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CARIBBEAN CENTRE FOR RENEWABLE ENERGY & ENERGY EFFICIENCY

AN INSTITUTION OF CARICOM

GEA
GUYANA ENERGY AGENCY

Training of Energy Systems Personnel on Integration of Hydropower

February 25, 2021

IRRP
INTEGRATED RESOURCE AND RESILIENCE PLANS

SUPPORTED BY

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DEUTSCHE ZUSAMMENARBEIT

IMPLEMENTED BY:
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Introducing

Tobias Dertmann

Hydropower Engineer (M.Sc. Mechanical Engineer)
Consultant (Hydropower / Hydro Pumped Storage)
Germany

Working for Guyana Energy Agency (GEA) since 2016
(German Development Agency, GIZ)

Located in Georgetown from 2016 – 2018 (GEA)

Responsible for Capacity Building in the Agency and Developing of Hydropower Project in Guyana

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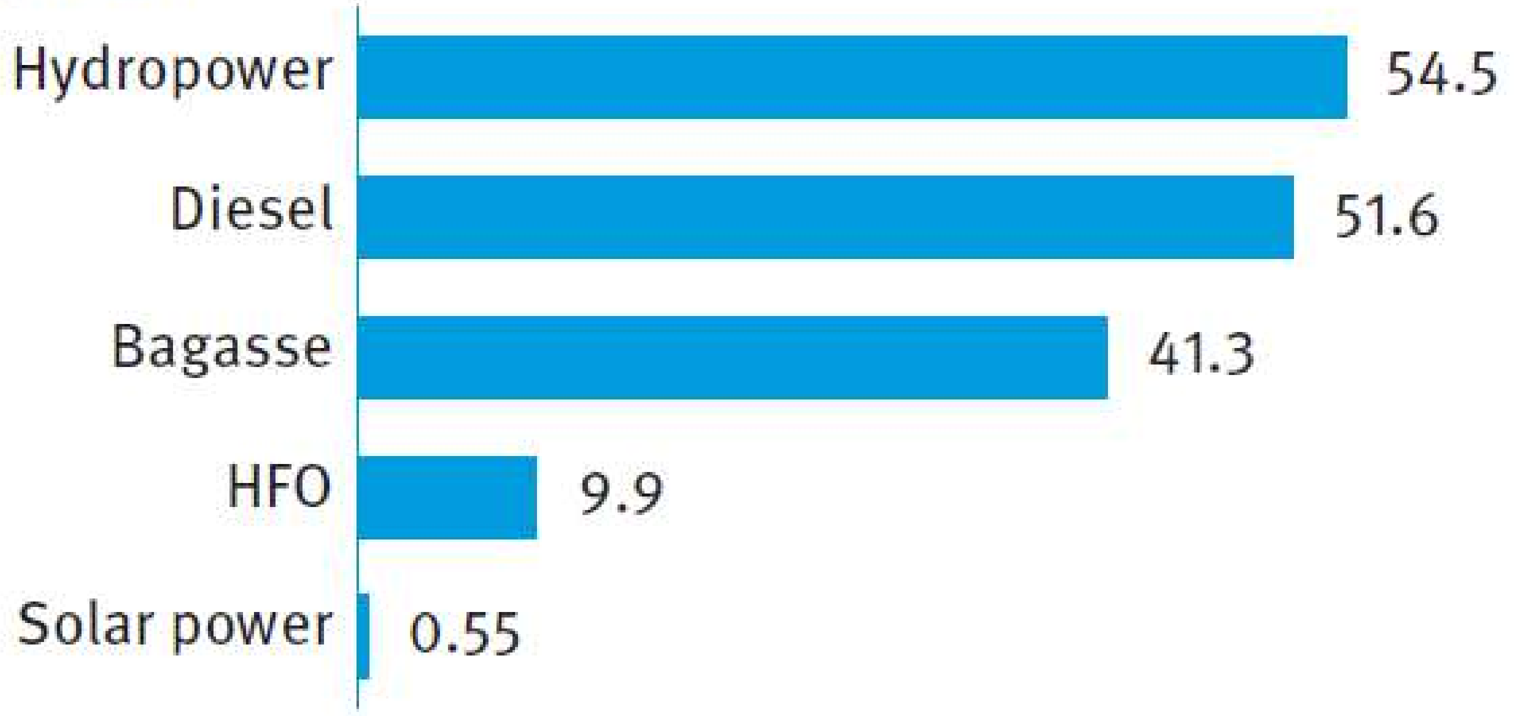
Overview of countries in the Caribbean

Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Cuba	11.5	23	100	6,407	20,459	66	64
Dominica	0.07	30	100	27	112	7	36
Dominican Republic	10.6	20	99	3,460	15,892	616	1,510
Grenada	0.1	64	92	51	223	0	0
Guadeloupe	0.4	2	N/A	573	1,791	11	34
Haiti	11.0	46	39	349	1,089	61	131
Jamaica	2.7	45	98	941	4,363	30	157
Puerto Rico	3.7	6	85	6,161	16,372	100	51
Saint Lucia	0.2	81	98	91	400	0	0
Saint Vincent and the Grenadines	0.1	48	97	58	166	7	37
Total	**40.4**	-	-	**18,118**	**60,867**	**898**	**2,020**

Source: *WSHPDR 2016*,[2] *WSHPDR 2019*,[3] WB,[4] WB[5]

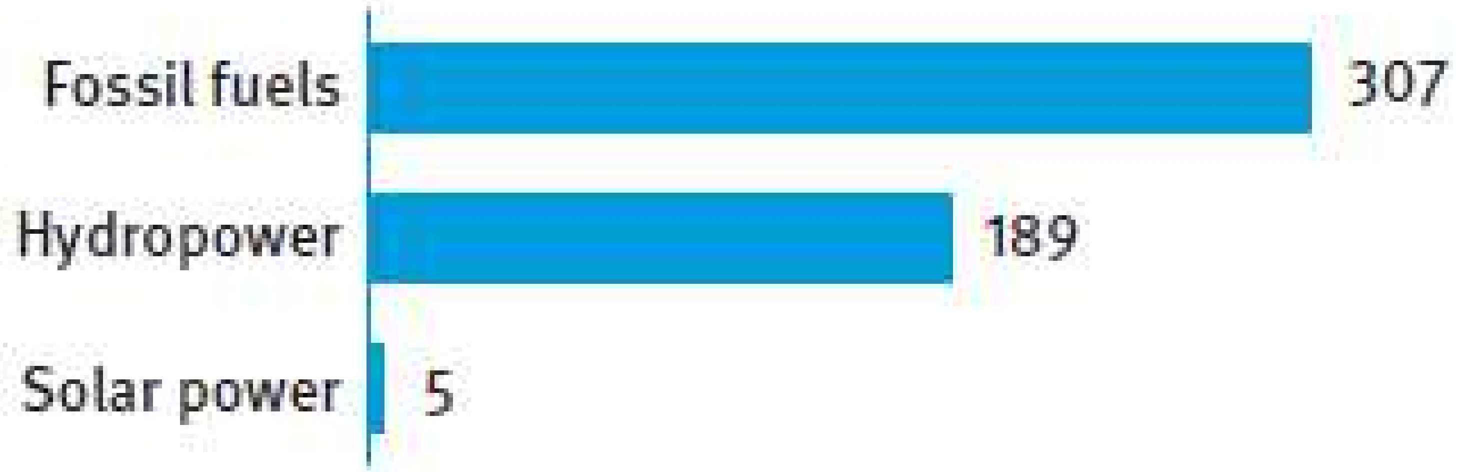
Introducing

Installed electricity capacity by source in Belize (MW)



Source: BEL[4]

Installed electricty capacity by source in Suriname (MW)



Source: World Energy Council,[9] United Nations Statistics Division[10]

Small hydropower capacities 2013/2016/2019 in Guyana (MW)

Source: *WSHPDR 2016*,[5] GEA,[8] *WSHPDR 2013*[9]

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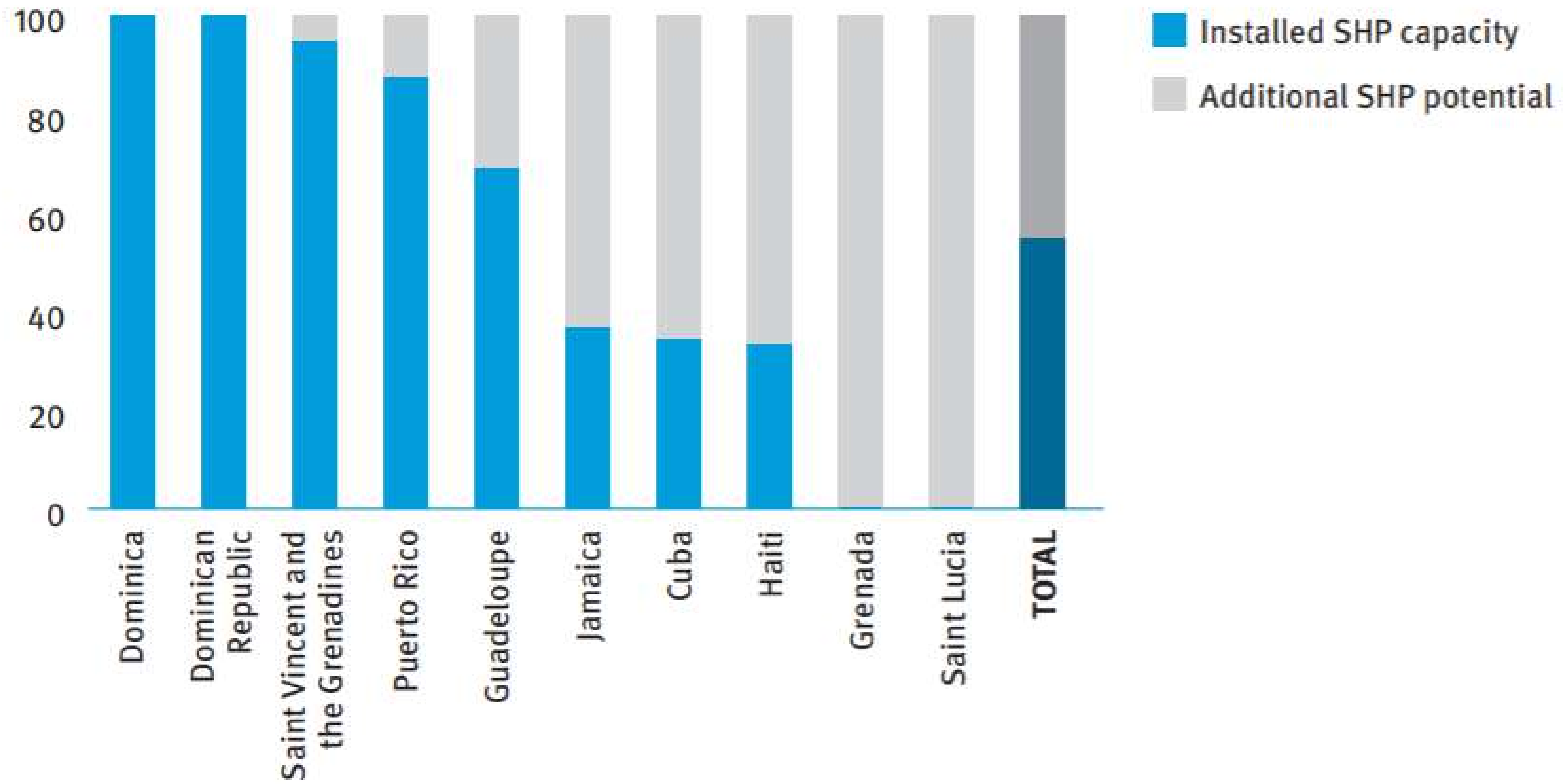
Utilized small hydropower potential by country in the Caribbean (local SHP definition) (%)



Source: *WSHPDR 2019* [3]

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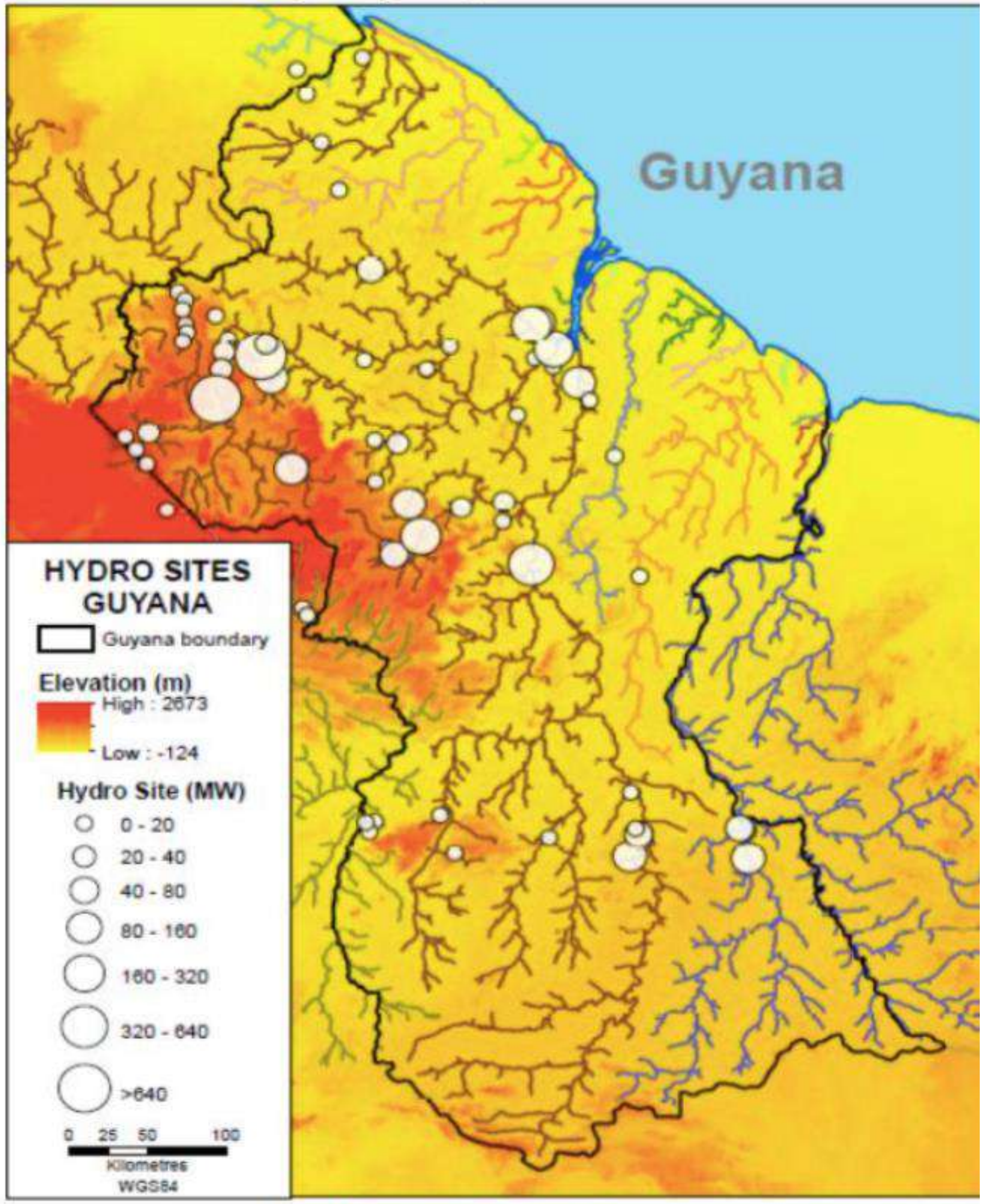
Map 7. Guyana hydroelectric resources



Source: Map processed for the study by consultant

Guyana has an explored (secured) hydropower potential of more than 7000 MW

25 MW explored potential of Small Hydropower (up to 10 MW) but several hundred MW potential in Small Hydro Power not explored (rural areas)

Guyana built its first hydropower station with 20 kW in 2019.
150 kW are under construction
2.2 MW under tendering (2021)
Further project are in the pipeline (small and large)

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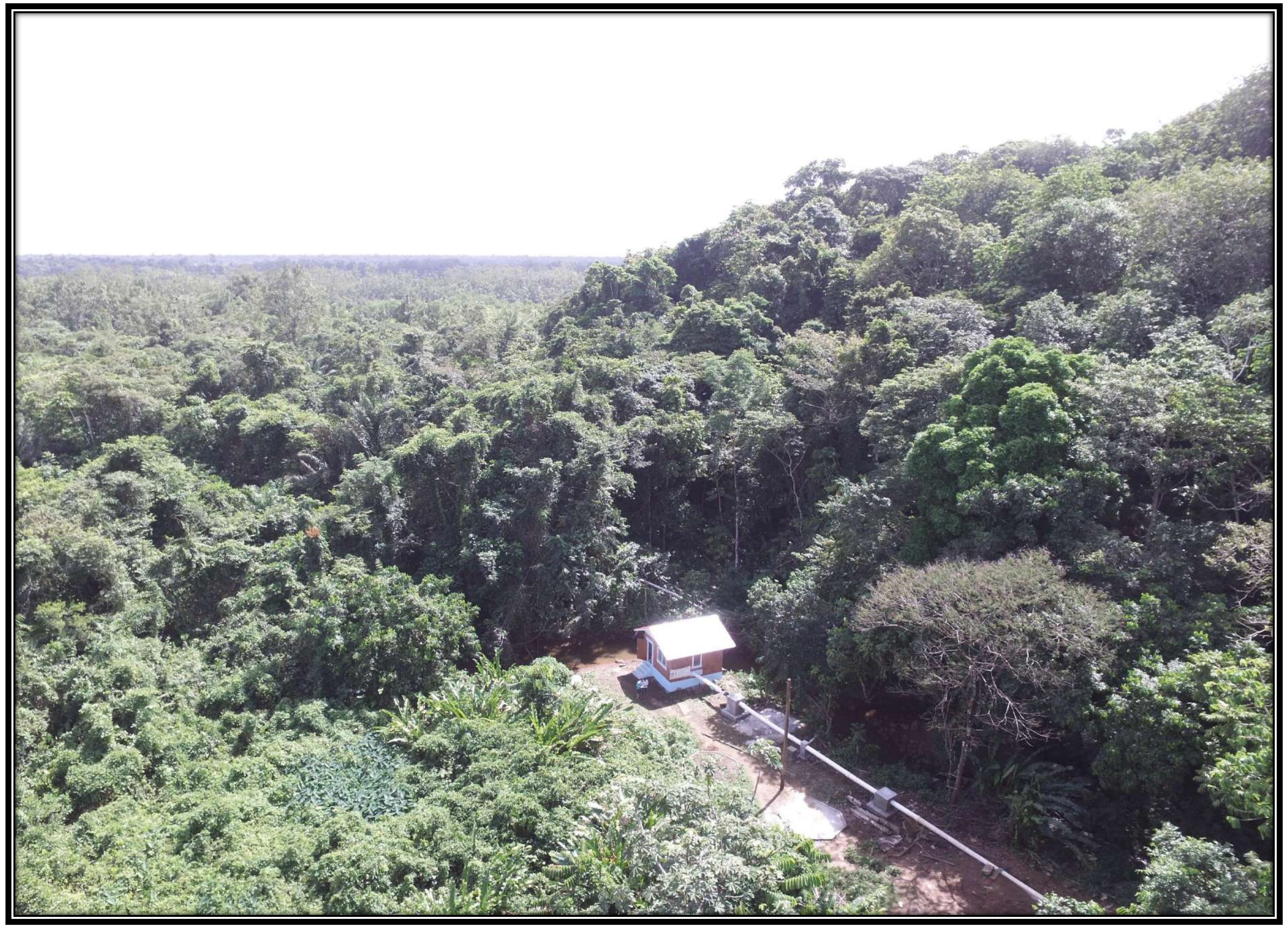


20 kW new developed “Hosororo” Hydropower Station, Region 1, Guyana
Guyana Energy Agency (GEA)

Introduction to small Hydropower Technology

Definition of Small Hydropower (Micro, Mini, Small)

Small hydro is the development of hydroelectric power on a scale suitable for local community and industry, or to contribute to distributed generation in a regional electricity grid. Precise definitions vary, but a "small hydro" project is less than 50 megawatts (MW), and can be further subdivide by scale into

- “small hydro” (~ 1 MW up to 10 MW)
- "mini" (~ 100 kW to 1MW)
- "micro" (~ 5 kW to 100 kW)
- "pico" (~ <5 kW)

The use of the term "small hydro" varies considerably around the world

Introduction to small Hydropower Technology

In contrast many hydroelectric projects are of enormous size, such as the generating plant at the Three Gorges Dam at 22,500 megawatts.

