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Combined production of electricity and potable water with a hybrid power plant and a desalination unit in the island of Kasos, Dodecanese, Greece

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Kasos, 20th of August 2014

Hybrid Power Plants - Introduction

Aim of a hybrid power plant

- A hybrid power plant for electricity production aims to cover an inflexible power demand, from non-guaranteed Renewable Energy Sources (R.E.S.) power plants.
- To approach the above target, the R.E.S. power plants should be combined with storage power plants.
- To ensure the uninterrupted cover of the power demand, the hybrid power plant is integrated with a back-up unit, which aims to undertake the requested power production when no power production is possible either from the R.E.S. or the storage power plant.

Aim of a hybrid power plant

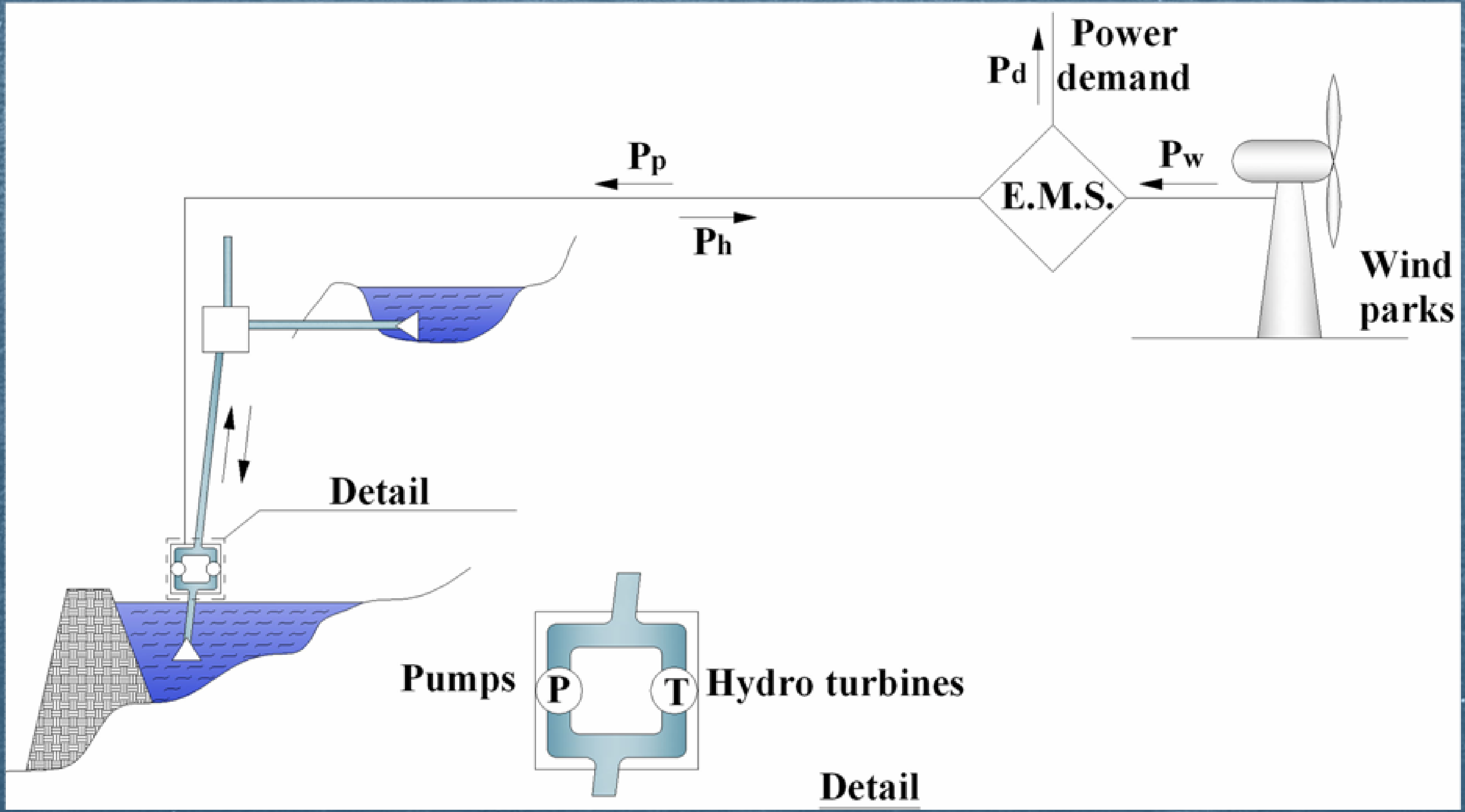
- According to the abovementioned, a hybrid power plant consists of the following discrete components:
  - non-guaranteed power production units (base units)
  - storage units
  - back-up units.

Hybrid power plants of large size

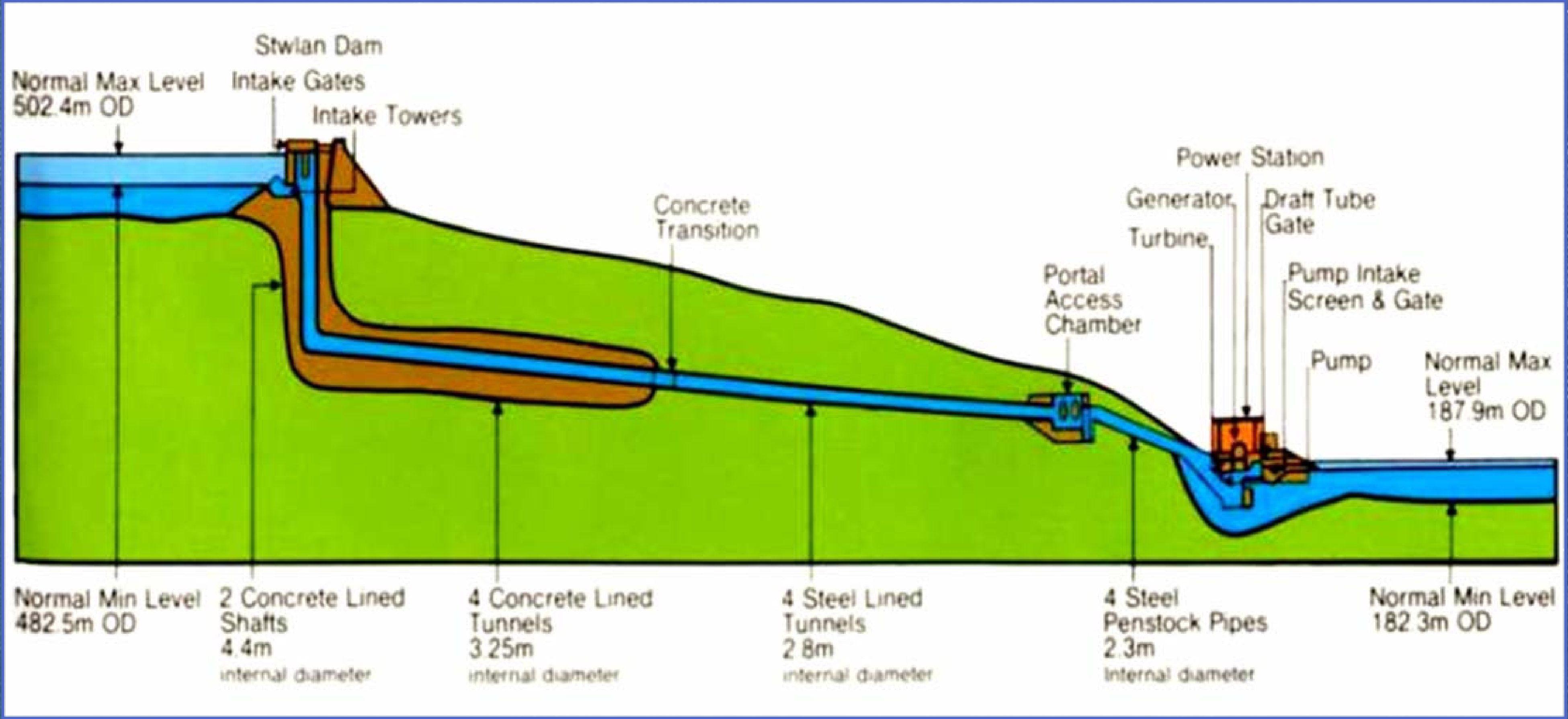
Synthesis of a hybrid power plant of large size

- The synthesis of hybrid power plants of large size (guaranteed powr production higher than 1MW) is approached by composing the following most technically mature and economically competitive technologies:
  - base units: wind parks
  - storage power plants: pumped hydro storage systems (PHS).

Synthesis of a hybrid power plant of large size



What is Pumped Hydro Storage



Indicative examples of operating PHS: Goldisthal (Germany)

- Hydro turbines power: 1.060MW
- Upper reservoir capacity: $12 \cdot 10^6 m^3$
- Net head: 300m.

Indicative examples of operating PHS: Kannagawa & Kazunogawa (Japan)

Indicative examples of operating PHS: Anapo (Sicily, Italy)

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- Hydro turbines power: 500MW
- Upper reservoir capacity: $5{,}6 \cdot 10^6 m^3$
- Lower reservoir capacity : $7{,}3 \cdot 10^6 m^3$
- Net head: 302m
- Penstock diameter: 6,5m.

