GEOELEC

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Training Course on Geothermal Electricity

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International Geothermal Market

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Geothermal resources

- Geothermal energy = the heat of the earth
- Geologic environment
  - Magmatic/volcanic
  - Thermal aquifers
  - Geopressured
  - Crustal heat

Geothermal resources	billion TOE	Fossil fuel reserves (end 2010)	billion TOE
Crustal heat	10.775.600	Coal	422
Magmatic/Volcanic	327.360	Oil	208
Geopressured	55.924	Natural gas	168
Aquifers, thermal	18		

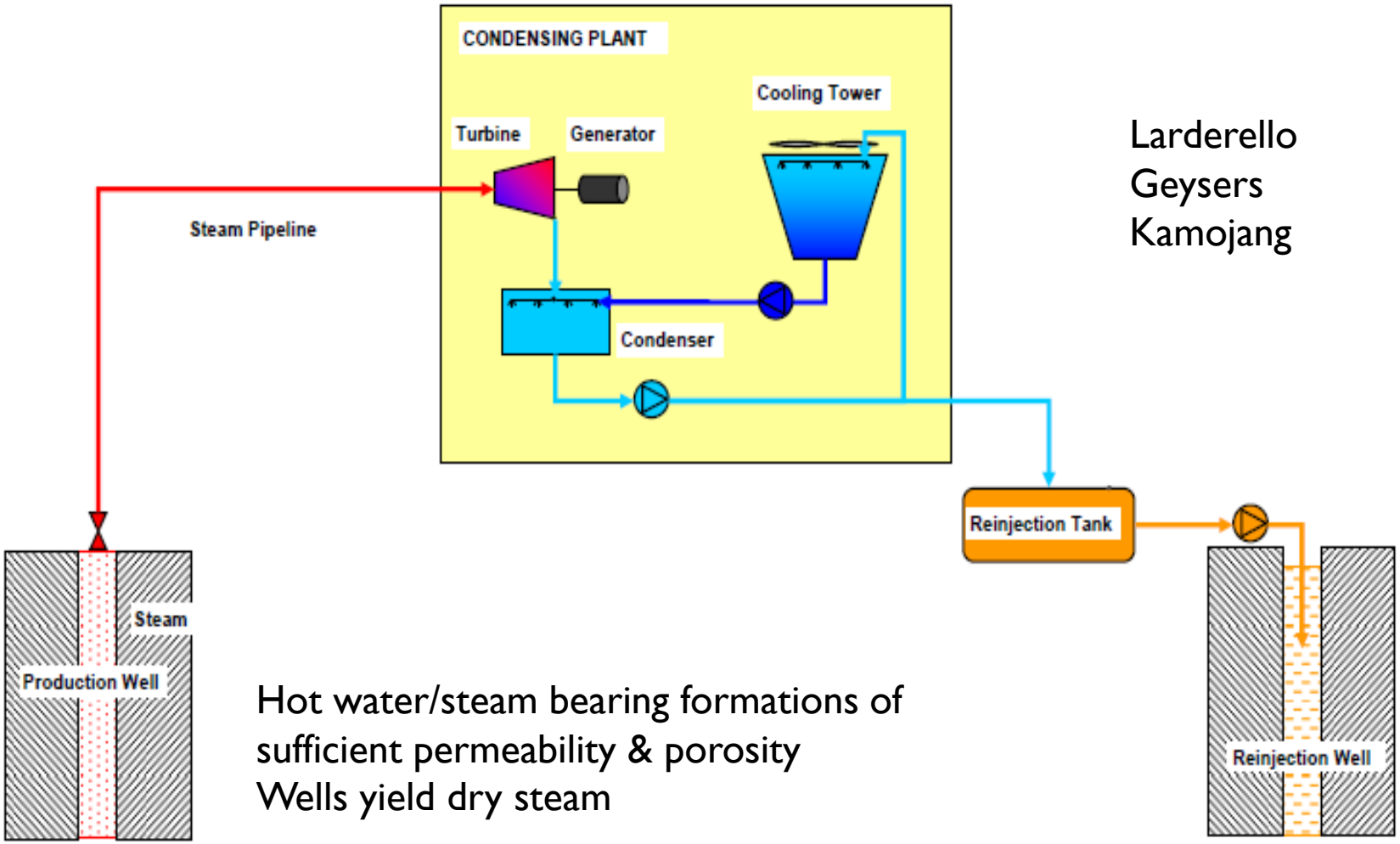
Exploitation technology: present

- Hydrothermal systems
  - Hot water/steam bearing formations of sufficient permeability & porosity
- Plant technology
  - Wells yield dry steam $\Rightarrow$ Dry steam condensing plants
  - Wells yield two phase fluid $\Rightarrow$ Flash condensing plants
  - Wells yield liquid water $\Rightarrow$ Binary plants
  - Combined cycle plants
  - Depths 2-3 km

Exploitation technology: the future

- Enhanced geothermal systems (EGS)
  - Inadequate natural permeability to sustain commercial production rates
  - An artificial reservoir is engineered by hydraulic fracturing, acidizing, propellants, etc.
  - Surface water is circulated through the system as heat transfer media
  - Depths 3-5 km
  - The future is now: a handful of EGS plants are in operation around the globe
  - First EGS plant producing electricity in Soultz
- Supercritical fluids
  - >350°C from depths 5-10 km

