

# Training Course on Geothermal Electricity

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## **International Geothermal Market**

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# Geothermal resources

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

<b>Geothermal resources</b>	<b>billion TOE</b>	<b>Fossil fuel reserves (end 2011)</b>	<b>billion TOE</b>
Crustal heat	10.775.600	Coal	422
Magmatic/Volcanic	327.360	Oil	234
Geopressured	55.924	Natural gas	188
Aquifers, thermal	18		



# Exploitation technology: present

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- ▶ **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



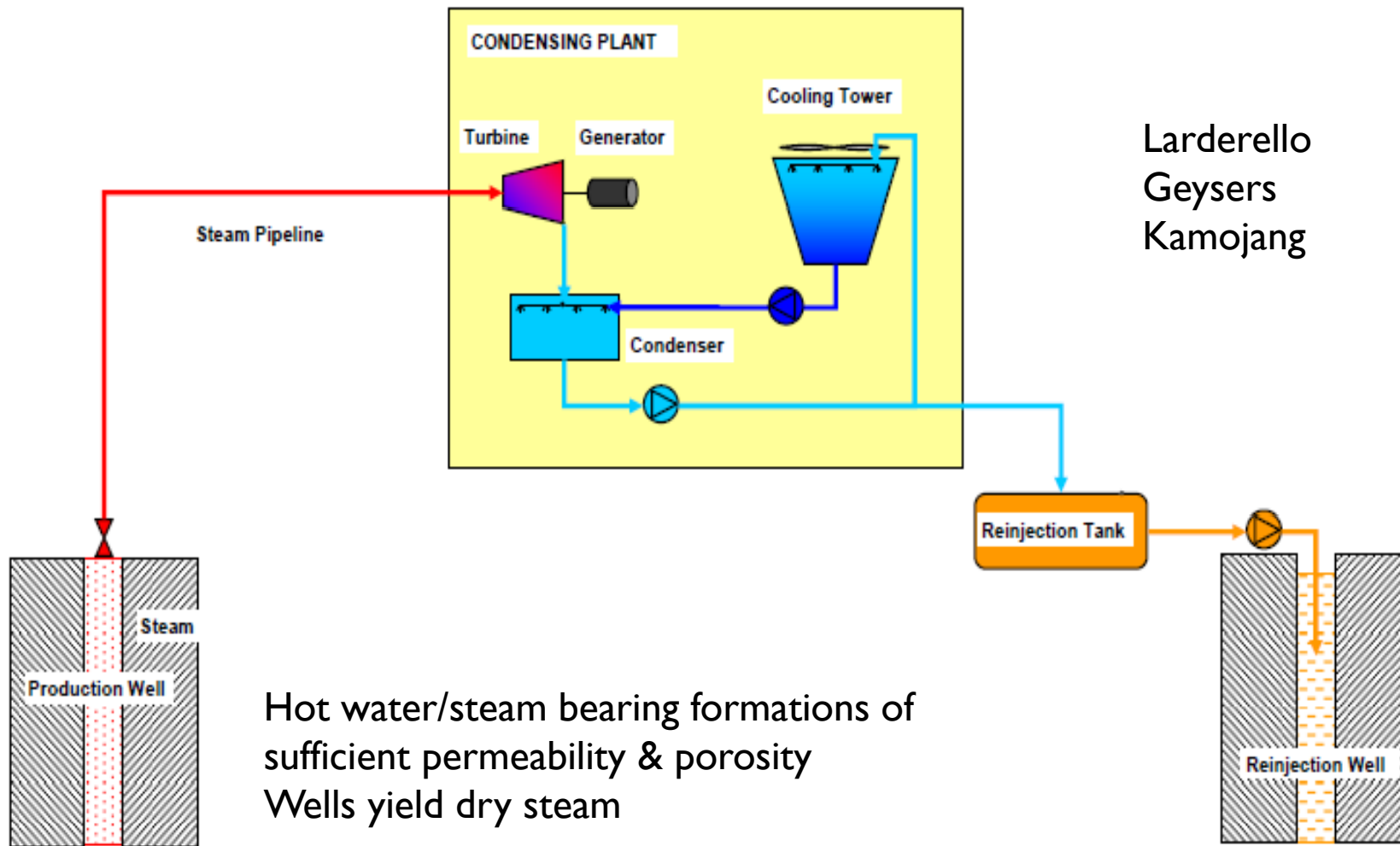
# Exploitation technology: the future

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- ▶ **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**
  - ▶  $>350^{\circ}\text{C}$  from depths 5-10 km