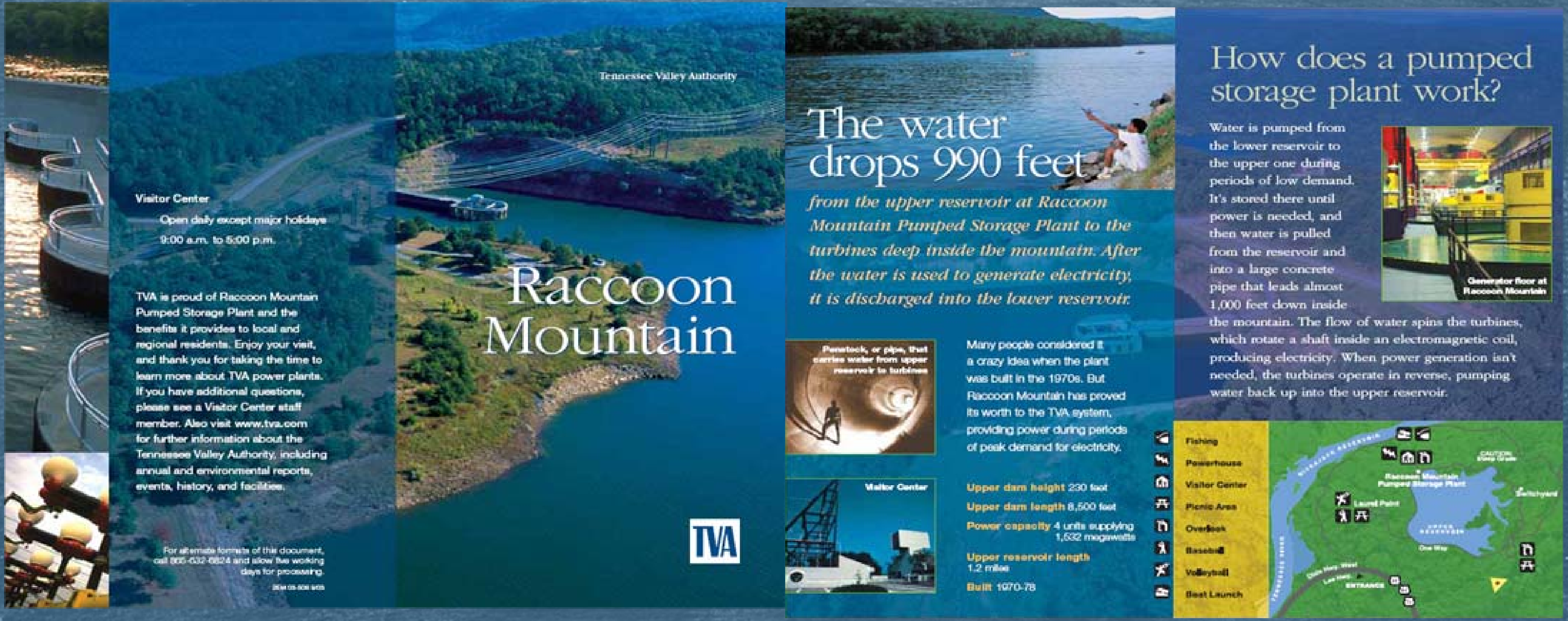
Indicative examples of operating PHS: Okinawa (Japan)

- Hydro turbines power: 32MW
- Upper reservoir capacity: $1 \cdot 10^6 m^3$
- Net head: 150m.

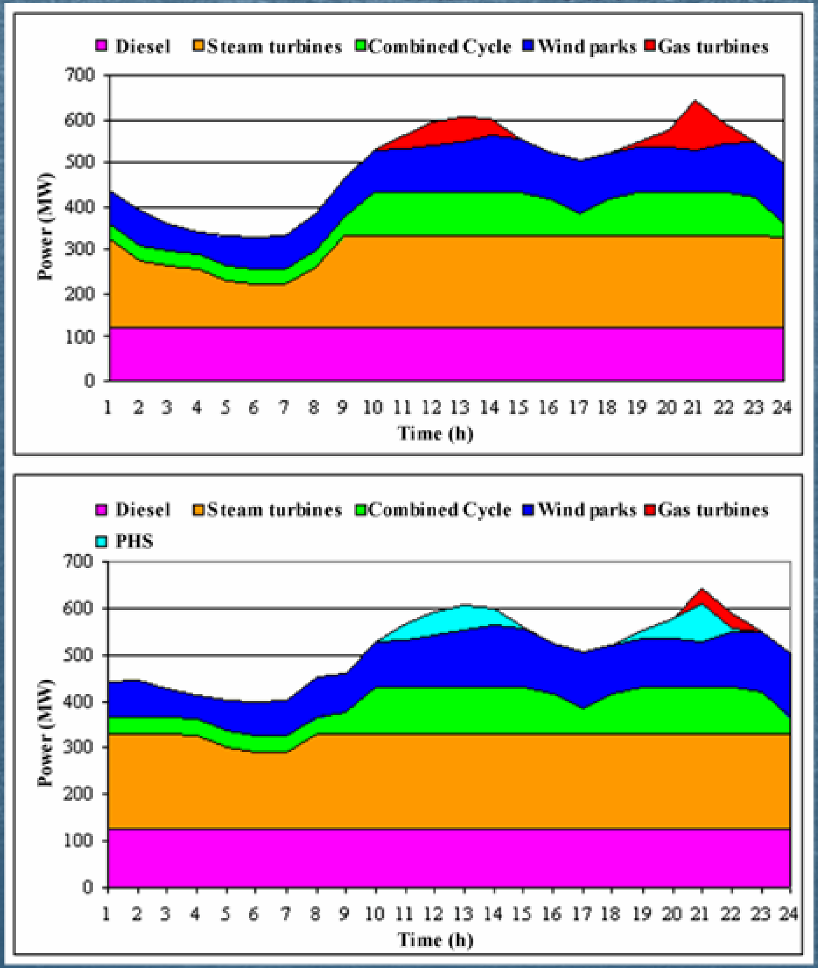
Indicative examples of operating PHS: : Dinorwig (Whales)

- Hydro turbines power: 1.728MW
- Upper reservoir capacity: $7 \cdot 10^6 m^3$
- Net head: 110m.

Indicative examples of operating PHS: : Raccoon Mountain (U.S.A.)

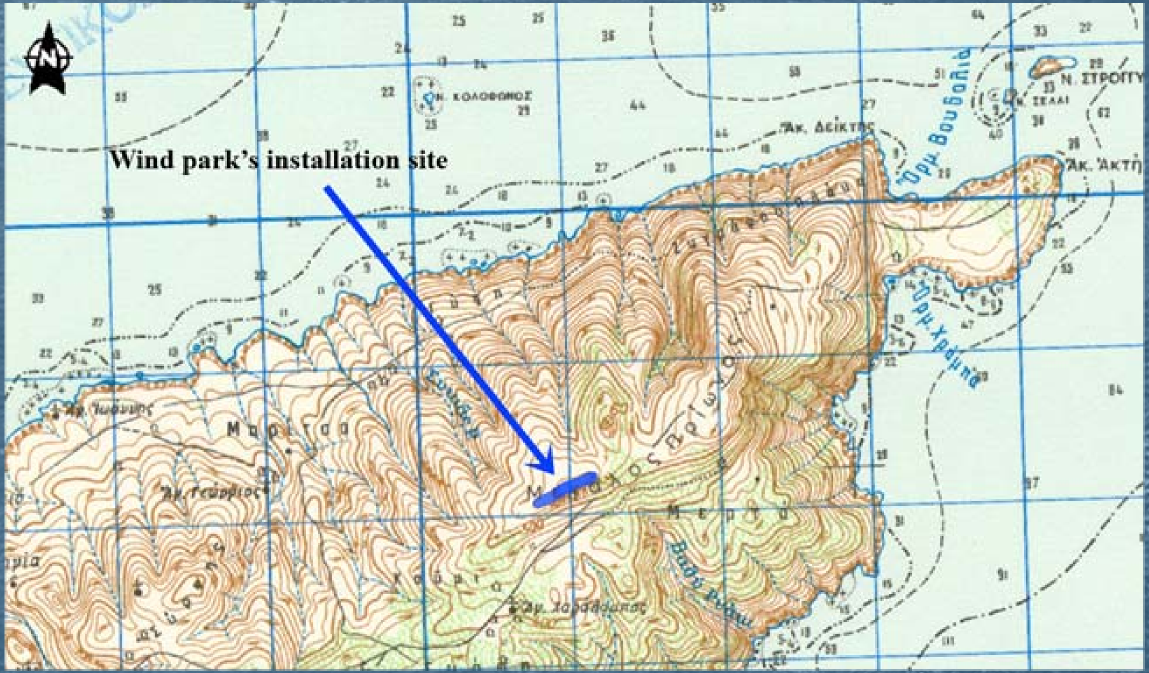


Hybrid power plants for power peak shaving



Hybrid power plant of Kasos

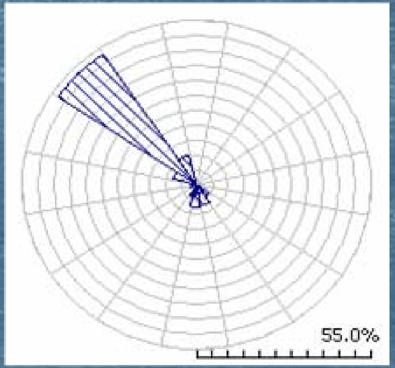
The siting of the hybrid power plant's wind park in Kasos

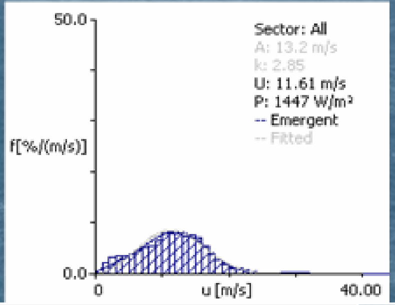


Wind potential measurements in the wind parks' installation site

Wind mast installation position coordinates	WGS'84	Latitude	35^{o} 24΄ 54.70΄΄ B
		Longitude	26^{o} 58΄ 46.40΄΄ A
Measurements period	Since		14/5/2010
	To		14/5/2011
	Duration (months)		12
Measurements height above ground (m)			22,5
Measurements position absolute altitude (m)			584,0