Dry steam plants



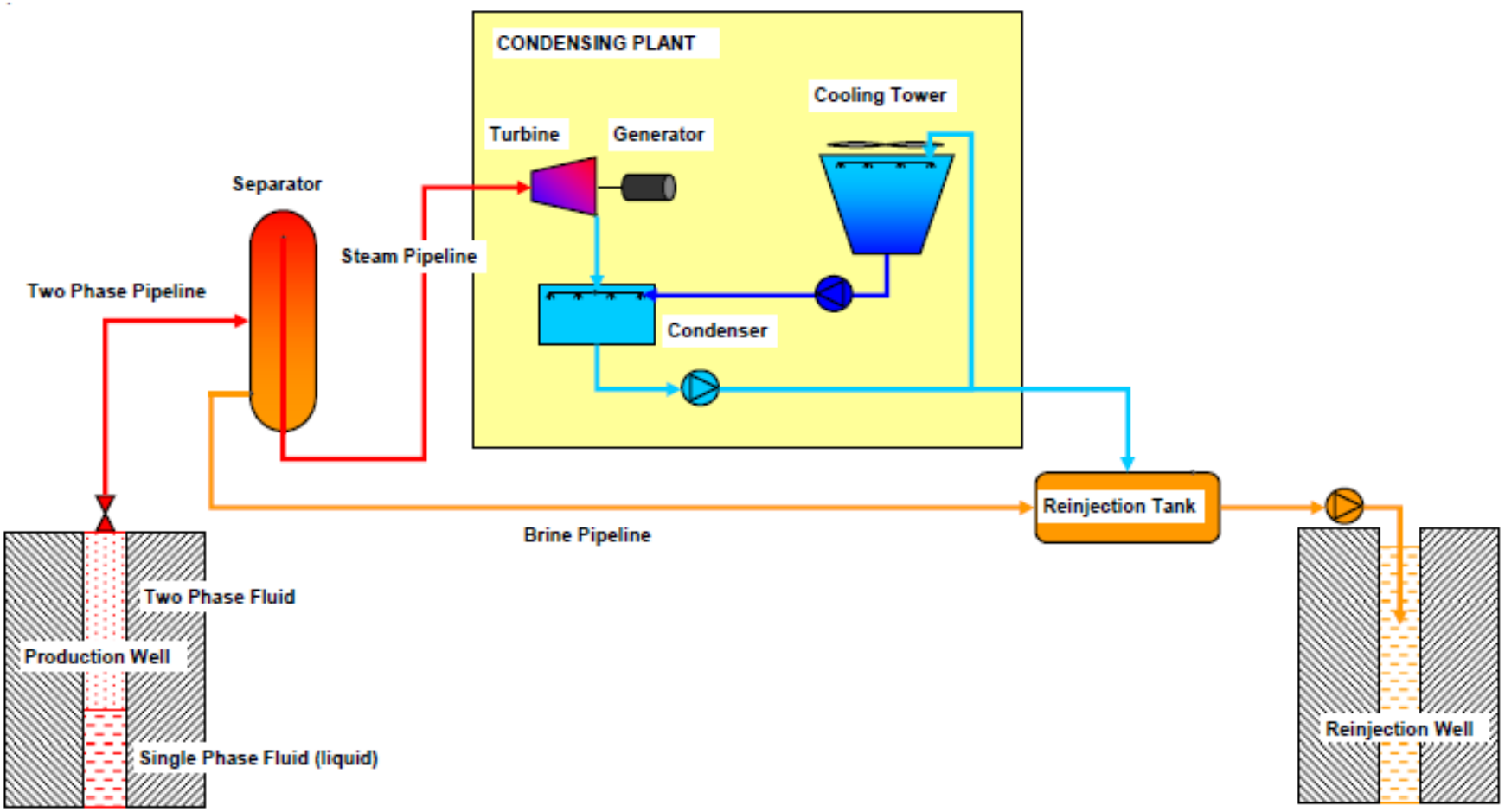
Larderello
Geysers
Kamojang

Hot water/steam bearing formations of sufficient permeability & porosity
Wells yield dry steam

40MW Nuova San Martino plant, Larderello

Photo from Cappetti G., Romagnoli P. and Sabatelli F. (2010). Geothermal Power Generation in Italy 2005–2009 Update Report

