The new Portuguese Hydropower Schemes developed by EDP

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Dam Engineering Division
EDP Produção

Para pr
1. Pressione a tecla F5
2. Prim
3. Seguidamente prima F5
4. Confirme premindo o botão

Definir Default

The new Portuguese Hydropower Schemes developed by EDP

Agenda:

- EDP Worldwide
- EDP Strategy in Hydropower
- EDP Hydropower Plants
- New EDP Hydropower Schemes
- Baixo Sabor Project
- Venda Nova III Project

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EDP Worldwide

≈12 000 employees
14 countries
40 nationalities

24,9 GW
installed power

+100%
since 2005

2,3 GW hydro power

Recently built and
under construction

#1 in
Europa

9,7 GW wind power

#4 in the
World

EDP Worldwide

Main companies

EDPR – North America
Installed power - 4,4 GW

EDPR – South America
Installed power - 204 MW

EDPRenováveis (EDPR)

EDPR - Europe
Installed power - 4,3 GW

Portugal

Installed power - 9,4 GW
Electricity - 6,1 millions of customers
Gas - 272 thousands of customers

Brasil

Installed power - 2,7 GW
Electricity - 3,3 millions of customers

Espanha

Installed power - 3,9 GW
Electricity - 1,1 millions of customers
Gas - thousands of customers

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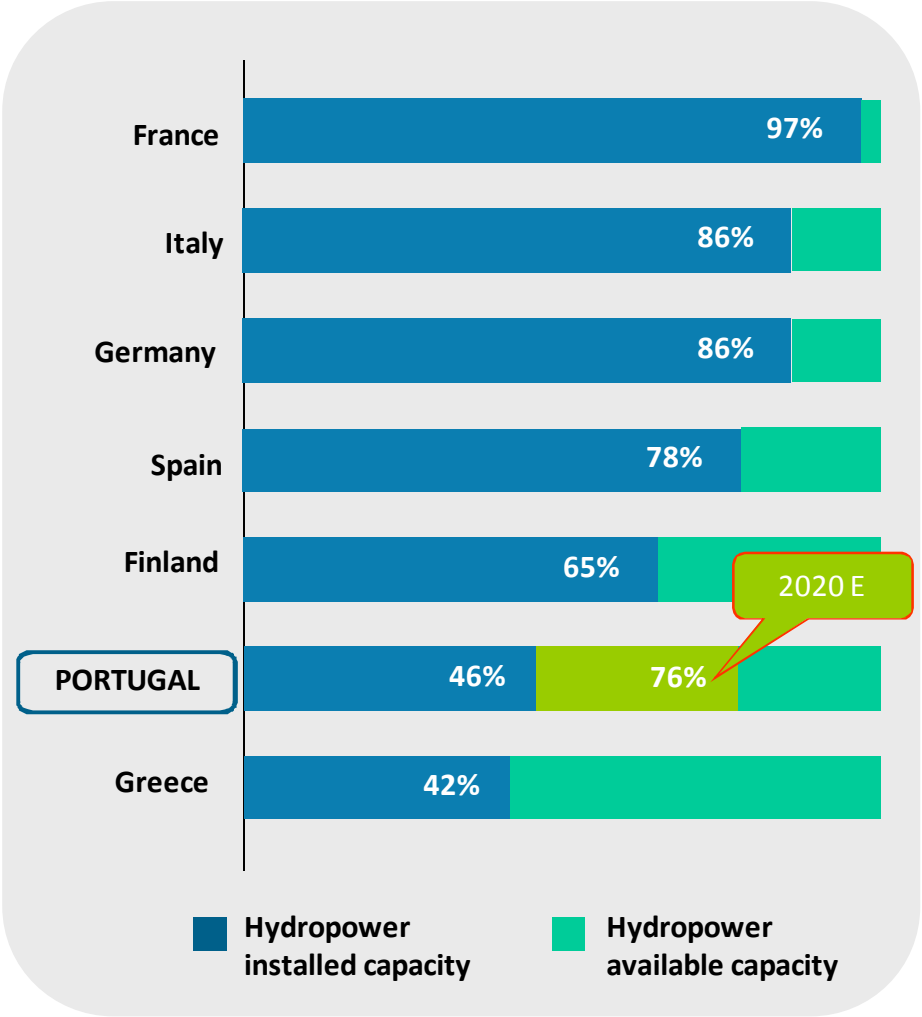
Importance of Hydroelectricity in EDP´s Portfolio

Potencial development of Hydropower in Europe



Source: Ministry of Economy (2011)

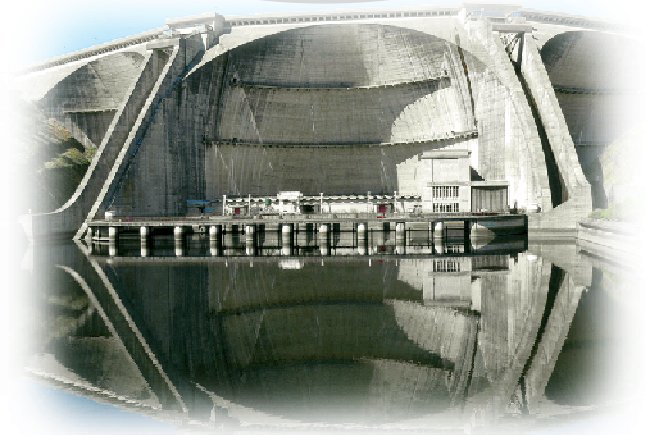
Growth drivers

- Twofold increase in the capacity of the interconnection with Spain
- Start of MIBEL (Iberian Electricity Market)
- Renewables objectives in % of primary energy
- Volatility of oil, coal and CO2 prices
- Growth of wind energy penetration increases the value of hydropower

Rationale and Strategic Importance of Hydroelectricity

Emergency water reserve

CO2 emissions reduction



Increase of water storage capacity

Contribution to the growth of wind power

Flood control and fire fighting

Contribution to the Portuguese economy

- Direct/indirect employment creation: ~35,000
- Deficit reduction

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Direção de Engenharia de Barragens

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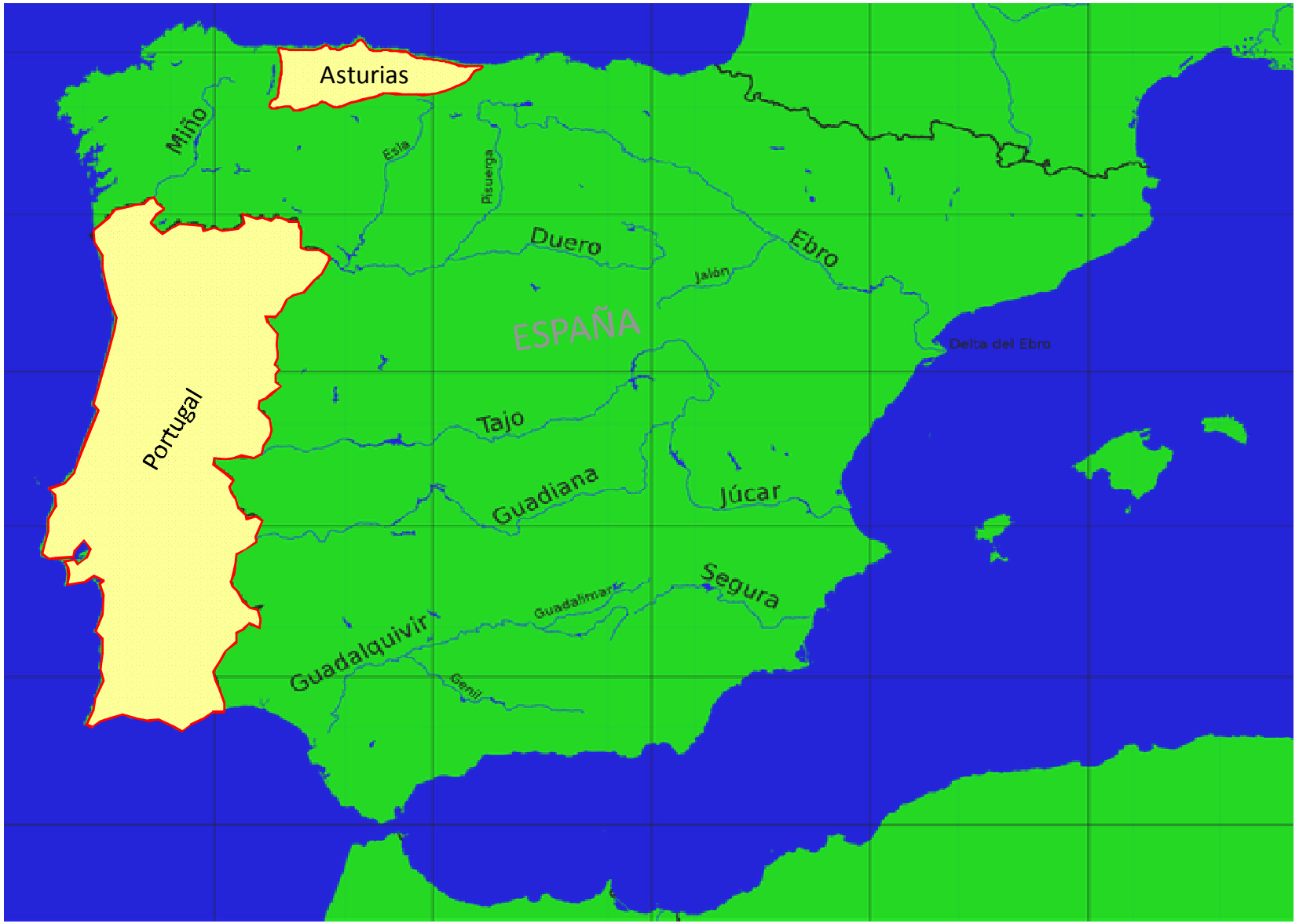
Hydro Power Plants in Iberia



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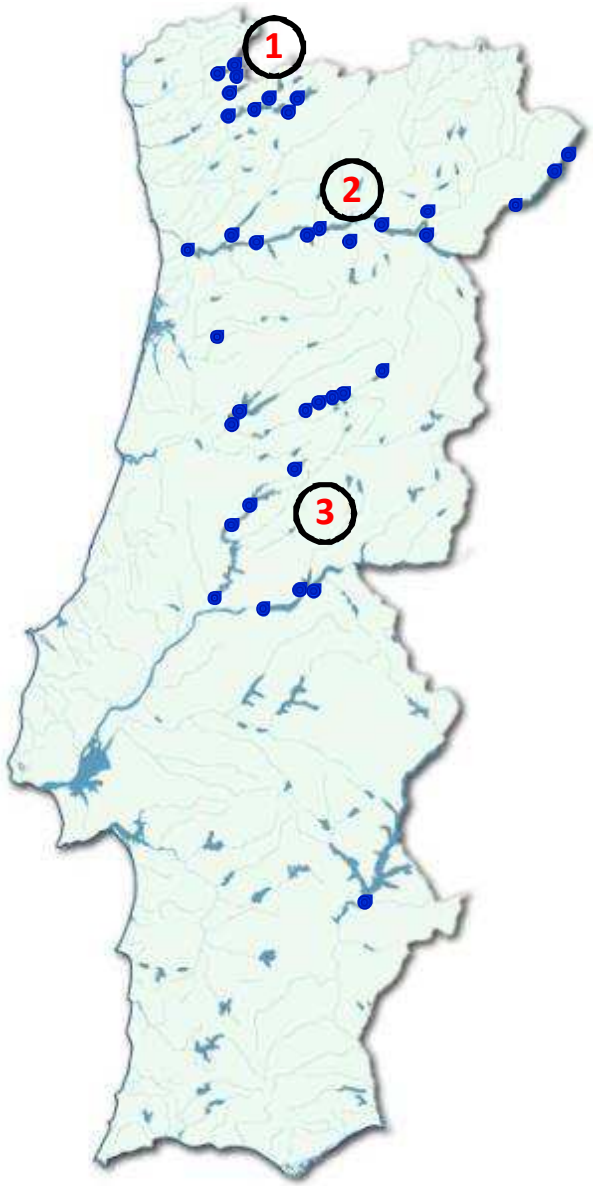
Hydro Power Plants of EDP Produção