# Dry steam plants



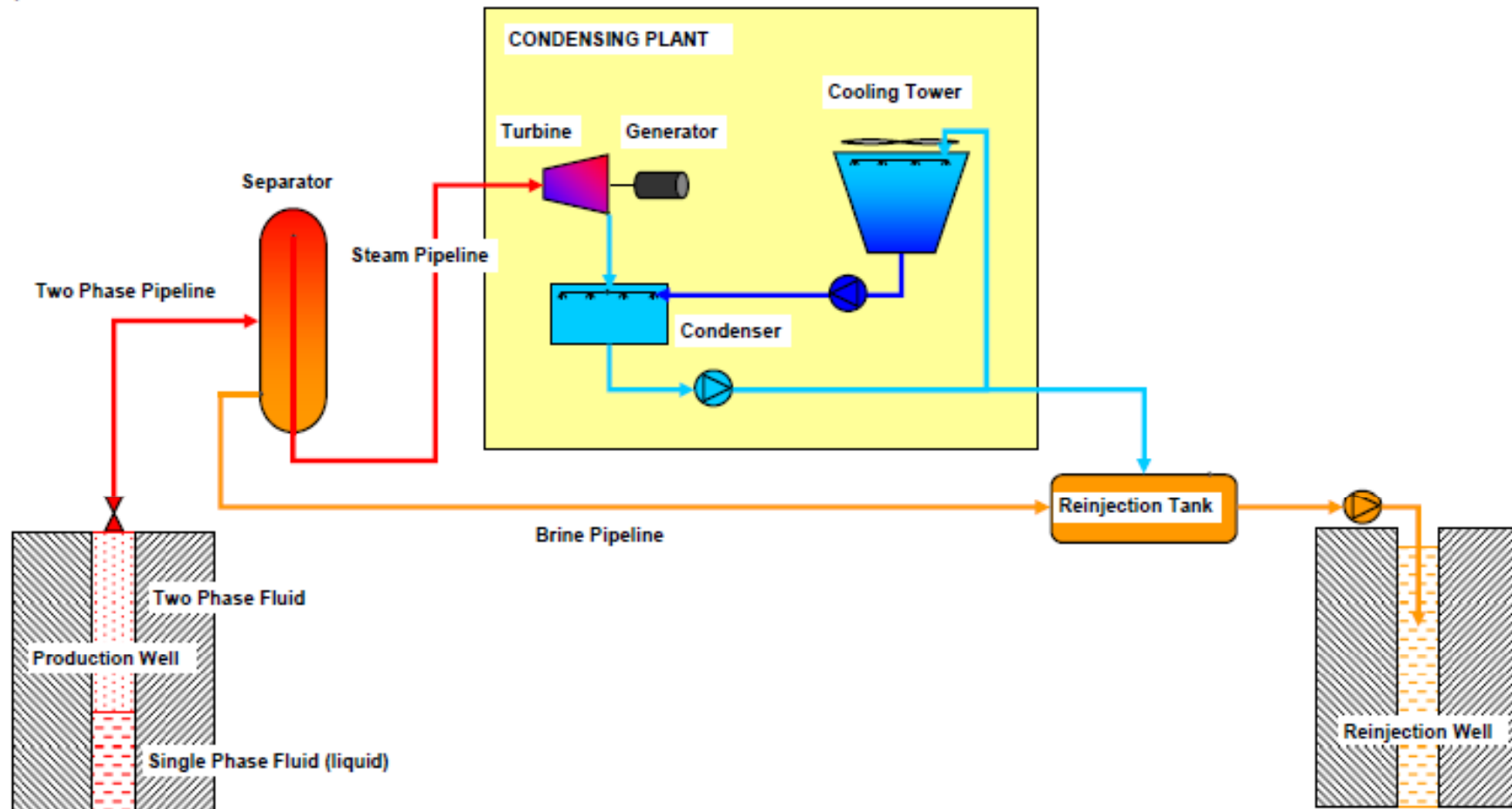
# 40MW Nuova San Martino plant, Larderello

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▶ 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





