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POSSIBILITIES OF ELECTRICITY PRODUCTION ON GEOTHERMAL BASE

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MŰEGYETEM 1782

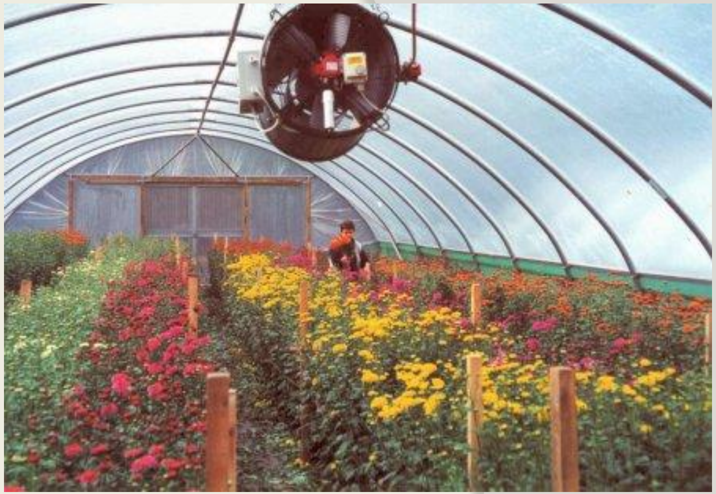
Utilisation possibilites

- Direct heat utilisation
- Electricity production

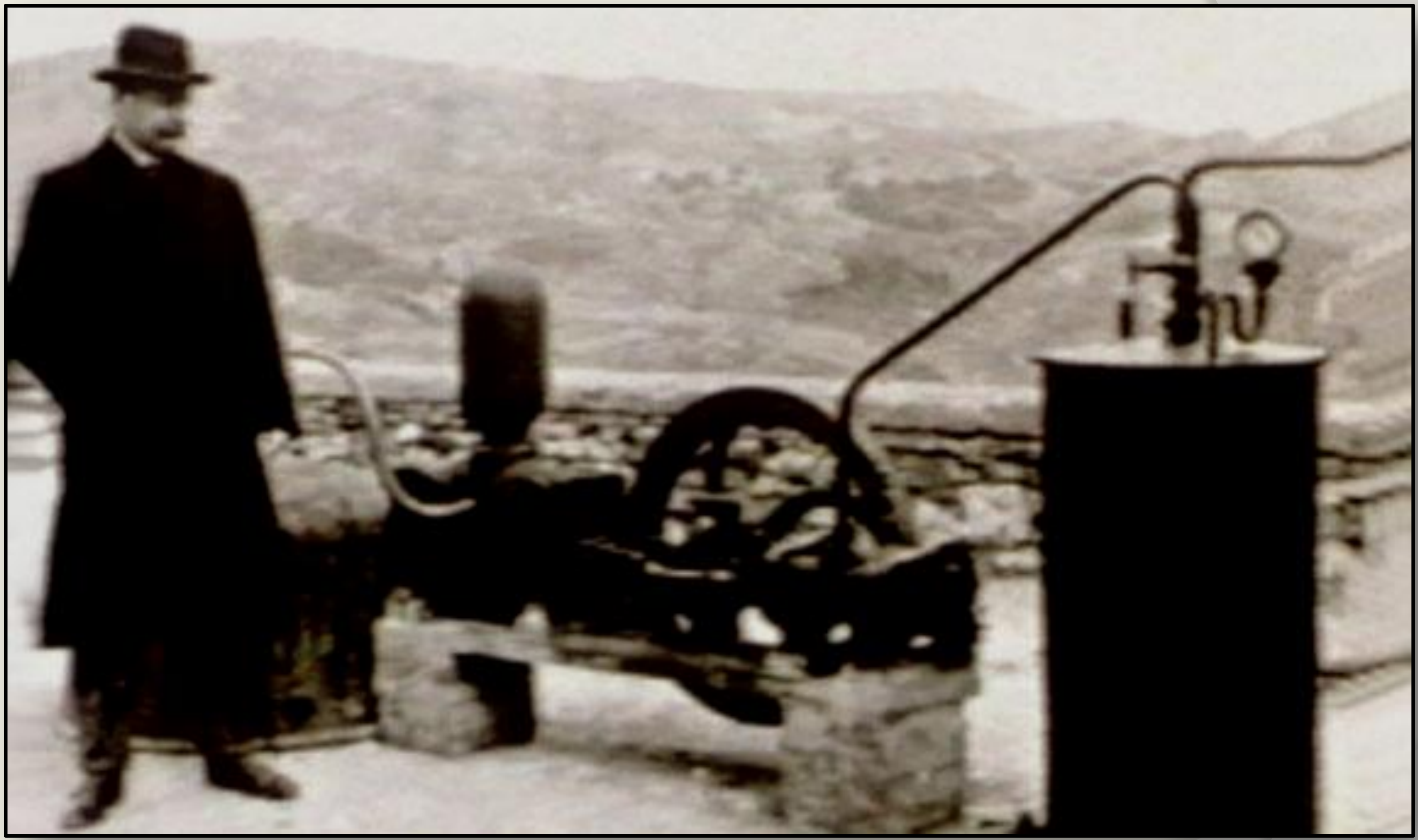