Hydro Power Plants(> 10 MW)



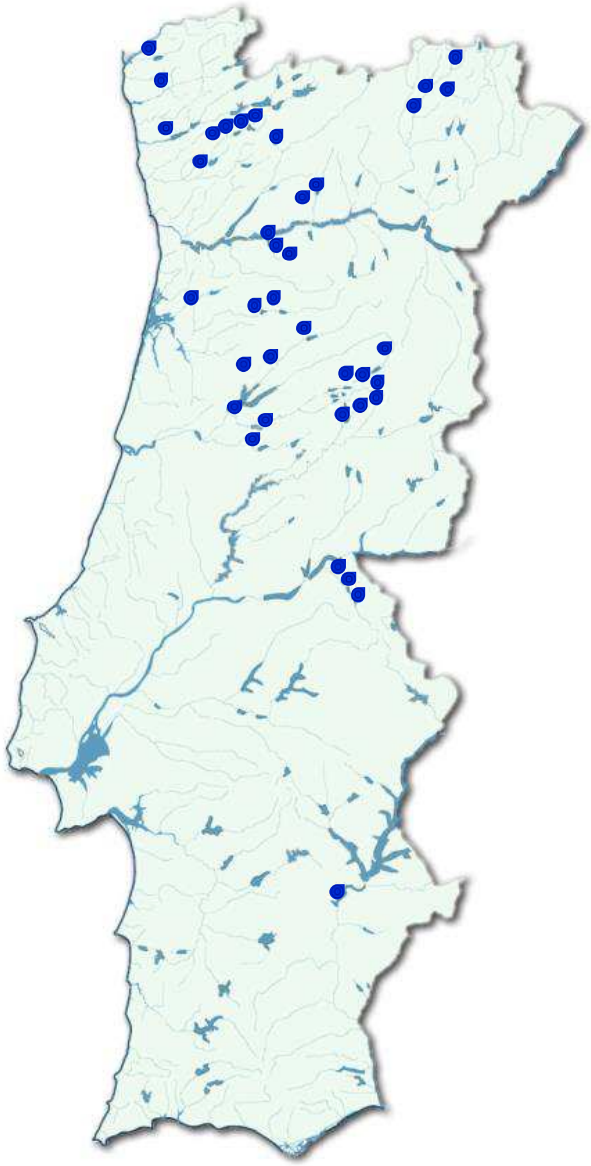
EDP Produção has in operation 80 hydro power plants, with a total installed capacity of 5 895 MW.

About 1 567 MW are installed in reversible units, allowing the operation in turbine and pump modes: Alto Rabagão, Frades, Salamonde II, V. Furnas, Torrão, Baixo Sabor, Feiticeiro, Aguieira, Alqueva e Alqueva II.

They are manly located in the North of Portugal in the 3 major watersheds:

- Cávado-Lima 1
- Douro 2
- Tejo-Mondego 3

Small Hydro(≤ 10 MW)



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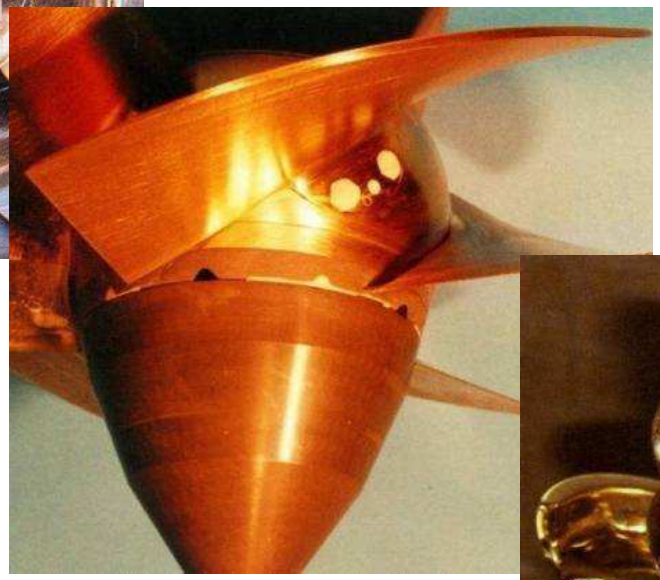
Hydro Power Plants of EDP Produção

3 Generation Centers
80 Hydro power plants
160 Generating units



96 Francis turbines type
34 Kaplan turbines type
25 Pelton turbines type
5 Bolbo turbines type

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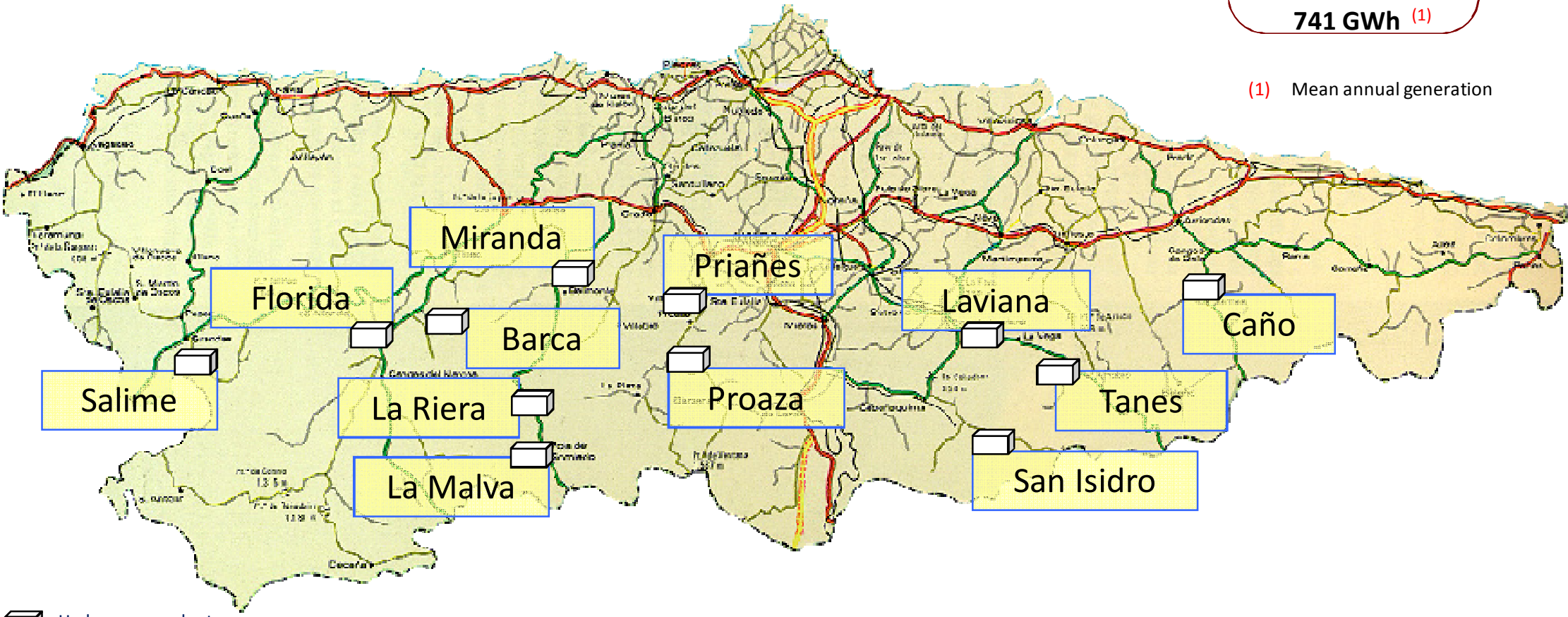
Hydro Power Plants of EDP in Spain

12 plants
33 units

432,7 MW

741 GWh (1)

(1) Mean annual generation



Hydro power plant

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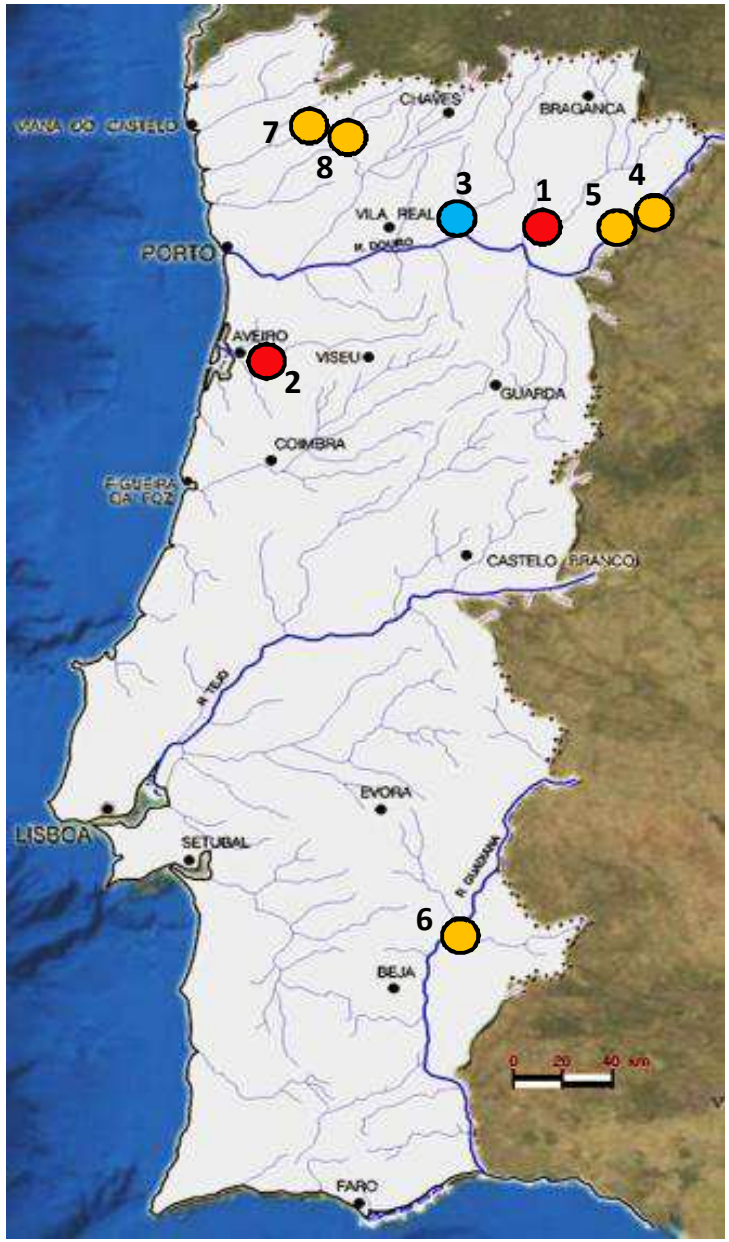
New Hydroelectric Projects



New projects:

1. Baixo Sabor
2. Ribeiradio-Ermida
3. Foz Tua

Repowering projects:

4. Picote II
5. Bemposta II
6. Alqueva II
7. Salamonde II
8. Venda Nova III

- New projects recently completed
- New projects under construction
- Repowering projects recently completed

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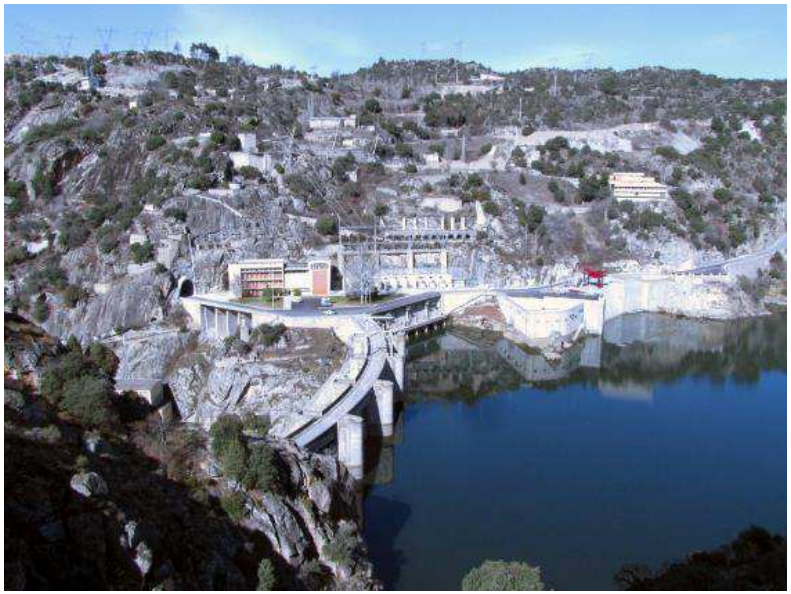
New Hydroelectric Projects

Project	MW	Start of Construction	Start of operation	Type
Picote II	246	2007	2011	Repowering
Bemposta II	191	2008	2011	Repowering
Alqueva II	256	2008	2012	Repowering with pumping
Baixo Sabor	189	2008	2016	New Power Plant with pumping
Ribeiradio-Ermida	82	2010	2015	New Power Plant
Salamonde II	224	2010	2016	Repowering with pumping
Venda Nova III	781	2010	2016	Repowering with pumping
Foz Tua	270	2011	2017	New Power Plant with pumping
TOTAL	2 239			

New Hydropower Projects

Picote II

This repowering project is located on the right bank of the international stretch of the Douro river. It includes a new headrace tunnel and a new underground powerhouse equipped with one generation unit.



