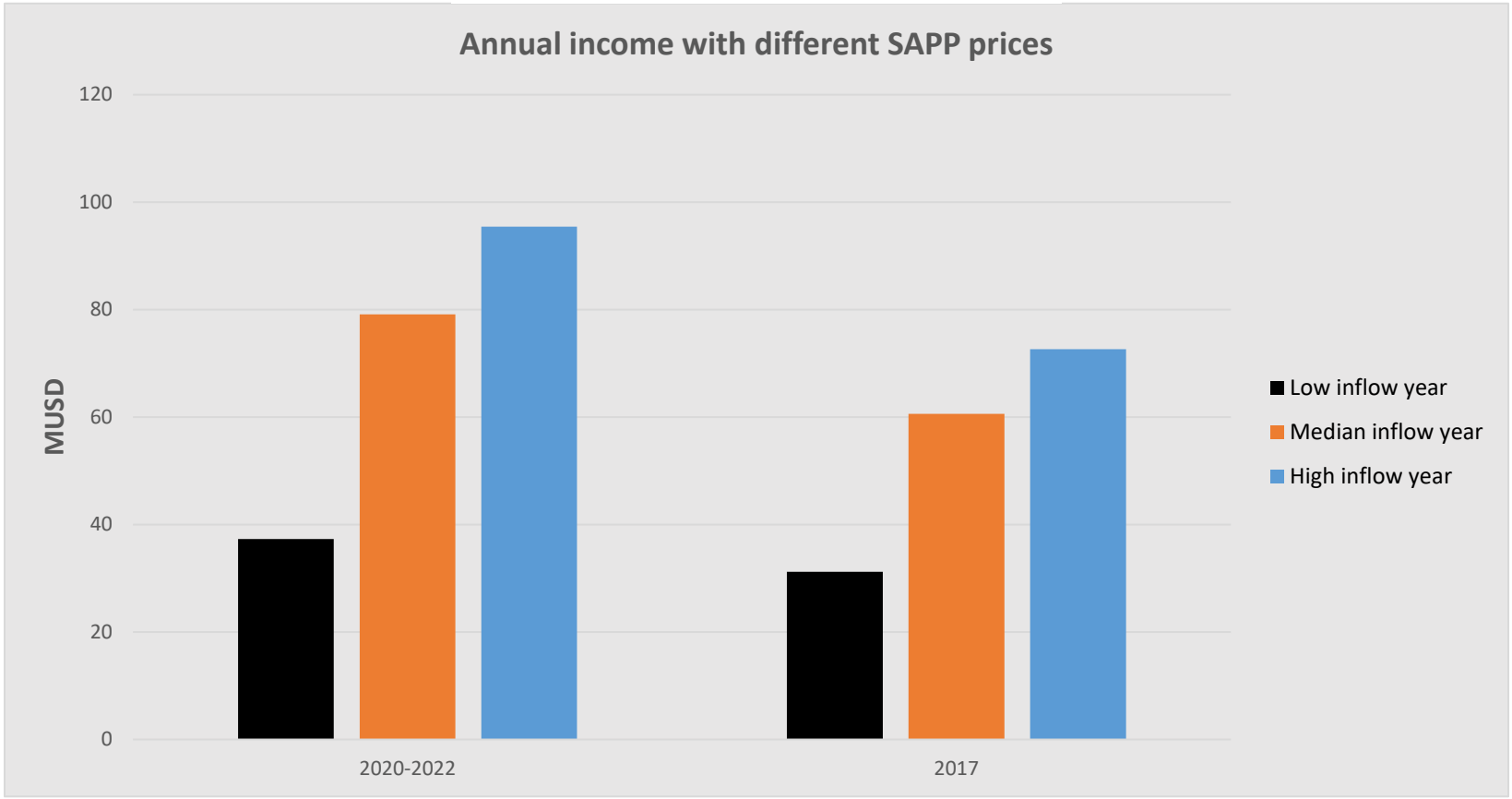
Annual income with different SAPP prices and different inflow years





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Thank you!

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