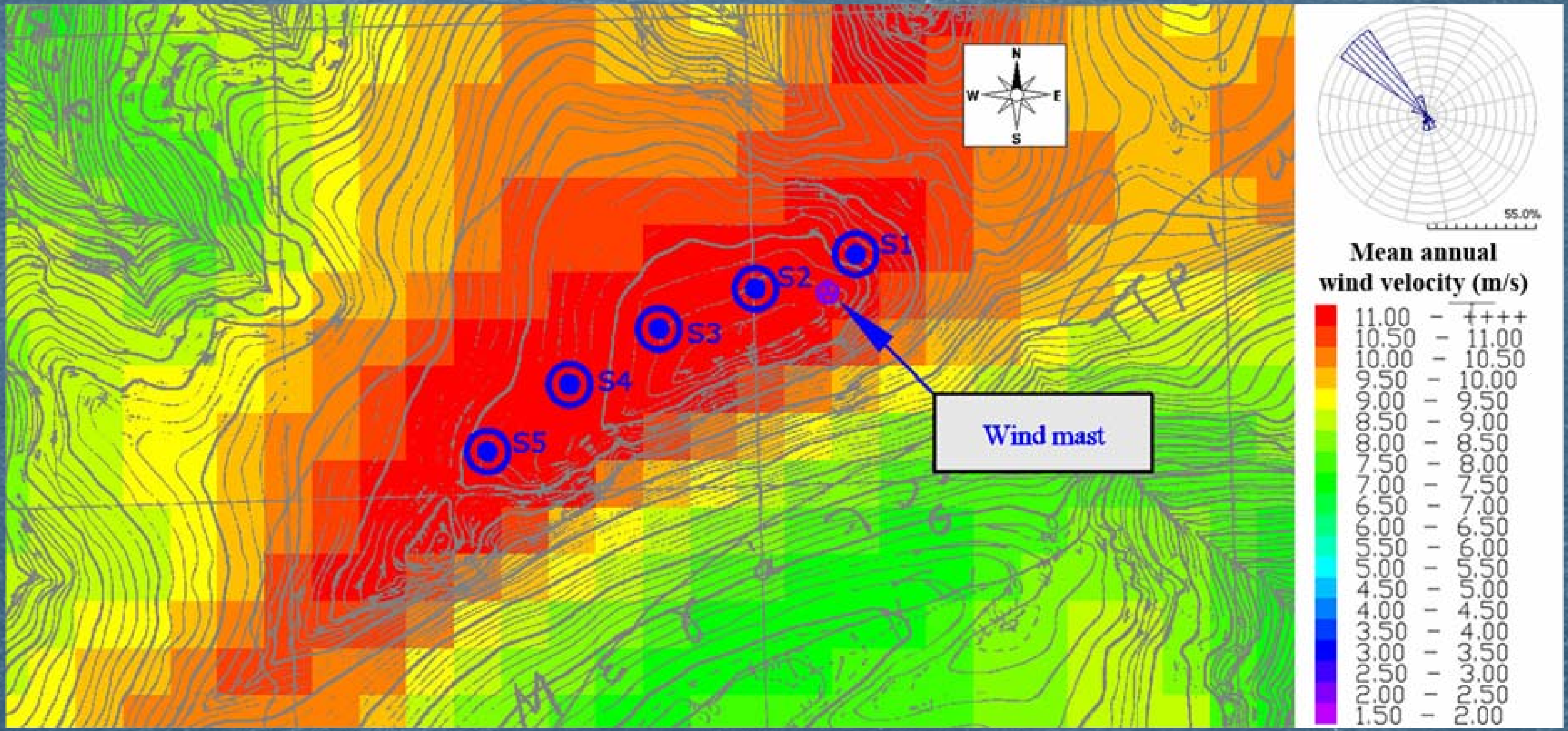
Wind potential measurements in the wind parks' installation site





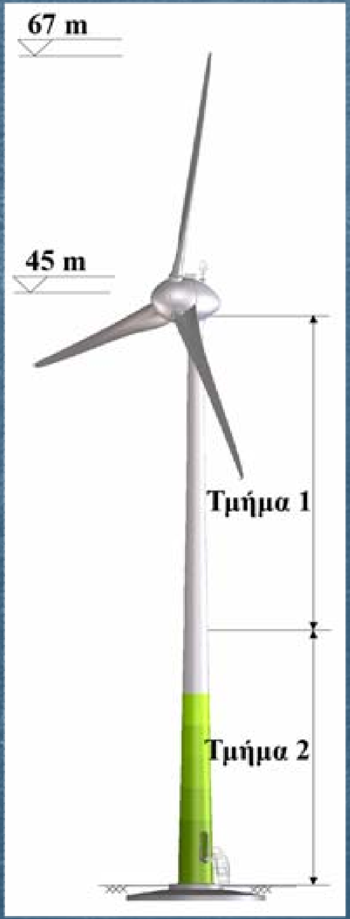
Weibull parameters	C (m/sec)	13,20
	k	2,85
Averaged annual wind velocity (m/sec)		11,61
Wind power density (W/m^2)		606,5