Main indicators	
Start of the construction works	2007
Commissioning Year	2011
Power	246 MW
Annual Average Generation	239 GWh

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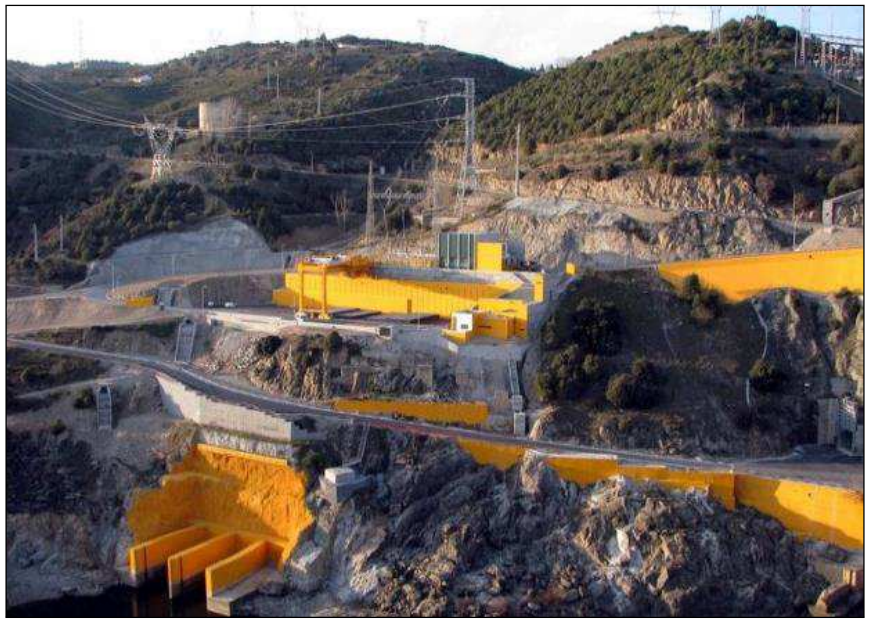
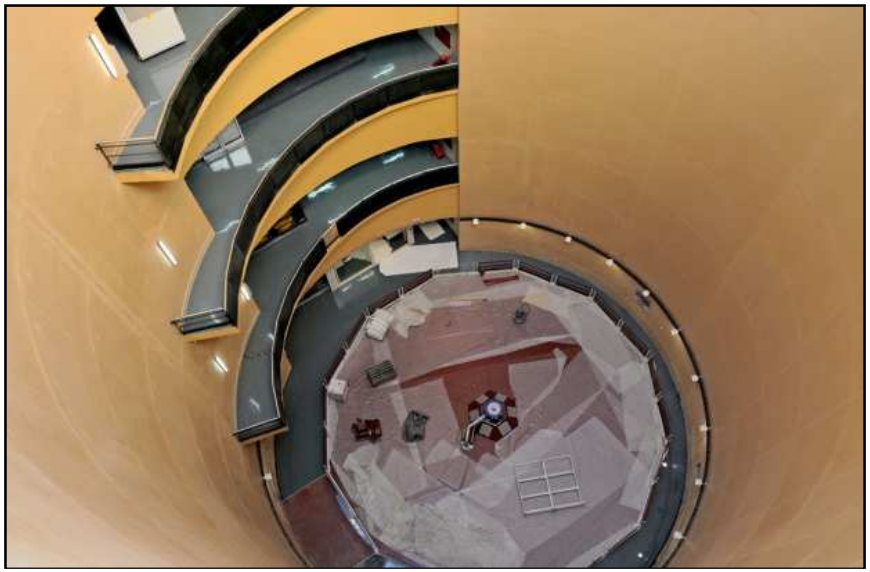
New Hydropower Projects

Bemposta II

This repowering project is also located on the right bank of the international stretch Douro river, downstream Picote. It includes a new headrace tunnel and new large shaft powerhouse, equipped with one generation unit.





Main indicators	
Start of the construction	2008
Commissioning Year	2011
Power	191 MW
Annual Average Generation	134 GWh

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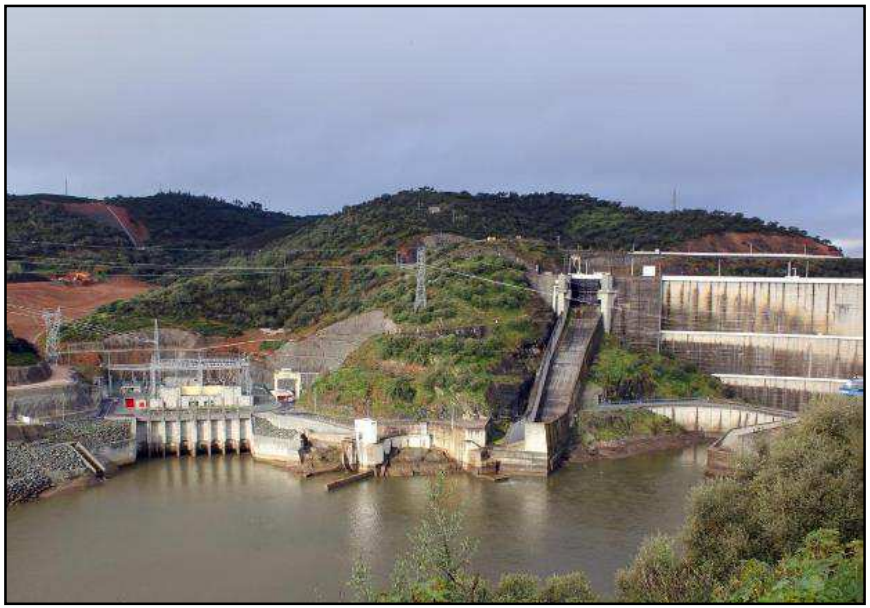
New Hydropower Projects

Alqueva II

This repowering project is located on the right bank of Guadiana river and includes two independent pressure tunnels and surface powerhouse, which is equipped with two reversible units.



Main indicators	
Start of the construction	2008
Commissioning Year	2012
Power	256 MW
Annual Average Generation	381 GWh

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New Hydropower Projects
Baixo Sabor

This scheme is located on the Sabor river, close to its confluence with Douro river. It comprises two power plants equipped with reversible units, enabling water pumping from the Douro river.

The upstream scheme includes a 123 m high arch dam and a downstream 45 m high gravity dam.

It creates the most important reservoir in the Douro river watershed with an strategic role associated to electricity generation.

Main indicators	
Start of the construction	2008
Commissioning Year	2016
Power	189 MW
Annual Average Generation	460 GWh

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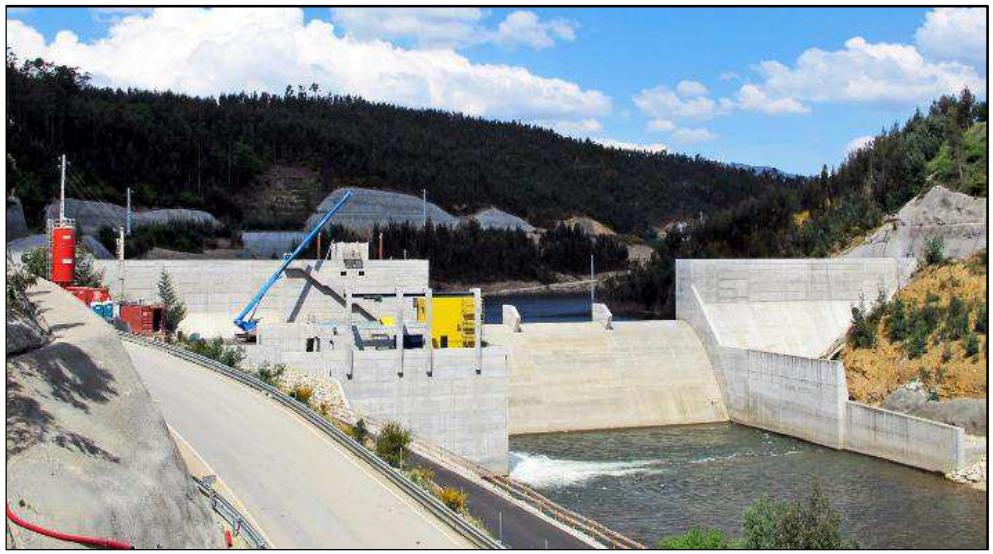
New Hydropower Projects
Ribeiradio-Ermida

The scheme is located on the Vouga river and comprises two concrete gravity dams: Ribeiradio (upstream) and Ermida(downstream), 74 m and 35 m high, respectively.

Ribeiradio powerhouse is equipped with a 72 MW unit and Ermida powerhouse one with two 5 MW units.



Main indicators	
Start of the construction	2010
Commissioning Year	2015
Power	82 MW
Annual Average Generation	139 GWh

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New Hydropower Projects
Venda Nova III

This is the second repowering in the Venda Nova dam reservoir and is located on the left bank of Cávado river.
It includes an new hydraulic circuit and a new underground powerhouse, which is equipped with two variable speed reversible units.
The installed capacity is the highest in Portugal.

Main indicators	
Start of the construction	2010
Commissioning Year	2016
Power	781 MW
Annual Average Generation	1441 GWh

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New Hydropower Projects
Salamonde II

This repowering project is located on the left bank of the Cávado river, downstream Venda Nova III.
It includes a new underground powerhouse, equipped with a reversible unit.
The works included the construction of an additional spillway to face the updated design flood.

Main indicators	
Start of the construction	2010
Commissioning Year	2016
Power	224 MW
Annual Average Generation	386 GWh

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New Hydropower Projects

Foz Tua

The power plant is located on the right bank of Tua river, close to its confluence with the Douro river, from which the water can be pumped. The underground powerhouse is equipped with two reversible units, installed in independent shafts, and connected to two pressure tunnels.

The concrete arch dam, inserted in a narrow valley, is 110 m high.