Flash condensing plants

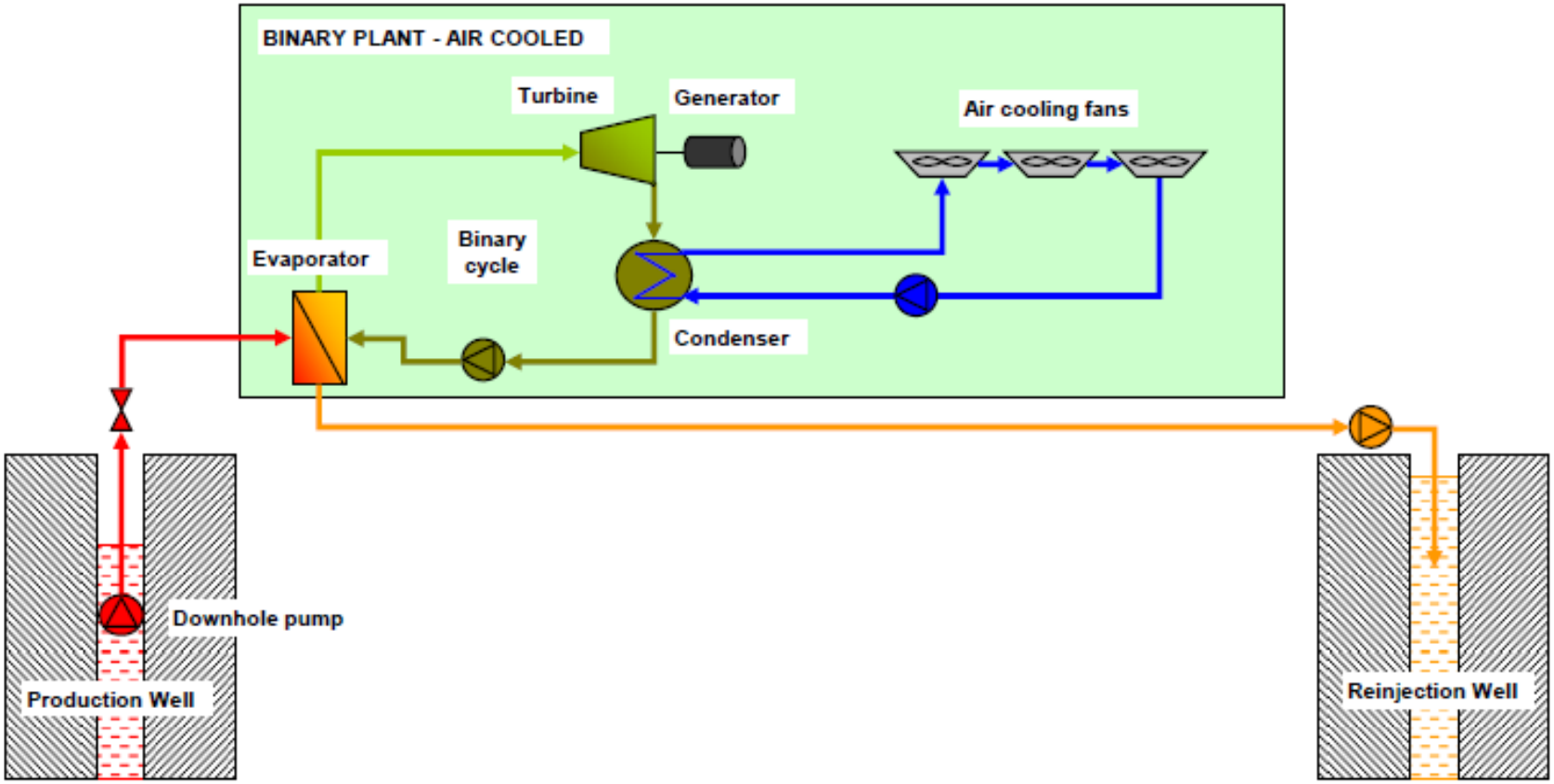


130 MWe Nga Awa Purua plant

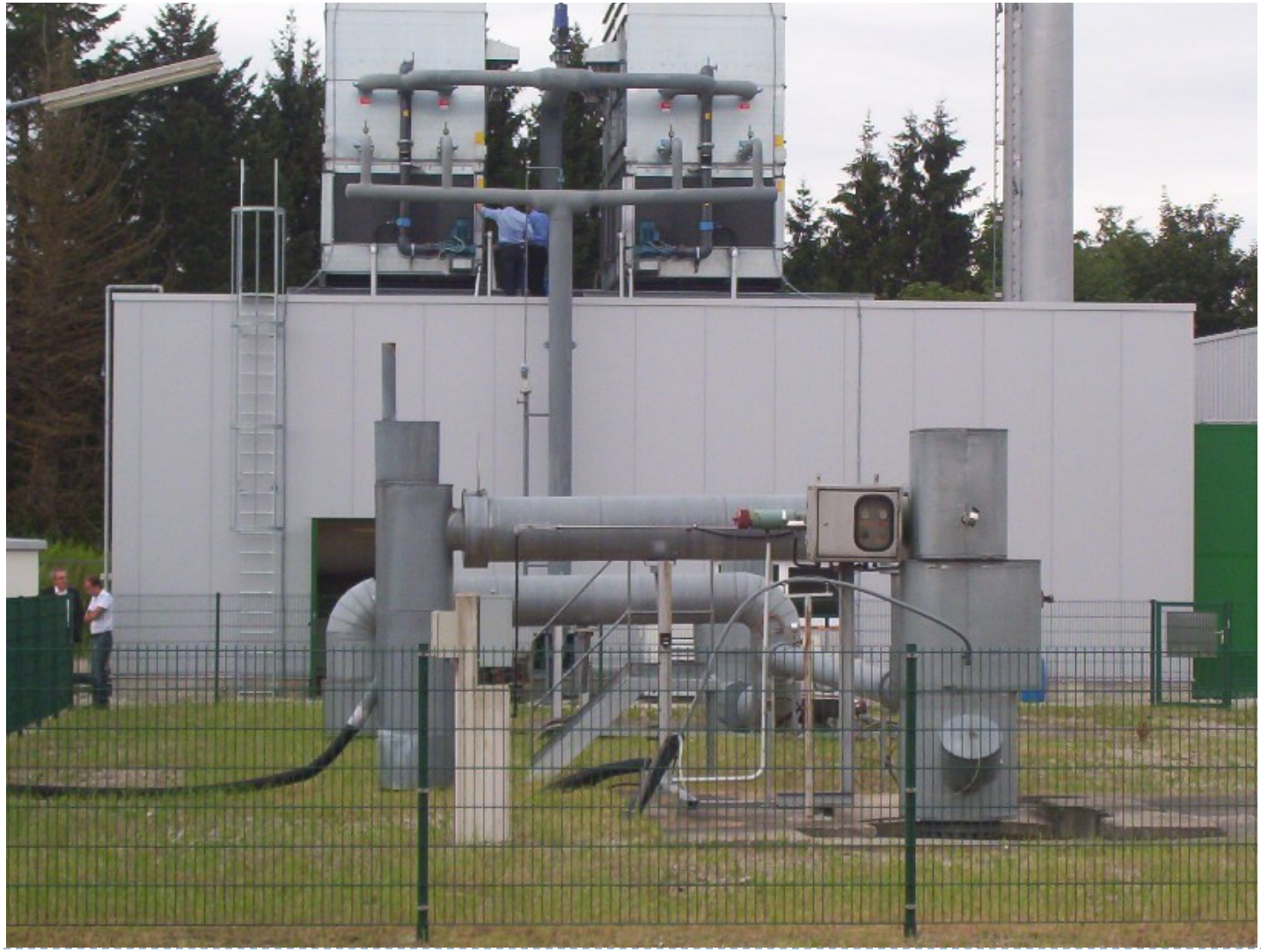
15 MWe Buillante plant

Photo: Jaudin F (2006). Geothermal fields of Guadeloupe, Martinique and La Réunion