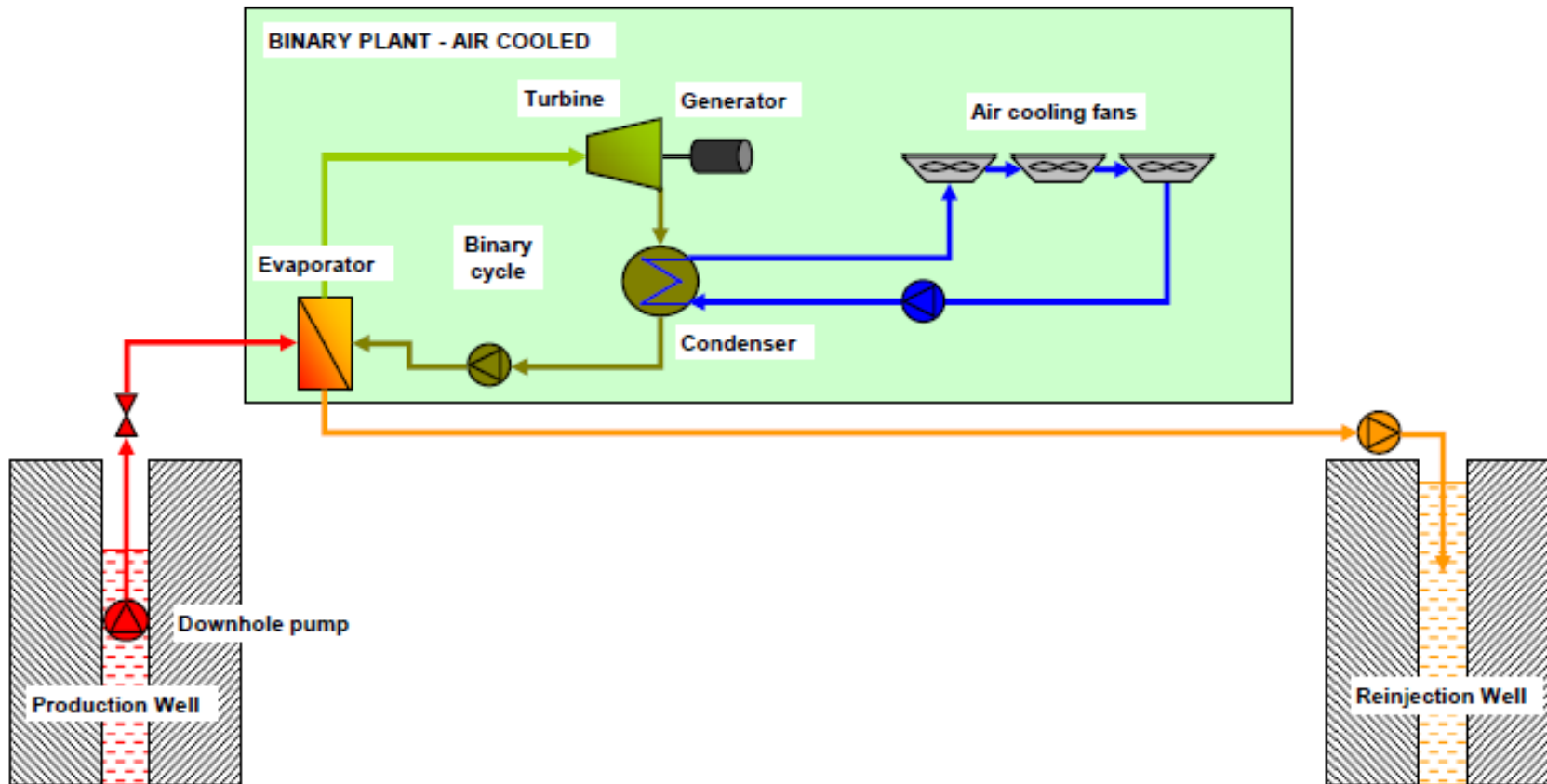
# 15 MWe Buillante plant

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

# Binary plants

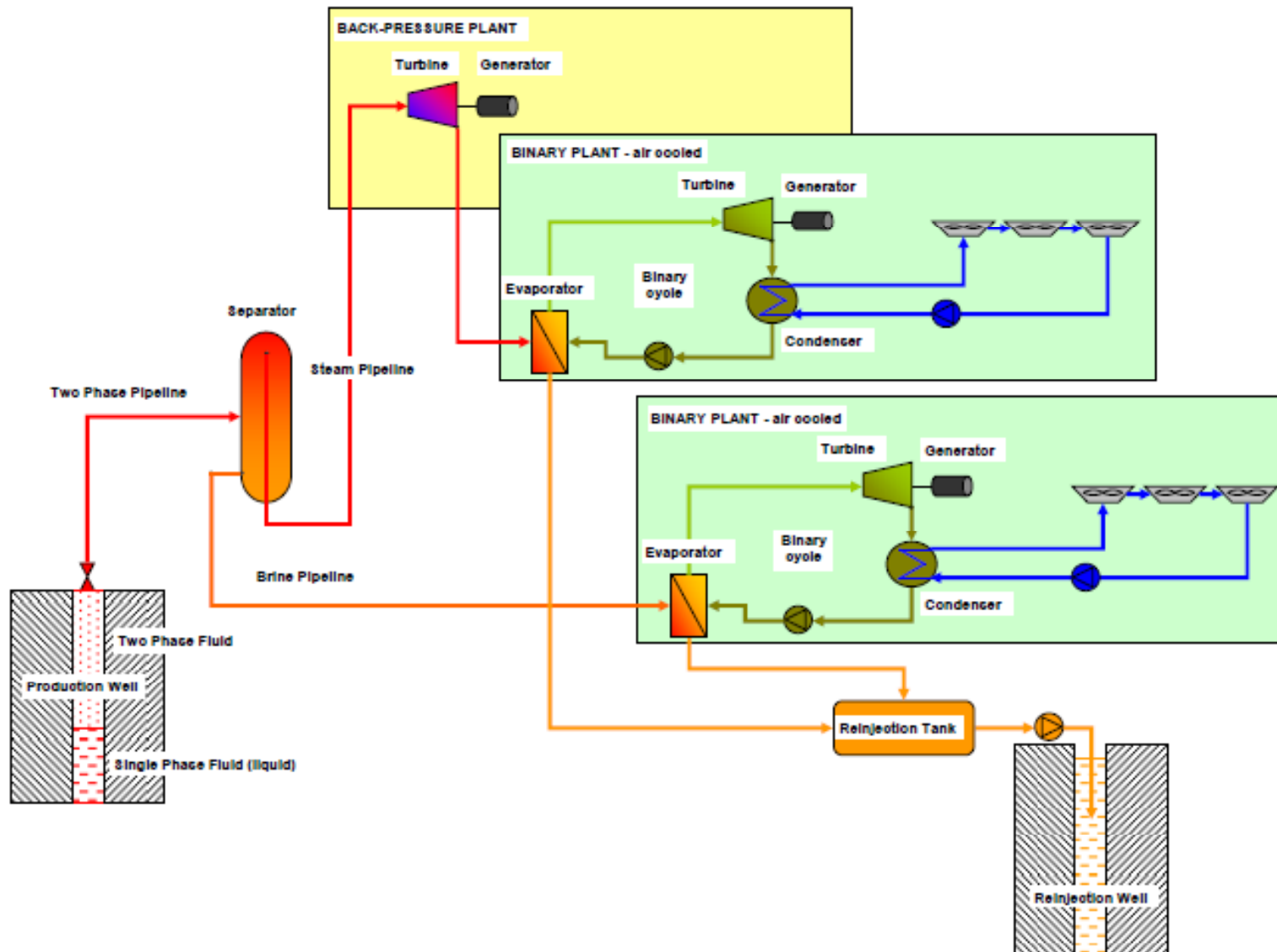


# 200 kW Simbach-Braunau unit