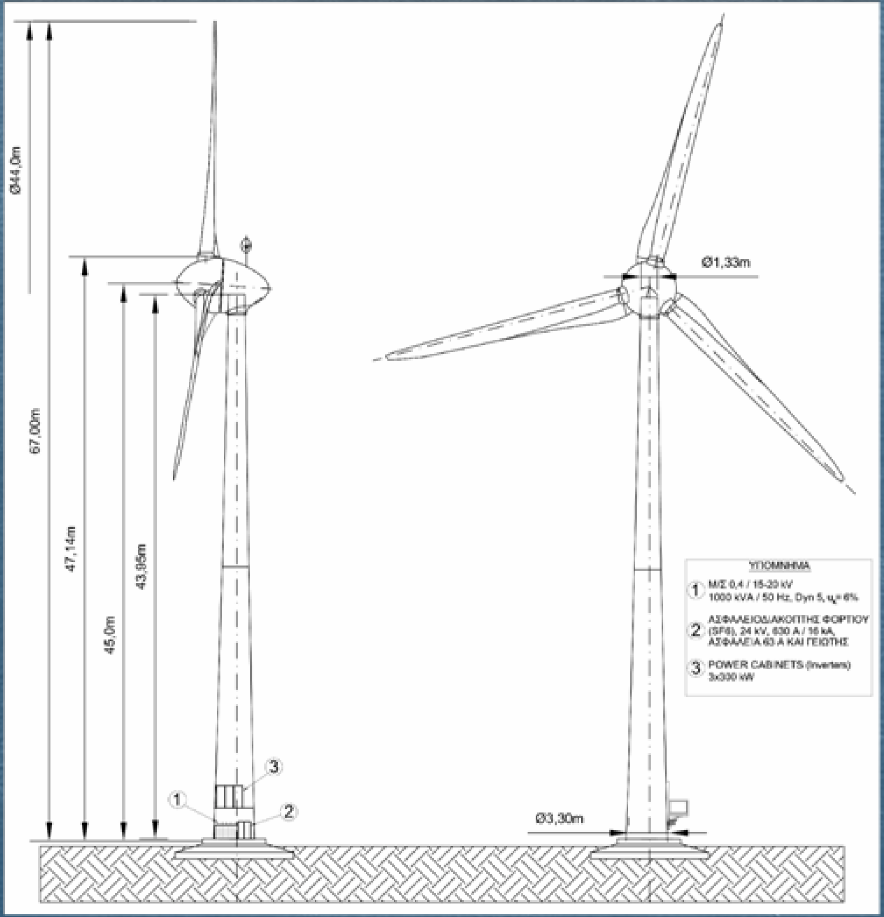
Wind potential map
Wind park siting



- Wind park nominal power 4,5MW
- Five wind turbines Enercon E-44 / 900kW

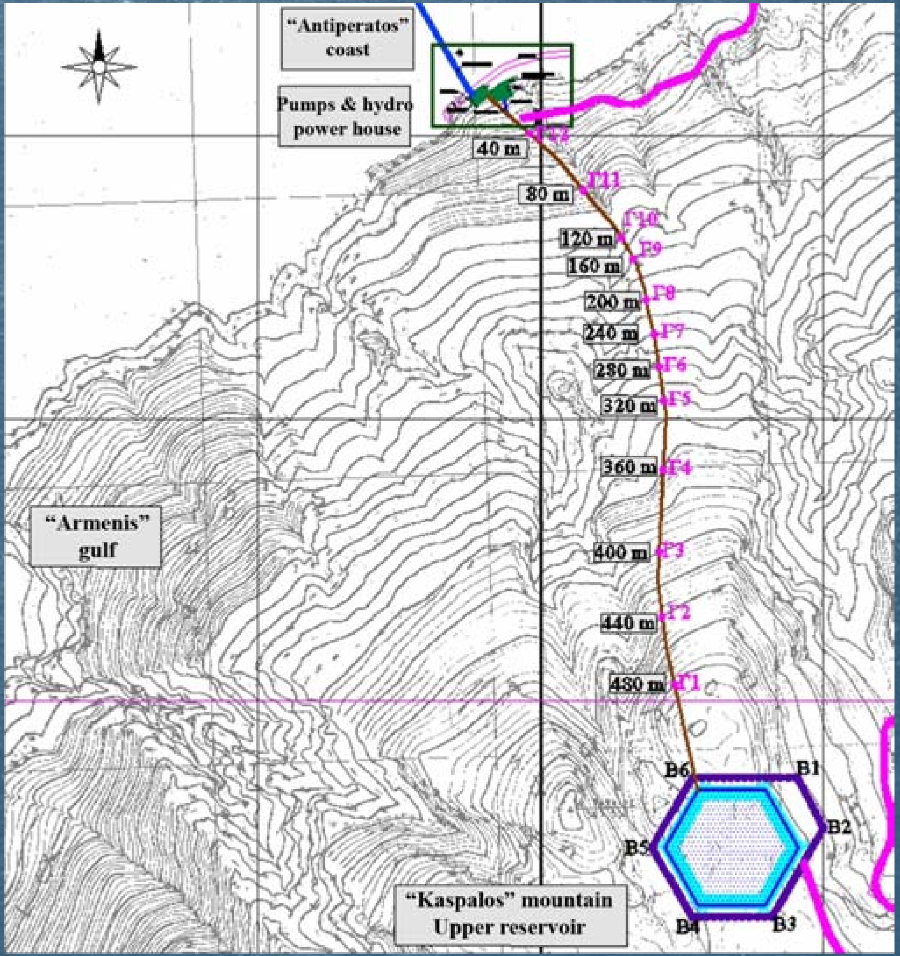
The selected wind turbine model



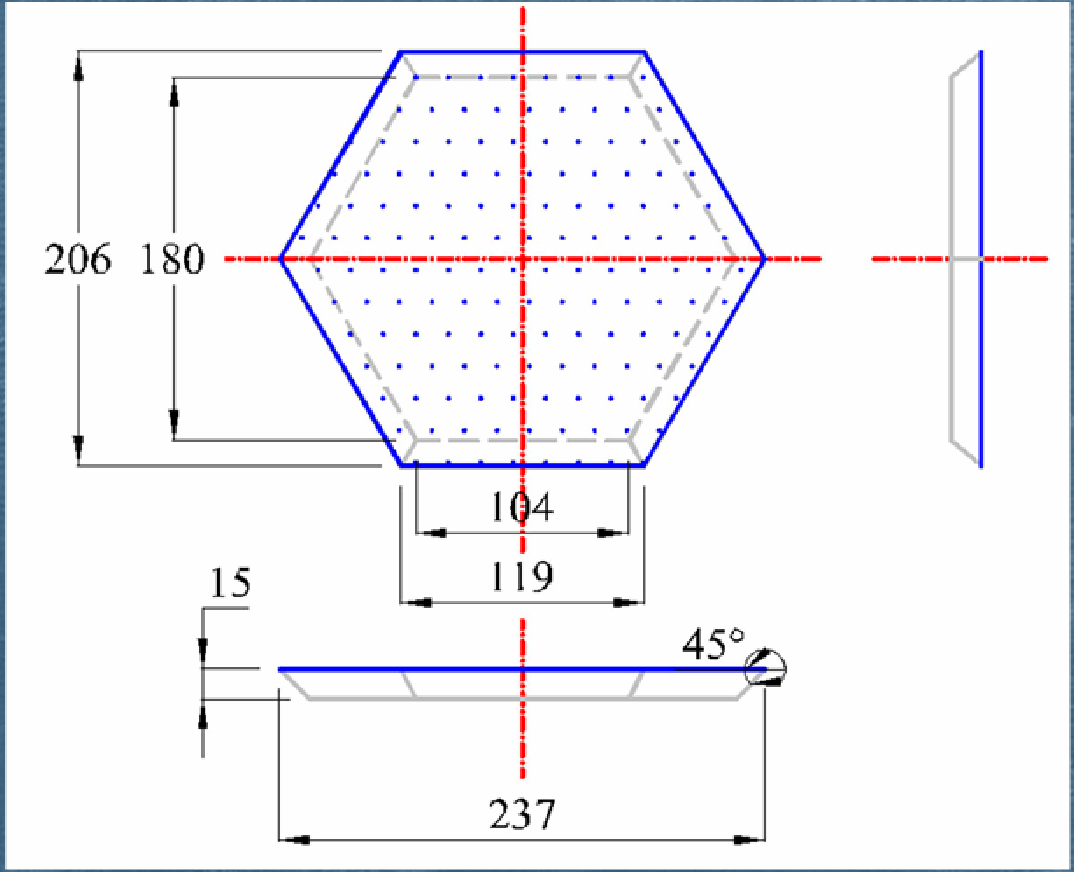


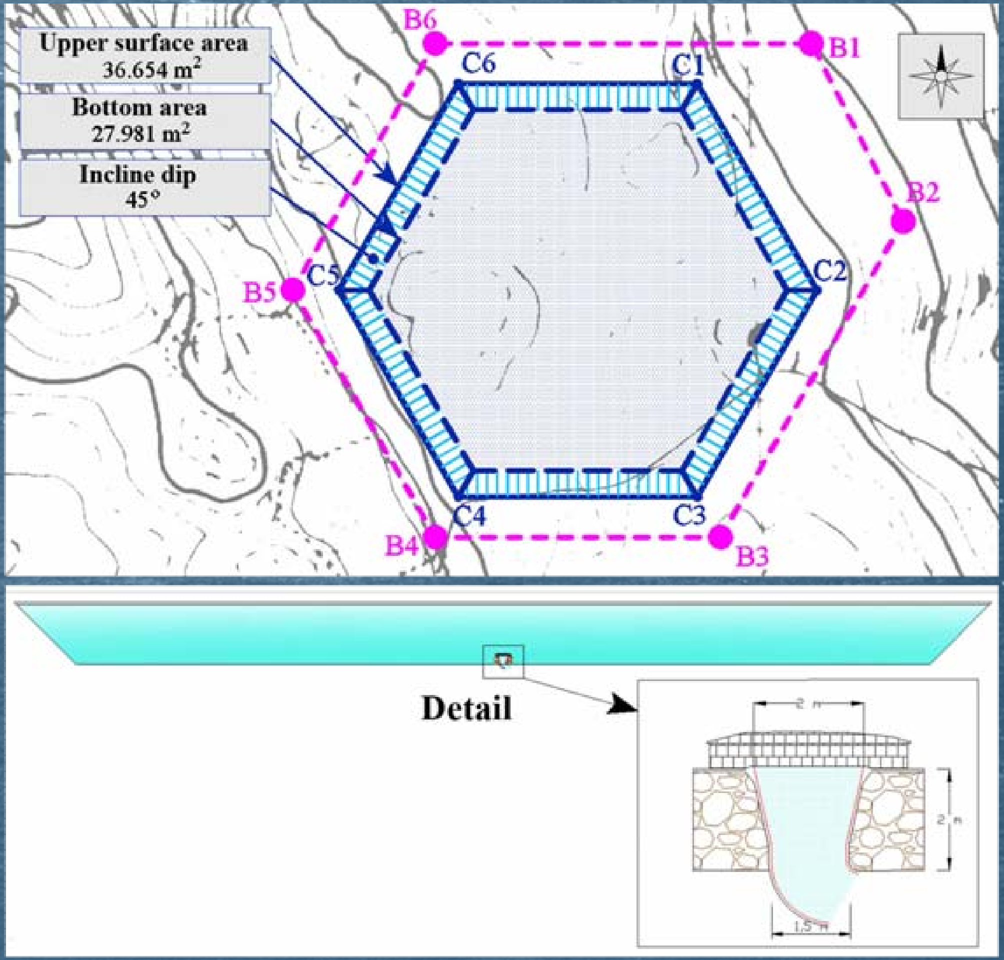
PHS siting


KASOS
Mountain
of Kapsalos
The island of Kasos


"Antiperatos"
coast
Pumps & hydro
power house
40 m
80 m
120 m
160 m
200 m
240 m
280 m
320 m
360 m
400 m
440 m
480 m
"Armenis"
gulf
B1
B2
B3
B4
B5
B6
"Kaspalos" mountain
Upper reservoir