Main indicators	
Start of the construction	2011
Commissioning Year	2017
Power	270 MW
Annual Average Generation	667 GWh

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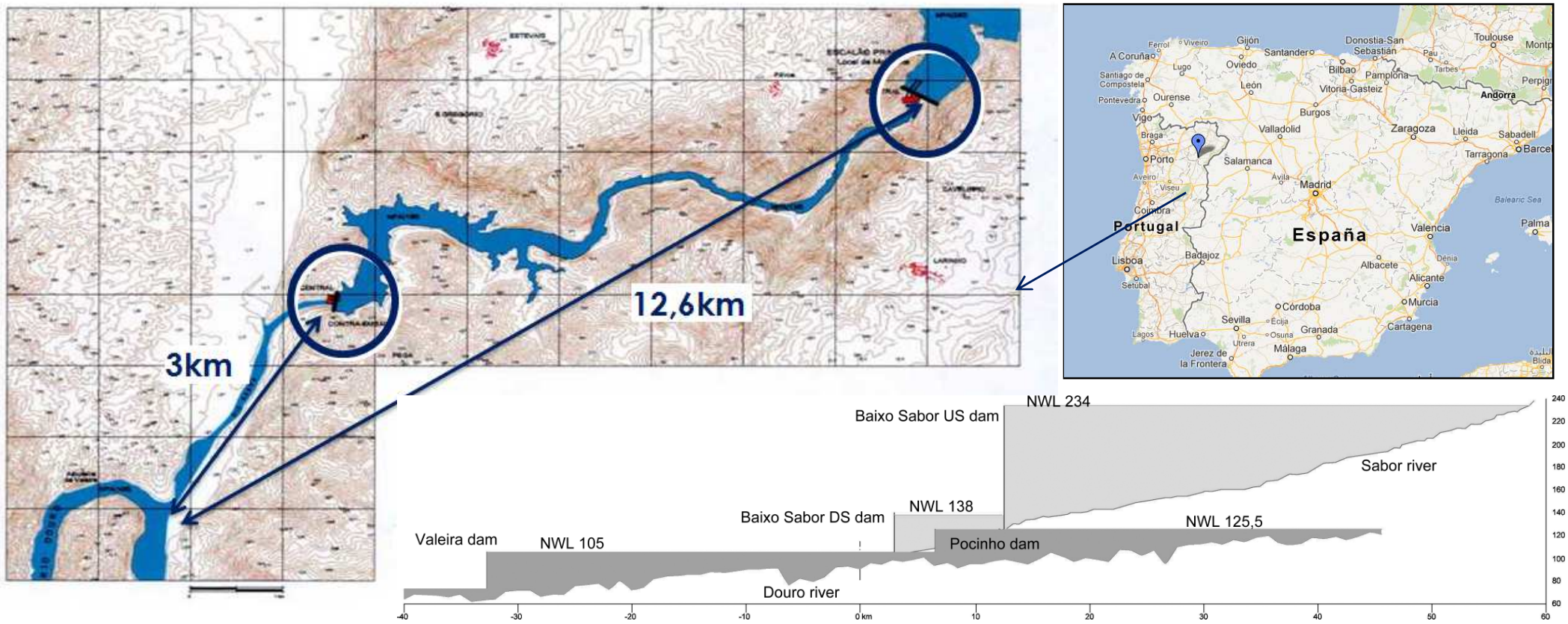
Baixo Sabor Project

Baixo Sabor scheme is located in the north-eastern of Portugal, in the lower stretch of the Sabor River – tributary of the right bank of Douro River



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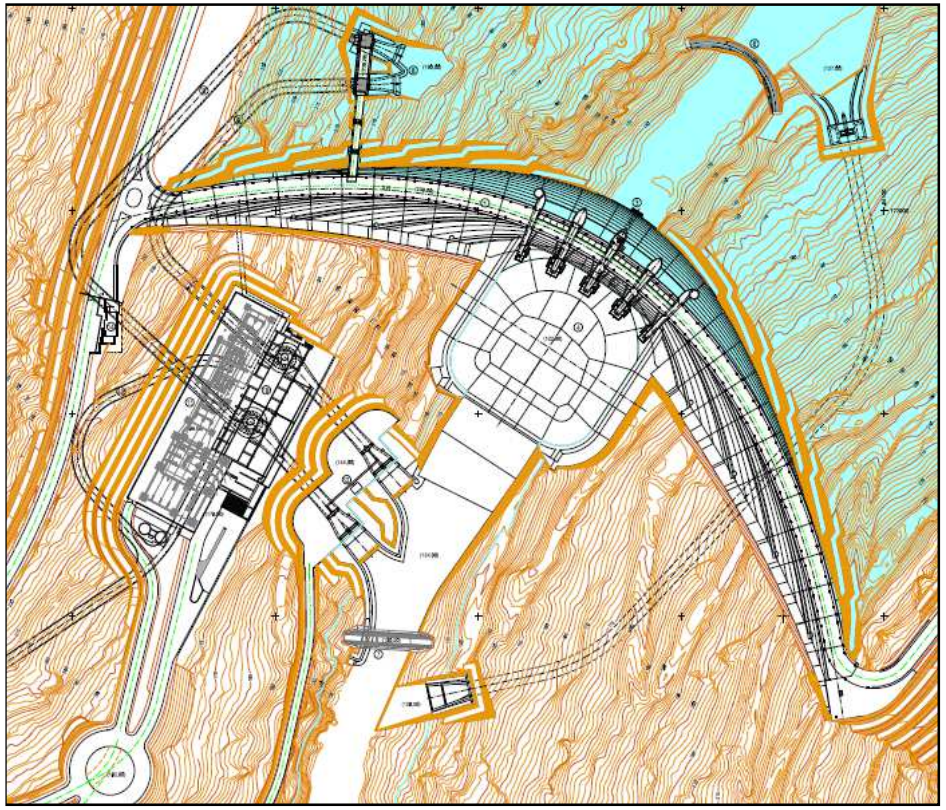
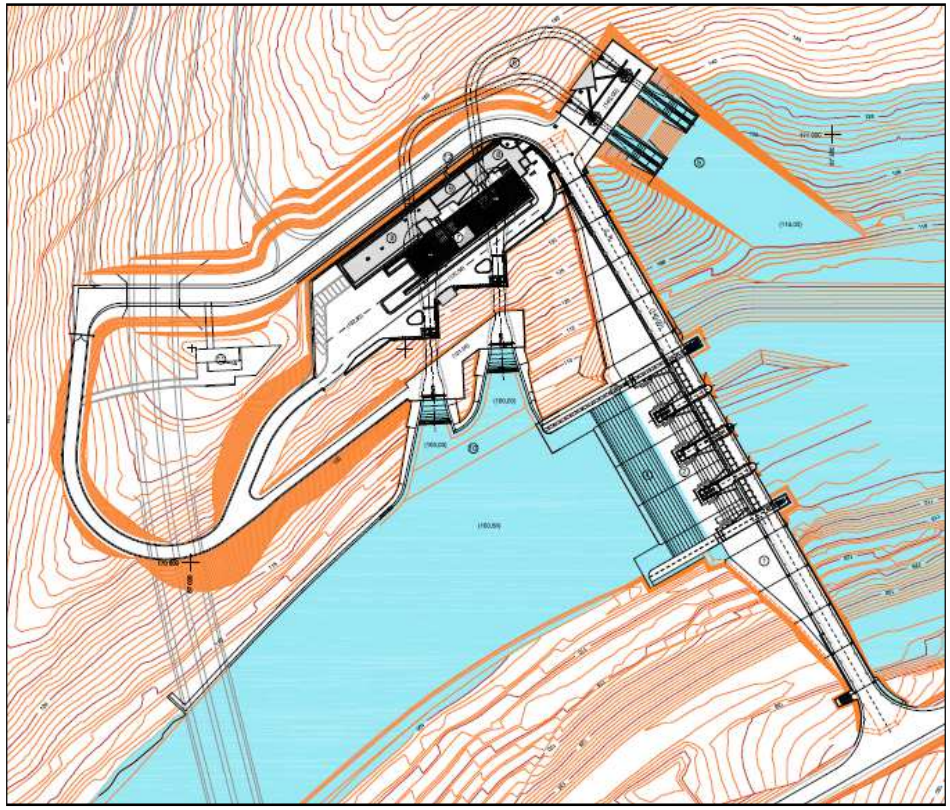
Baixo Sabor Project

The global project includes two dams, Baixo Sabor (upstream) and Feiticeiro (downstream)

Reversible units were installed in the two powerhouses to enable the water pumping from the upper Portuguese stretch of the Douro River to the large reservoir of the upstream dam



Baixo Sabor scheme (upstream)



Feiticeiro scheme (downstream)

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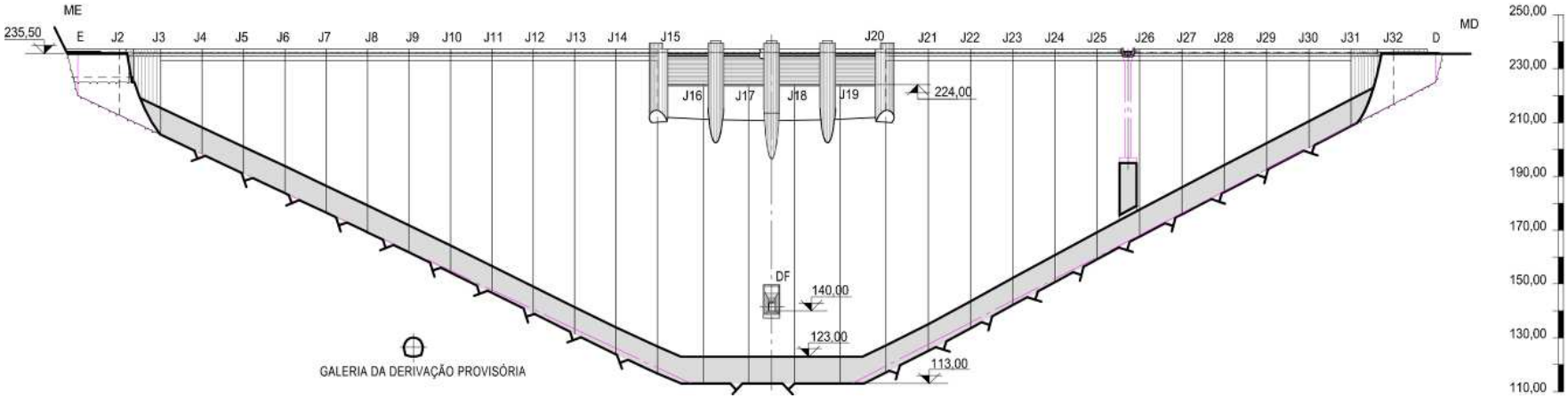
Baixo Sabor Project

Concrete arch dam characteristics:

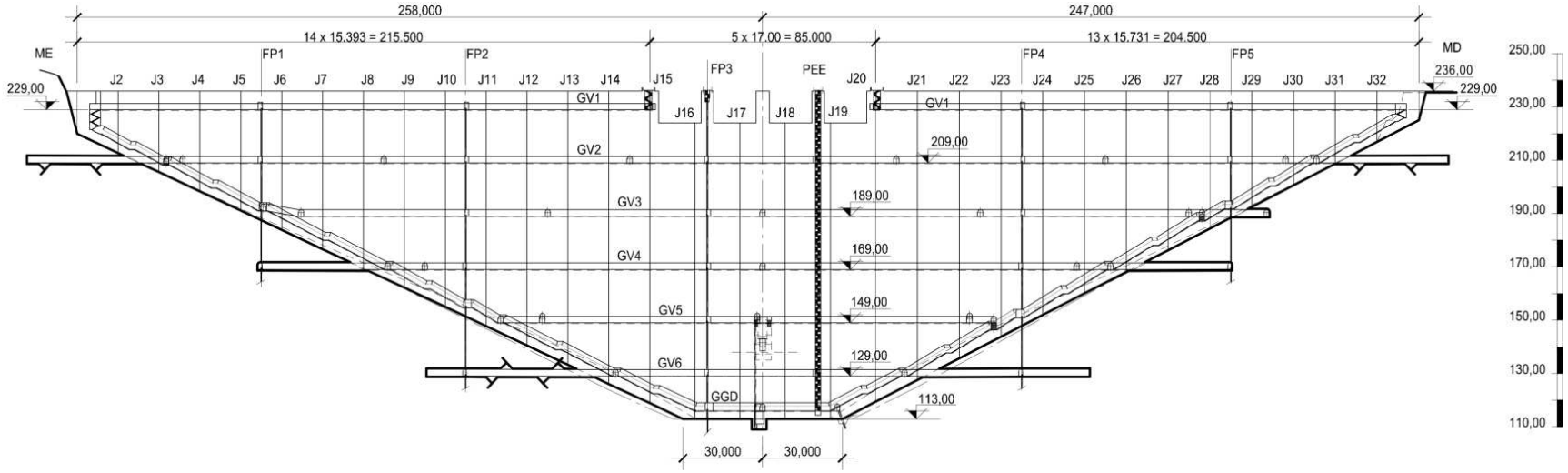
Height	123 m
Crest length	505 m
Concrete volume	670 000 m^3
Excavation volume	560 000 m^3
Reservoir Capacity	1095 million m^3
Surface Spillway spans	4x16 m
Surface Spillway discharge capacity	5000 m^3/s
Bottom outlet discharge capacity	220 m^3/s
Vertical contraction joints	32 (provided with shear keys)