# Combined cycle flash/binary plants



# 34 MWe Rotokawa plant

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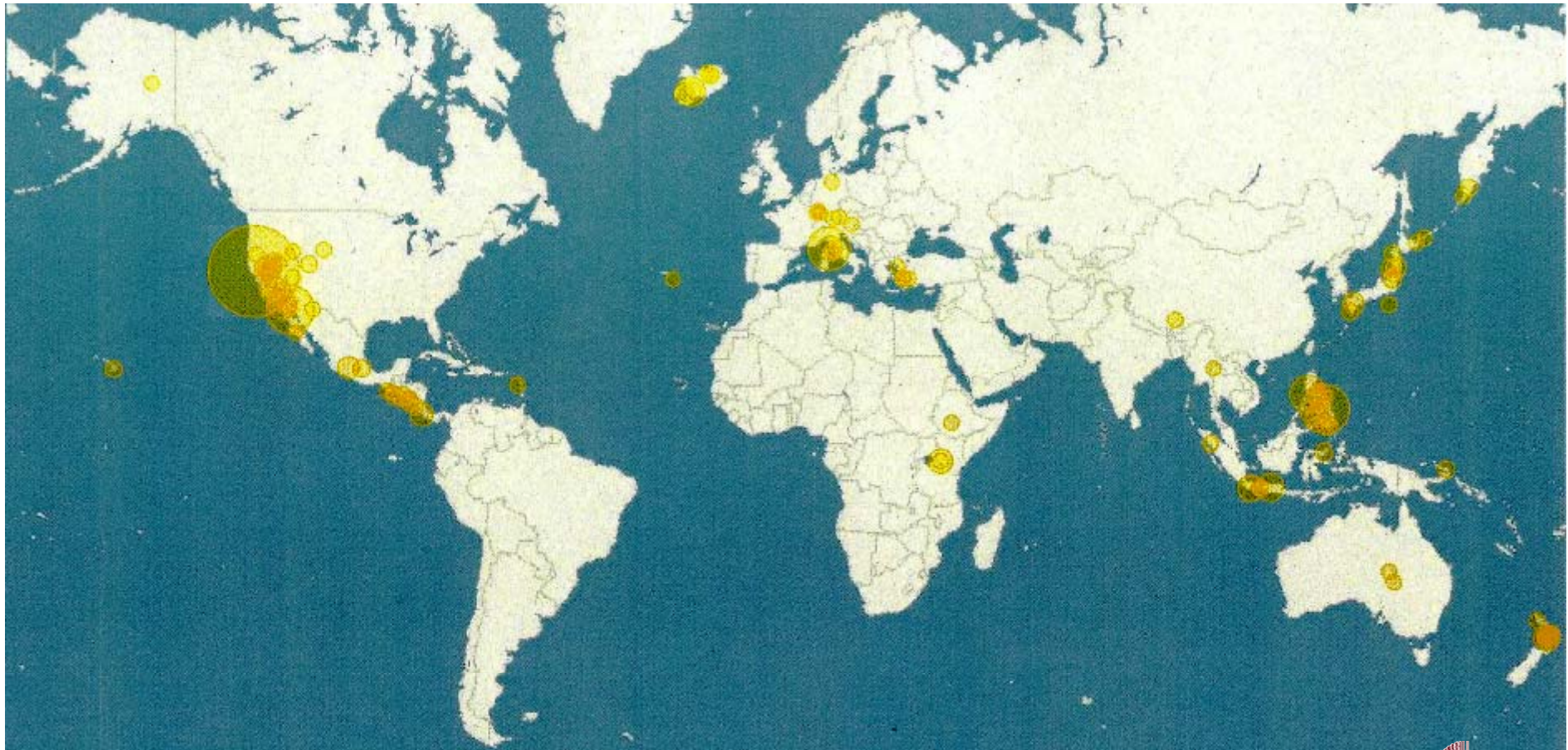
▶ Photo: Mighty River Power & Tauhara North No 2 Trust Brochure