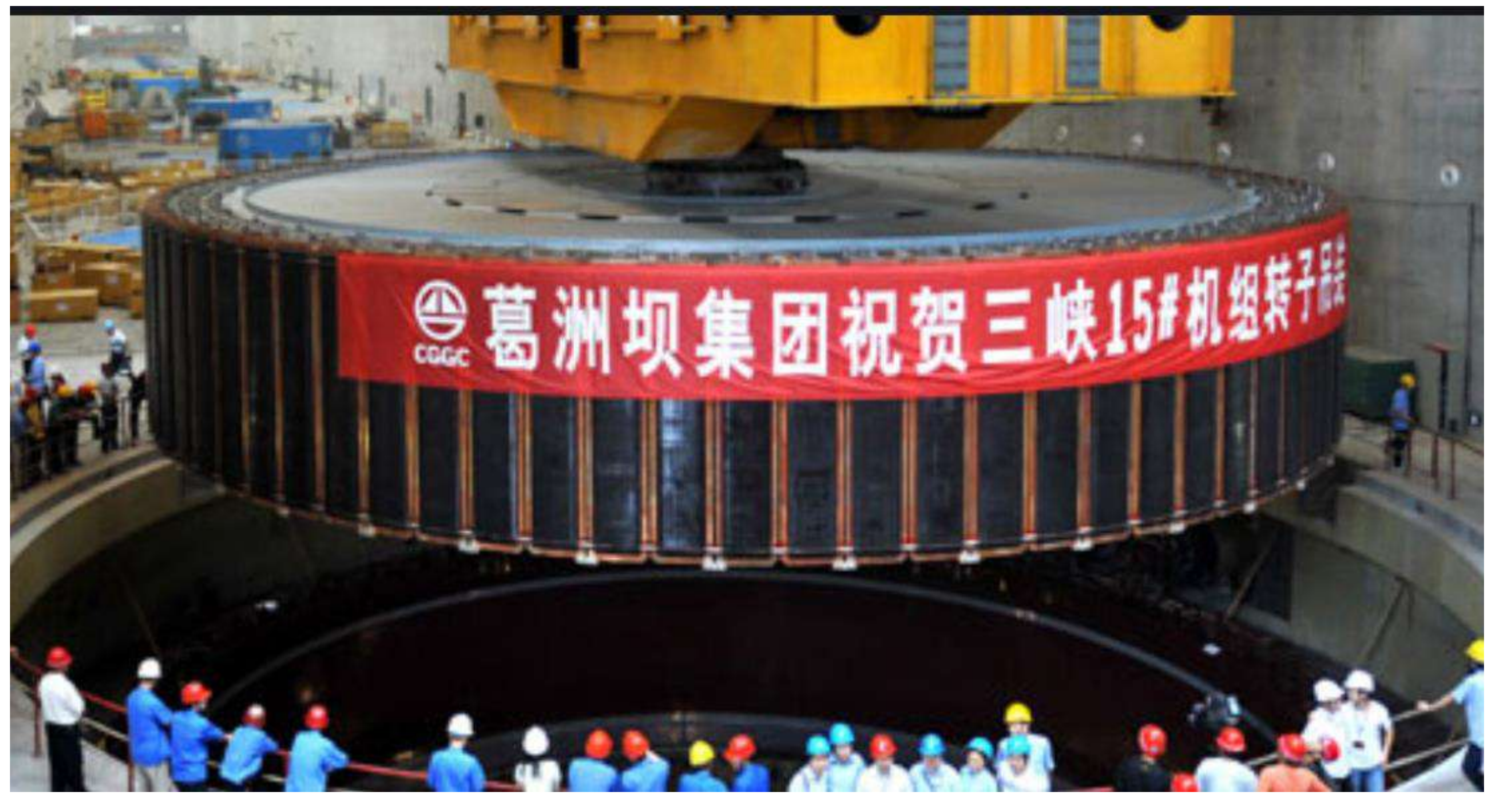
Small hydro projects may be built in isolated areas that would be uneconomic to serve from a national electricity grid, or in areas where a national grid does not exist.

22,500,000 kW (large hydro)

1 and 2 kW (pico/small hydro)

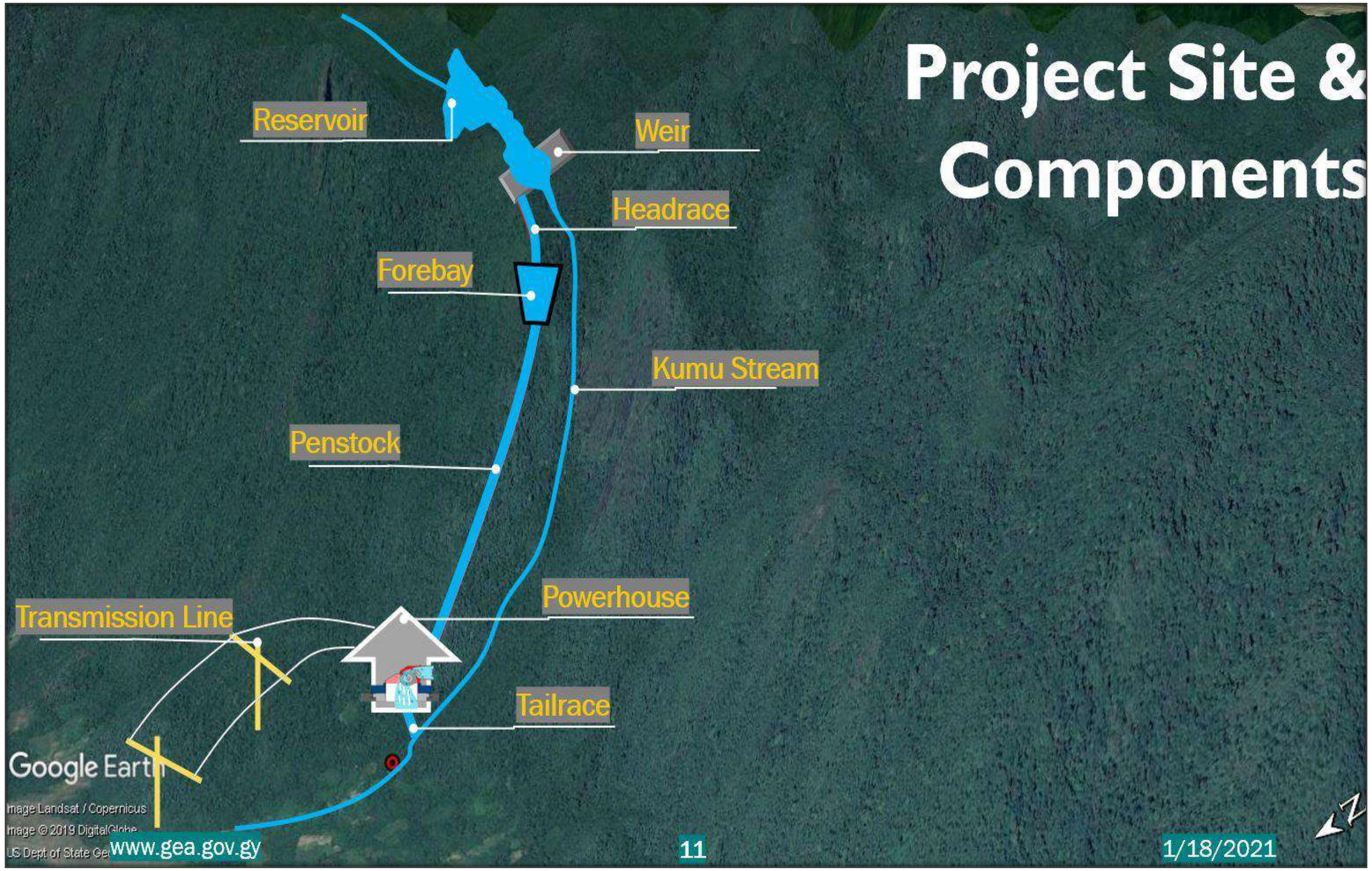
Introduction to small Hydropower Technology

Difference between large and small hydro
Compare to
Difference between large and small PV systems



Example Small Hydro (~ 1 MW up to 10 MW)

1.5 MW Kumu Hydropower Station
Region 9, Guyana (Tendering 2021)



Example Mini Hydro
(~ 100 kW to 1 MW)

700 kW Moco Moco Hydropower Station
Region 9, Guyana (1999, under Rehabilitation)

Example Micro Hydro

20 kW Hosororo Hydropower Station
Region 1, Guyana (2019)

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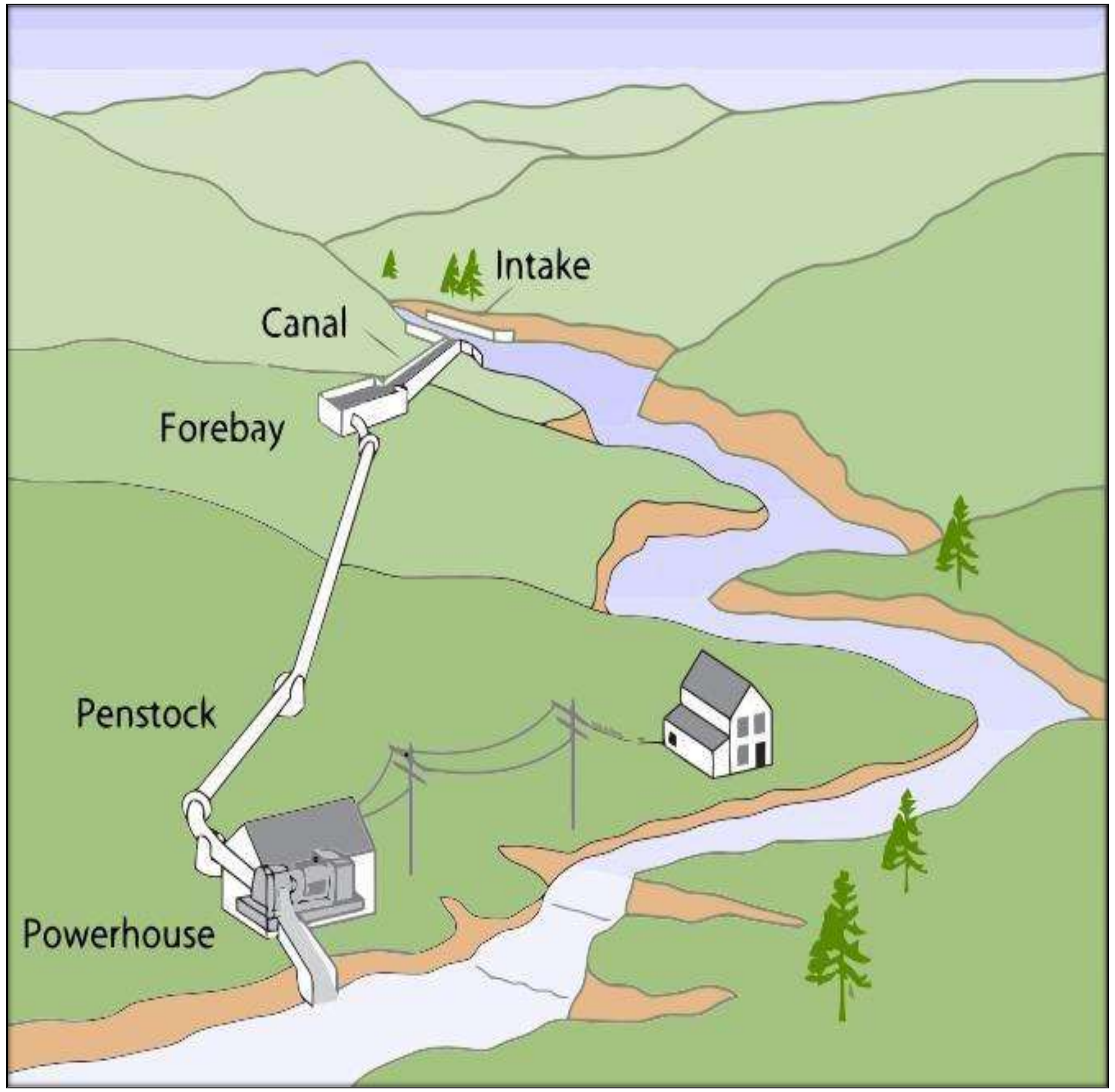
Example Pico Hydro

5 kW (Type: Flow Turbine)
(planed near Kaieteur Falls, Guyana)

Types of Hydropower Plants

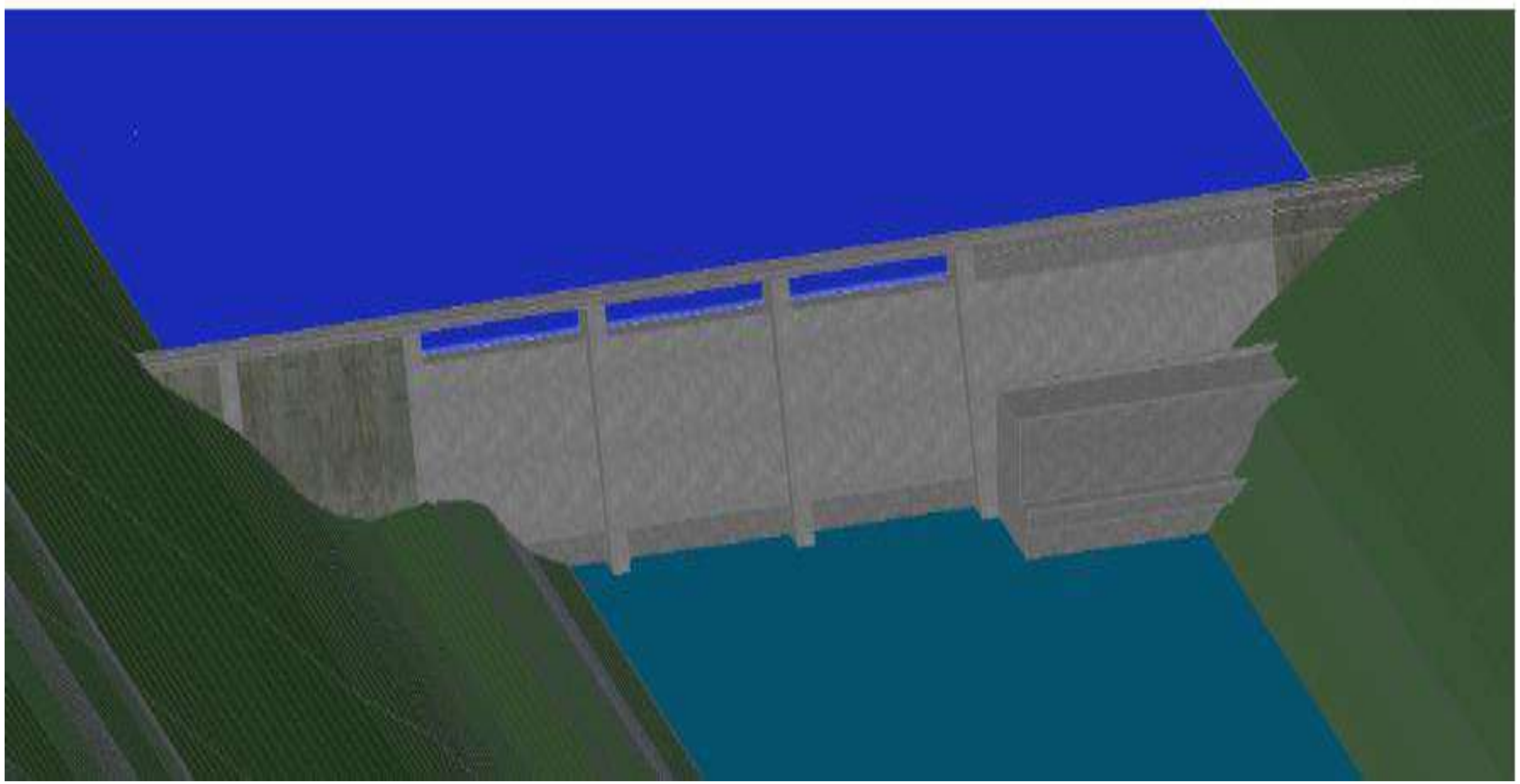
- Run of River and with Reservoir (Storage)
- High (up to 1000 m) and Low Head (5 m)
- Turbine Types: Pelton, Francis, Kaplan (Main Types)

Example 1: Run of River Systems (high head)



Typical Run-of-the-Rivers Hydro-Station (source: resarchgate.net)

Example 2: Run of River, low head : 12 MW Tiger Hill, Guyana (Feasibility Study)



12MW "Tiger Hill", Run-of-River Plant, Guyana (GEA)

Example 2: Run of River Systems: 12 MW Tiger Hill, Guyana (Feasibility Study)

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Example 2: Run of River Systems: 12 MW Tiger Hill, Guyana (Feasibility Study)

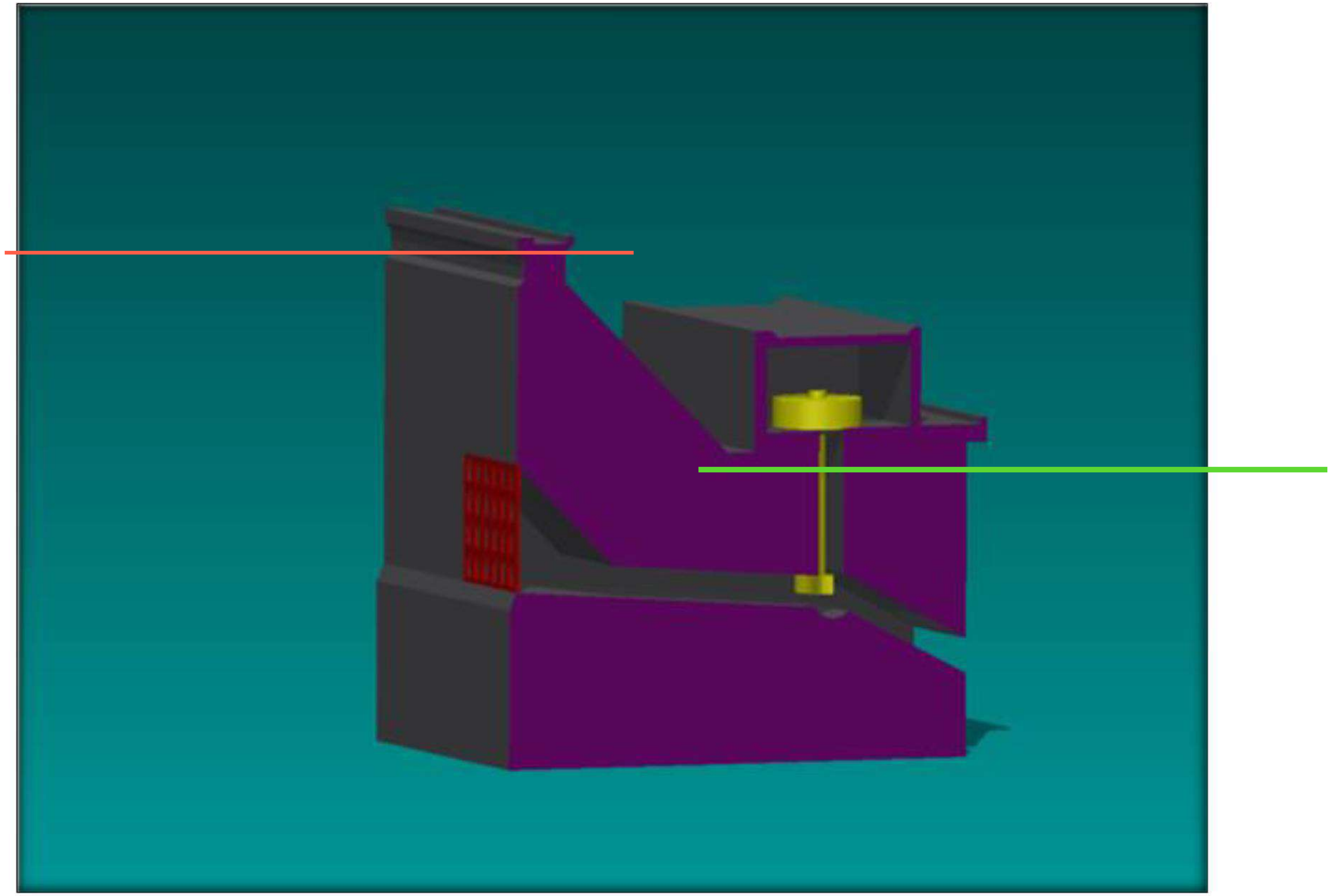

Figure 24, Integrated Power House (with trash rack, turbine, generator, without inlet gate and valve)

Example 2: Run of River Systems: 12 MW Tiger Hill, Guyana (Feasibility Study)