Baixo Sabor Project

Longitudinal dam definition



Upstream face



Galleries and shafts (reference surface)

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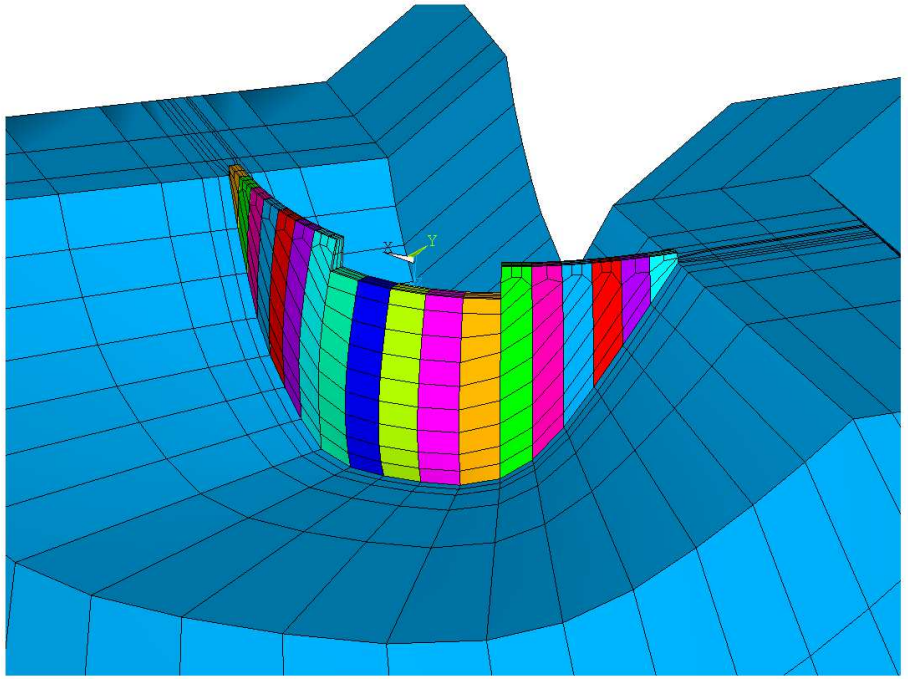
Baixo Sabor Project

Structural Analysis



- Detailed structural behavior of dam-foundation structure was performed by finite element analysis
- EDP used optimization algorithms to obtain the arch dam shape definition
- Load combinations were considered according to the Portuguese Regulation requirements:
  - dead weight
  - hydrostatic pressure
  - extreme fields of the seasonal variations of temperature
  - basis design (BDE) and maximum design (MDE) earthquake
- LNEC (Laboratório Nacional de Engenharia Civil) developed specific studies concerning deterioration scenarios of the concrete and dam foundation, as well as the seismic analysis for the MDE

Baixo Sabor Project

Foundation characteristics

- The dam foundation consists in a medium to large grained porphyroide two micas granite
- Foundation rock mass – three geotechnical zones were defined as follows:

Zone	Weathering grade	Fracturing grade	Em [Gpa]
ZG1	W1 to W2	F1 to F3	17.5
ZG2	W2 to W3	F2 to F4	7.5
ZG3	W3 to W5	F3 to F5	<5

- An important foundation fault detected in the left bank required a containing wall and a pre-stressed anchor beam

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Baixo Sabor Project

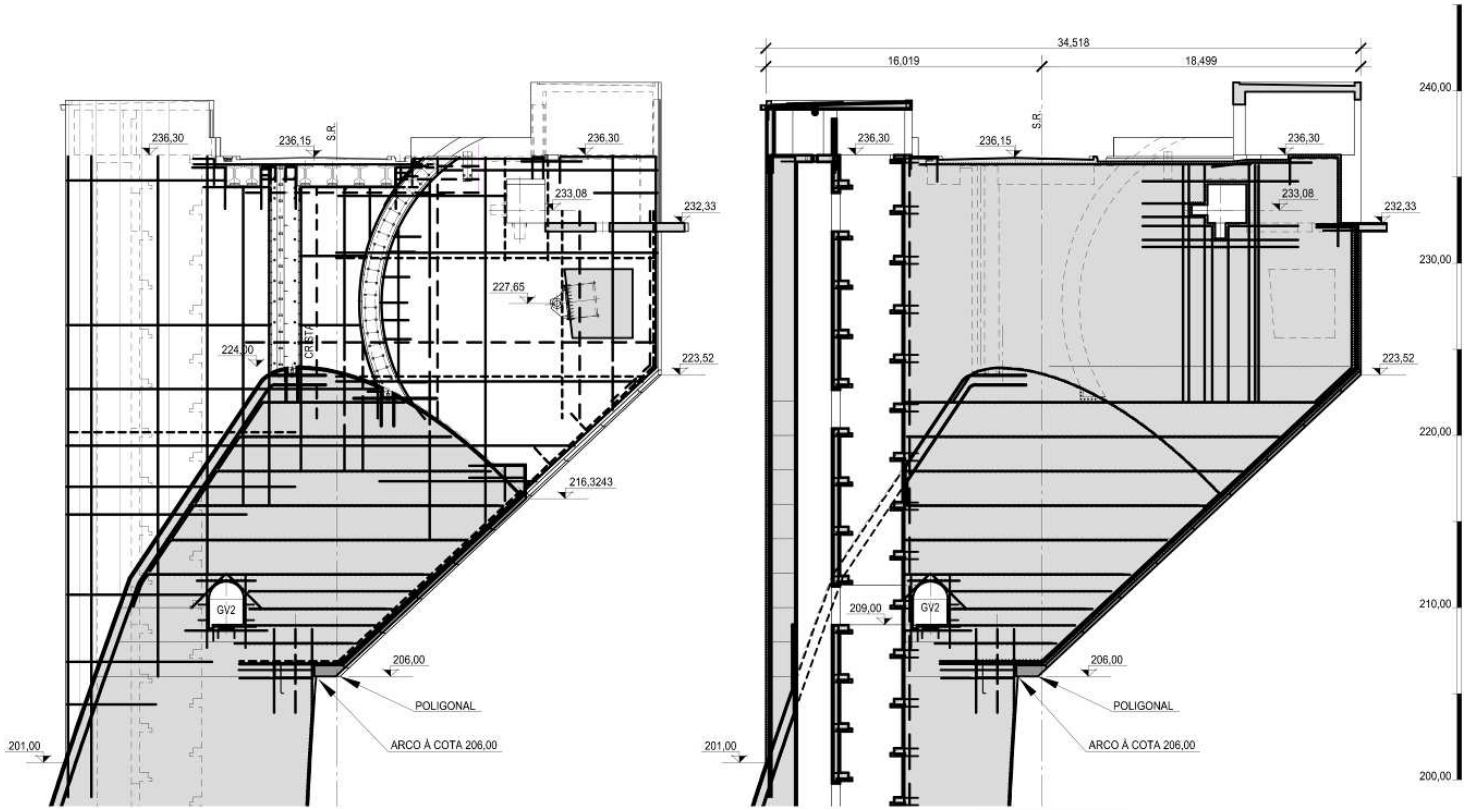
Superficial faults treatment

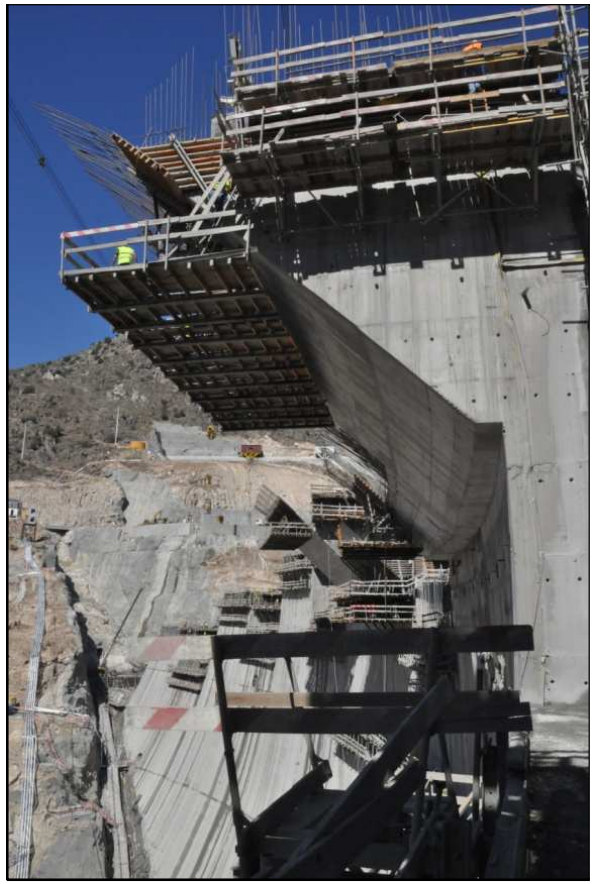
- In the river bed and in the right bank smaller faults were identified and treated by the substitution of the fault material by reinforced concrete
- On the river bed, an additional gallery was left inside the dam in order to enable a later foundation treatment

Baixo Sabor Project

Spillway section

- The location of the spillway enforced the adjustment of the upper zone of the arch dam
- Detailed structural behavior of dam-pier structure was obtained by finite element analysis
- Non pre-stressed reinforcement solution proved to be adequate





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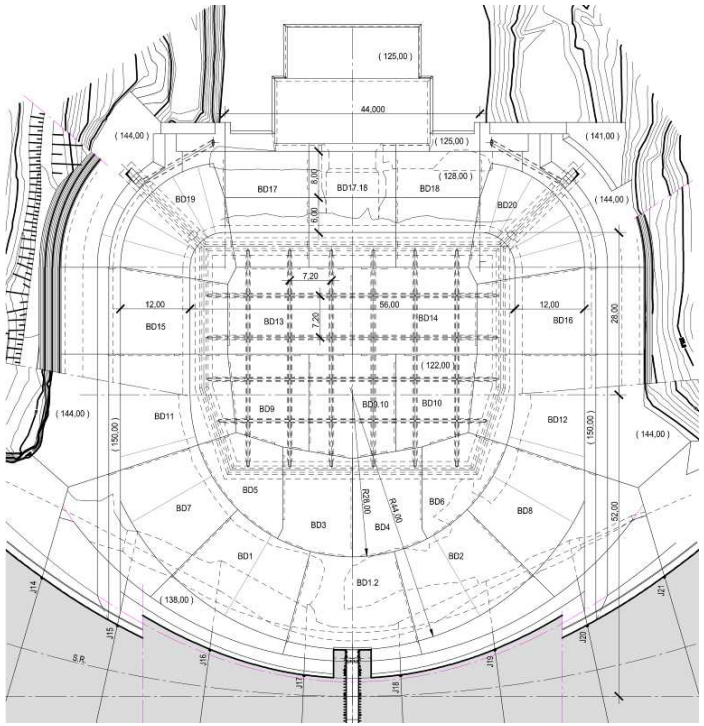
Baixo Sabor Project

Spillway plunge pool

- The shell shaped downstream plunge pool is composed of 23 blocks separated by vertical joints
- Anchorages into foundation mass were provided to face dynamic uplift forces