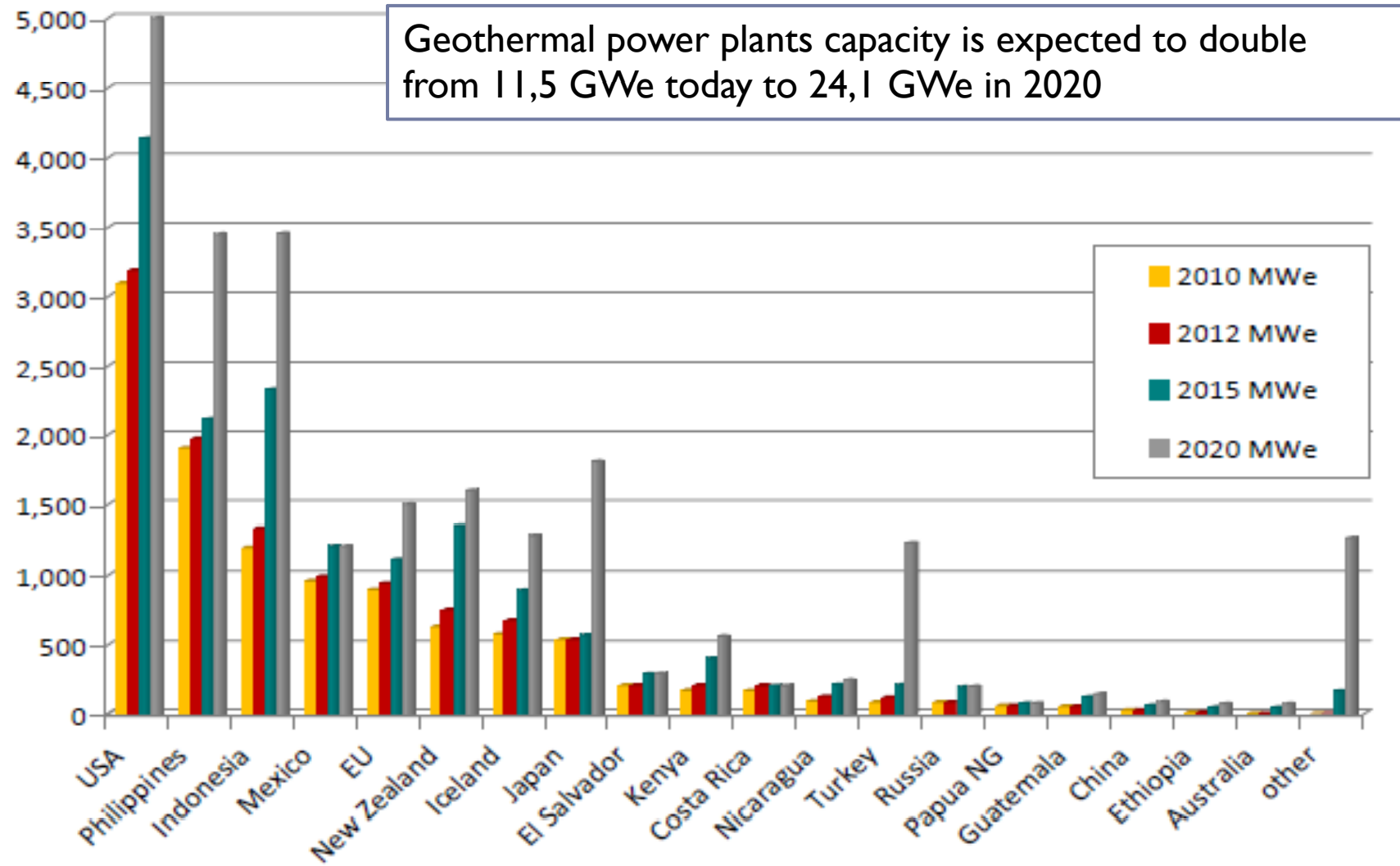
# Location of geothermal power plants

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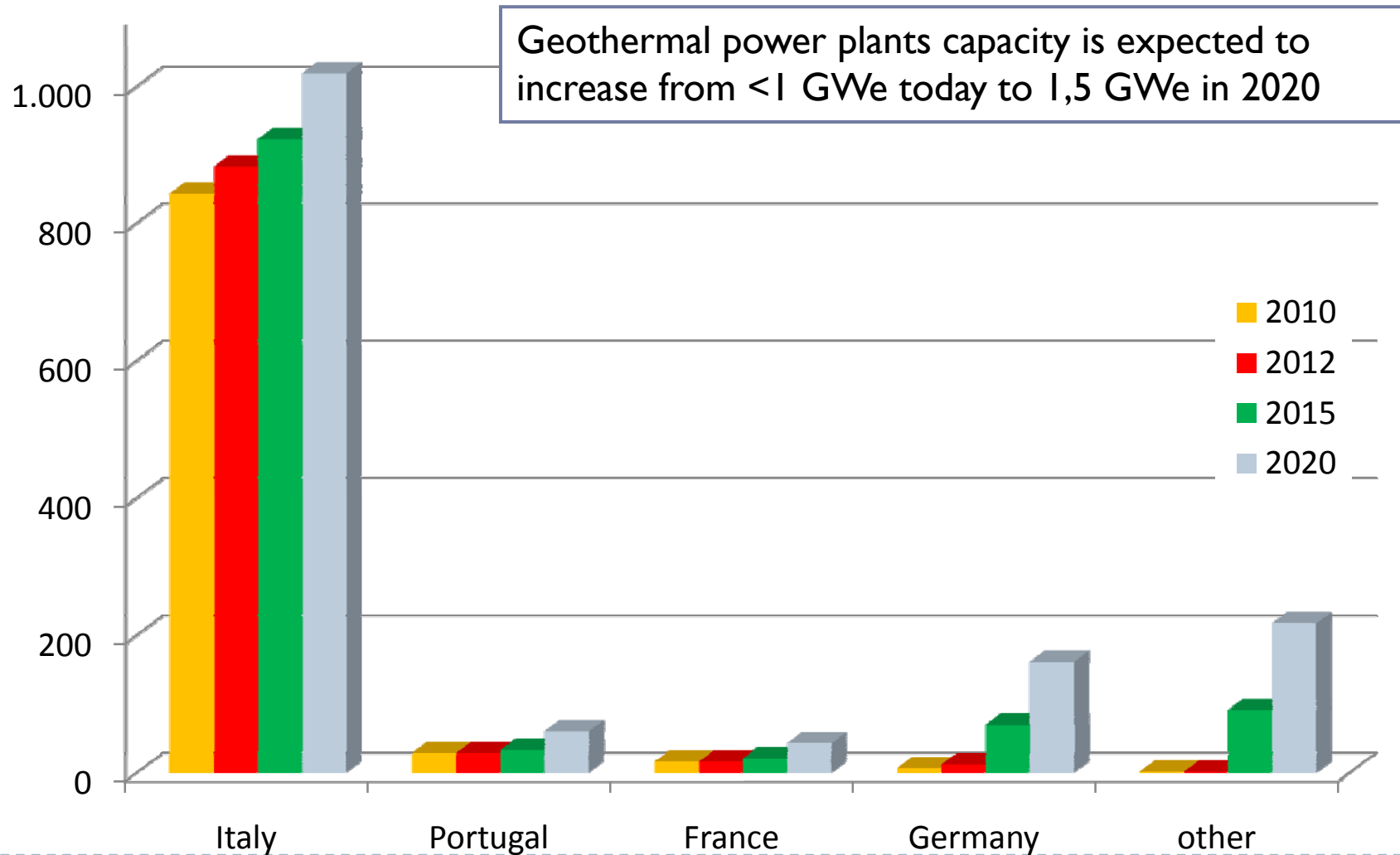
- ▶ tectonic plates boundaries
- ▶ hydrothermal systems
- ▶ volcanic/magmatic environments