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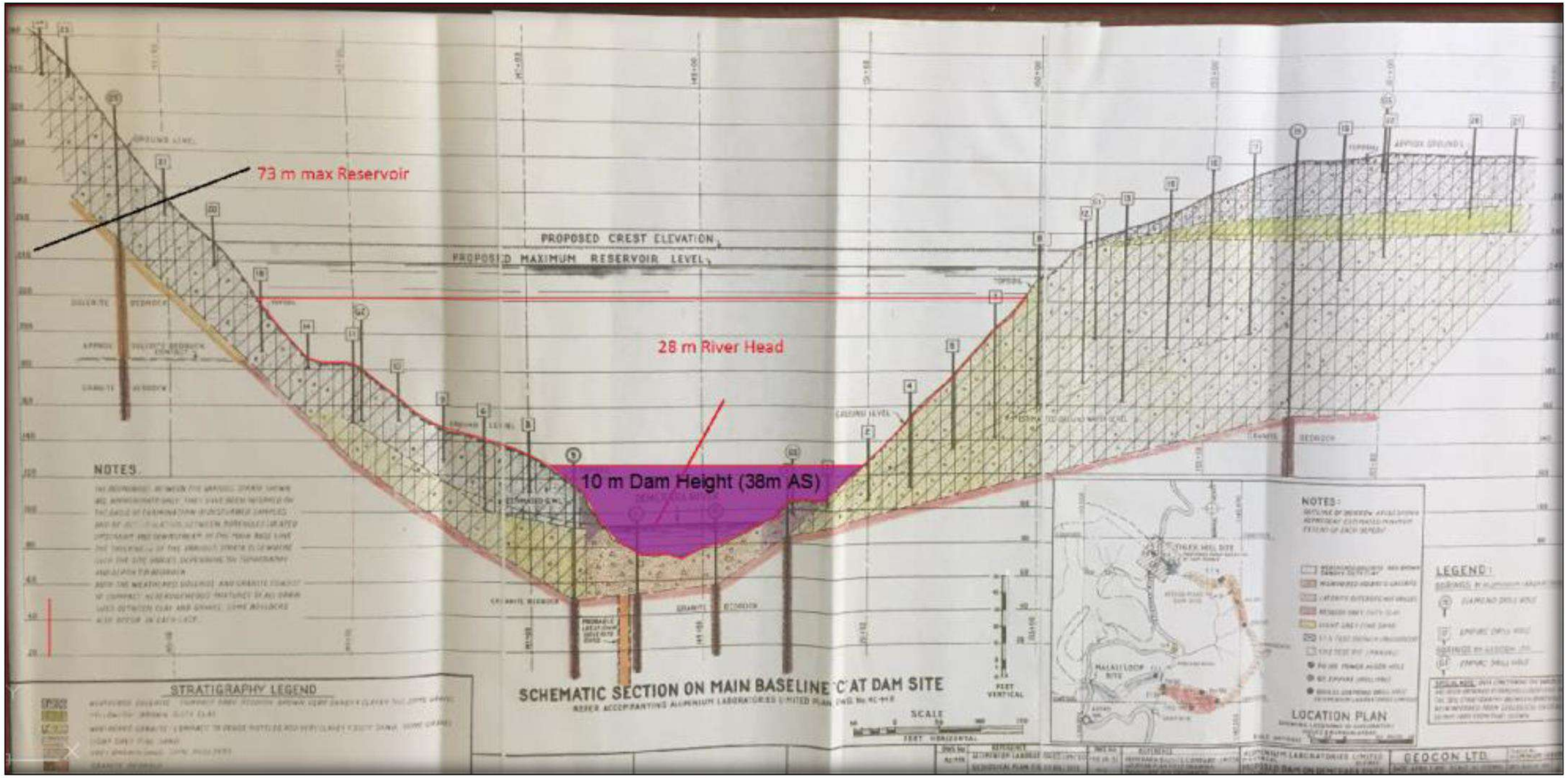

Figure 23, Illustration of the 10 m dam and comparison with the original planed 50 m dam (DEMBRA Study, GEA)

Example 2: Run of River Systems: 12 MW Tiger Hill, Guyana (Feasibility Study)

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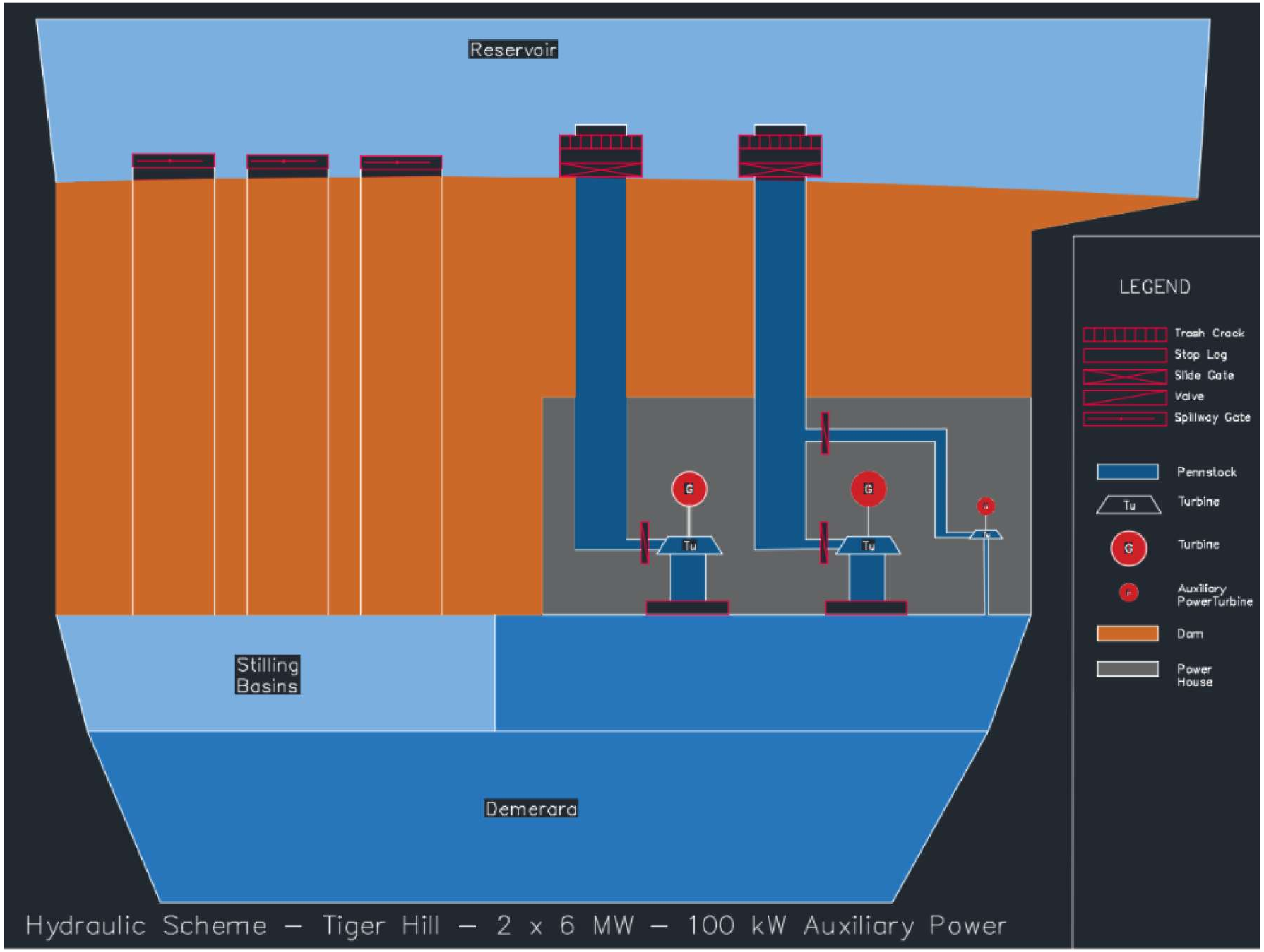
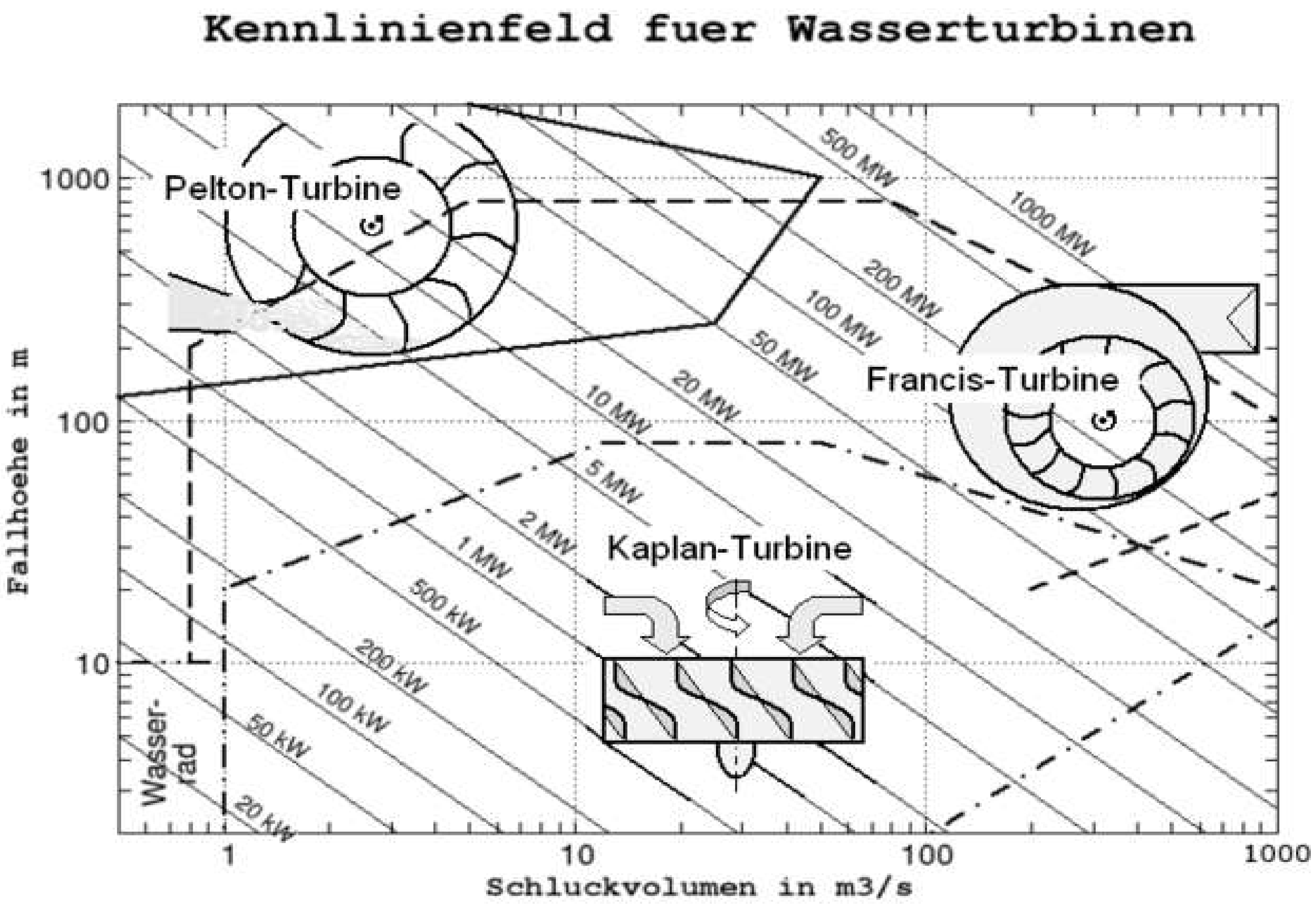


Types of Hydropower Turbines

Hydropower Turbine-Types can be divided in three main Types:



source: Wikipedia

Types of Hydropower Turbines

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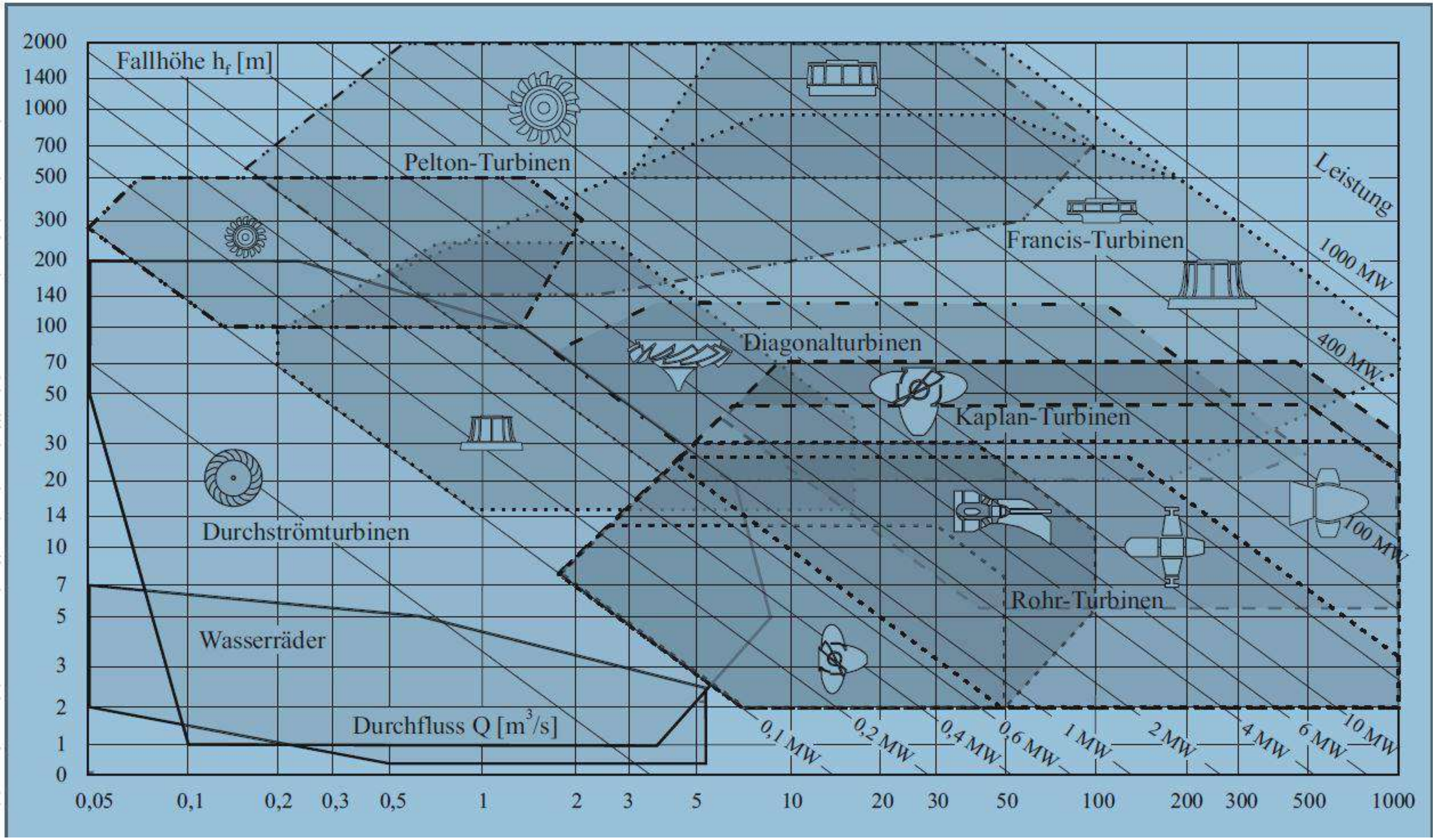

source: book “Wasserkraftanlagen“
Giesecke Mosonyi

Types of Hydropower Turbines

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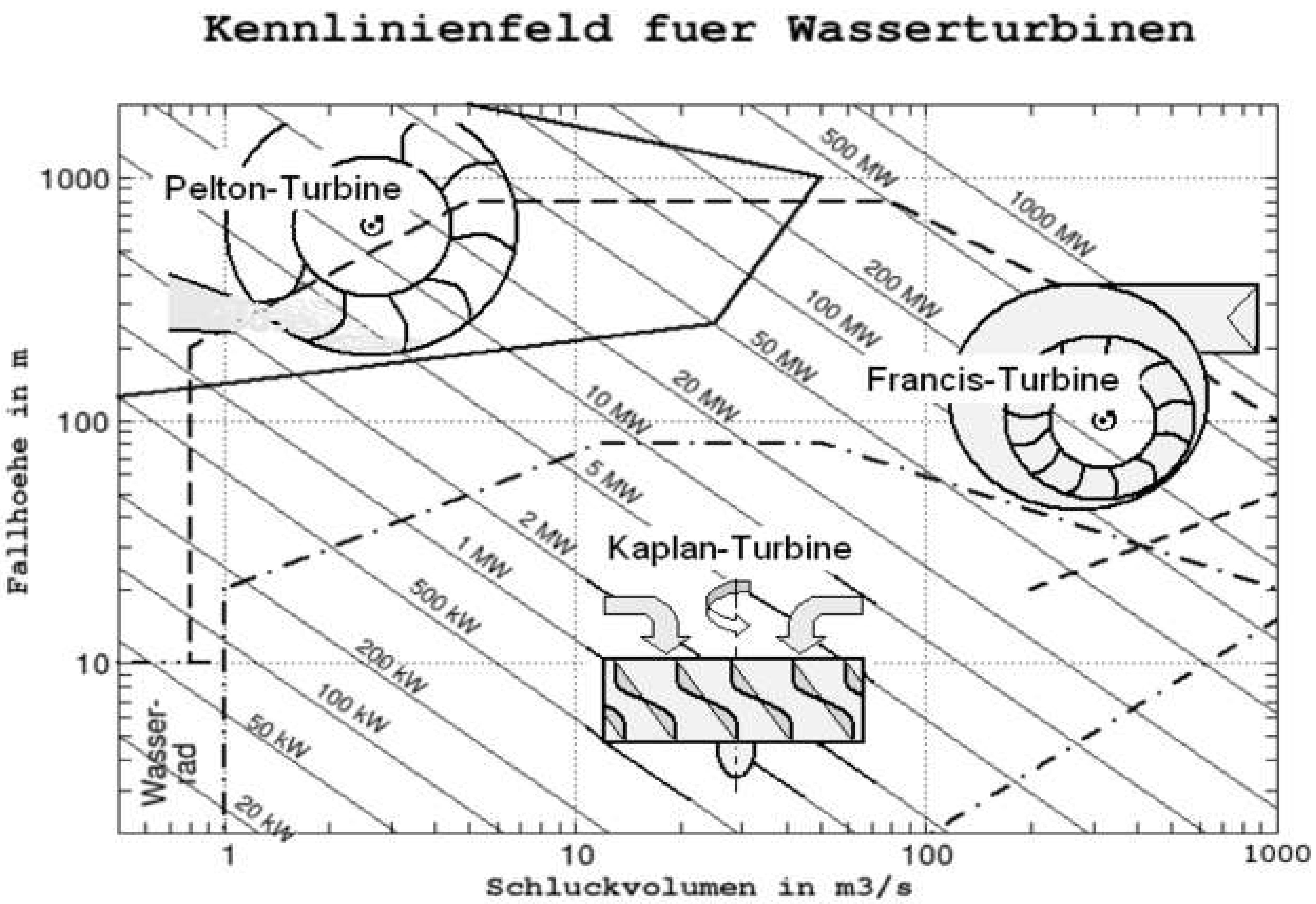
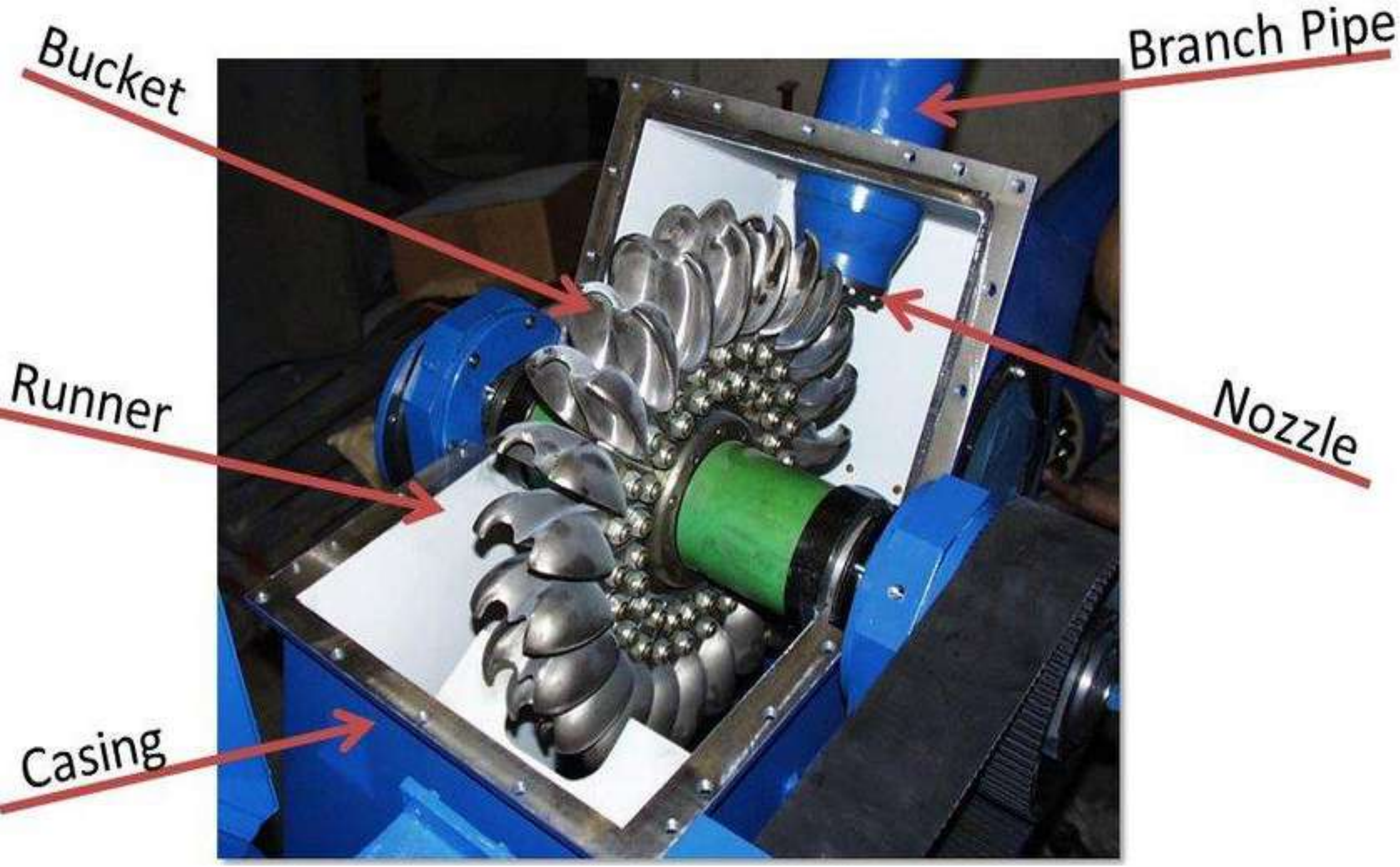