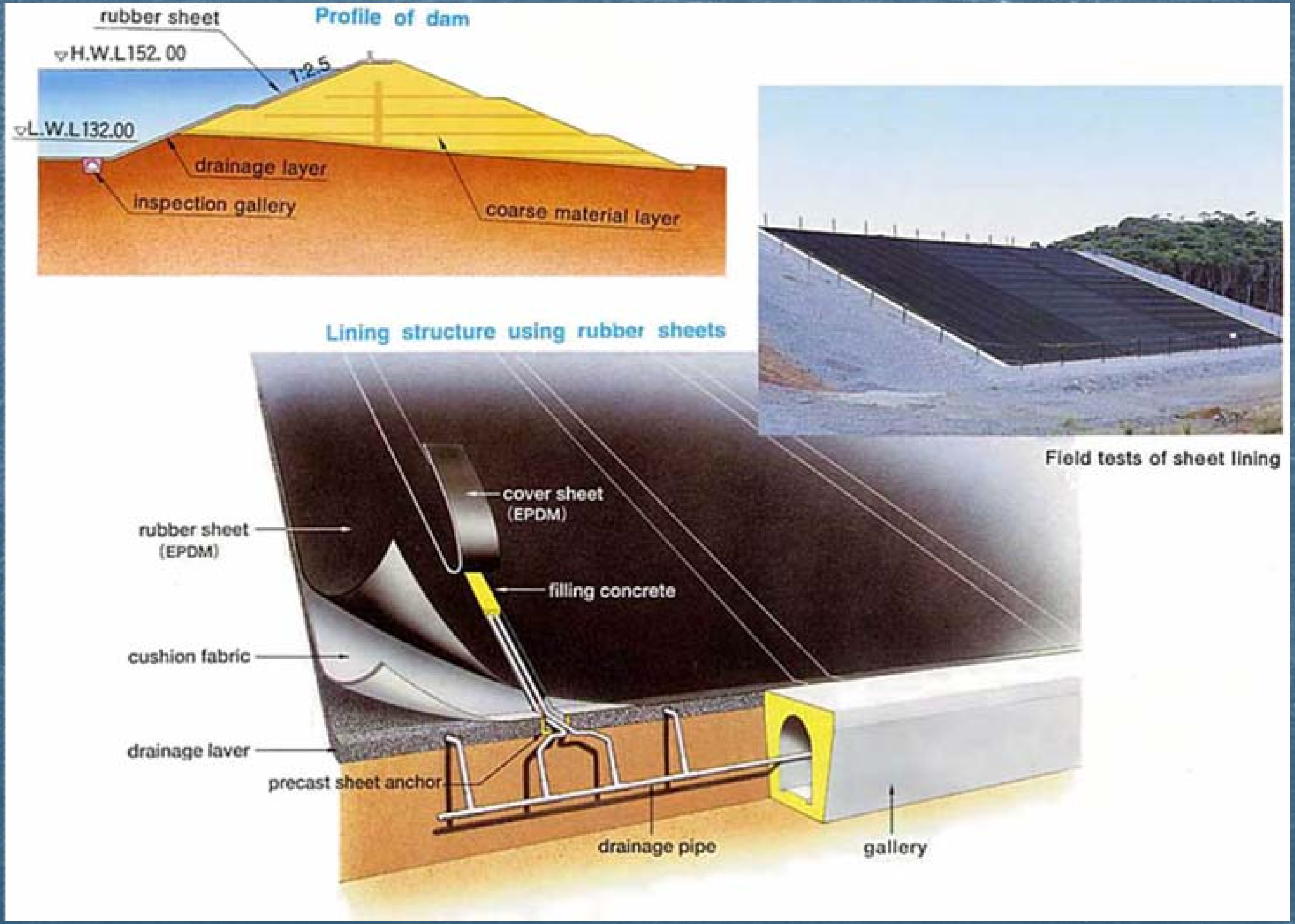
Upper reservoir design





The upper reservoir installation area

Sealing of upper reservoir

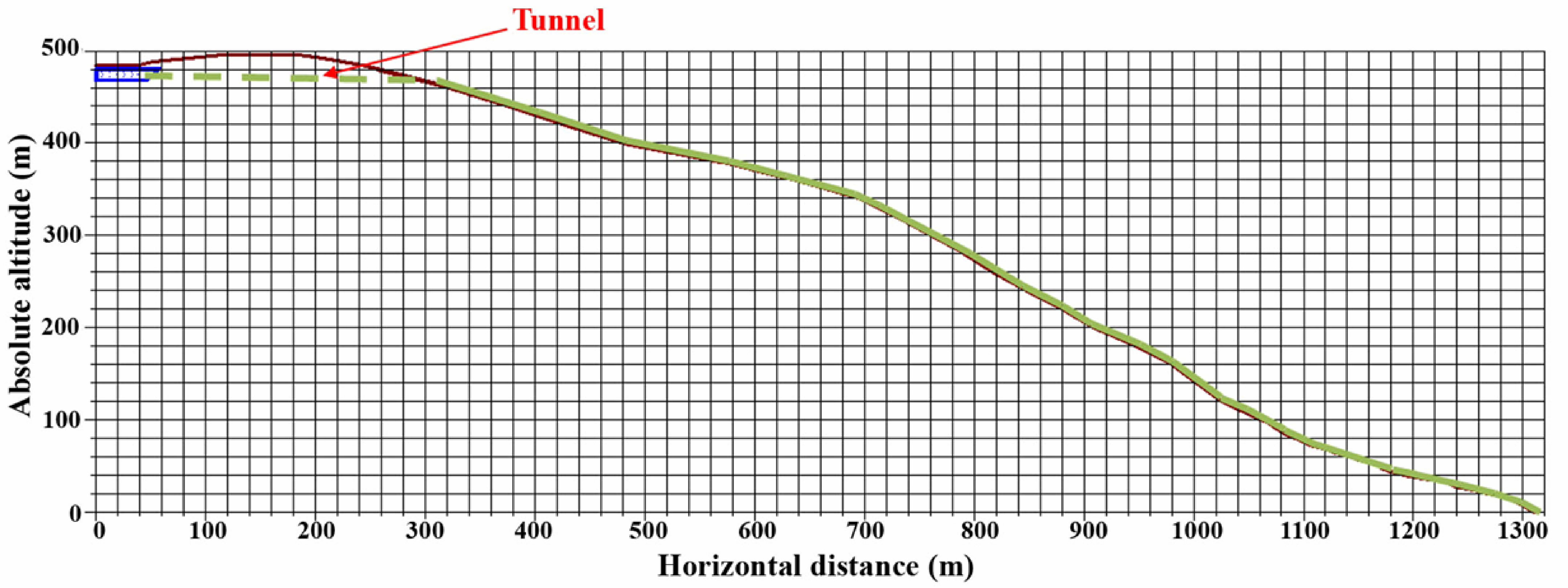


Fundamental features of upper reservoir

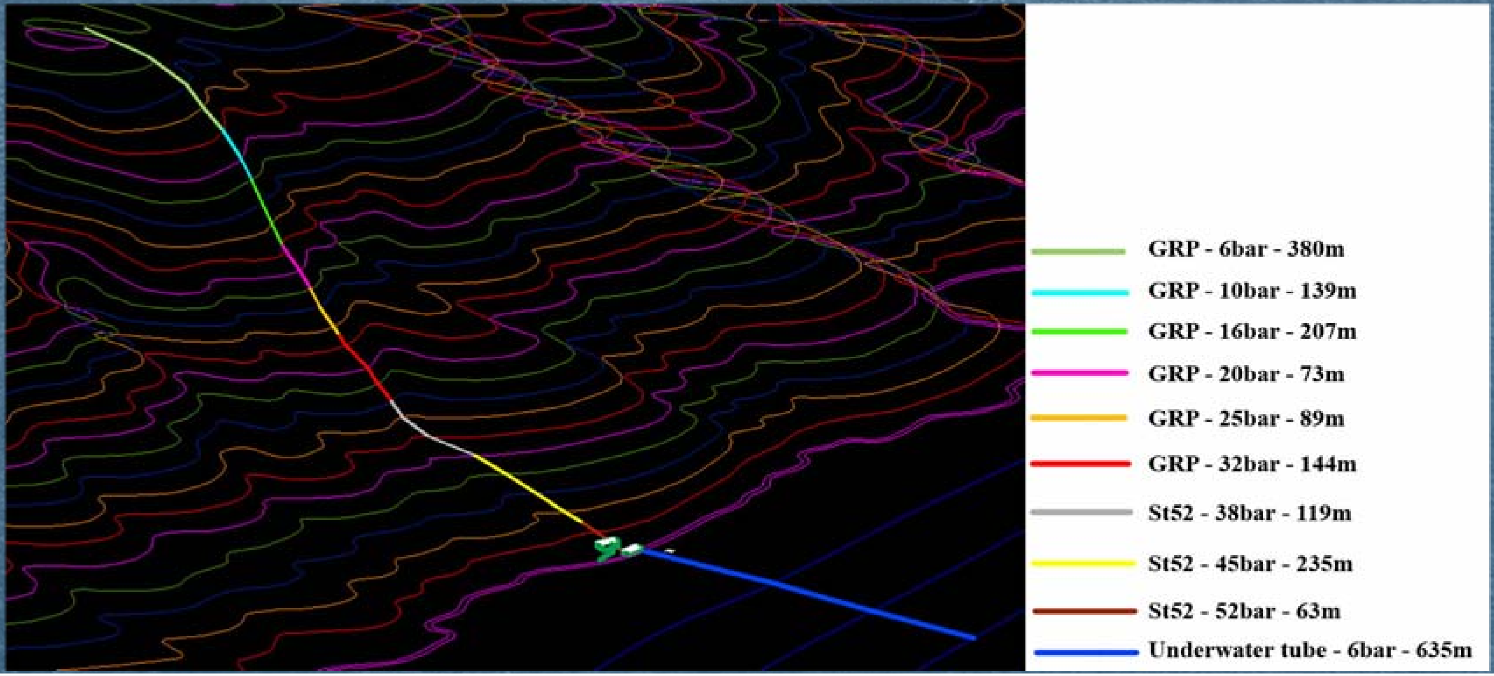
Total capacity (m^3)	483.313
Effective capacity (m^3)	465.062
Maximum absolute altitude of the reservoir's surface (m^2)	36.654
Area of the reservoir's bottom (m^2)	27.981
Installation area absolute altitude (m)	480
Bottom's absolute altitude (m)	465
Maximum reservoir's depth (m)	15
Slope of the reservoir's sides (^{o})	45
Total digging works volume (m^3)	86.394