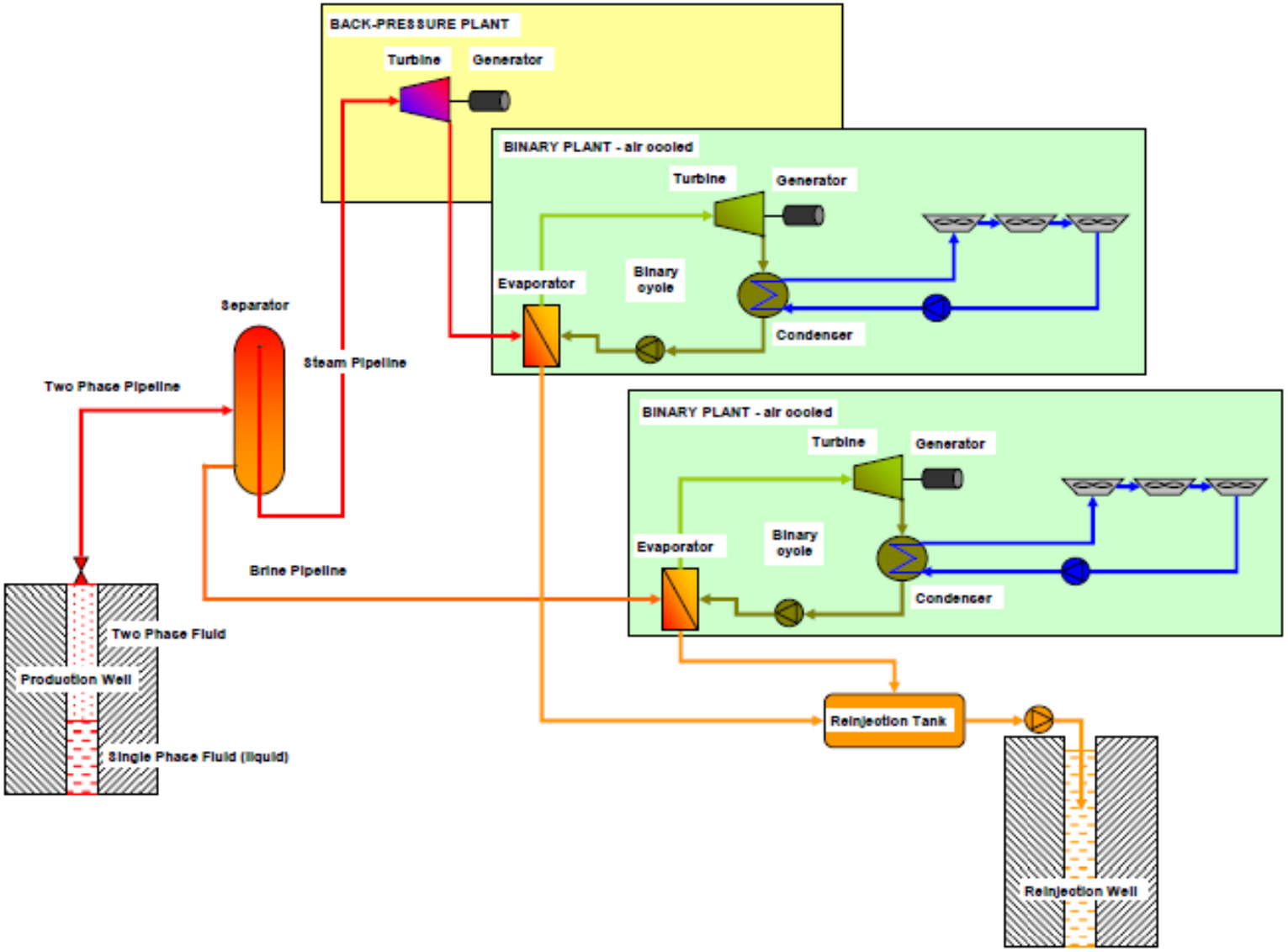
Binary plants



200 kW Simbach-Braunau unit



Combined cycle flash/binary plants

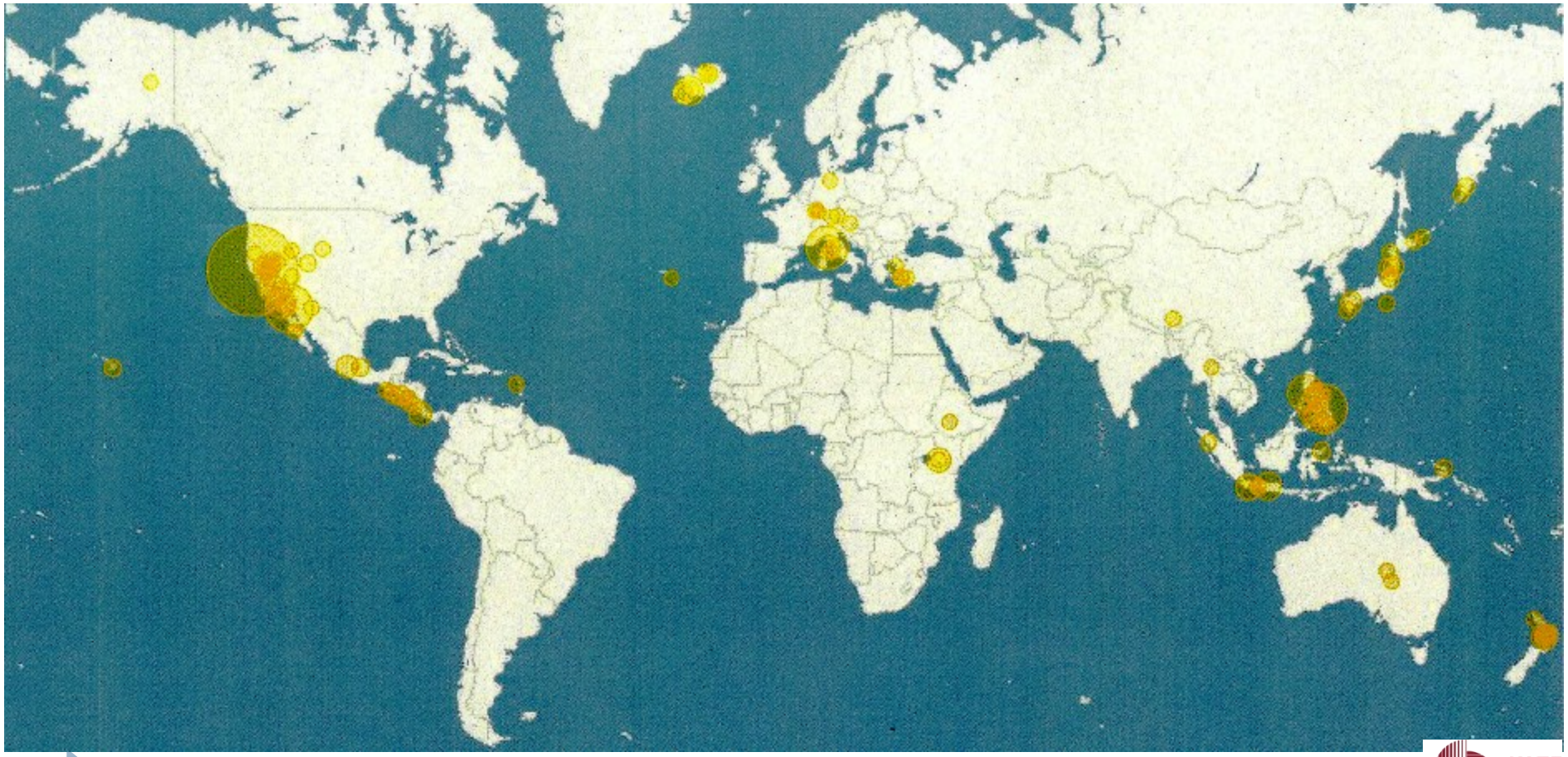