Baixo Sabor Project

Dam construction stage

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Baixo Sabor Project

Filling of the reservoir

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Baixo Sabor Project

Dam after the first filling of the reservoir

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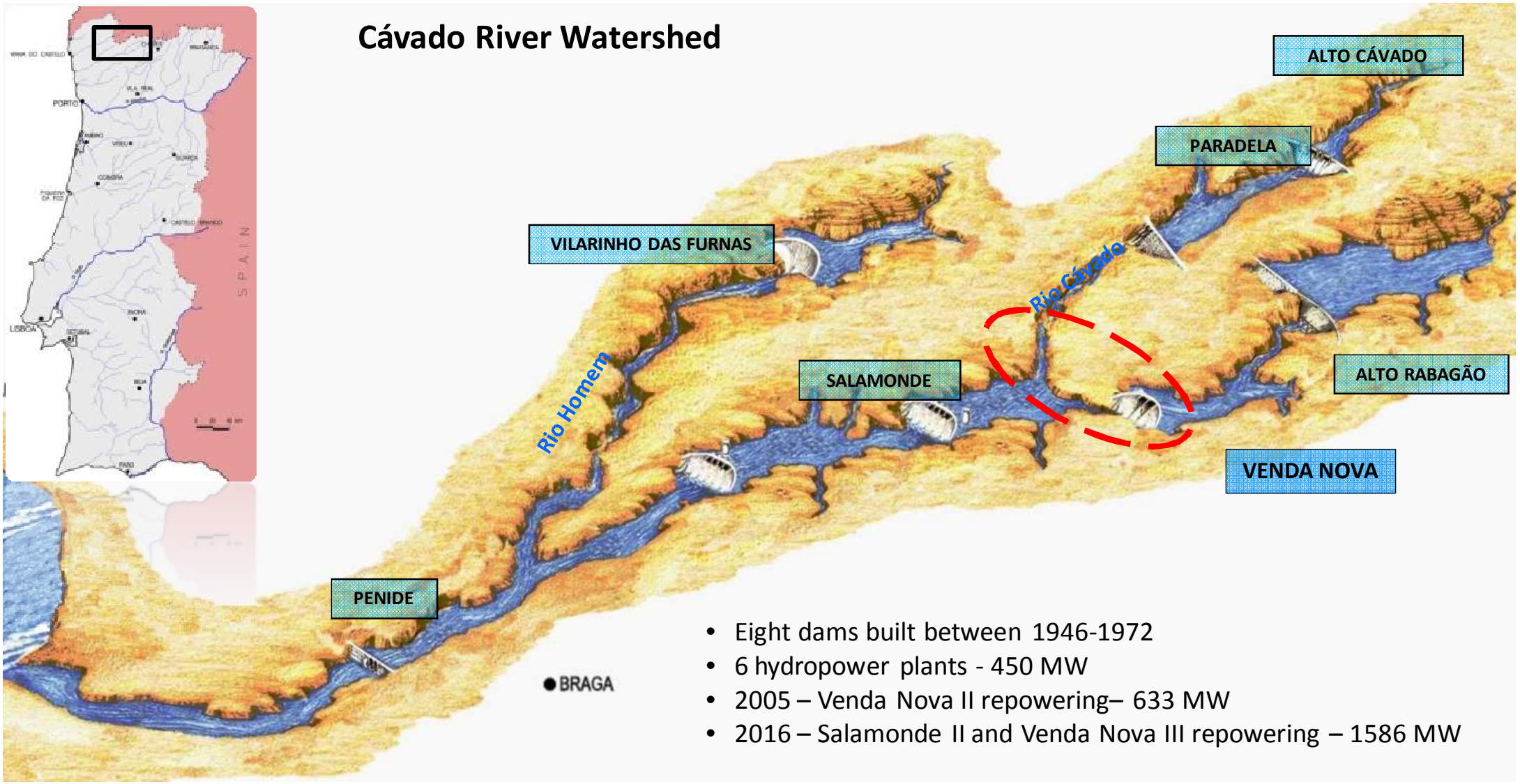
Venda Nova III Project



- Eight dams built between 1946-1972
- 6 hydropower plants - 450 MW
- 2005 – Venda Nova II repowering– 633 MW
- 2016 – Salamonde II and Venda Nova III repowering – 1586 MW

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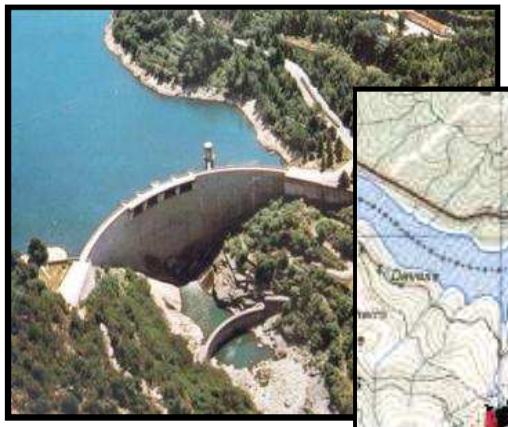
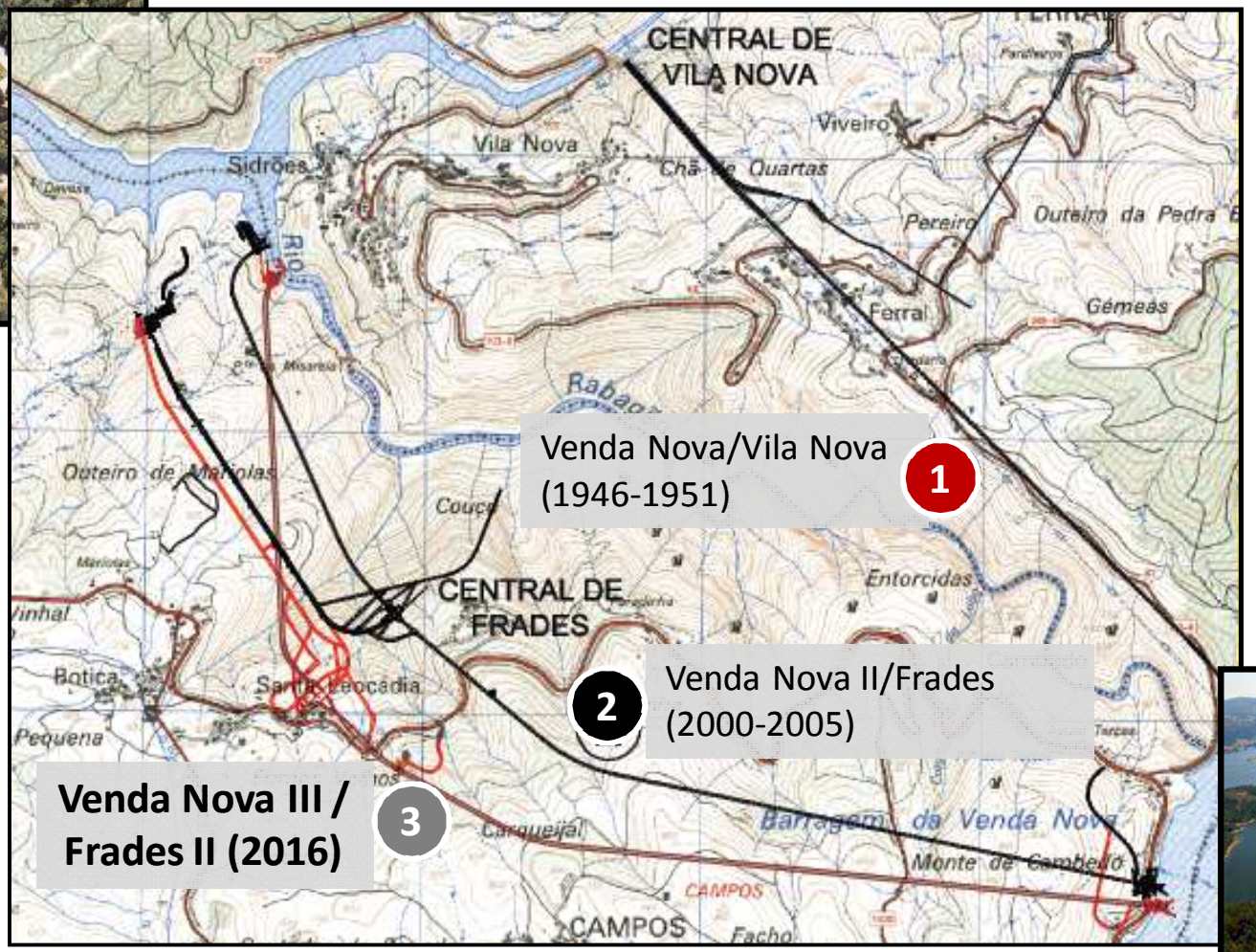
Direção de Engenharia de Barragens

Venda Nova III Project

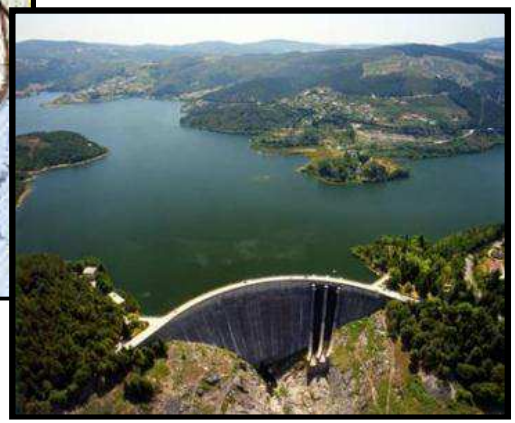
Salamonde Reservoir



Venda Nova III configuration



Venda Nova Reservoir



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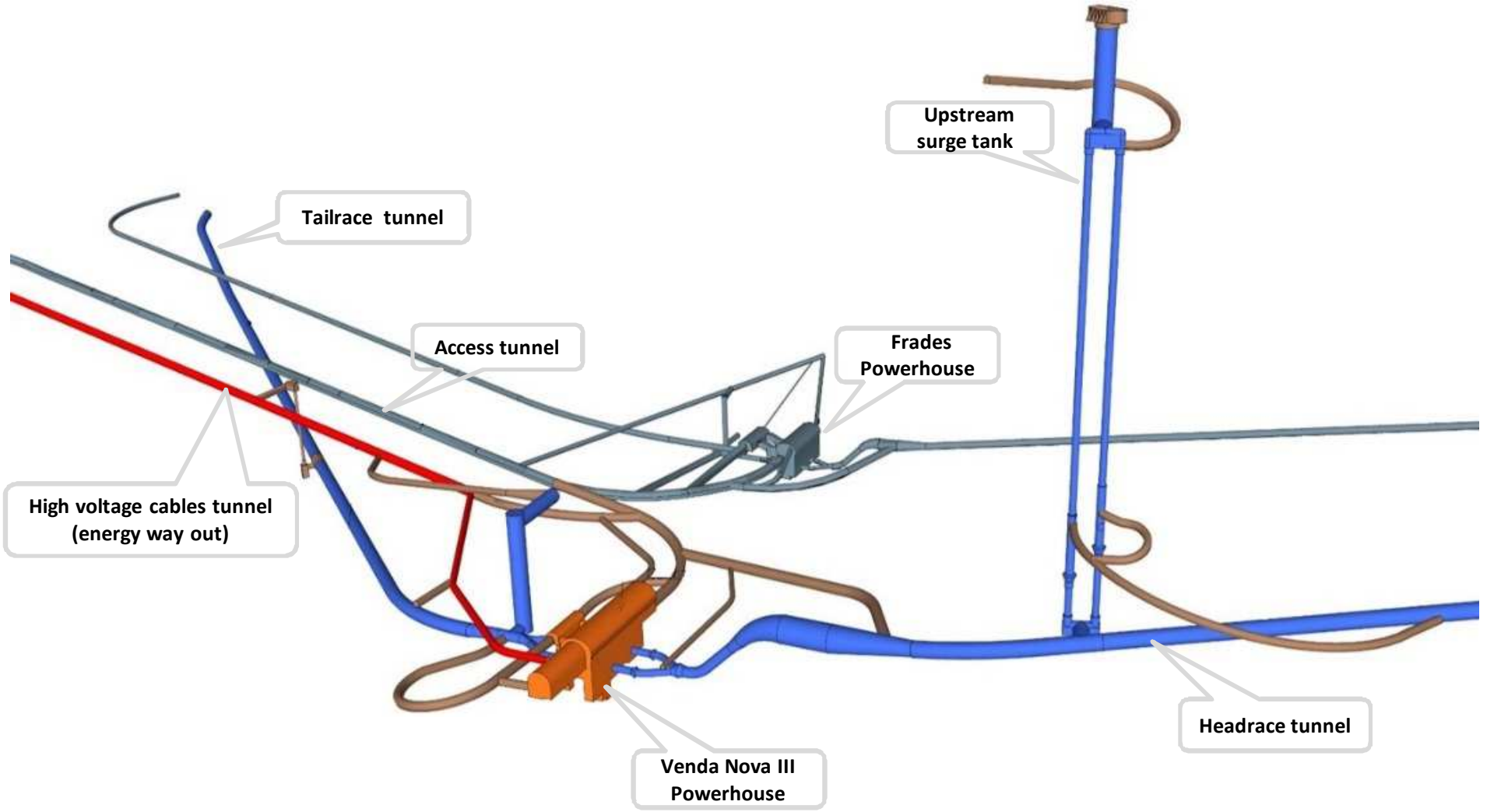
Venda Nova III Project