Penstock installation

Penstock vertical cross-section view



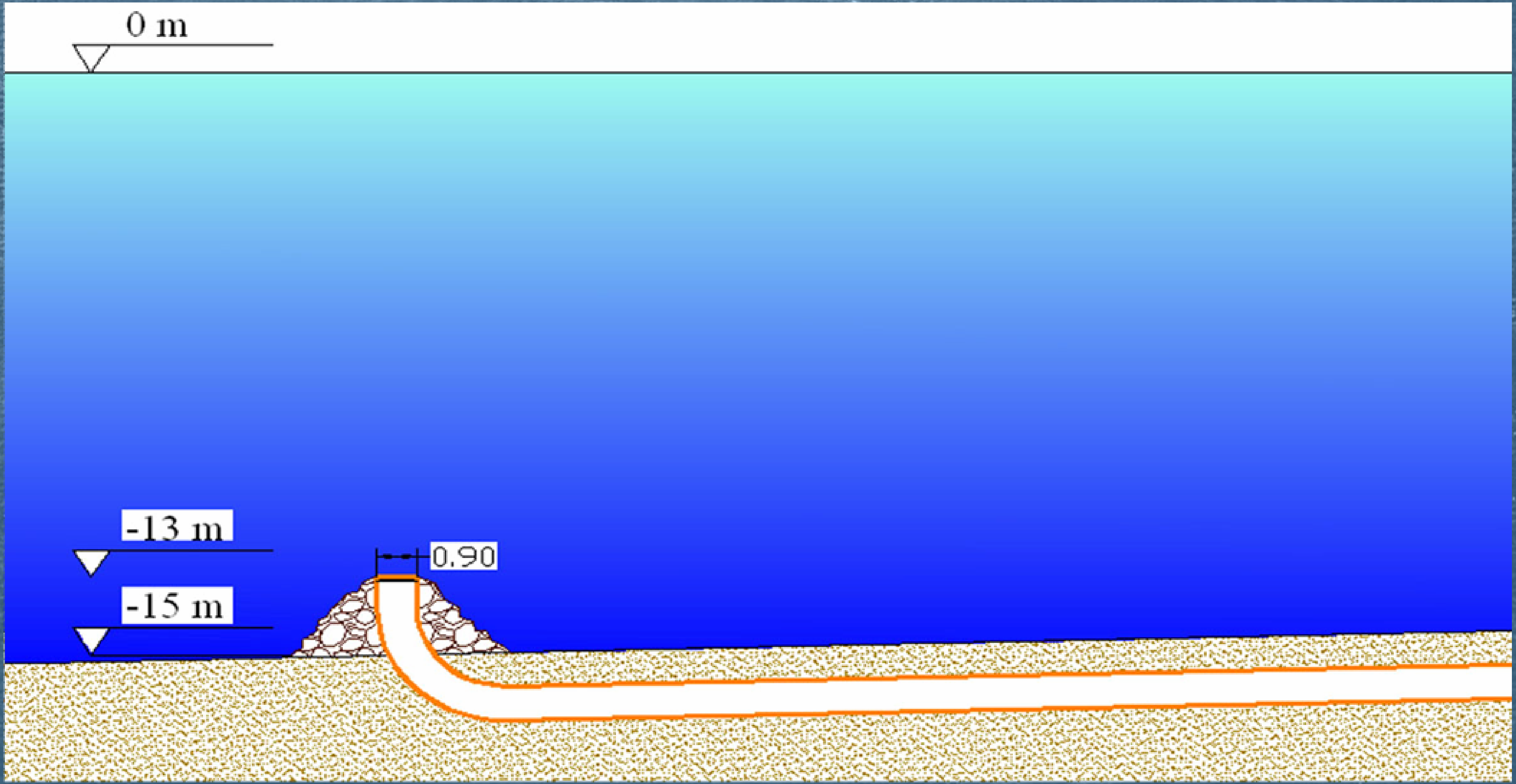
Penstock route 3-D view



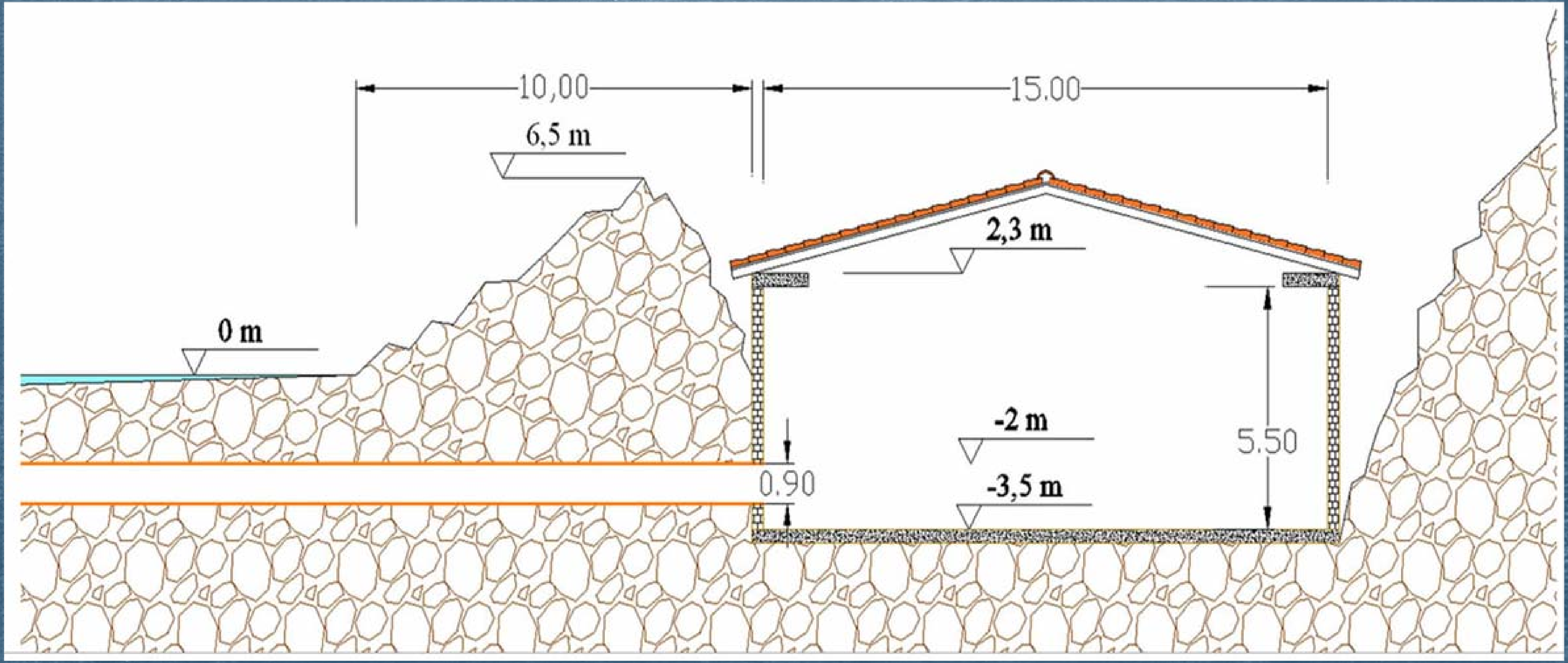
Total length of GRP tubes (m)	1.032,74
Total length of steel tubes (m)	417,07
Total tubes length (m)	1.449,81
Tubes inner diameter (m)	0,90