34 MWe Rotokawa plant

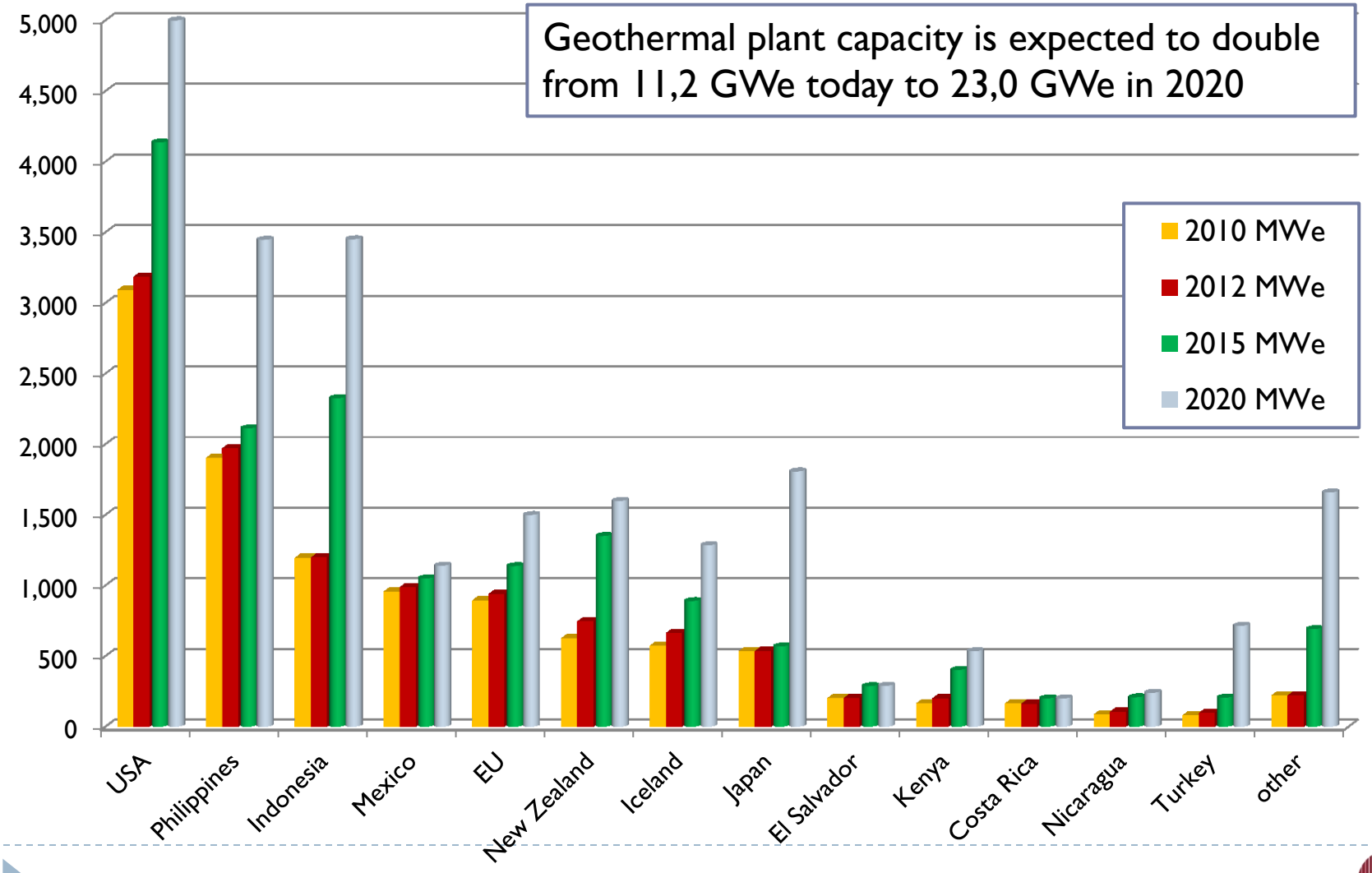
Photo: Mighty River Power & Tauhara North No 2 Trust Brochure