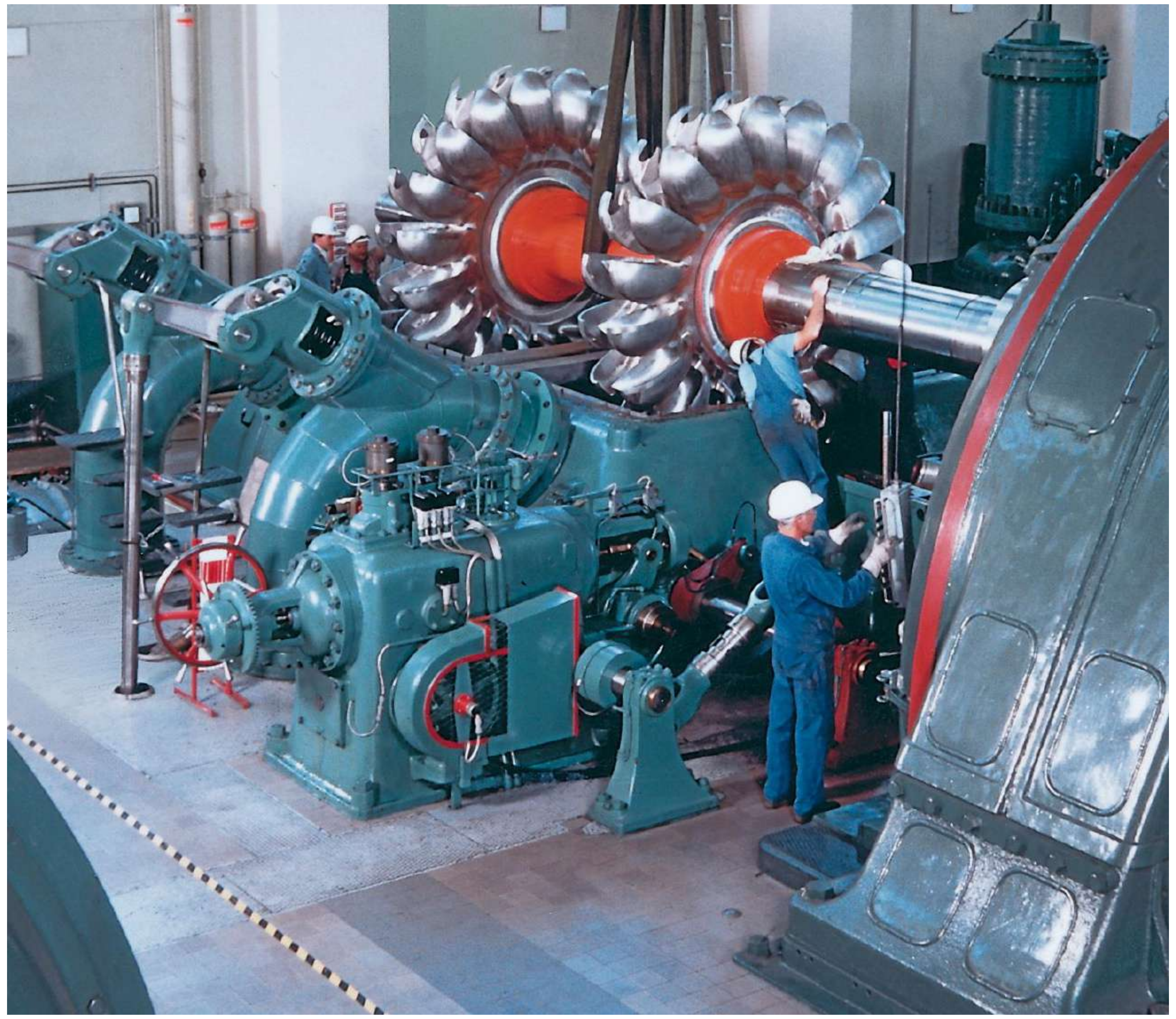
source: Wikipedia

Pelton Turbine (1879 by Lester Pelton)

High head >> 100m up to 1000m – IMPULSE TYPE



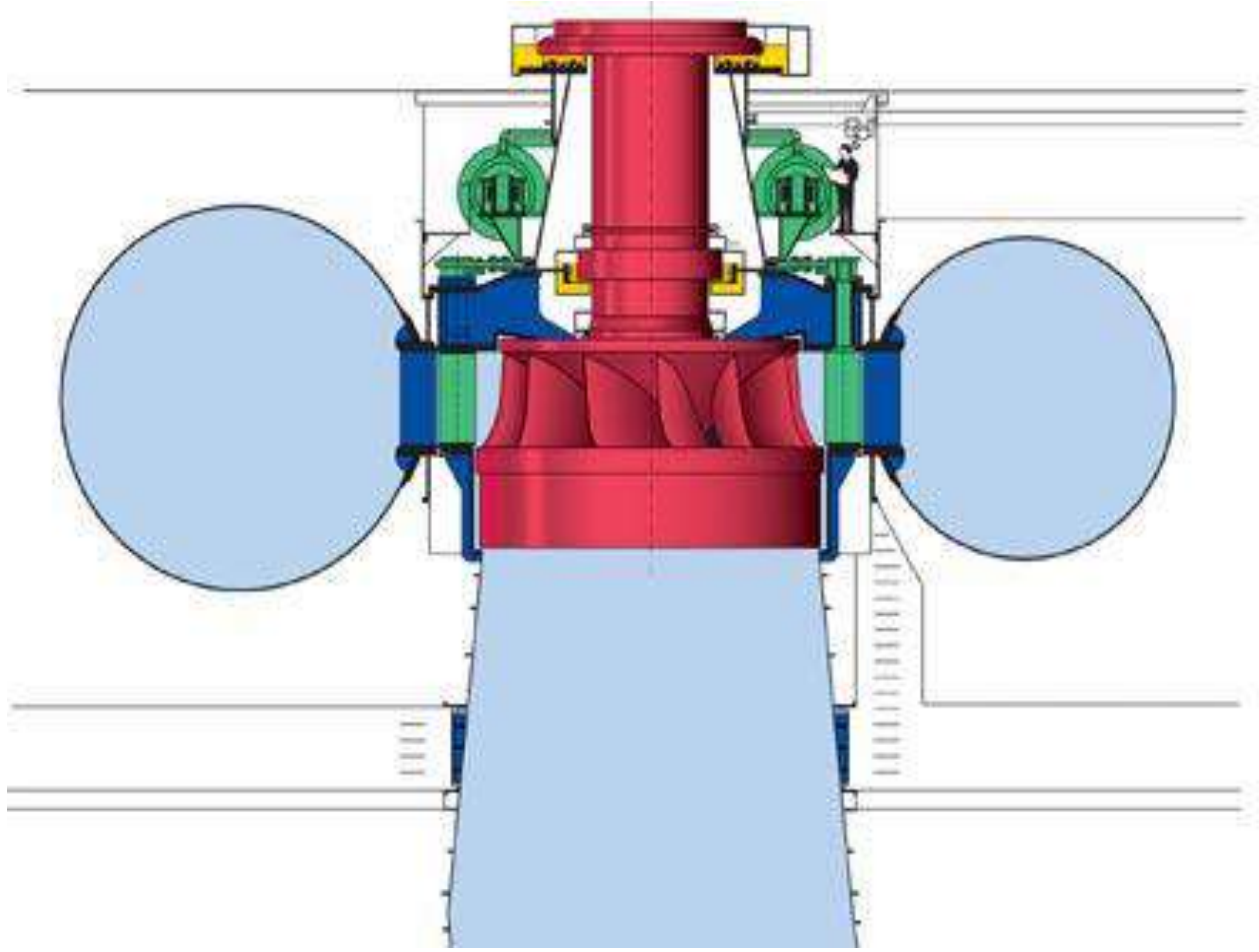
source: resarchgate.net

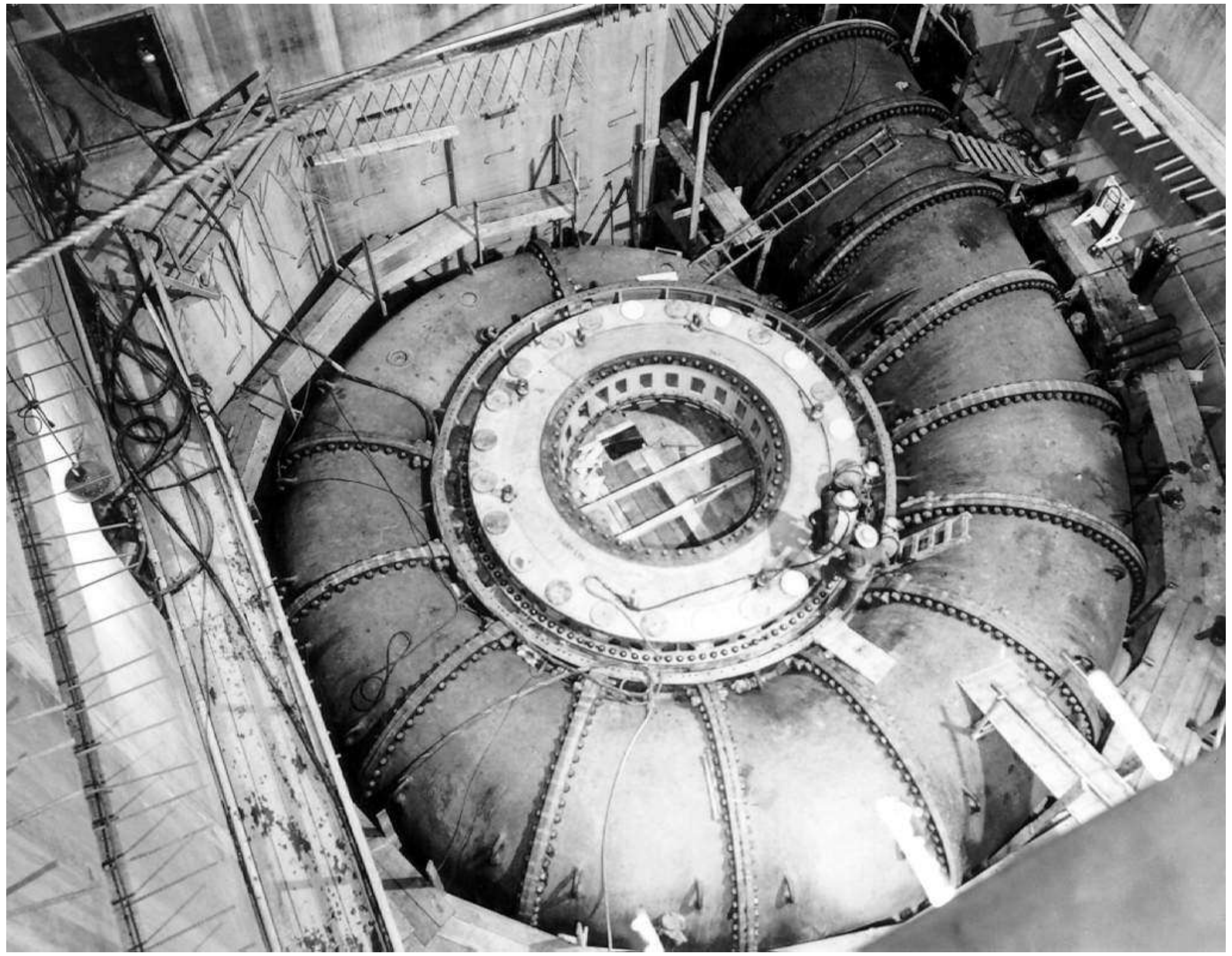


source: Wikipedia (large Pelton Turbine

Francis Turbine
(by James Francis 1848)

Medium and High Head and Medium and High Flow

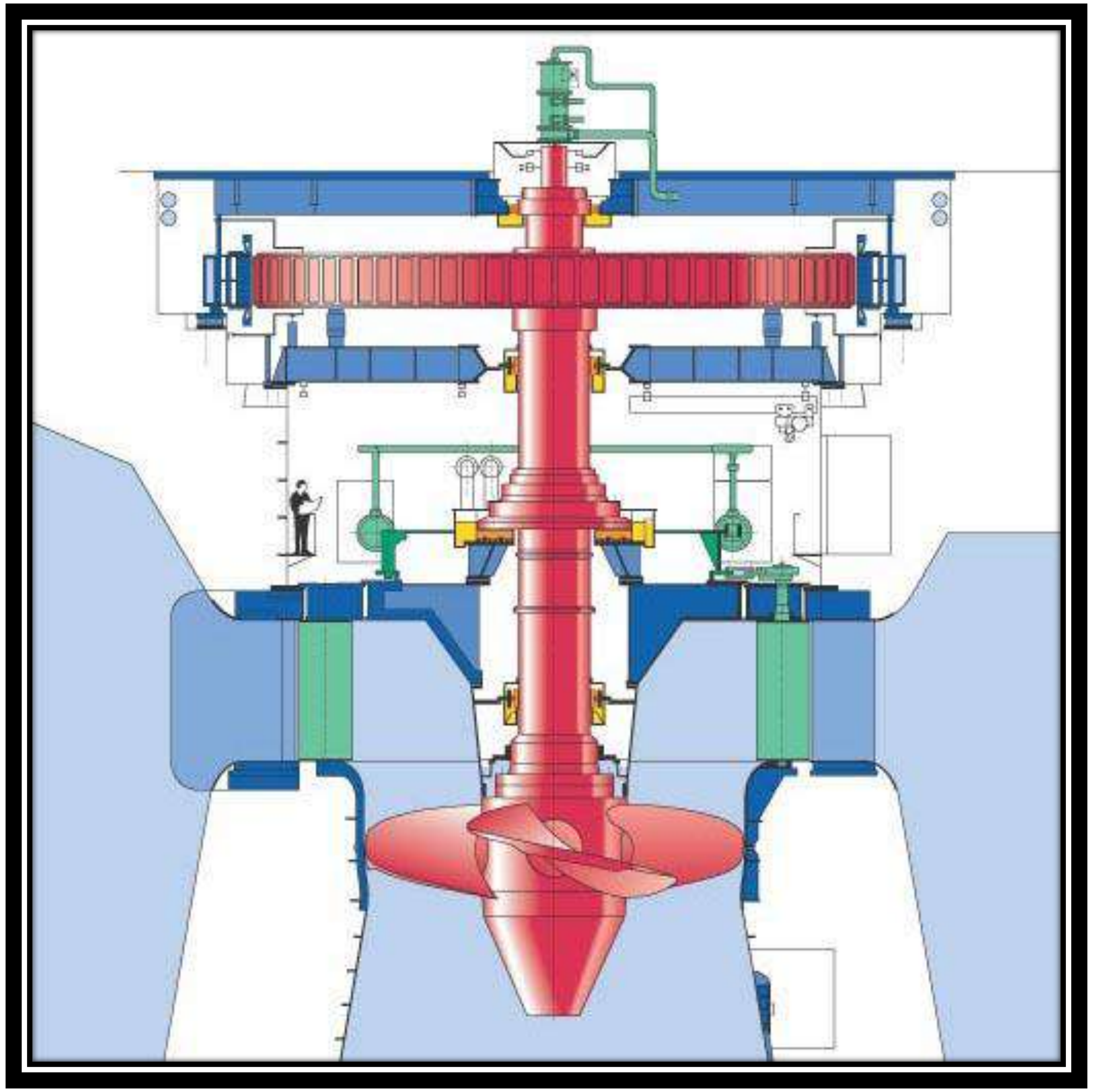




source: Wikipedia

source: Wikipedia

Kaplan Turbine by Victor Kaplan 1913
low head, high flow
efficiency up to 95%



source: Voith-Siemens

Unique features of hydropower technology compared to other types of renewable energies

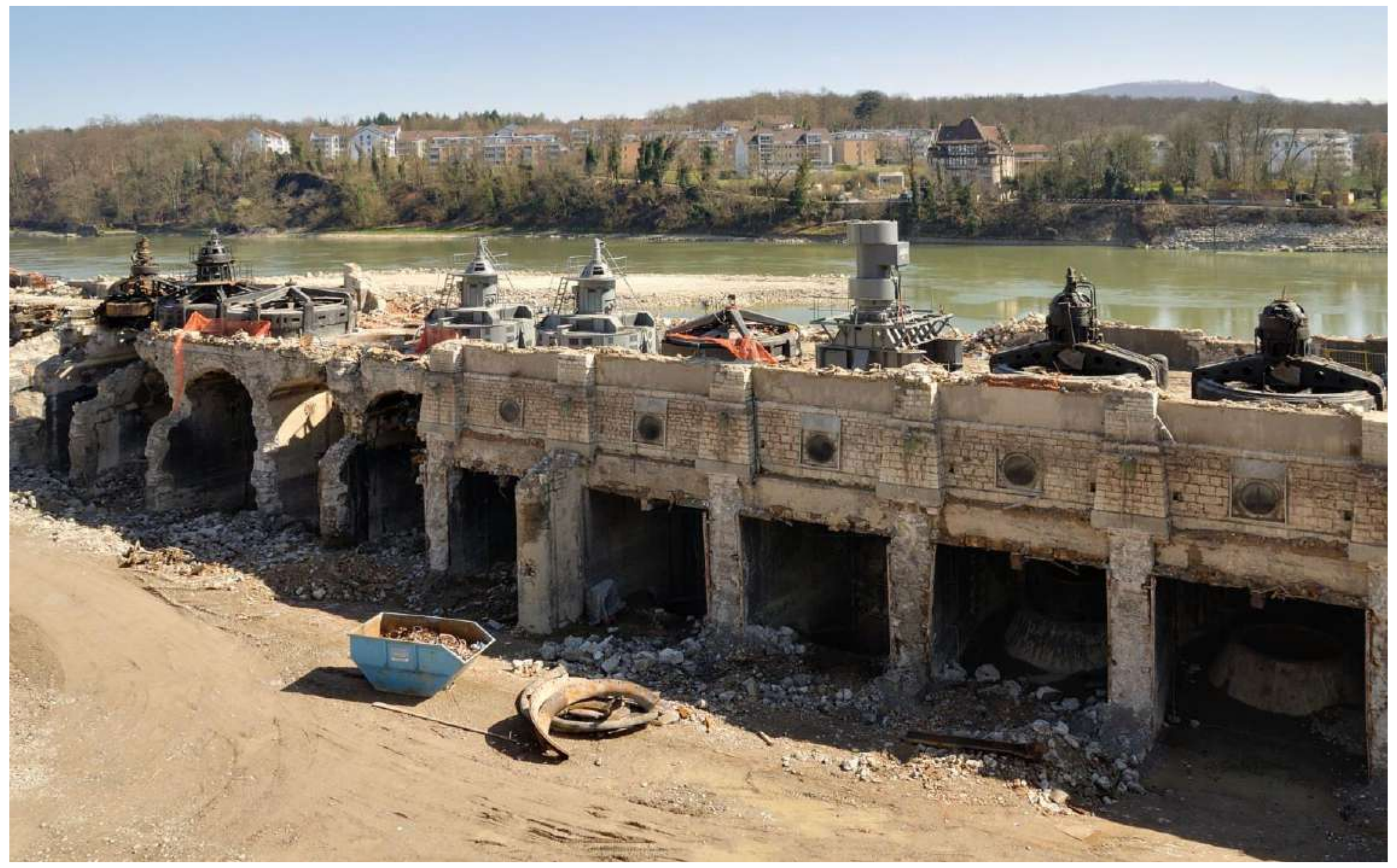
- Lifetime
- Rotating Masses for Net Stabilization
- Power Regulation
- Long Term Storage