Example of penstock installation from the PHS in El Hiero, Canary islands, Spain

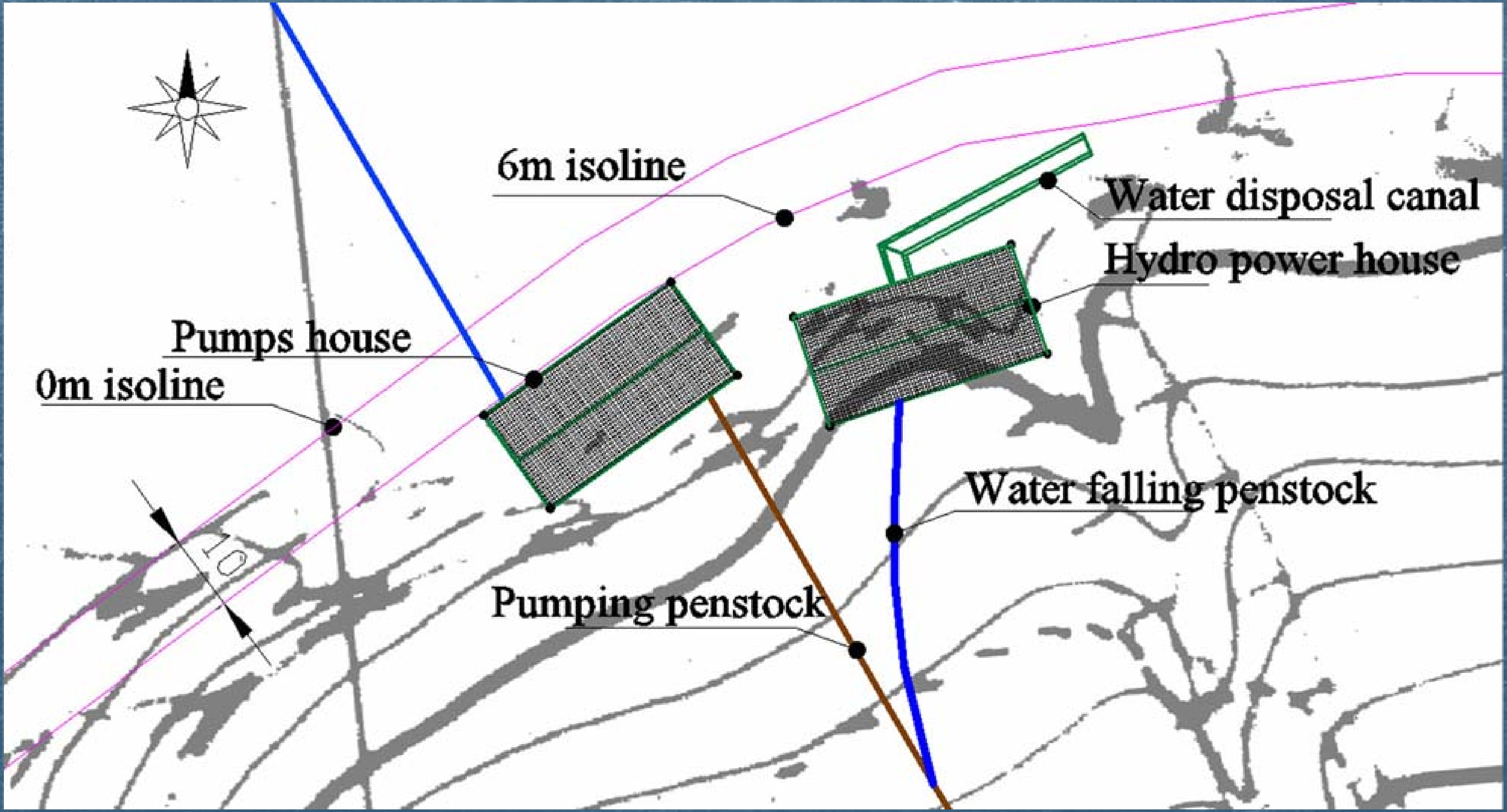
Underwater penstock installation



Pumps station suction side



Pump station and hydro power plant siting



Pump station and hydro power plant installation area

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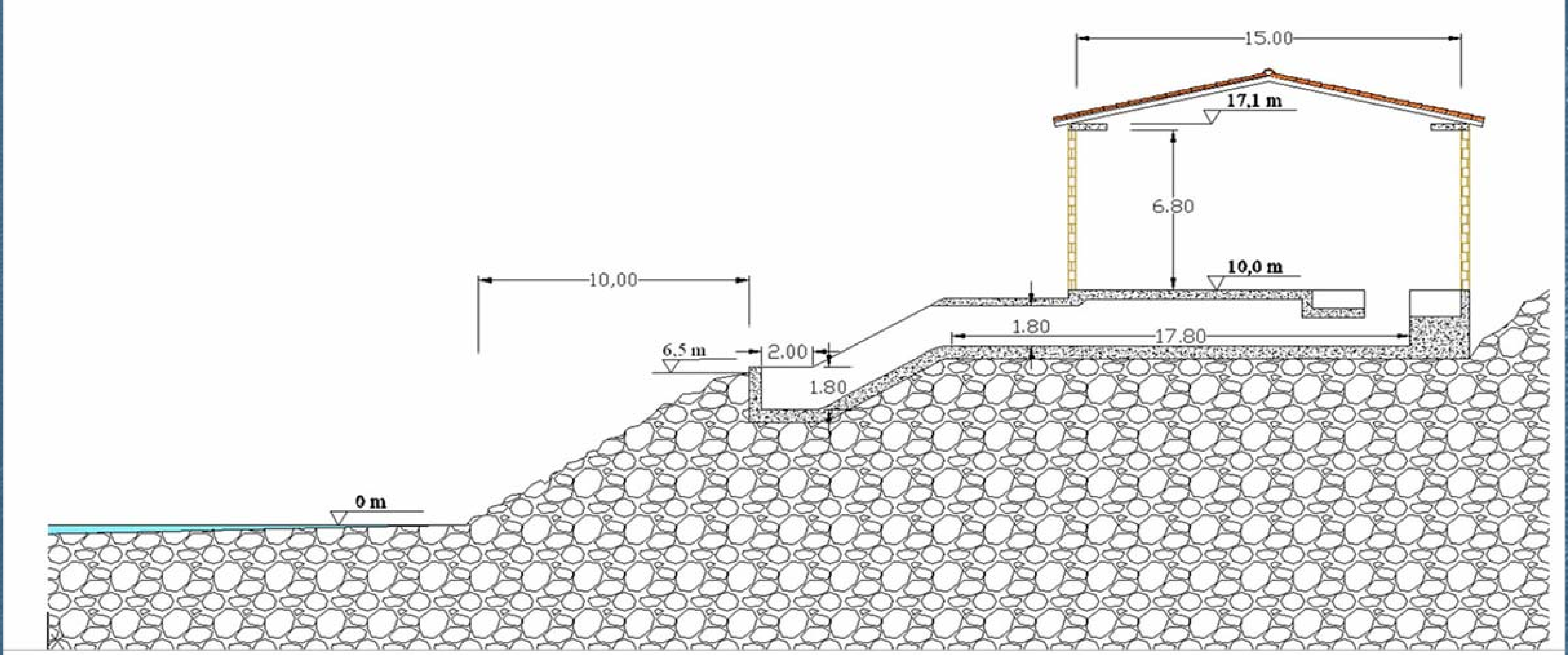
Hydro power plant vertical cross-section view



Hydro turbines and pumps nominal power

Type	Model	Nominal power per unit (kW)	Number of units	Total nominal power (kW)
Hydro turbine	Pelton, horizontal shaft	2.075	2	4.150
Pump	Multi-stage, horizontal shaft	560	8	4.480

Guaranteed power production

	Day power demand peak period	Night power demand peak period	Total time of guaranteed power production per day
Winter period (from 15th of October to 15th of April)	10:00 – 16:00	16:00 – 21:00	11
Symmer period (from 15th of April to 15th of October)	10:00 – 17:00	17:00 – 21:00	11

Guaranteed power production: 4MW

Annual energy production
The perspective of desalination

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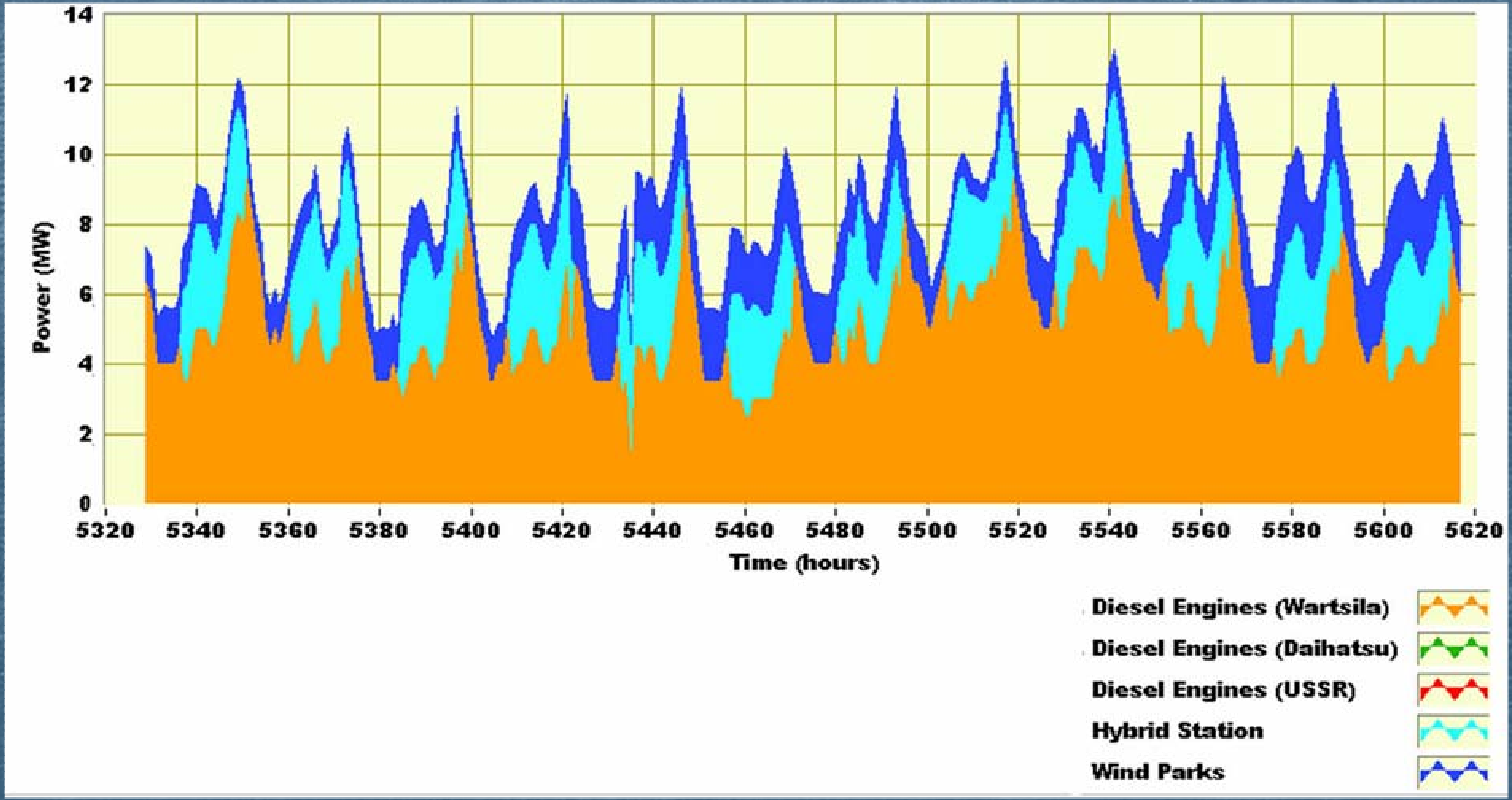
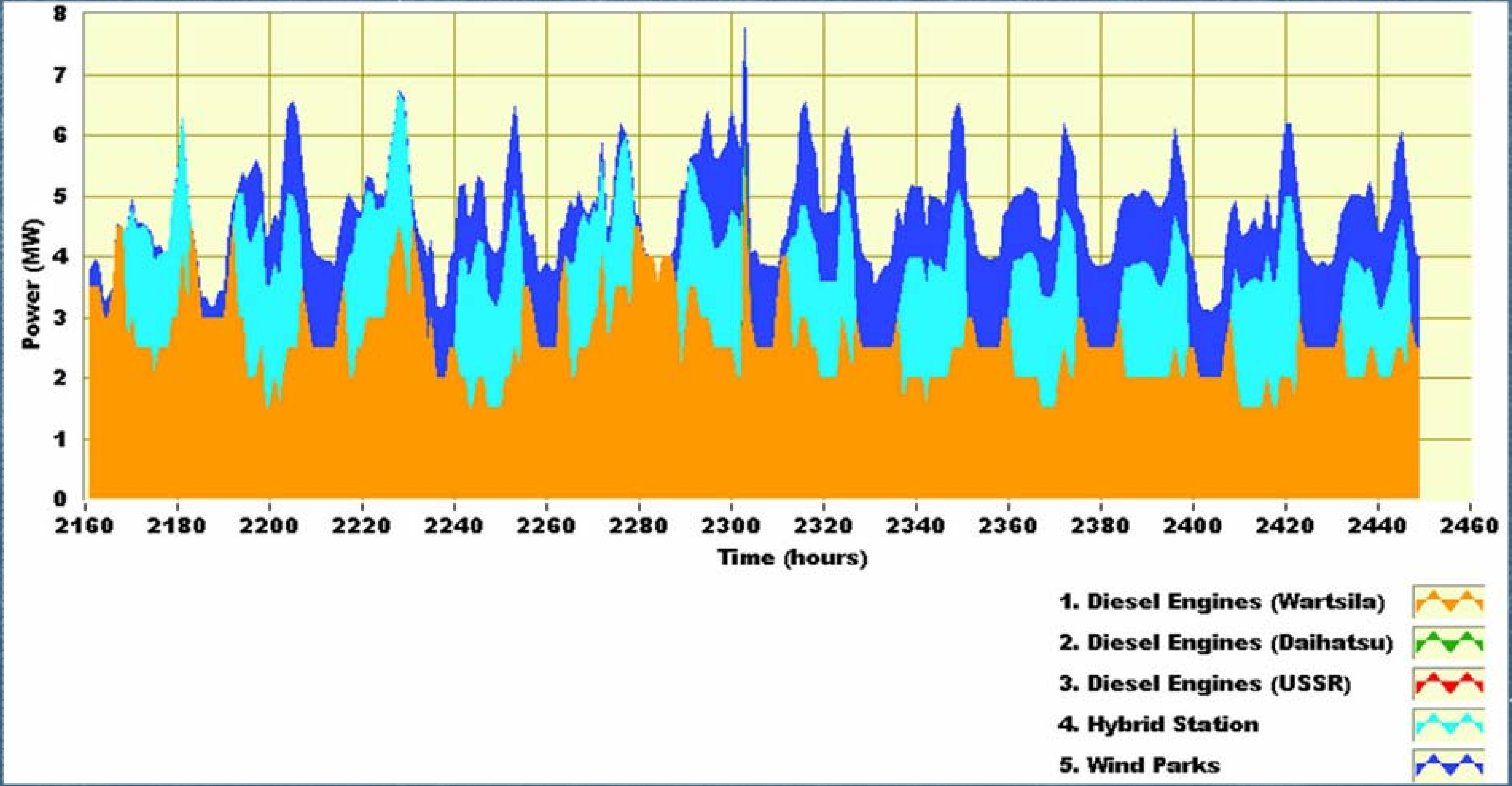
Wind park's annual electricity production (MWh)	20.714
Hydro turbines annual electricity production (MWh)	11.478
Annual energy storage from the wind parks (MWh)	17.922
Annual energy storage from thermal generators (MWh)	0.00
PHS overall efficiency (%)	64,05
Wind park annual electricity production surplus (MWh)	2.792