Location of geothermal power plants

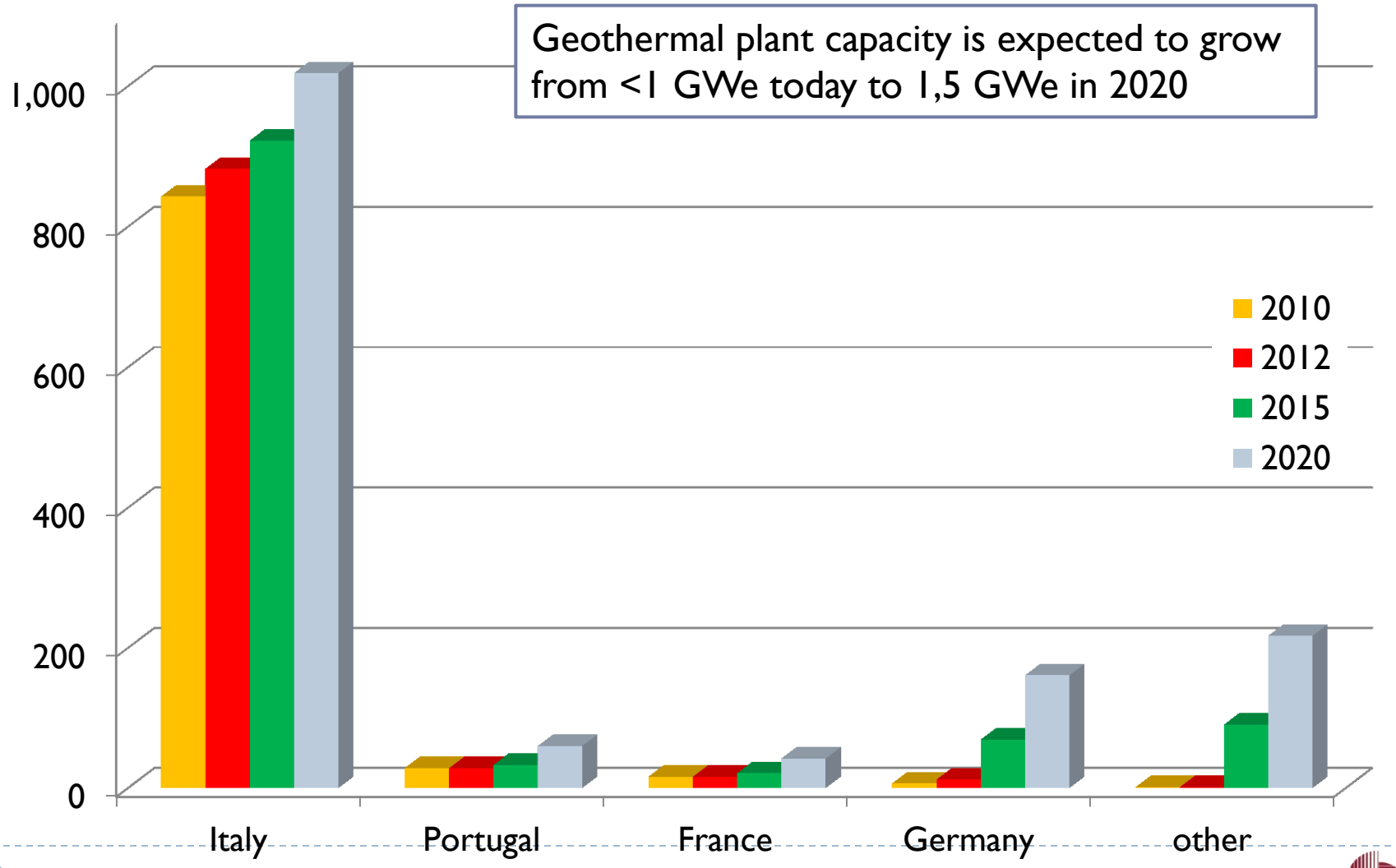
- tectonic plates boundaries
- hydrothermal systems
- volcanic/magmatic environments