Lifetime

Example: Run-of-River plant “Rheinfelden” – Germany (10 MW)
1889 – 2011 (122 years of continuous operation!)
The old powerhouse was closed due to a new construction because of the relocation by 300m


1887 Construction


2010 – last year of operating


Demolition after 122 years

hydropower plants can have an unlimited lifetime with maintenance work

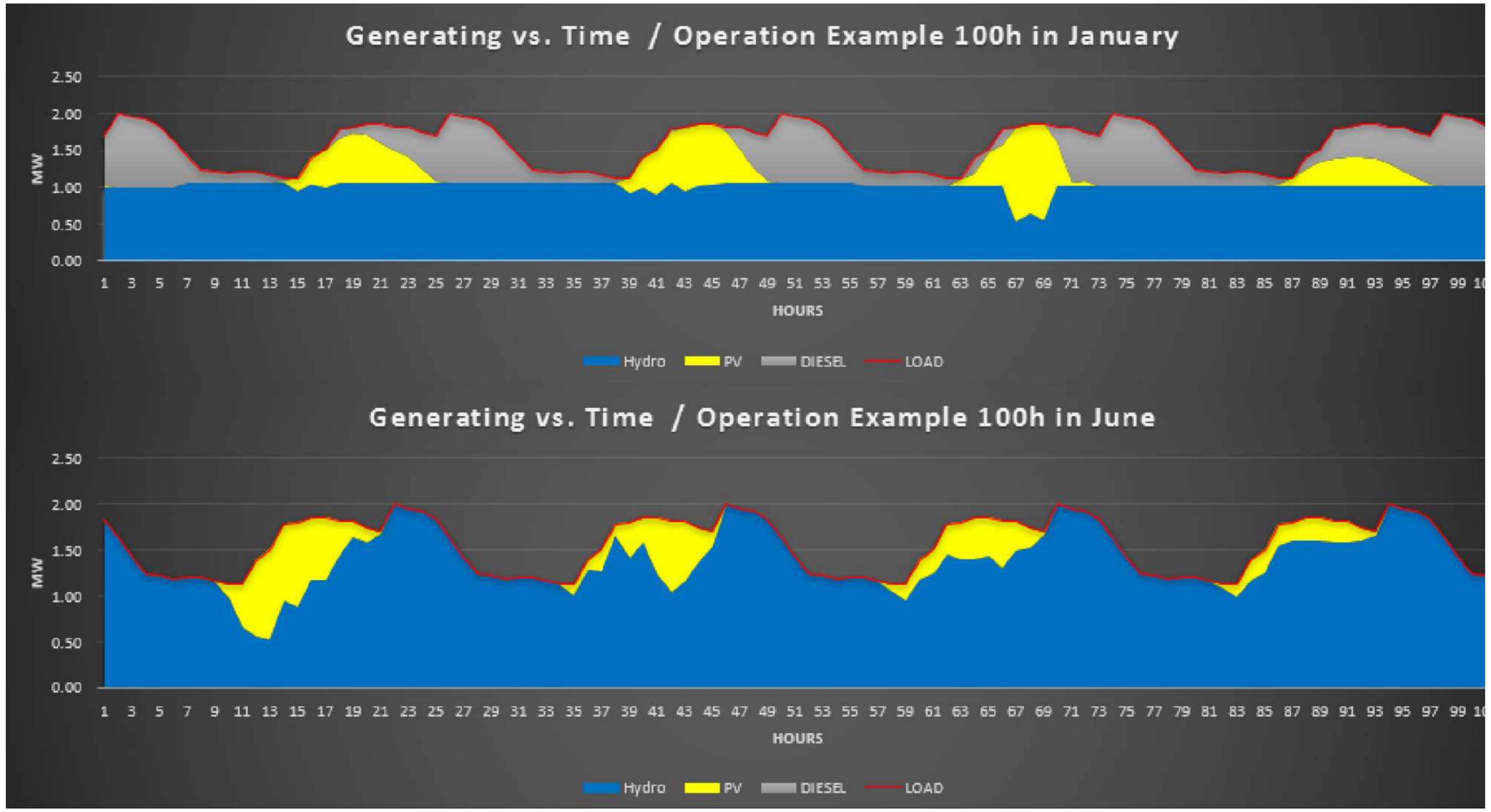
Rotating Masses for the Net Stabilisation

Rotating generators from hydropower plants can replace the flywheel masses and the moment of inertia of conventional generators (diesel, coal, gas). Flywheels are important for grid stabilisation and are becoming increasingly important in grids with a high share of renewable energies (REACTIVE POWER)

Extreme Large Rotating Mass of a Kaplan Turbine/Generator Unit

Power Regulation

Even run-of-river power plants have a certain storage volume. This means that the output of hydropower plants can be regulated over a wide range and can adapt to fluctuating demand and generation. This can be a period of seconds/minutes. With seasonal storage, the adjustment is even feasible over months. Fluctuating non-regulatable renewable energies such as solar and wind power can be optimally balanced in combined operation with hydropower



Small Hydro Simulation with PV/Diesel (GEA, 2MW Simulation)

Long Term Storage (passive storage)

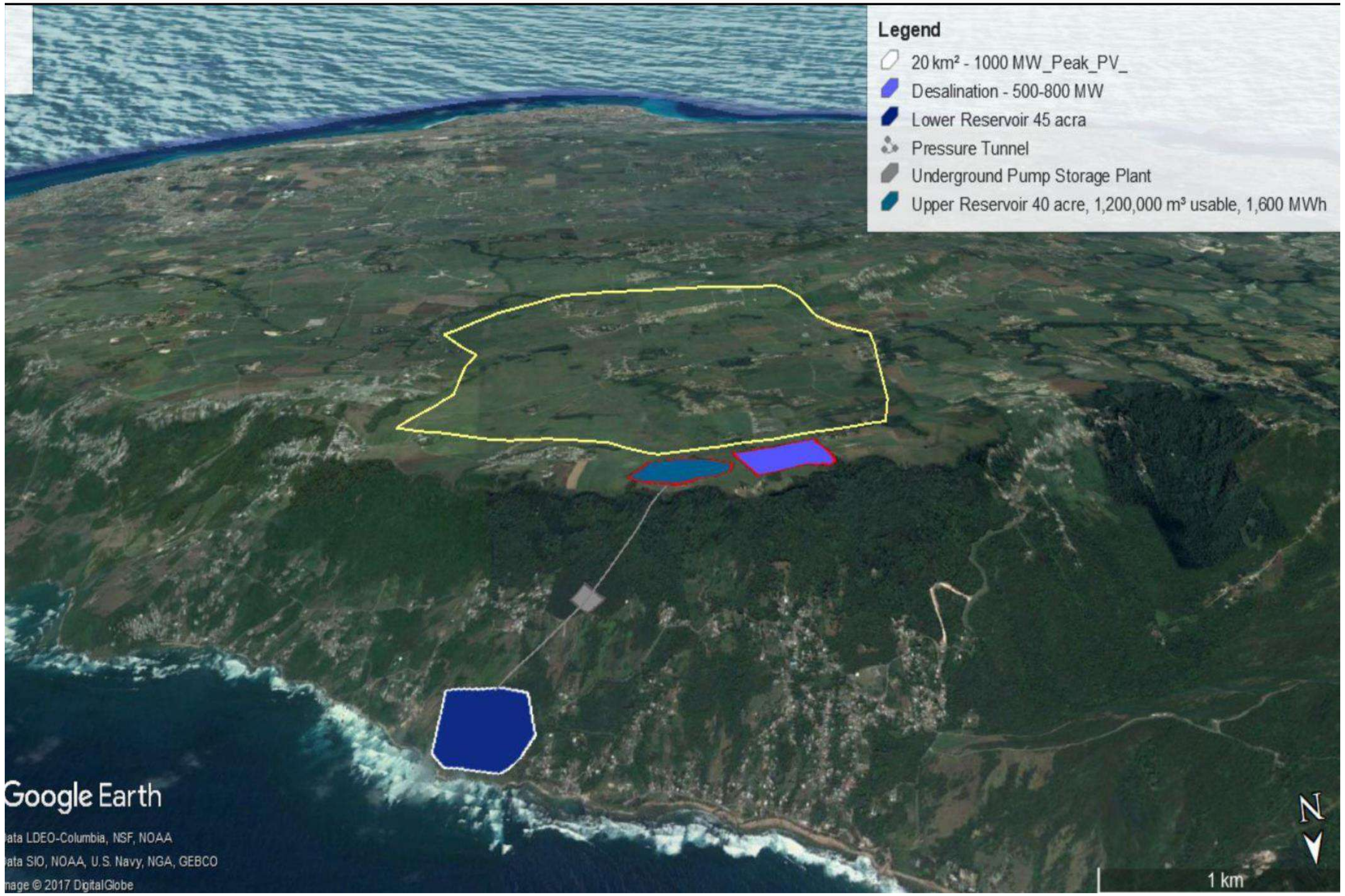
Hydropower Plants with large water reservoirs are able to storage energy for weeks and months (seasonal long/term storage). When becoming a 100% renewable energy system it will be necessary to implement large amounts of energy storage capacities.
The Brokopondo Reservoir in Suriname is on the biggest in the world
1560 km² surface with 20 billion cubic meter of water volume.

180 MW Hydropower Plant in Suriname with the large Brokopondo Reservoir (source:_GEA)

Suriname (Wikipedia)

Pumped Storage (active Storage)

Example: 100% Renewable Energy Storage for Barbados (Simulation)



Layout and Dimensions for a 1 GW PV-Peak and Pumped Storage System (Barbados, 2018)

Pumped Storage (active Storage)

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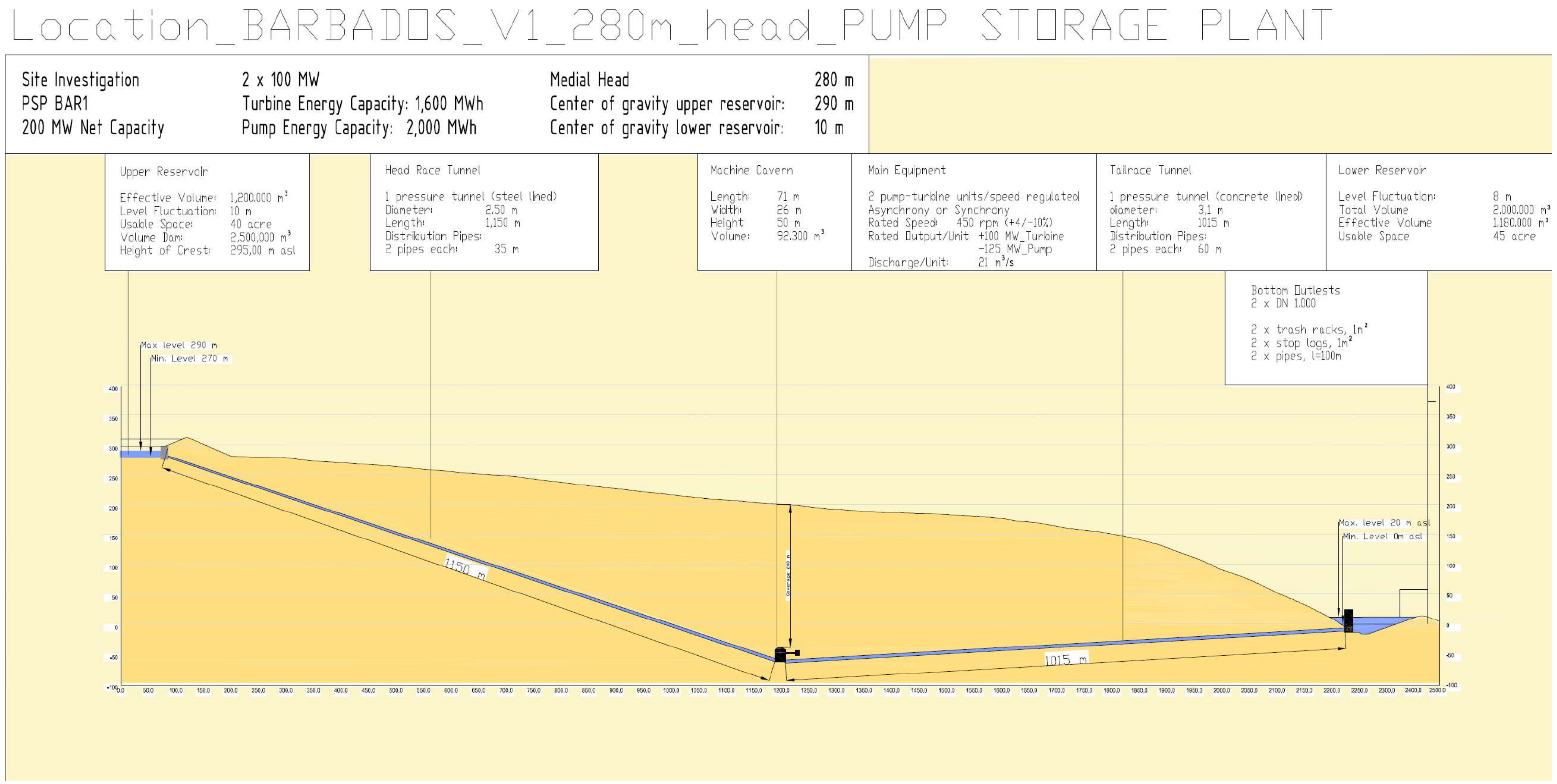
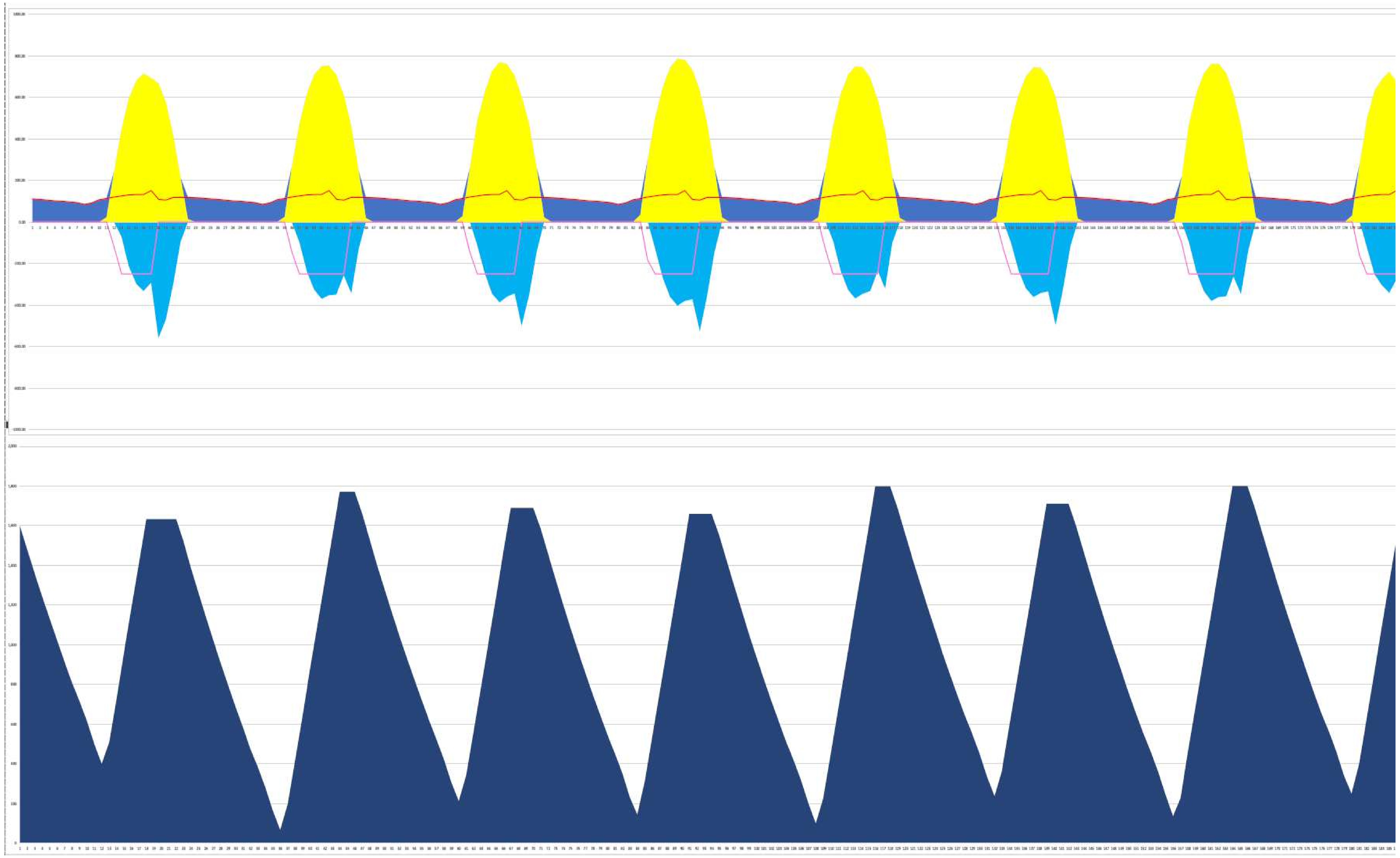
Example: 100% Renewable Energy Storage for Barbados (Simulation)



Cross-section and Main Parameter of the Barbados Pumped Storage System (2018, Tobias Dertmann)

Pumped Storage (active Storage)