Schematic Layout



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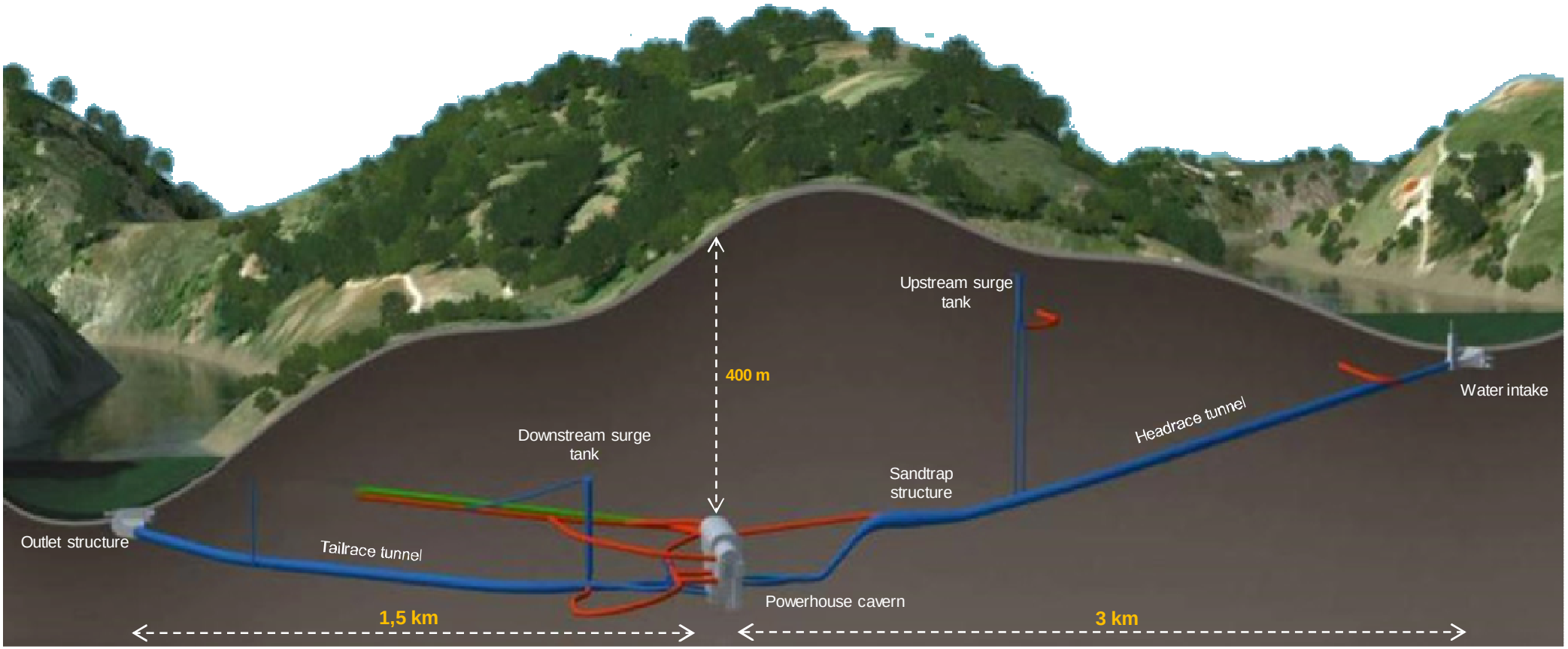
Venda Nova III Project

Schematic Layout



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Venda Nova III Project

Intake

- Turbine flow 200 m^3/s
- Pumping flow 160 m^3/s

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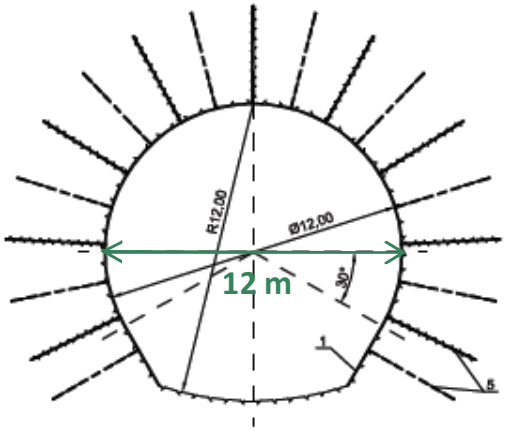
Direção de Engenharia de Barragens

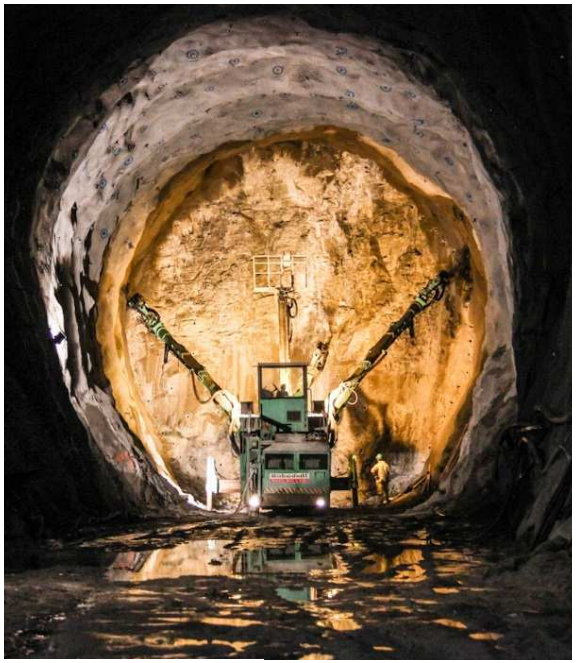
Venda Nova III Project

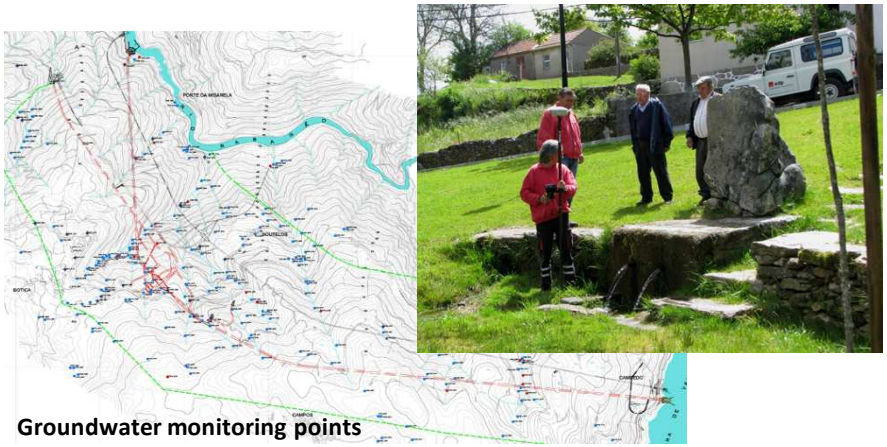
Hydraulic Tunnels

Main features

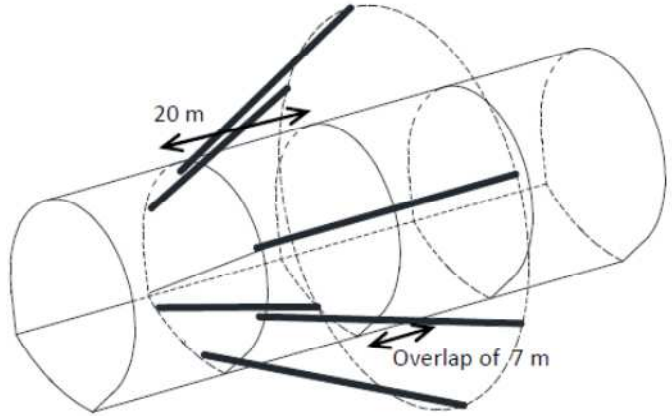
- Large diameter (12 m) for unlined tunnels (shotcrete + rockbolts) and high design pressures (max. 50 bar)
- Full face drill and blast excavation
- Systematic hydrogeological survey/treatment in the excavation stage
- Groundwater monitoring plan involving land owners: 270 monitoring points over 10 years







Groundwater monitoring points



Underground hydrogeological survey

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Venda Nova III Project

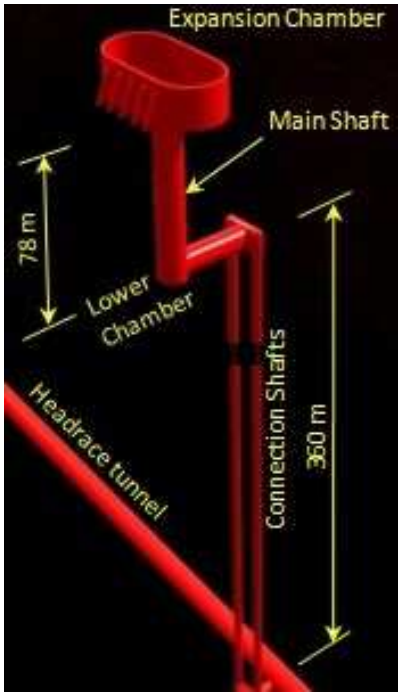
Upstream Surge Tank

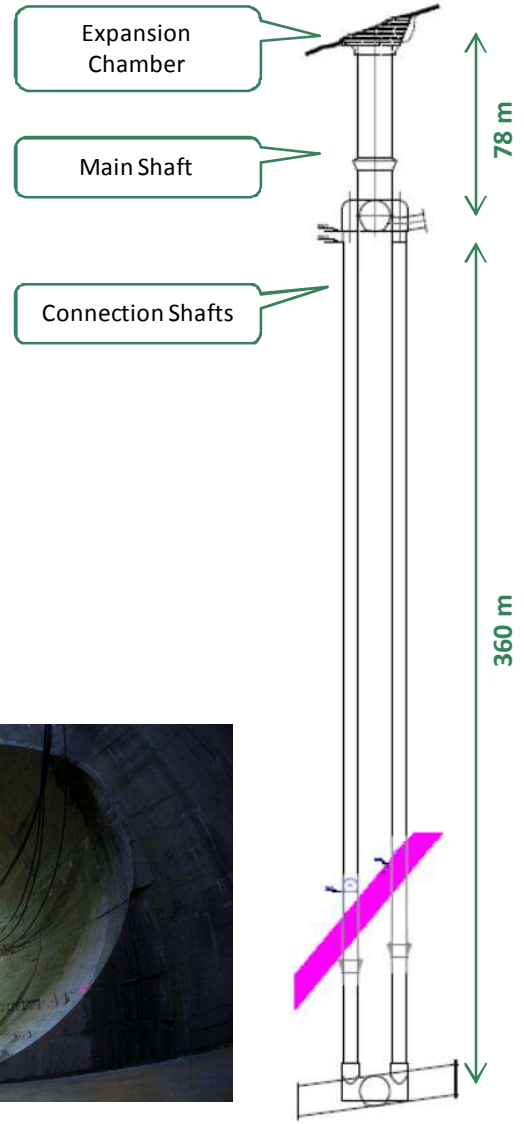
Main features

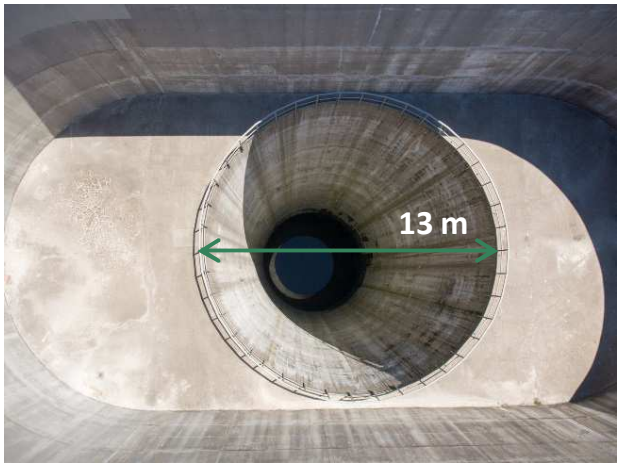
Protection of the turbines against water hammer