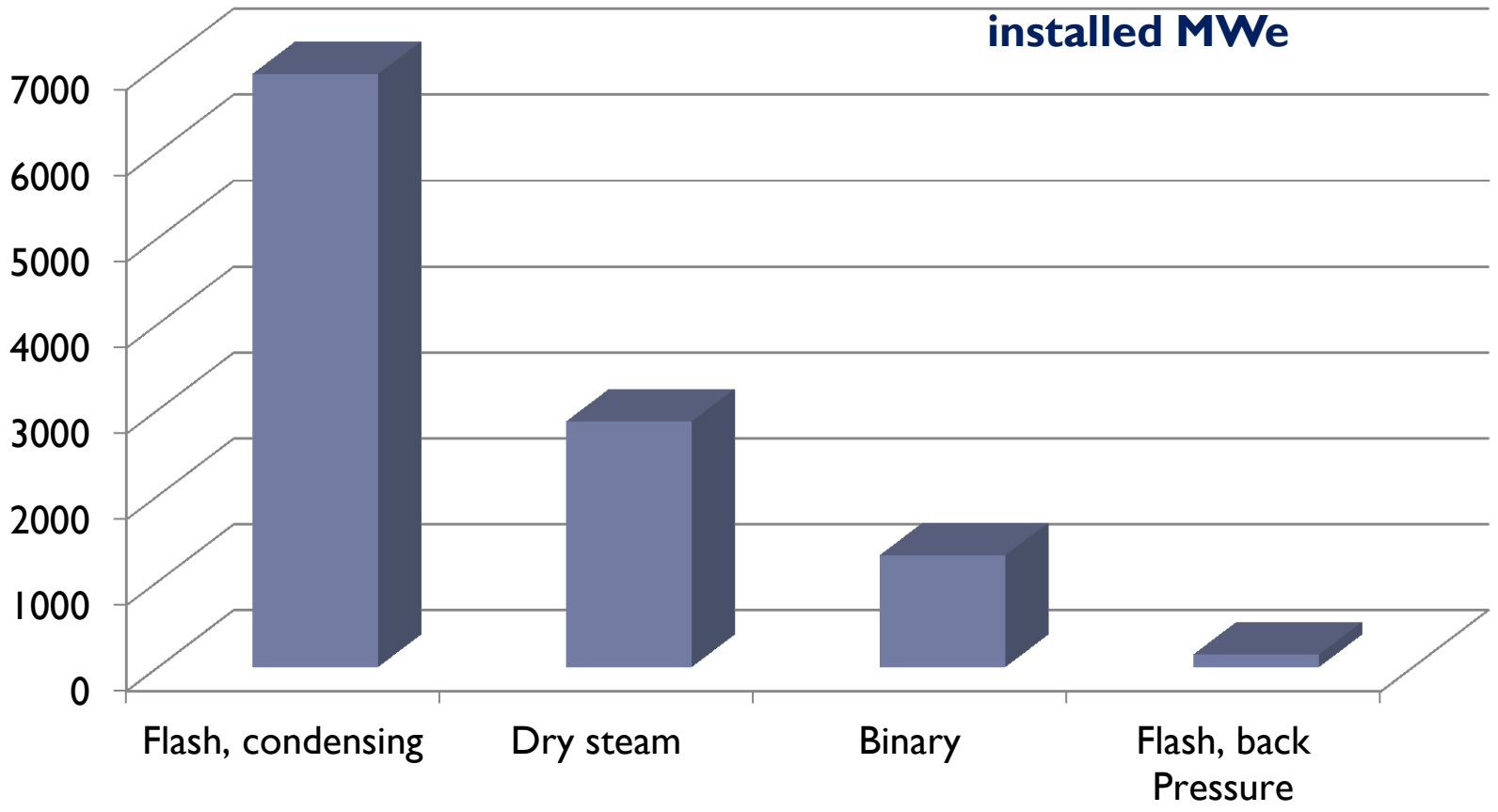
Installed capacity: world



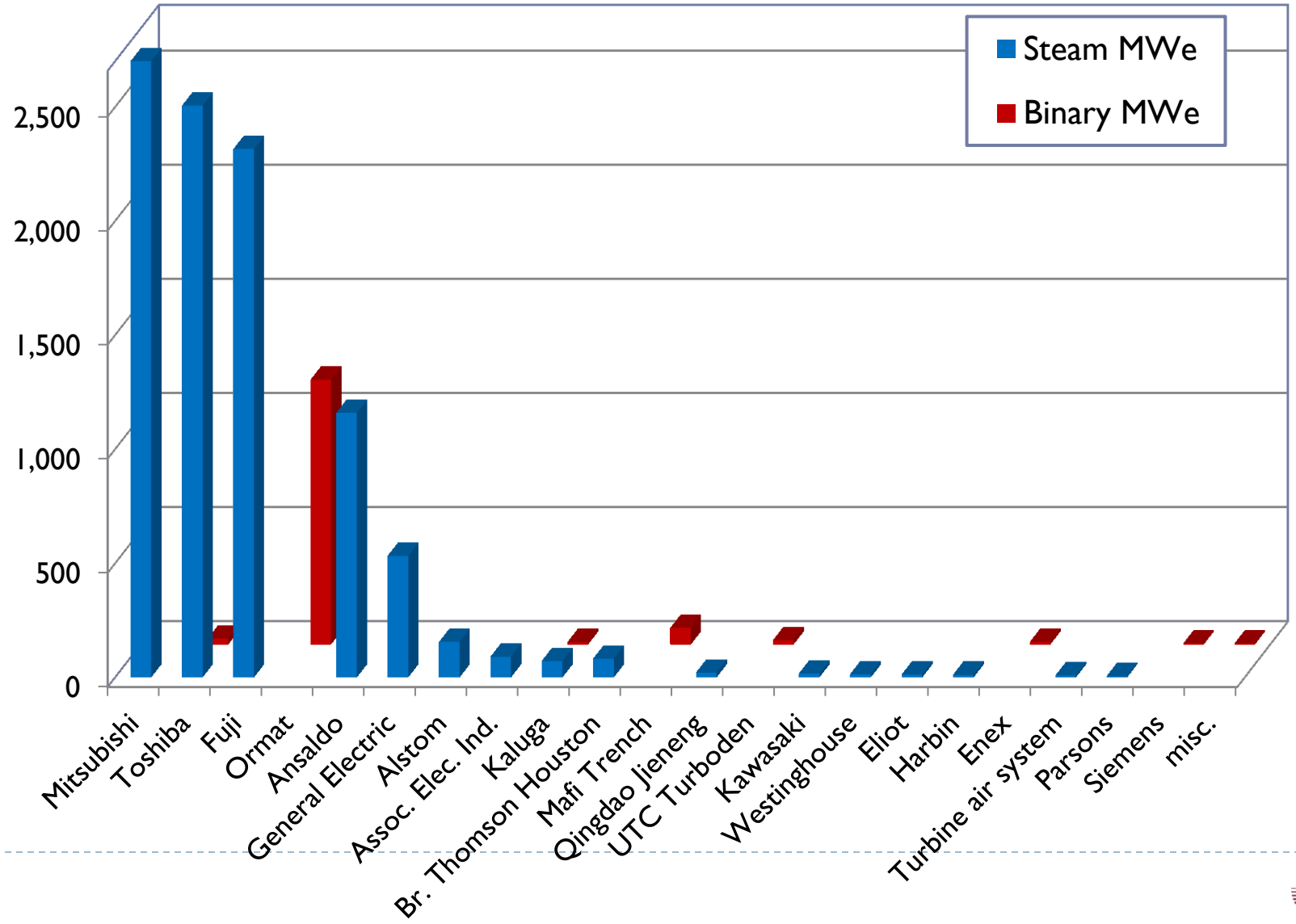
Installed capacity: EU



Plant types


installed MWe
7000
6000
5000
4000
3000
2000
1000
0
Flash, condensing
Dry steam
Binary
Flash, back Pressure

Plant manufacturers



Plant & Energy costs

recent projects	Investment, €/MWe			Energy production costs, €/kWh		
	Flash	Binary	EGS	Flash	Binary	EGS
USA	2.700.000	3.100.000	6.200.000	0,055	0,060	0,100
Indonesia, New Zealand, Philippines	2.300.000			0,044		
Central America	1.900.000			0,042		
EU		4.500.000	11.600.000		0,090	0,200
Chile	3.600.000			0,072		
Germany		6.500.000			0,100	
Turkey	2.750.000			0,063		

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Market size & growth

	2012			2012-2020	
	installed capacity MWe	annual sales electricity GWh	annual sales value billion €	annual growth capacity MWe	annual growth investments billion €
World	11.242	70.500	7,05	1.450	3,75
EU	941	6.150	1,20	65	0,43

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Market barriers

- Lengthy permitting procedures
- Lack of regulations
- High investment risk
- Access to finance
- Few companies with know how & competent personnel