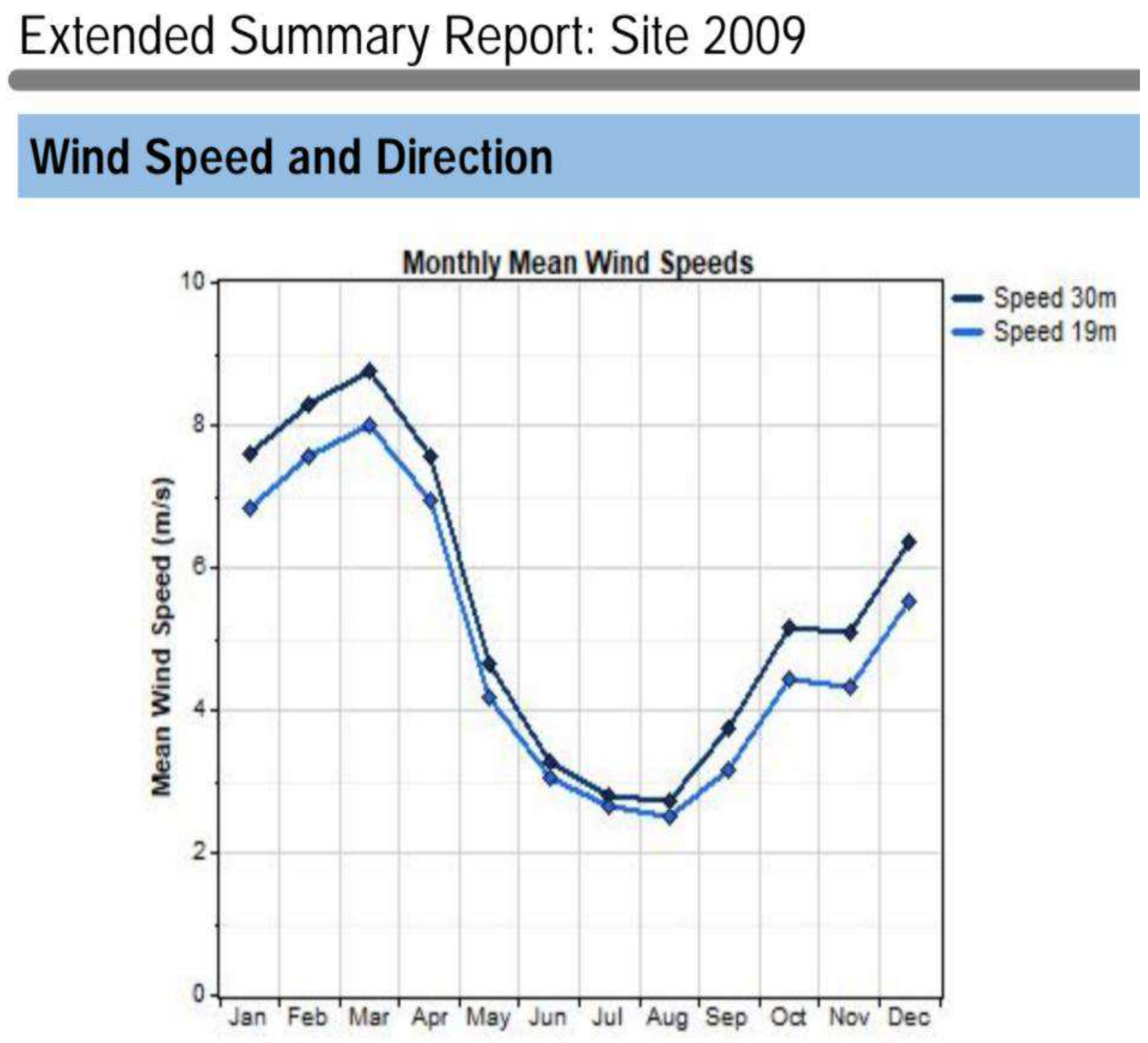
Example: 100% Renewable Energy Storage for Barbados (Simulation)



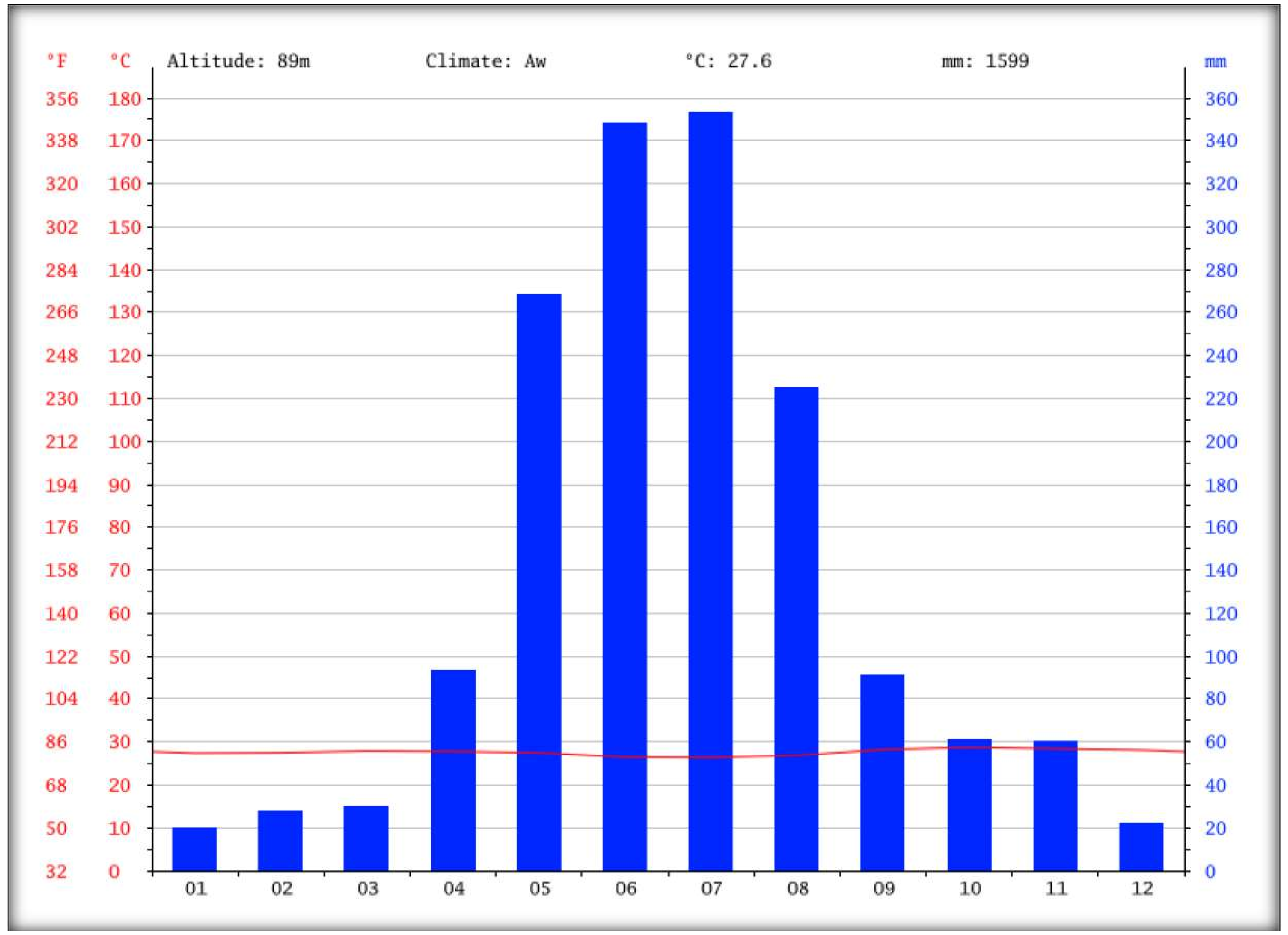
Run of the daily storage cycle

Balancing wind and solar energy over the year

In most of the regions during the rainy seasons (high generation of hydro) the PV and Wind energy potential is decreasing and increasing in the dry seasons



GEA wind Speed Recordings near Lethem (Guyana)



Average precipitation rates in Lethem (Guyana)

Development steps of a hydropower projects in rural areas

- Initial Survey (day/s)
- Level and Flow Measurements (years)
- Data Analysis (weeks/months)
- (Pre)-Feasibility Study (weeks/months)
- Further Surveys (Topo Survey/Geological) if needed (months to years)
- Economic / Financing (months/years)
- Environmental and Social Impact Assessment (ESIA) – (months/years)
- Tender / Construction (1-2 years)
- Testing/Commissioning/Handover/Training (months/year)

Initial Survey (day/s)

When investigating a potential hydropower site, the first time, in addition to the visual inspection, initial measurements and estimations of the hydropower potential are made (head, flow, electrical consumers)

First Survey to the proposed dam site of the Kumu Hydropower Station (500m head), Guyana 2016

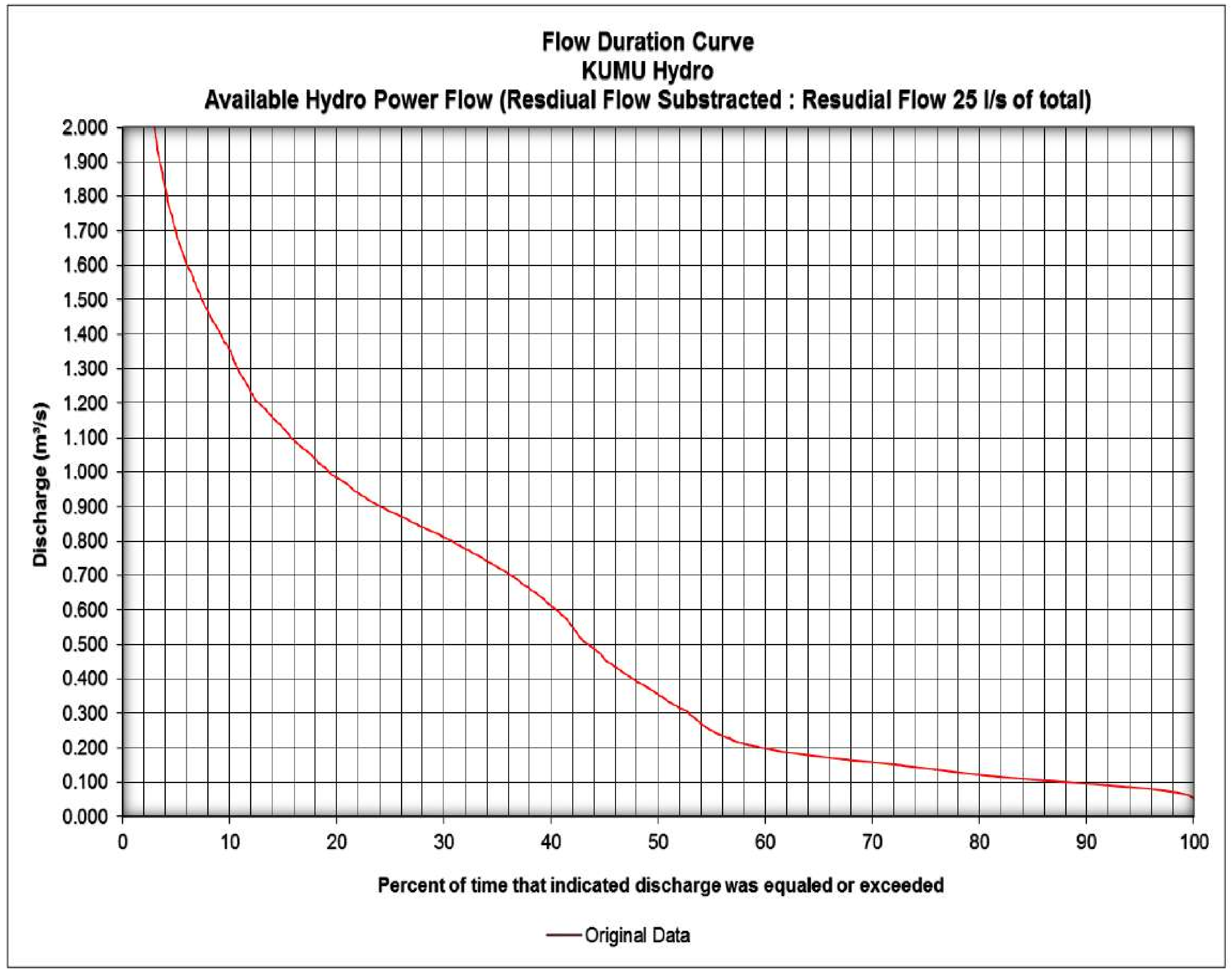
Level and Flow Measurements (years)

If the initial survey showing a positive hydro energy potential. The next step will be to install a permanent level logger and performing of flow measurements.
Time of date recording depends on the size of the project. Larger projects with higher budget normally need more data (up to several years of recording).

Logger Station and Flow Measurements (1.5 MW Kumu Project, Guyana)

Data Analysis

Analysis of the recording and flow measurements. The most important result of the data analysis is the development of the flow duration curve (FDC). From this curve it can be determined what size (capacity) the power plant has and how much work can be generated per year



Flow Duration Curve (1.5 MW Kumu Station, Guyana)

Data Analysis

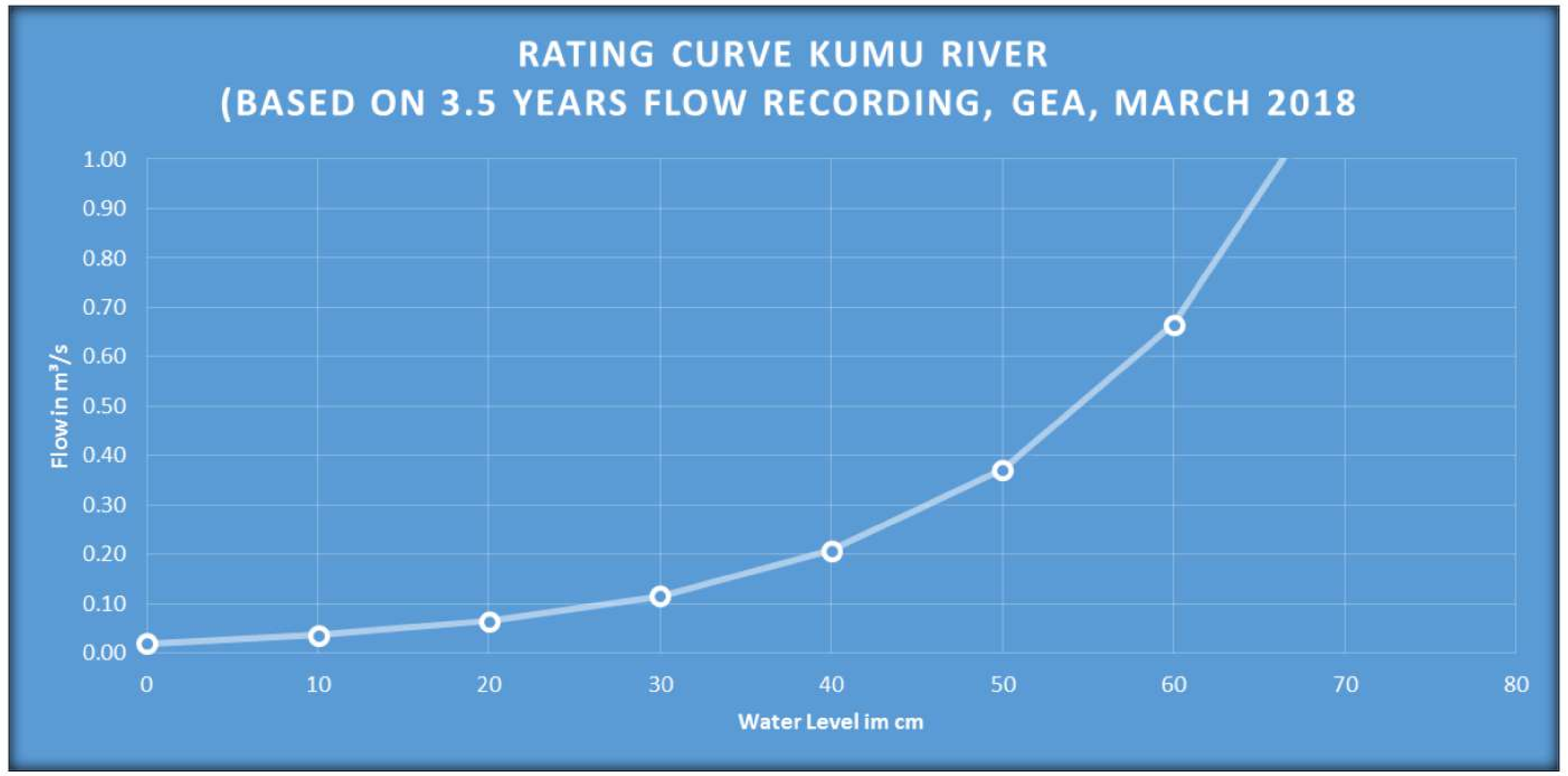
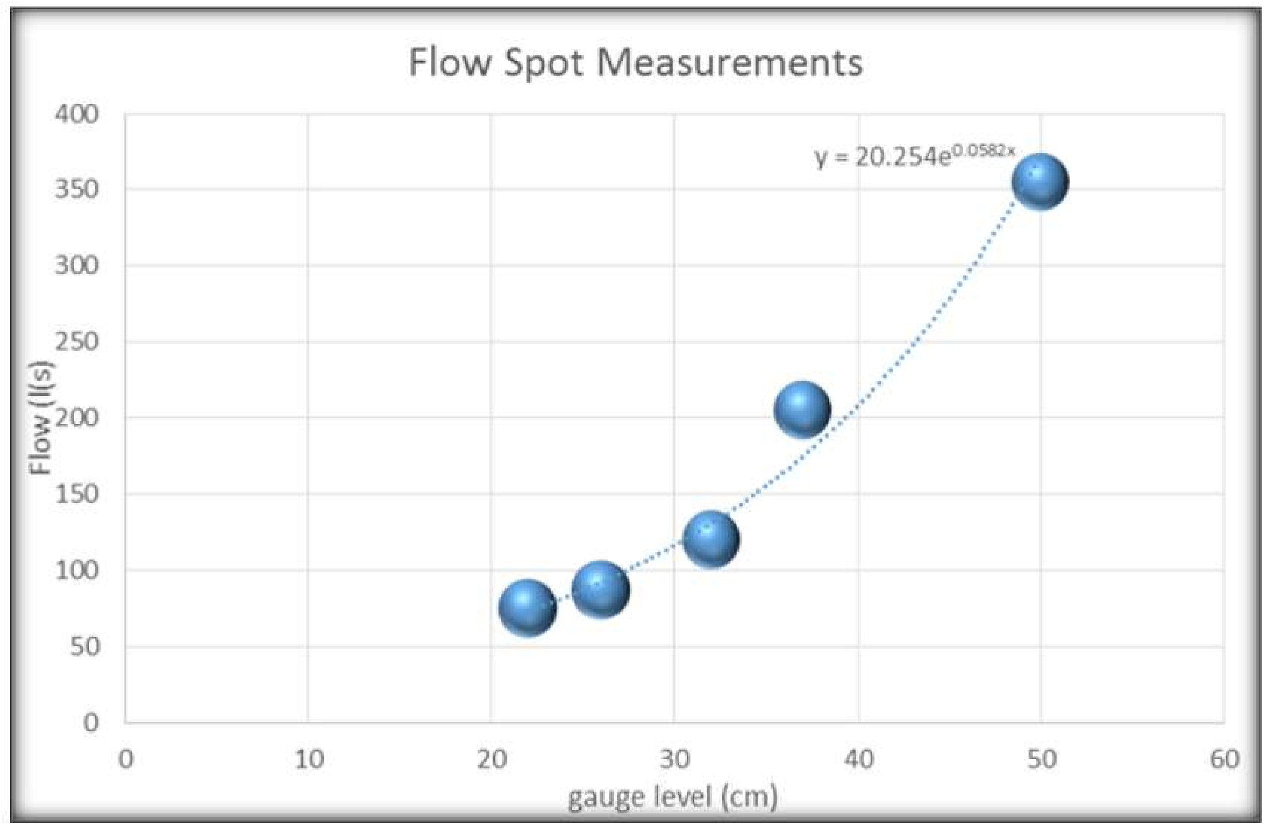
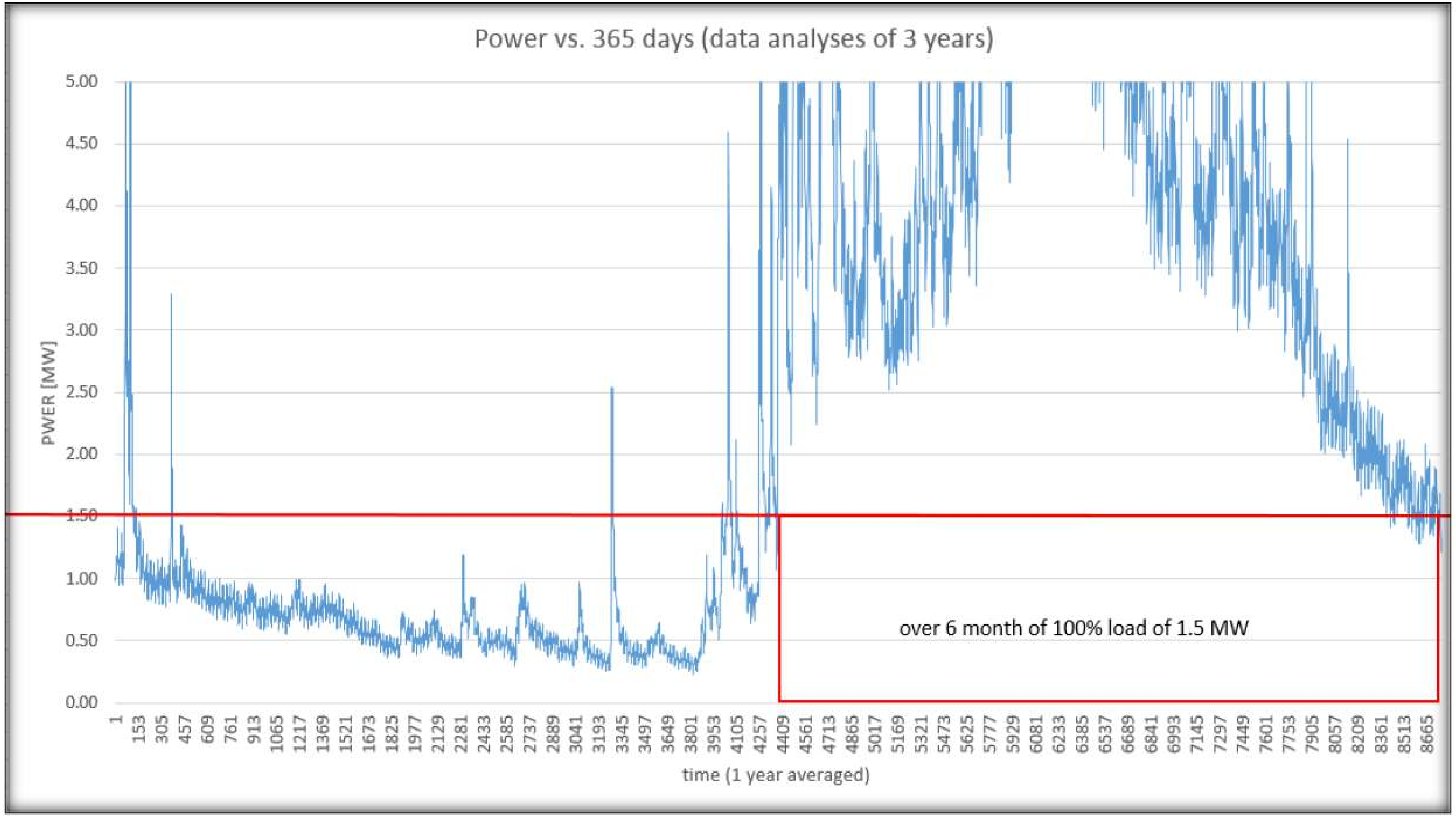


Figure 13, Generated Rating Curve



Rating Curve and Flow Measurements (1.5 MW Kumu Station, Guyana)

Data Analysis



(Pre)-Feasibility Study

A feasibility study provides information on whether a project is technically feasible and economically viable. The main parameters and dimensioning of the plant should already be determined in a feasibility study. For smaller plants, a full feasibility study can be carried out directly. For larger projects, a pre-feasibility (cheaper and faster) study is carried out first. If this is positive, the project developer/investor can proceed with a full feasibility study.