# Installed capacity: world

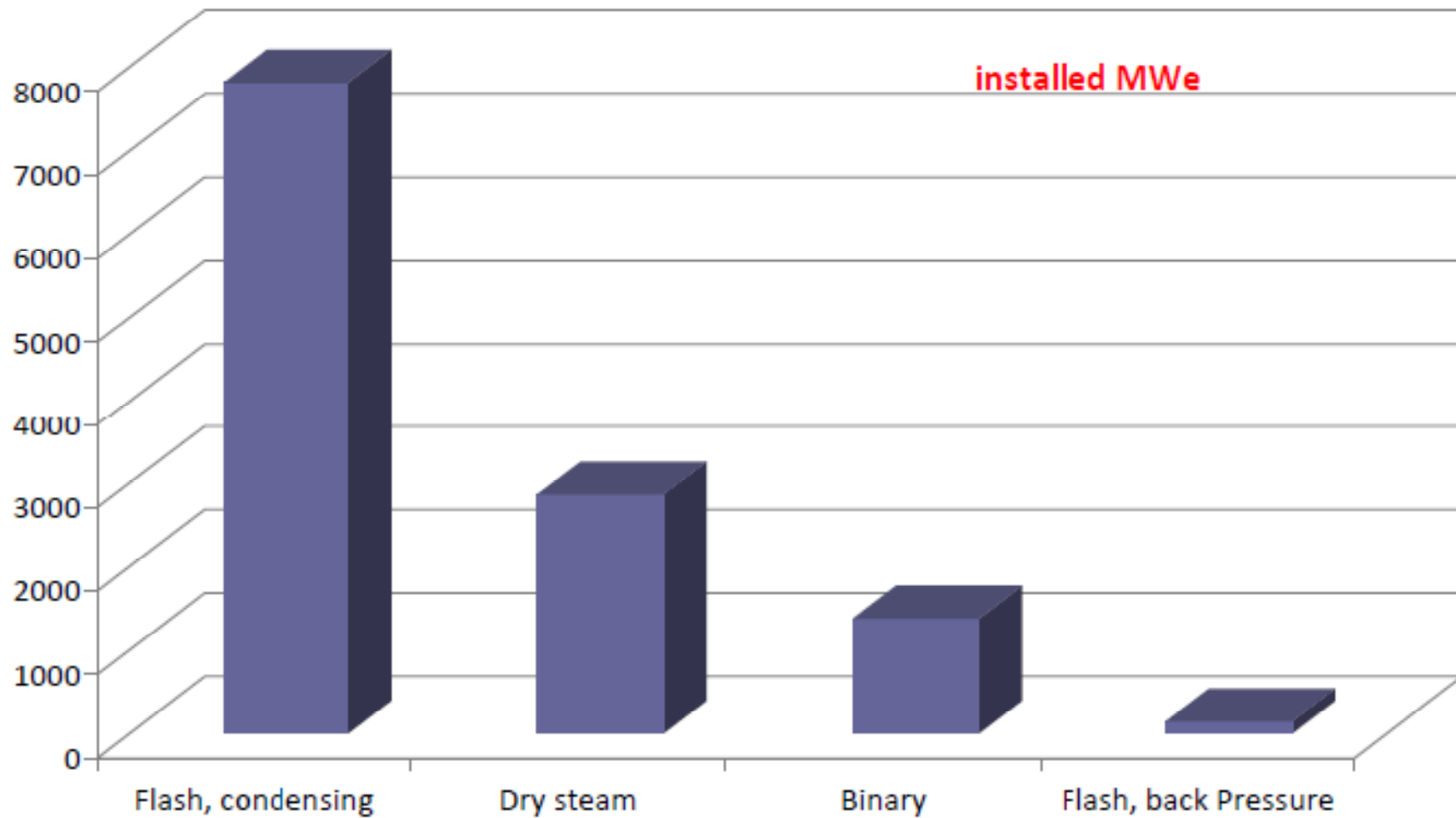


# Installed capacity: EU

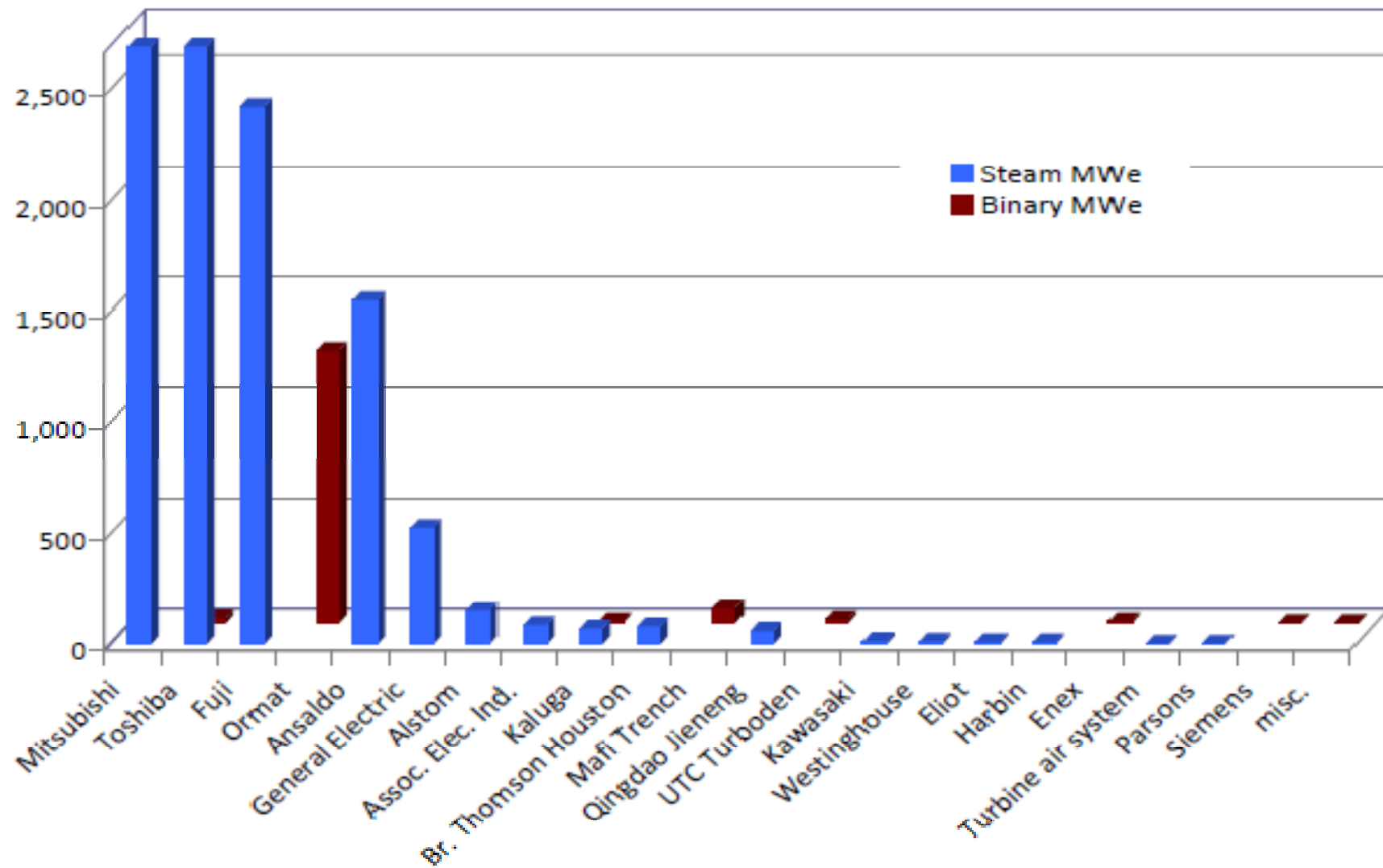




# Plant types



# Plant manufacturers



# Plant & Energy costs

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

# Market size & growth

	2012			2012-2020	
	installed capacity MWe	annual sales electricity GWh	value billion €	annual growth capacity MWe	investments billion €
<b>World</b>	11.456	71.887	7,2	1.588	4,4
<b>EU</b>	941	5.982	0,9	70	0,5