Incentives: USA

Jurisdiction	Statute	Incentive Title	Tax	Type	Taxpayer	yrs	Amount	Max	Expire
Federal	§45	Renewable Electr. Prod.	Income	Credit	Producer	10	$0.022/kWh	-	2013
	§48	Investment Energy Property	Income	Credit	Owner	5	10%	-	2016
	§168(e)3	Certain Energy Property	Income	Deduction	Owner	5	200% DB	-	2016
	§54C	New Clean RE Bonds	Income	Credit	Holder	-	0 interest	-	Limit
Alabama	§40-18-	Altern. Energy Prod. Faclt.	Income	Credit	Utility	20	5%	-	2015
	§40-9B-4	Altern. Energy Prod. Faclt.	Property	Abatement	Utility	-	100%		2018
Delaware	§2040	Clean Energy Mfg Jobs	Income	Credit	Manufacturer	-	$750/J & $100k	$500k	-
Florida	196.175	RES Devices	Property	Exemption	Owner	10	100%	-	-
	220.193	Renewable Energy Prod.	Income	Credit	Producer	-	$0.01/kWh	$1mio	2016
Maryland	§10-720	RE Production	Income	Credit	Producer	5	$0.0085/kWh	$2.5mio	2015
N. Jersey	§54:10A	Altern.Energy Tech. Co	Income	Credit	Investor	3	30%	$500k	-
	§54:4-3.	RE Systems	Property	Exemption	Owner	-	100%		

- *… non exhaustive*

Feed in tariffs (or equivalent)/premiums

country	€/kWh	country	€/kWh	country	€/kWh
Japan <15MW >15MW	0,4077 0,2692	Italy (feed-in premium)	0,1300 0,0990	Belgium (Flanders) green certificates (min)	0,0900
Switzerland <5 MW >20MW	0,3330 0,1890	Slovenia - feed-in premium	0,1524 0,1036	Portugal: Azores only	0,0884
Germany EGS other	0,3000 0,2500	UK (2 ROCs per MWh)	0,1422	Austria	0,0750
France continental	0,2800 0,2000	Indonesia max min	0,1308 0,0833	Estonia (feed-in premium)	0,0537
France overseas	0,1600 0,1300	Greece	0,1220		
Slovakia	0,1905	Romania max-min (2 green cert. per MWh)	0,1100 0,0540		
Czech Rep. - feed-in premium	0,1810 0,1420	Hungary max min	0,1070 0,0390		

- The trend is to replace feed-in tariffs with feed-in premiums

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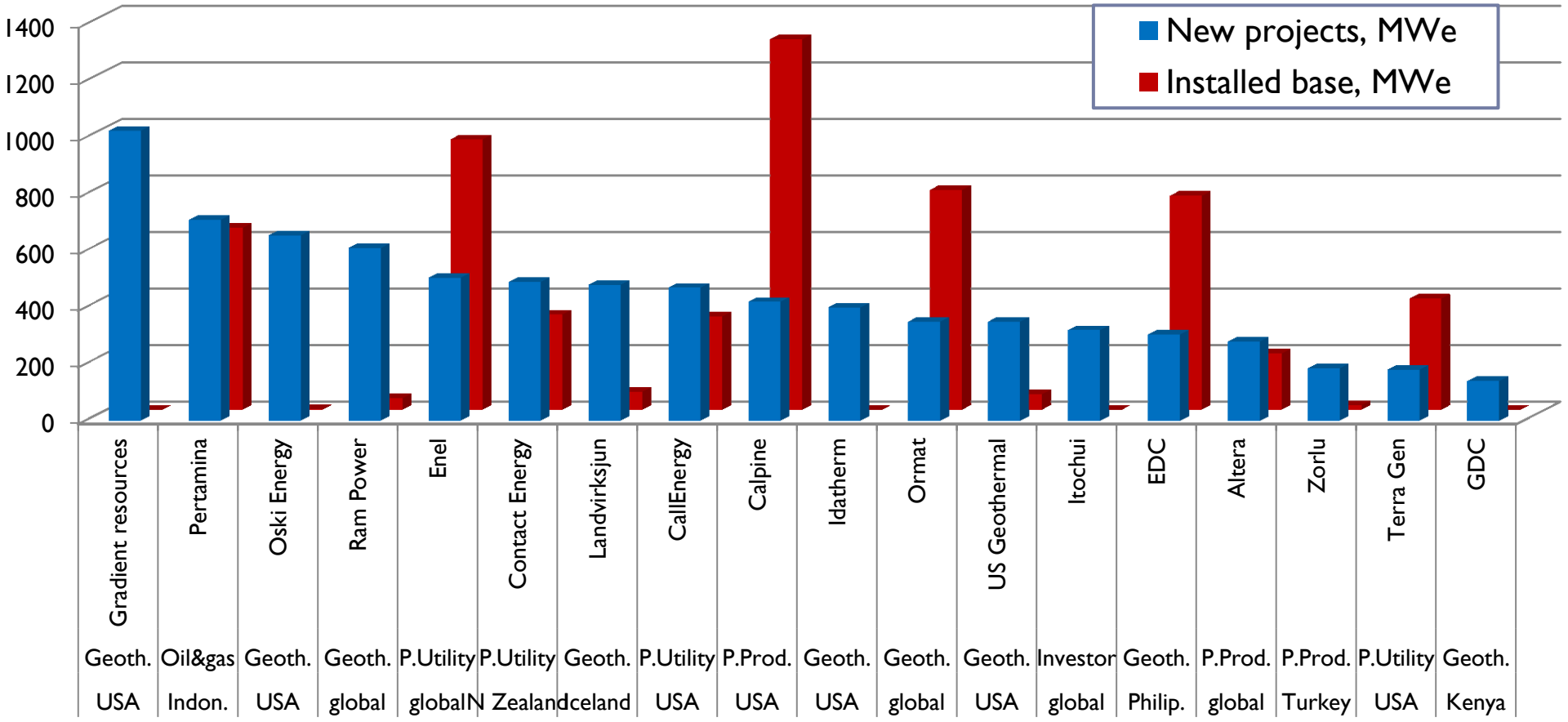
Incentives: developing countries

- Carbon tax credits
- World bank loans

Companies developing the market



- 67% of global capacity under development

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thank you for your attention

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