Key Figures

1.5 MW Kumu Run-of-River Hydropower Plant

Location	Region 9, Guyana
Name of River:	Kumu River (Amazon River System)
Mean River Discharge:	Q_{mean} = 0.640 m^3/s
Rated Turbine Discharge	$Q_{Turbine}$ = 0.33 m^3/s (2 x 0.165 m^3/s)
Rated Head:	H_r = 580 m
Annual Plant Output:	9,679 MWh / year
Rated Capacity:	1.5 MW (2 x 750 kW)
Load Factor:	74 %
Total Power Plant Efficiency:	81 %
Elevation of Weir Crest:	710 m ASL
Width of Weir	20 m
Dam Height:	3 m
Length of Head Race Pipeline:	500 m
Diameter of Head Race Pipeline:	700 mm
Length of Penstock:	1,750 m
Diameter of Penstock:	350 mm
Length Transmission Line:	14 km
Voltage Level:	13.8 kV
Distribution Network:	Lethem Power Grid
CO_2 Savings:	5,807,400 kg/year
Levelized Cost of Electricity Kumu: (5% Interest Rate, 25 years lifetime)	6.47 US cents/kWh

Cost Estimation:

CAPEX:	**6,420,000 USD***
Specific Costs:	**4280 USD/kW ***

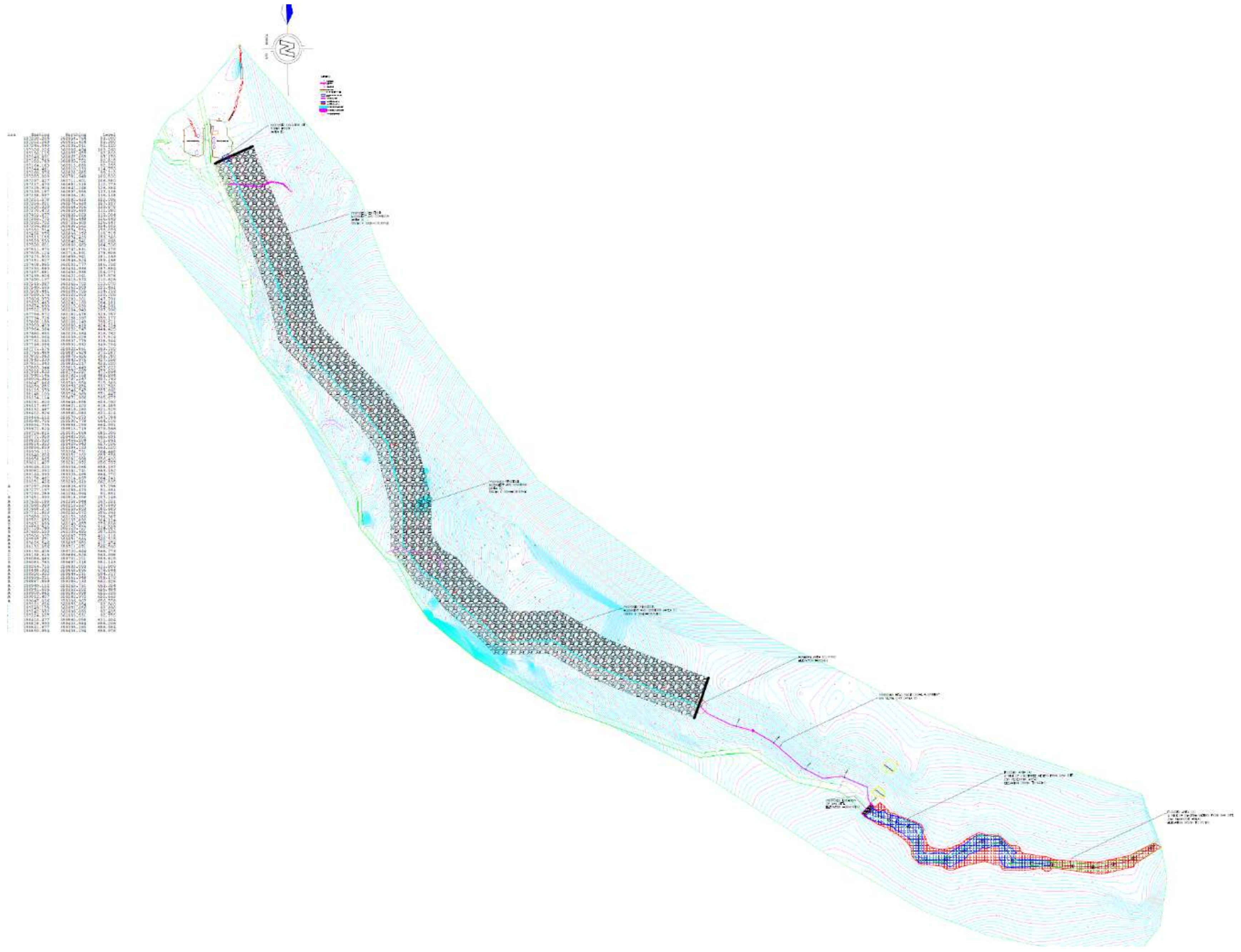
*included transmission line

- 2 -

Guyana Energy Agency – August 2018

Further Surveys (Topo Survey/Geological) if needed

Especially in unknown terrain, it can be important to obtain further, especially topographic and/or geological information. This can be made available to potential project developers during the tendering process. In this way, the project can be accelerated, and more favourable bids can be obtained, as the risks for the bidders can be minimised.



Detailed Topo Survey of the Project complete unknown project area.

Project Area with very few Topographic Information

Economic / Financing

The economic viability of the project should already be presented in the feasibility study. The financing of the project depends especially on the costs and the amount of energy production. Other factors are also considered in the financing, which can also vary depending on the objective and type of financing (reduction of fossil fuels, reduction of the electricity price, private financing, green financing, international financing, loan or grant, interest rate and many more) can be different.

CAPEX:	6.420.000
OPEX:	3 %/a
Electricity Sales:	9,679 MWh/a
Loan (Development Bank)	75 % (4.815.000 USD)
Equity	25 % (1.605.000 USD)
Equity Interest Rate:	10 %
Loan Interest Rate:	10 %
Finance Duration (Loan)	7 years
Yearly Price Increase:	2%
Project Construction Time:	1 years
Project Lifetime	25 years
Sales Price	0.20 USD/Cent
Yearly Sales Price Increase:	2%

Example of Financial Model for Small Hydro Power Project

Environmental and Social Impact Assessment (ESIA)
Environmental Assessment & Management Plan (EAMP)
Environmental Impact Assessment (EIA)
Environmental Management Plan (EMP)

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A process for predicting and assessing the potential environmental and social impacts of a proposed project, evaluating alternatives and designing appropriate mitigation, management and monitoring measures.

Example EAMP Content

Tender / Construction

(months/years)

Most of the Caribbean countries have little or no experience with hydropower projects. This also applies to the local construction companies. For this reason, it can be difficult to obtain suitable offers for small hydropower projects. In Guyana, many developments have taken place in the field of small hydropower plants in recent years. Hydropower plants have been built for the first time or are under construction. And there are still some projects to come. For the entire Caribbean region, it would therefore be useful to bundle all the knowledge on project development for small hydropower plants and make it available centrally to all interested parties.

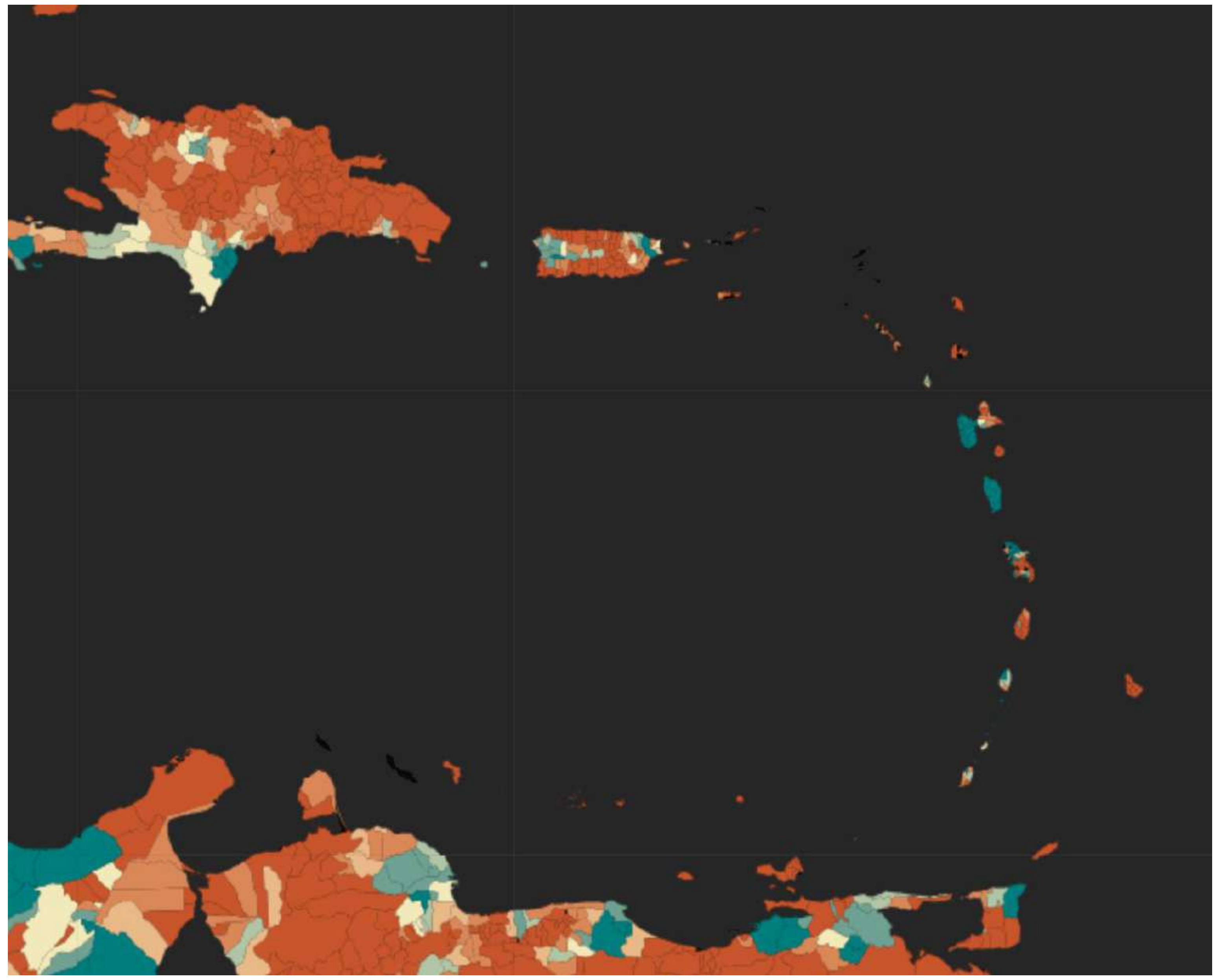
Testing/Commissioning/Handover/Training

Testing/Commissioning/Handover/Training
Each hydropower plant is different from the others and each is unique in itself. Suitable personnel must be trained to operate a hydropower plant.

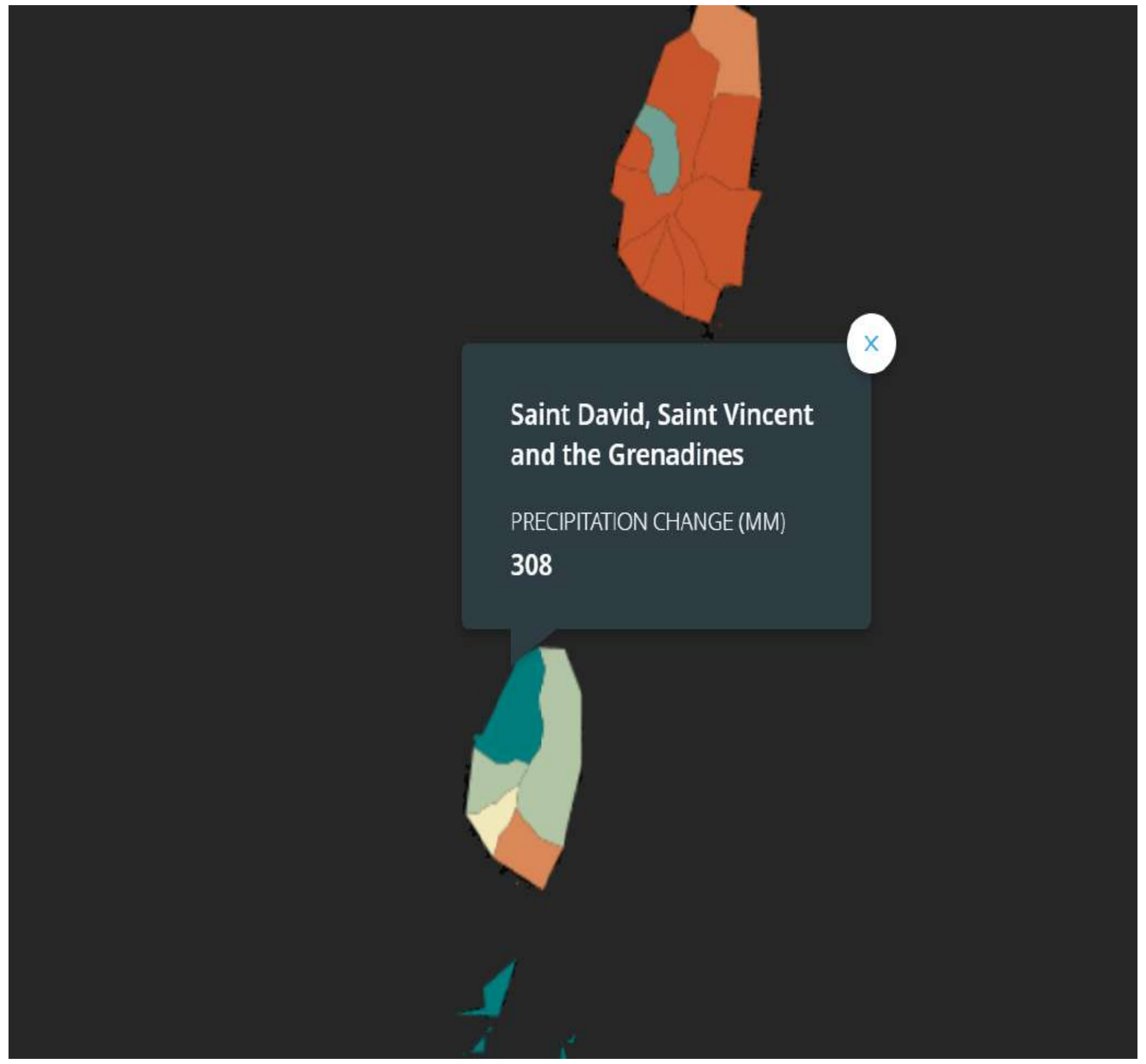
Hydropower Technology and Climate Change

General expected Impact of Climate Change on Hydropower

The biggest influence of climate change on hydropower is the amount of precipitation. In general, local-specific forecasts for the precipitation range are exceedingly difficult to make. Even within the Caribbean, there are regions with higher as well as lower rainfall.



"therevelator.org
(Interactive Map: Precipitation in the 2050s)
Red means lower rainfall. Green means higher rainfall



Even within small regions, both positive and negative forecasts of precipitation are made.

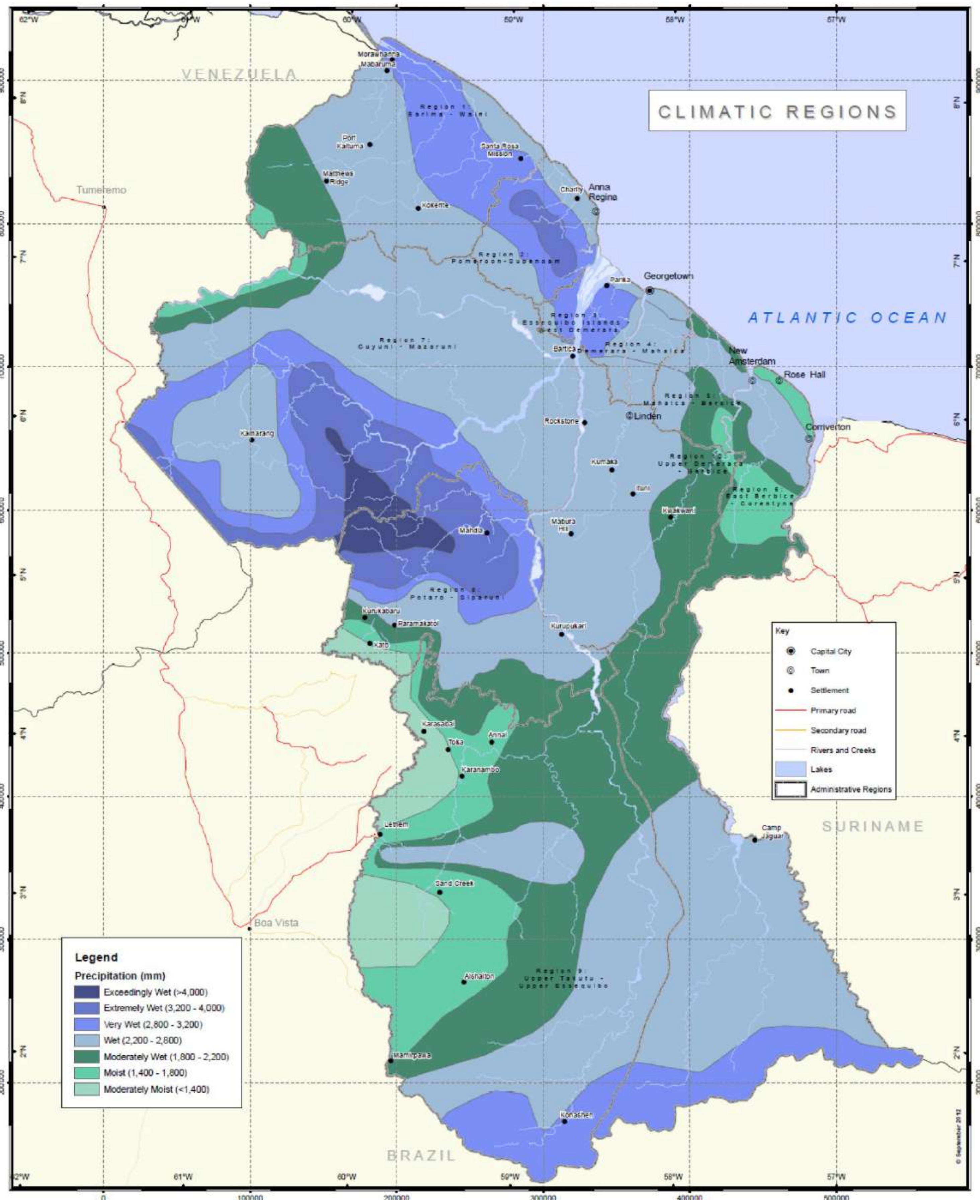
Specific expected Impact of Climate Change (Example Guyana)