Given that the wind park's electricity annual surplus is estimated at 2.792MWh and the electricity annual rejection from the existing wind parks is estimated at 1.761MWh, the possibility for potable water production via a desalination plant is estimated annually at 1,8 millions m^3 by exploiting the above electricity surplus from the wind parks, assuming a specific electricity consumption by the desalination unit of 2,5kWh/m^3 of potable water.

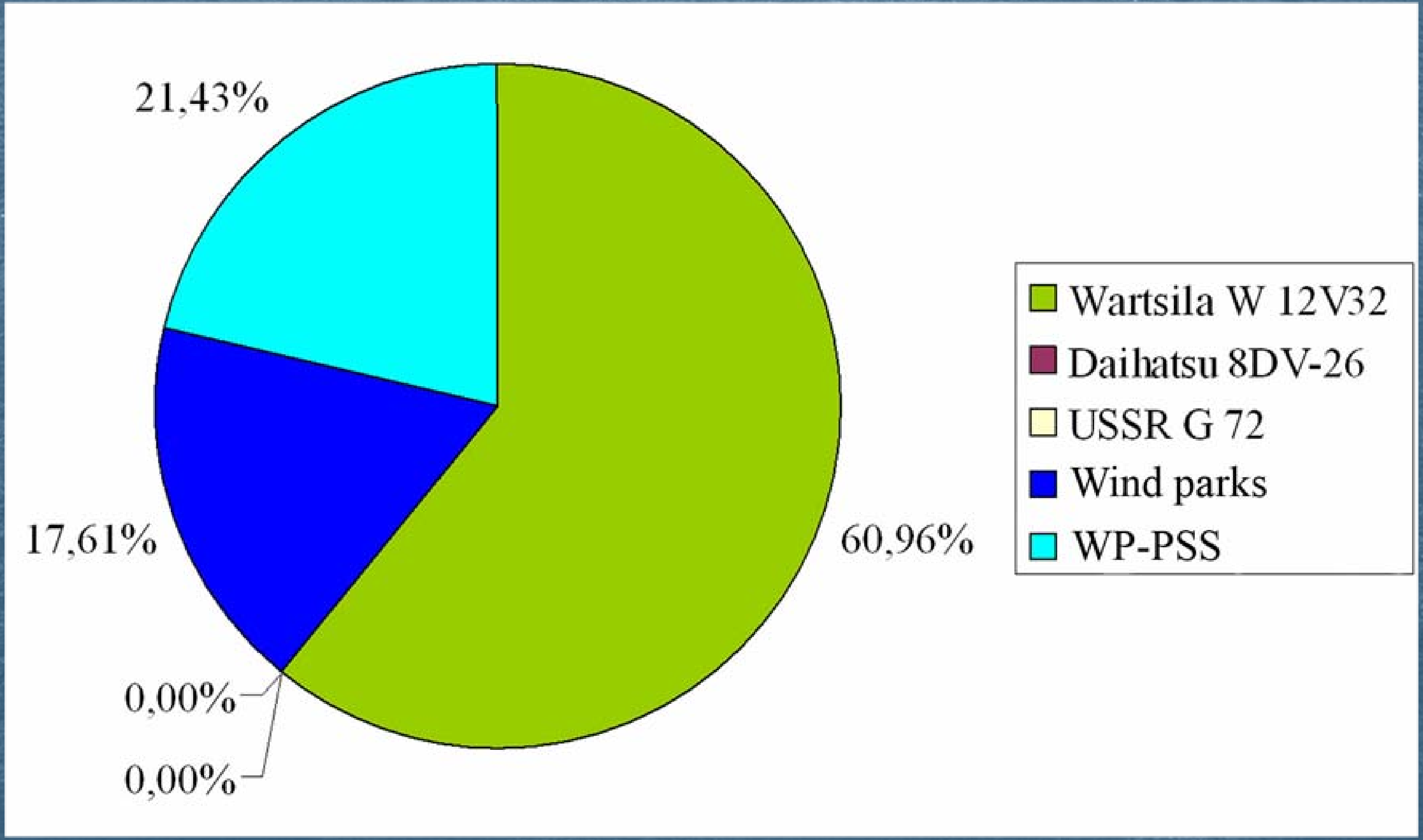
Power production synthesis
High power demand season (August)



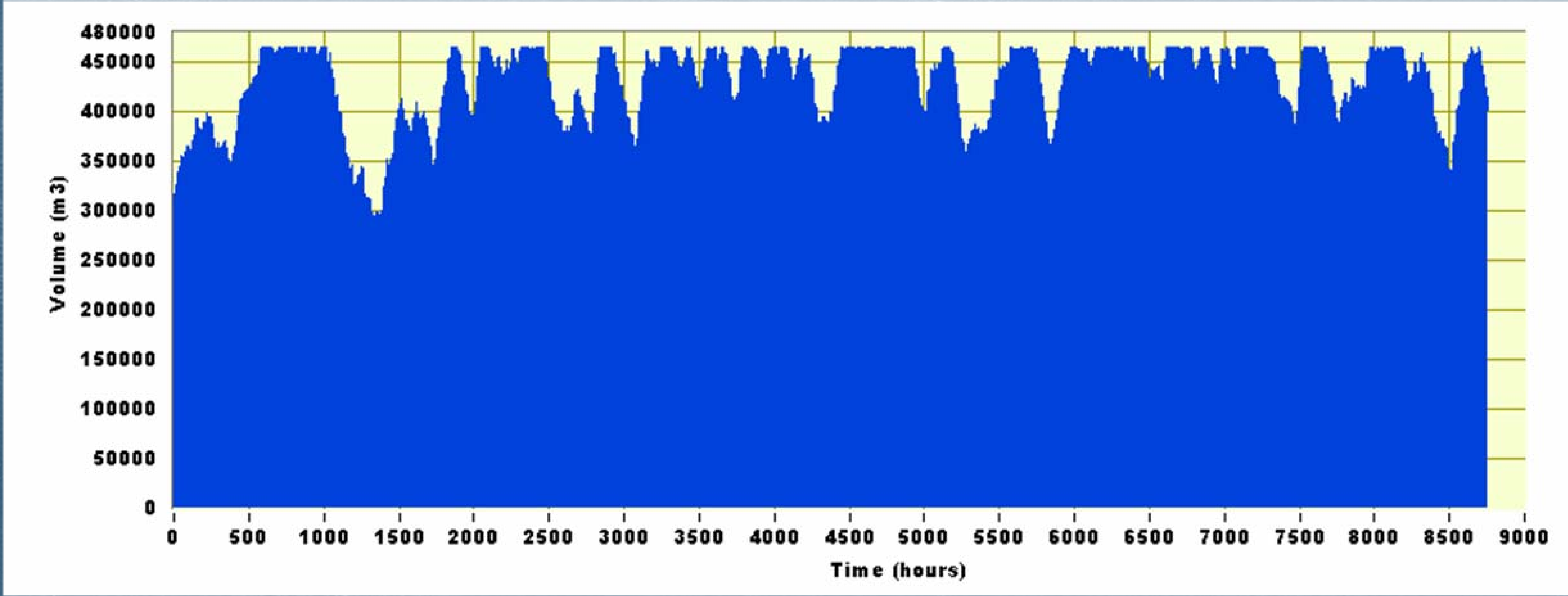
Power production synthesis
Low power demand season (April)



Percentage distribution of the annual electricity production



Upper reservoir stored water volume annual variation



Hybrid power plant set-up cost

No	Set-up cost component	Cost (€)
1	Wind park	4.800.000
2	Hydro power plant	2.800.000
3	Pump station	2.240.000
4	Upper reservoir	4.300.000
5	Penstock	2.400.000
6	New roads cosntruction	600.000
7	Connection grid	800.000
8	Other infrastructure works	900.000
9	Buildings	500.000
10	SCADA	2.200.000
11	Consulting and licensing	300.000
12	Other costs	500.000
	Total cost	22.340.000

Benefits for the island of Kasos

- Contribution to the energy supply secutiry.
- Availability of abundant potable water with low cost.
- Public compensation rates for the Municipality of Kasos of about 110.000 annualy.
- Five permanent work positions.
- Disposal of around half of the project's budget locally in the island of Kasos, during the set-up of the project.
- Improvement of the existing infrastructure of electricity and roads networks.

Thank you for your attention

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