# Market barriers

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- ▶ 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	Expir e
<b>Federal</b>	§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
<b>Alabama</b>	§40-18-	Altern. Energy Prod. Fact.	Income	Credit	Utility	20	5%	-	2015
	§40-9B-4	Altern. Energy Prod. Fact.	Property	Abatement	Utility	-	100%	-	2018
<b>Delaware</b>	§2040	Clean Energy Mfg Jobs	Income	Credit	Manufacturer	-	\$750/J & \$100k	\$500k	-
<b>Florida</b>	196.175	RES Devices	Property	Exemption	Owner	10	100%	-	-
	220.193	Renewable Energy Prod.	Income	Credit	Producer	-	\$0.01/kWh	\$1mio	2016
<b>Maryland</b>	§10-720	RE Production	Income	Credit	Producer	5	\$0.0085/kWh	\$2.5mio	2015
<b>N. Jersey</b>	§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	0,4077	Italy	0,1300	Estonia	0,0537
>15MW	0,2692	- feed-in premiums	0,0800	- feed-in premium	
Switzerland <5 MW	0,3330	Croatia	0,1910	Romania max-min	0,1100
>20MW	0,1890			2 green cert. per MWh	0,0540
Germany EGS	0,3000	Slovenia	0,1524	Hungary max-min	0,1070
other	0,2500	- feed-in premium	0,1036		0,0390
France continental	0,2800	UK	0,1422	Turkey max-min	0,1020
	0,2000	- 2 ROCs per MWh			0,0390
France overseas	0,1600	Indonesia max - min	0,1308	Belgium min	0,0900
	0,1300		0,0833	- green certificates	
Slovakia	0,1905	Greece	0,1220	Portugal – Azores	0,0840
				Austria	0,0743
Czech Rep.	0,1810	Netherlands	0,0680	Spain	0,0765
- feed-in premium	0,1420	- feed-in premium		- feed-in premium	0,0427

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

# Incentives: developing countries

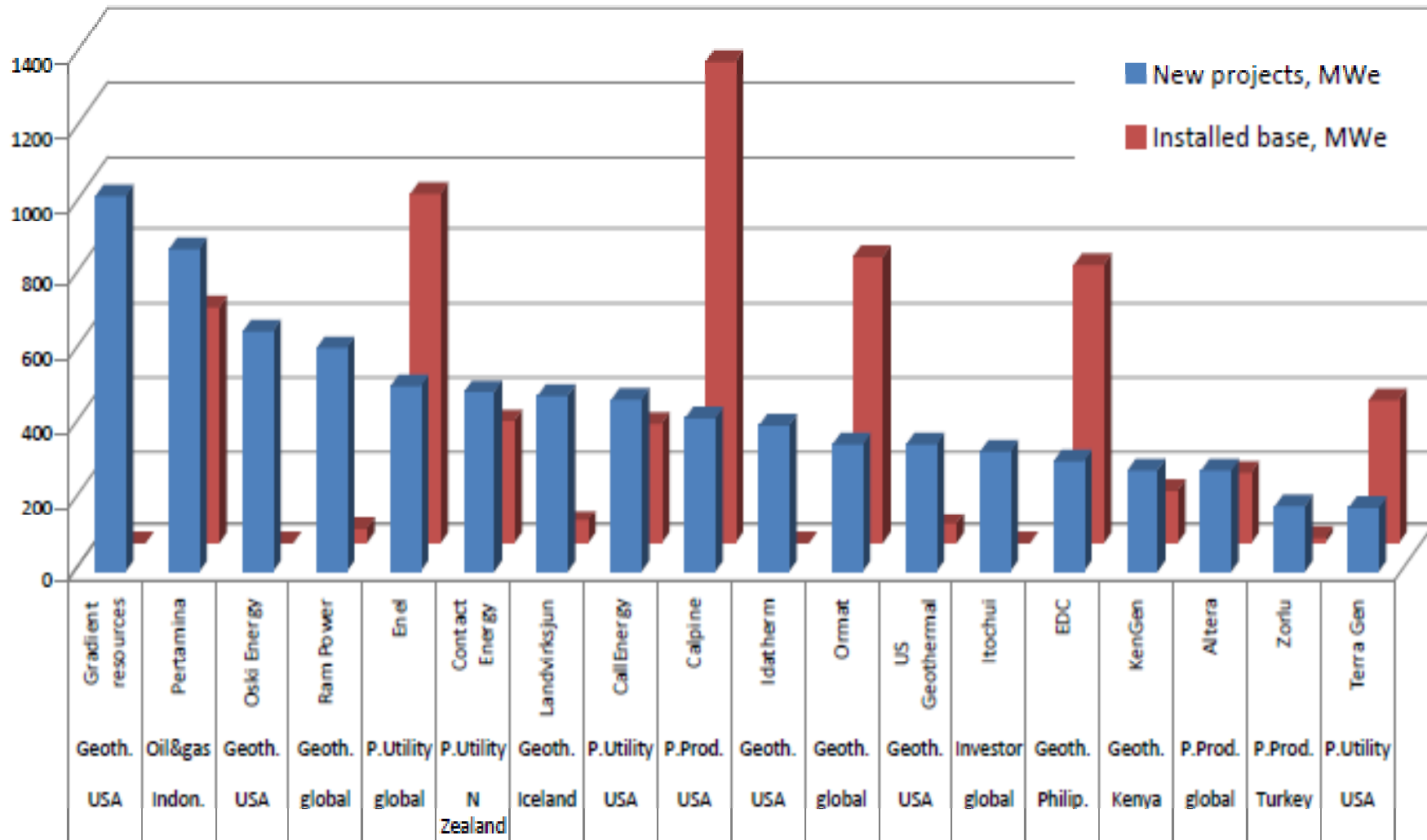
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- ▶ Carbon tax credits
- ▶ World bank : \$1710 million total, \$336 in 2012
- ▶ European investment bank : \$256 million
- ▶ Asian development bank : \$557
- ▶ African development bank : \$129 million
- ▶ Interamerican development bank : \$416 million
- ▶ Japan international cooperation agency
- ▶ French development agency
- ▶ German development bank KfW
- ▶ National development banks





# Companies developing the market



▶ ~65% of global capacity under development

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*thank you for your attention*