Unusual layout

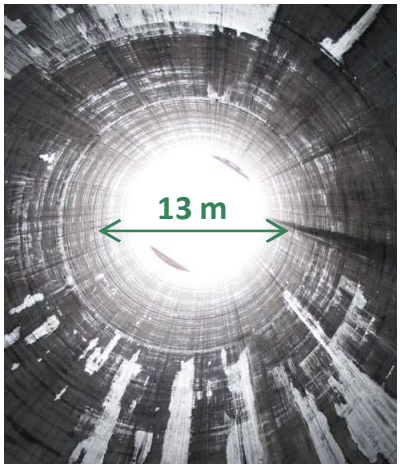
- Open air expansion chamber
- Concrete lined main shaft (13 x 80 m)
- Twin unlined connection shafts (raise boring 5,40 m x 360 m)







Expansion Chamber (view from the top)



Main Shaft (view from the bottom)

Lower Chamber

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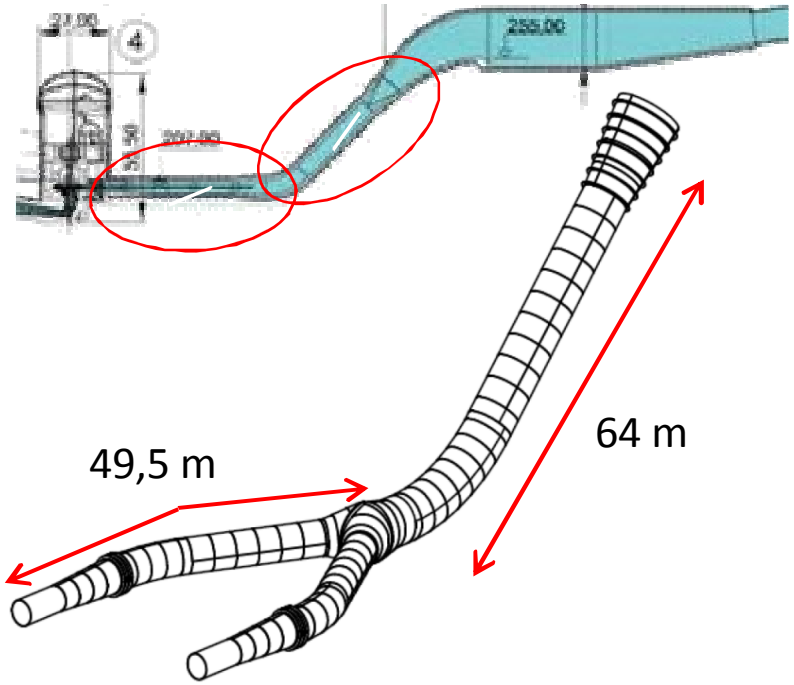
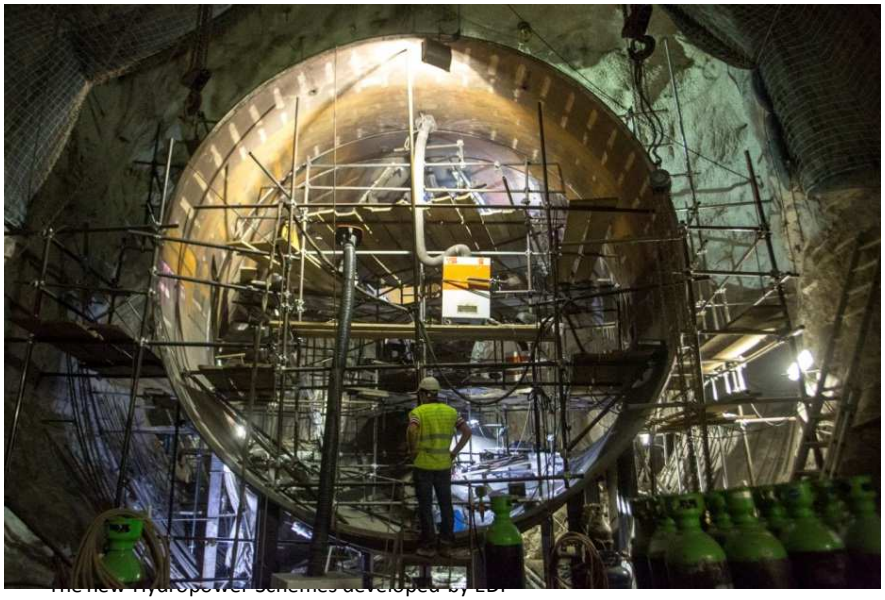


Penstock liner erection



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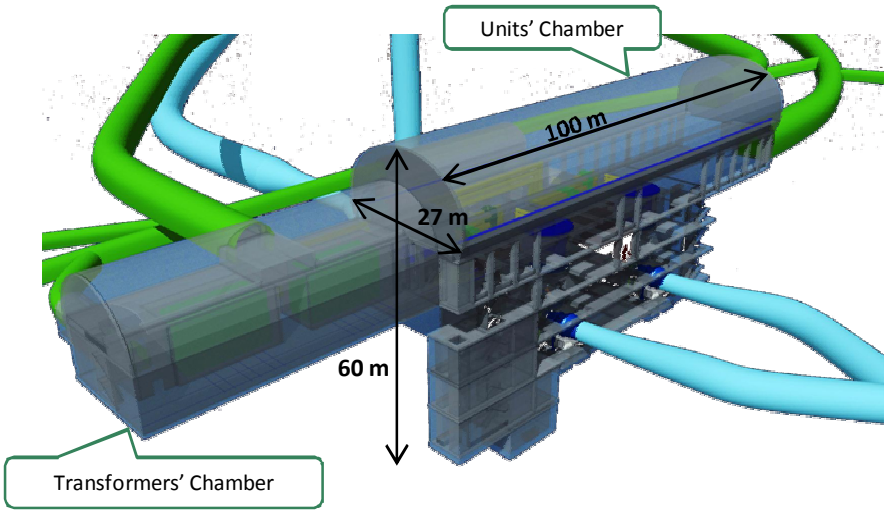
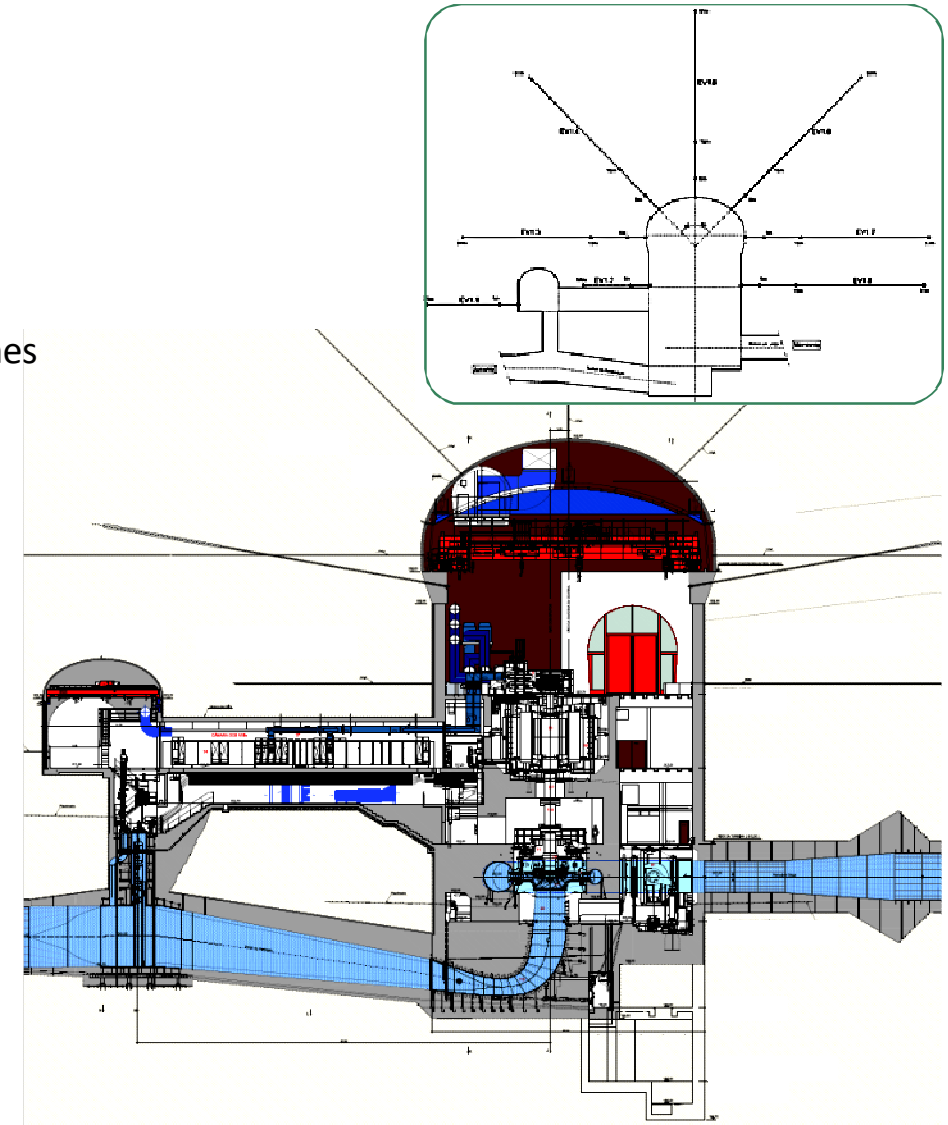
Powerhouse Cavern

- 2 contiguous chambers for the turbines and transformers
- 100 x 60 x 27 m units' chamber size
- Roof arch with passive support (shotcrete + rockbolts)
- Pre-stressed anchored beams supporting 2 x 280 ton cranes
- 32 multi-point rod extensometers





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Powerhouse construction stages

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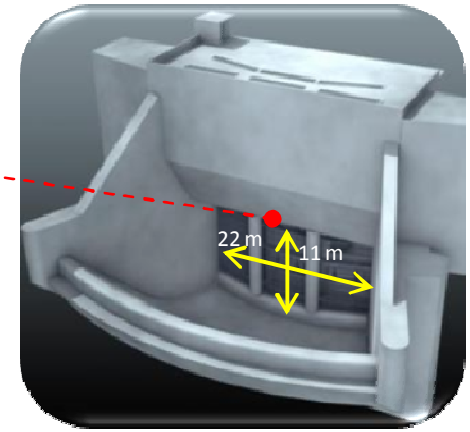
Outlet structure



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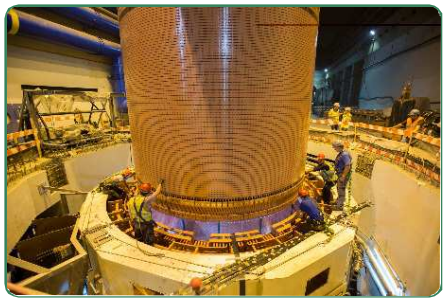
Final Remarks

Venda Nova III Repowering Project:

- Has generation capacity similar to a nuclear plant, however provided by an underground powerplant that takes advantage of renewable resources (water + wind) and boosts clean energy usage (pumped storage)
- Required unusual design solutions and complex construction challenges due to the distinctive features of the project
- Is a demonstration that development, environment and social concerns are compatible with underground projects, even in sensitive regions






Sincères remerciements

pour toute votre attention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