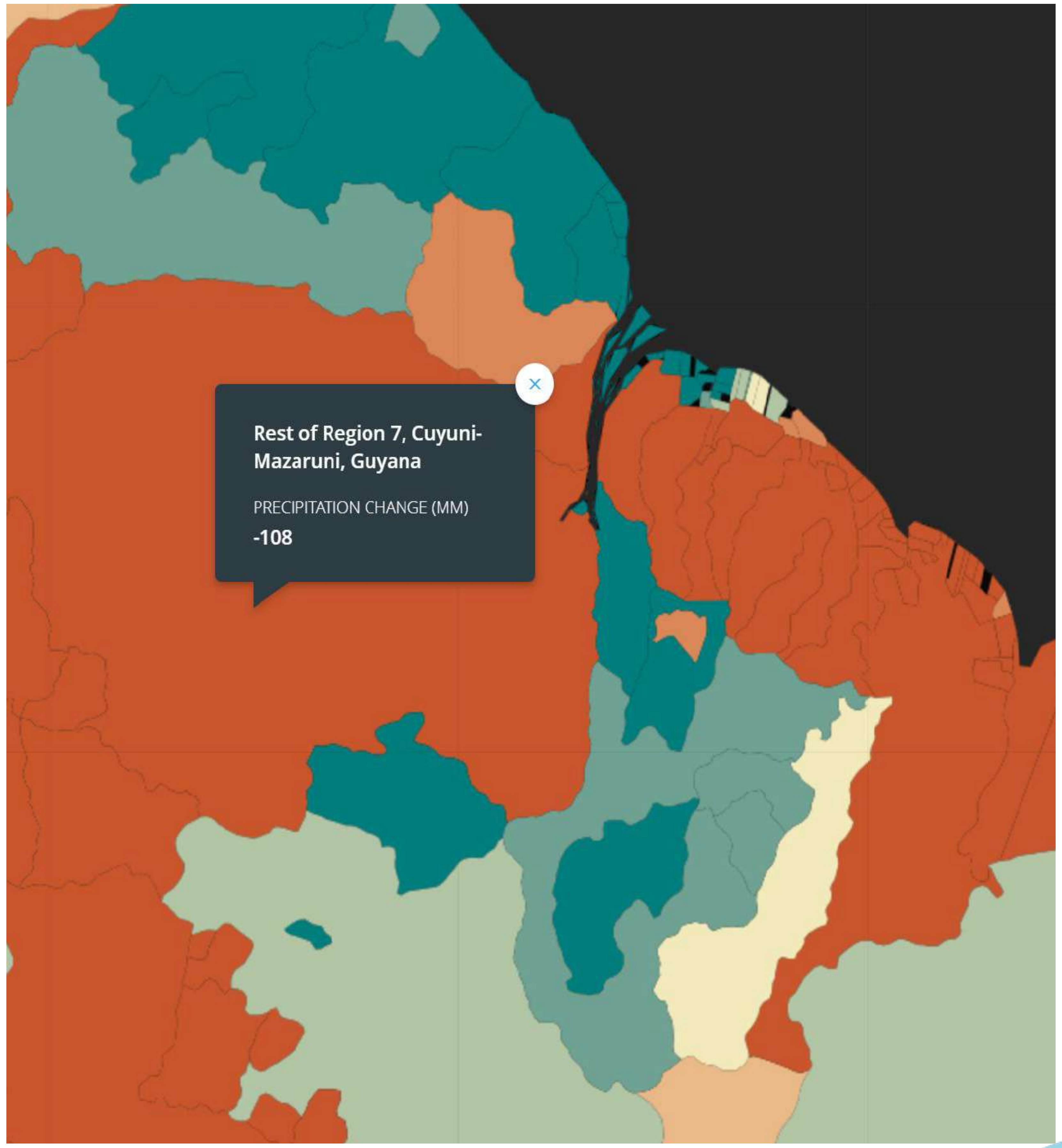
CARIBBEAN CENTRE FOR RENEWABLE ENERGY & ENERGY EFFICIENCY

AN INSITUTION OF CARICOM

GUYANA ENERGY AGENCY

Example: Guyana Region 7 Cuyuni -Mazaruni: Average Precipitation: 2500 mm/year
Predicted Change in Precipitation: -108 mm/year
>> Change: -4,3%





Integration of Hydropower into Grid

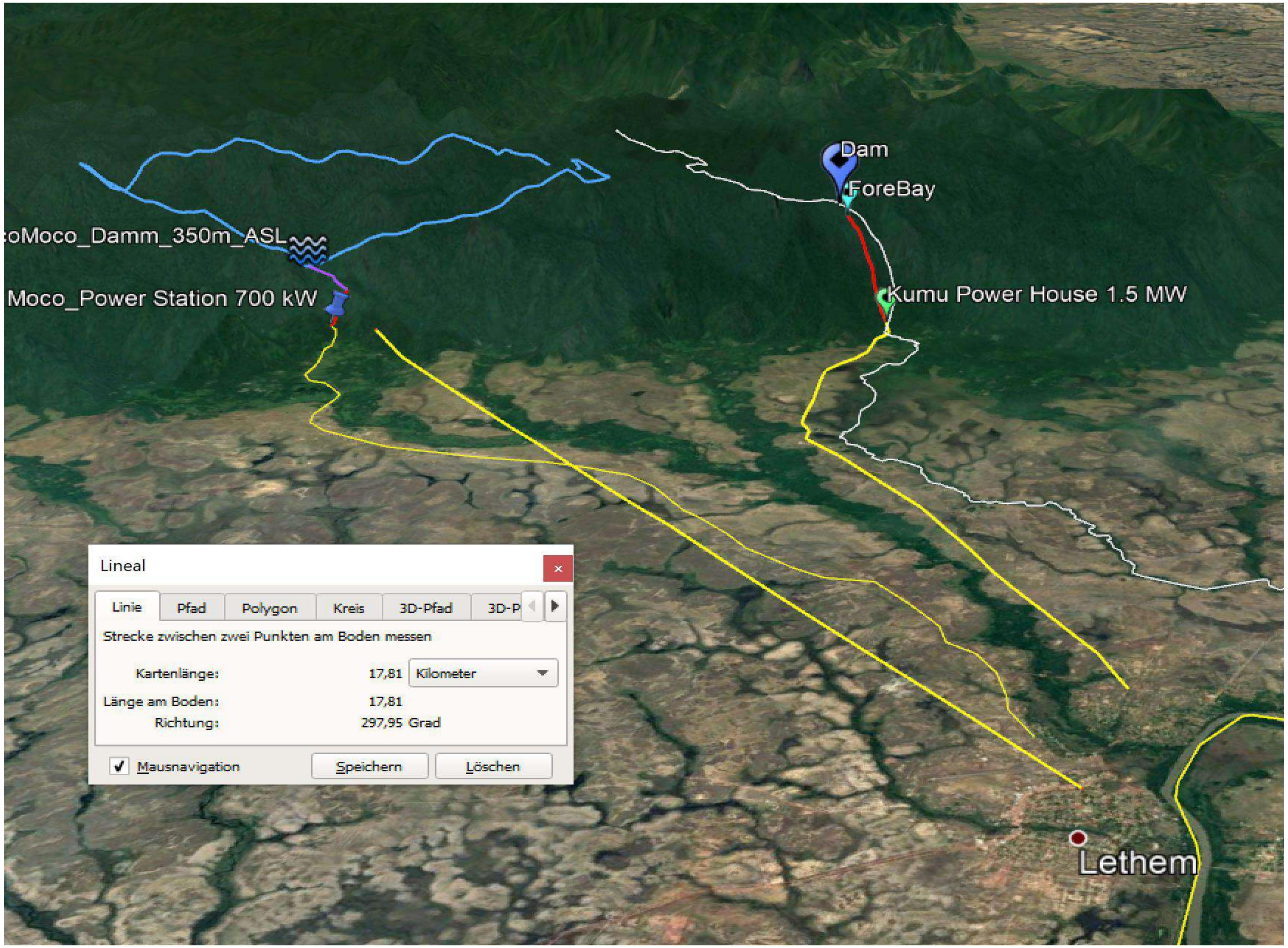
The Challenge of different location of power generation and load centres

The special feature of hydropower plants is the determination of the location.

The location of a hydropower plant is determined by the hydrological and topographic characteristics.

Thus, the location of the load centre must always be considered together with the location of the hydropower centre

The Challenge of different location of power generation and load centres



Transmission Lines

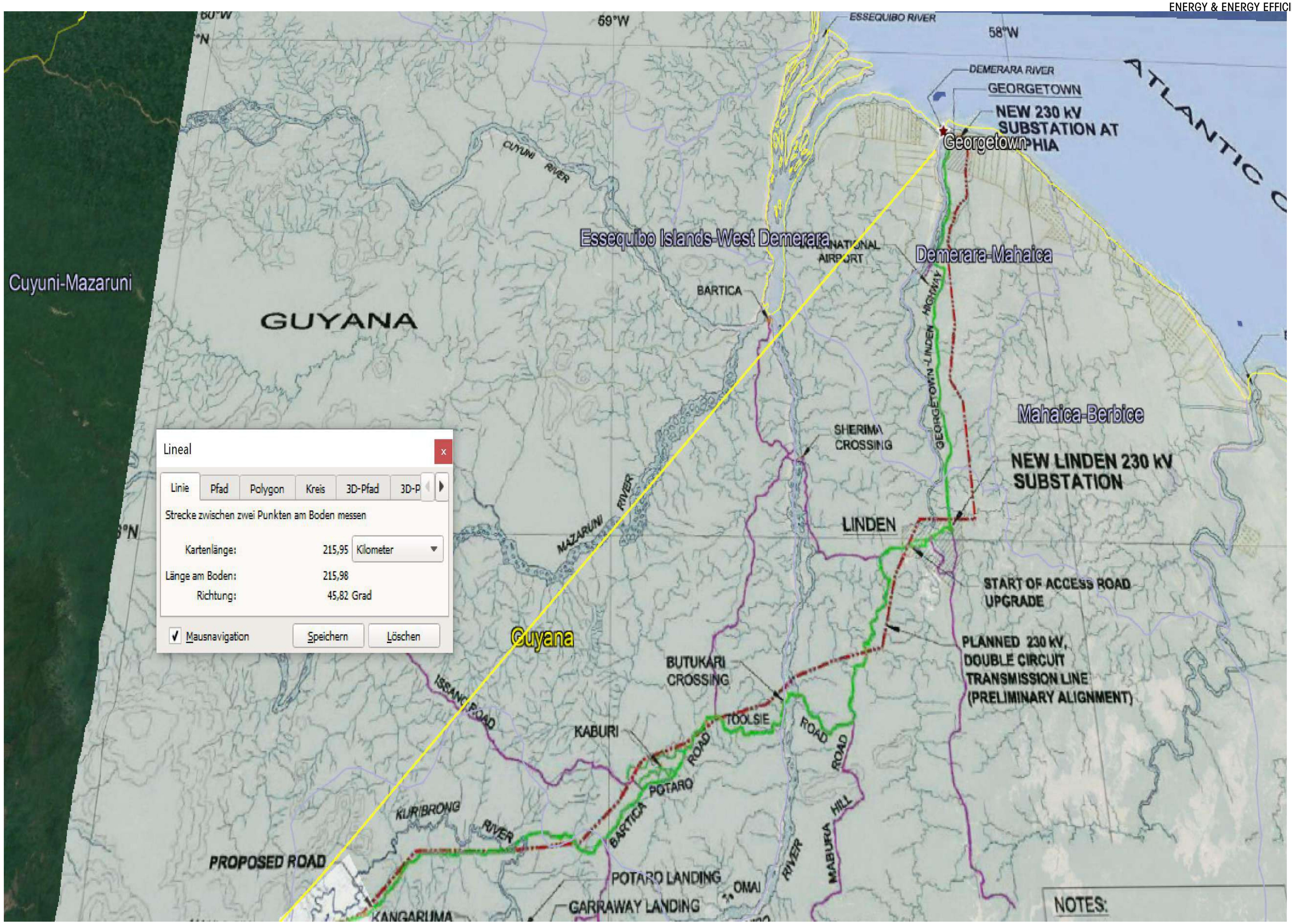
In the case of large-scale plants, the distance between a hydropower plant and the consumption centre can be several 100 km.

The costs for the connection are usually included in the economic feasibility.

The ecological impact must also be taken into account.

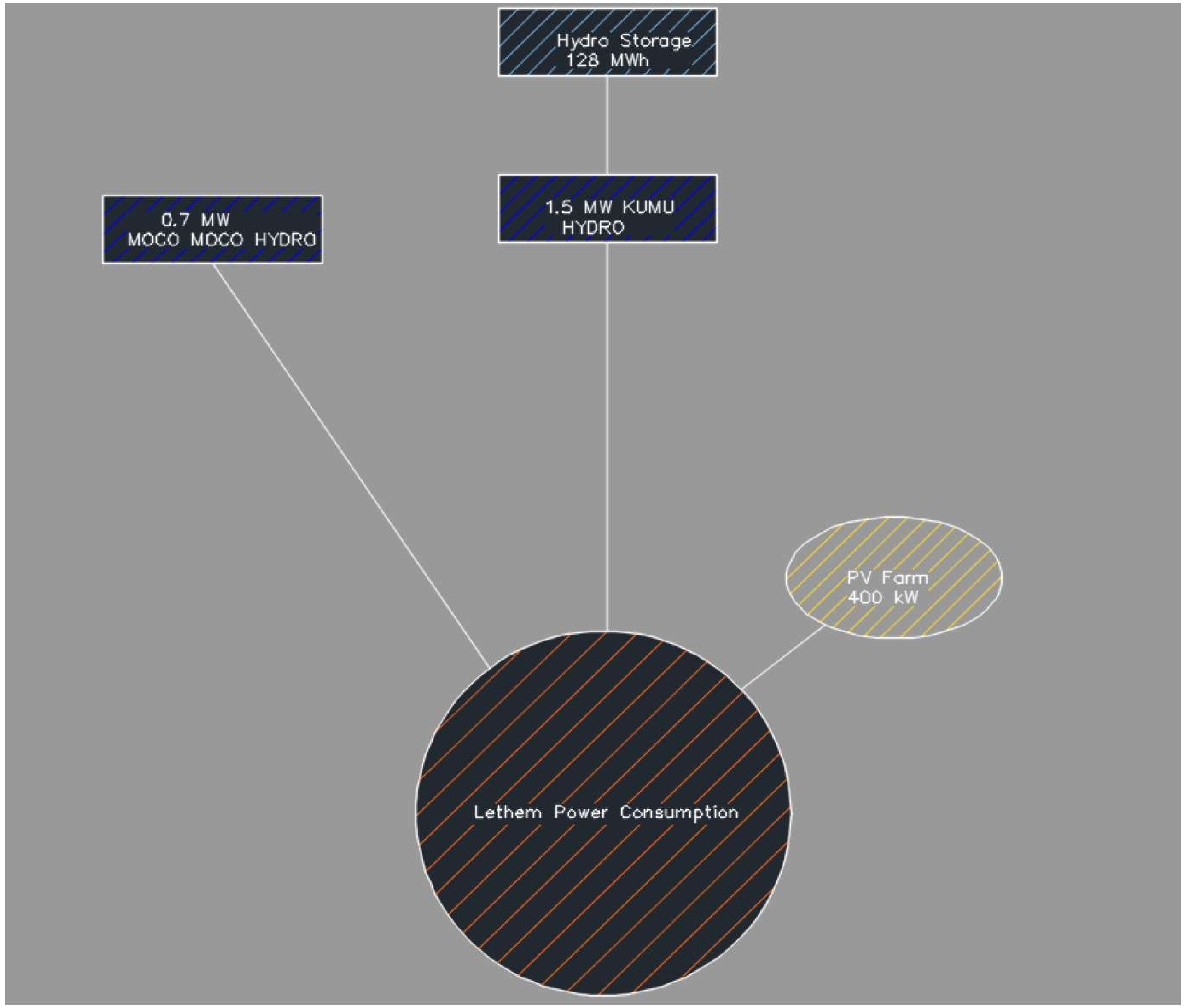
On the other hand, a long power transmission capacity can greatly accelerate economic development along the line.

Transmission Lines



Hydropower Station as Master Grid Controller

(Example on Lethem Grid with the double hydro feed in project Moco Moco + Kumu)



Hydropower Station as Master Grid Controller

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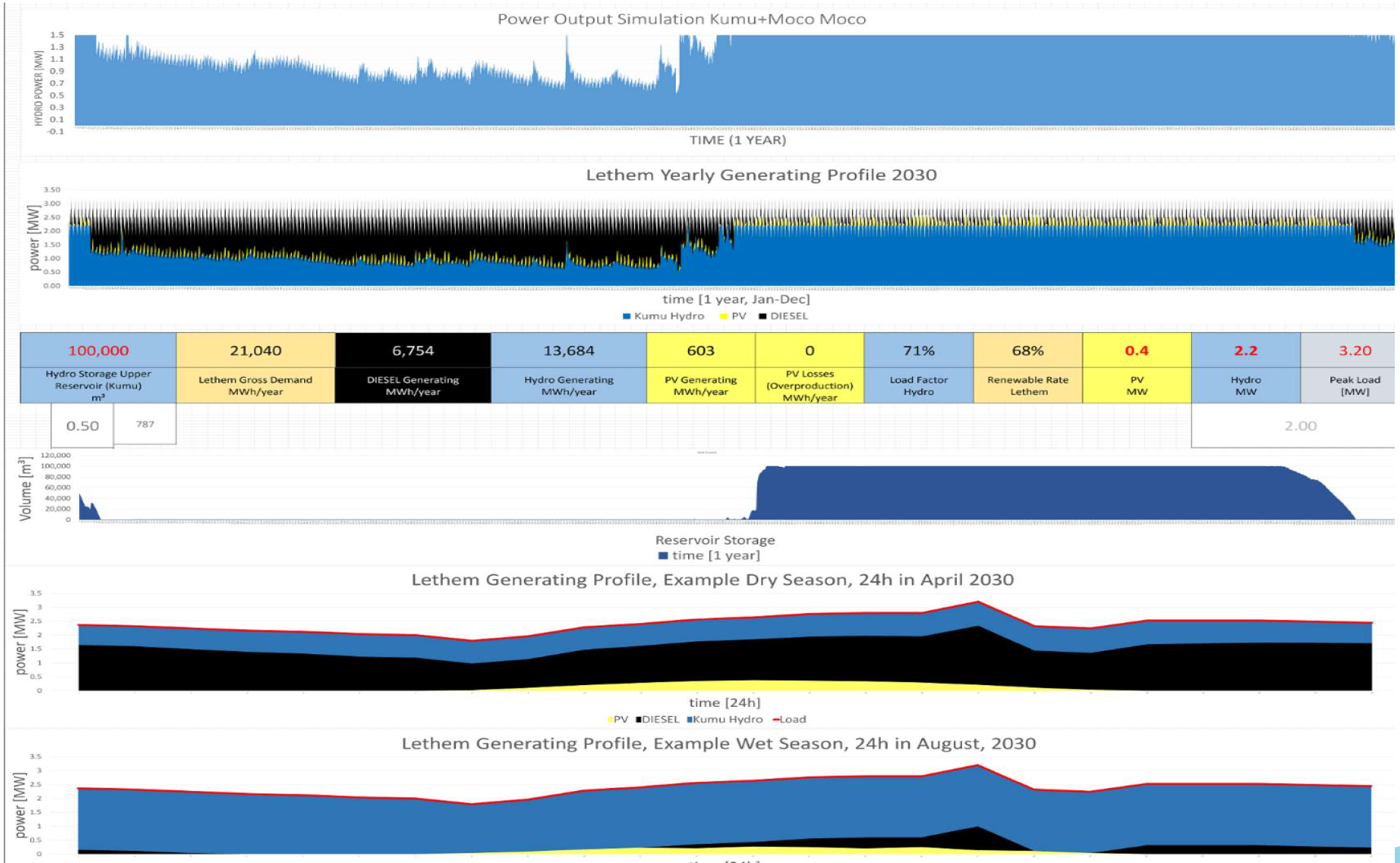

THANK YOU FOR YOUR ATTENTION

QUESTIONNAIRE