Direct heat utilisation

<u>Examples:</u>

- space heating
- agricultural applications
- industrial applications
- geothermal heat pump app.
- balneological applications
- ice melting
- heating fish farms

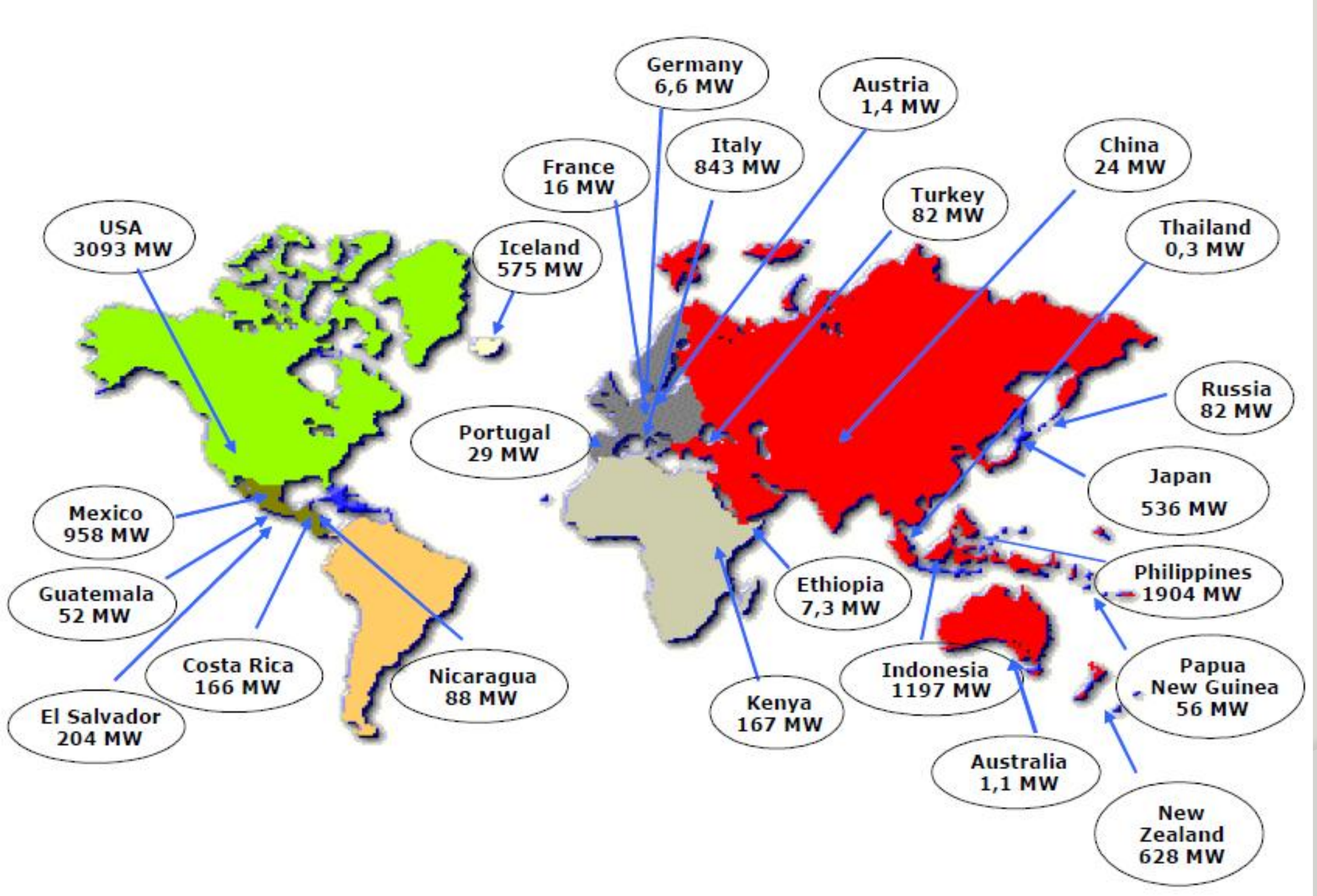


Electricity production



The first geothermal based power plant. Italy, Larderello, 1904.

Electricity production

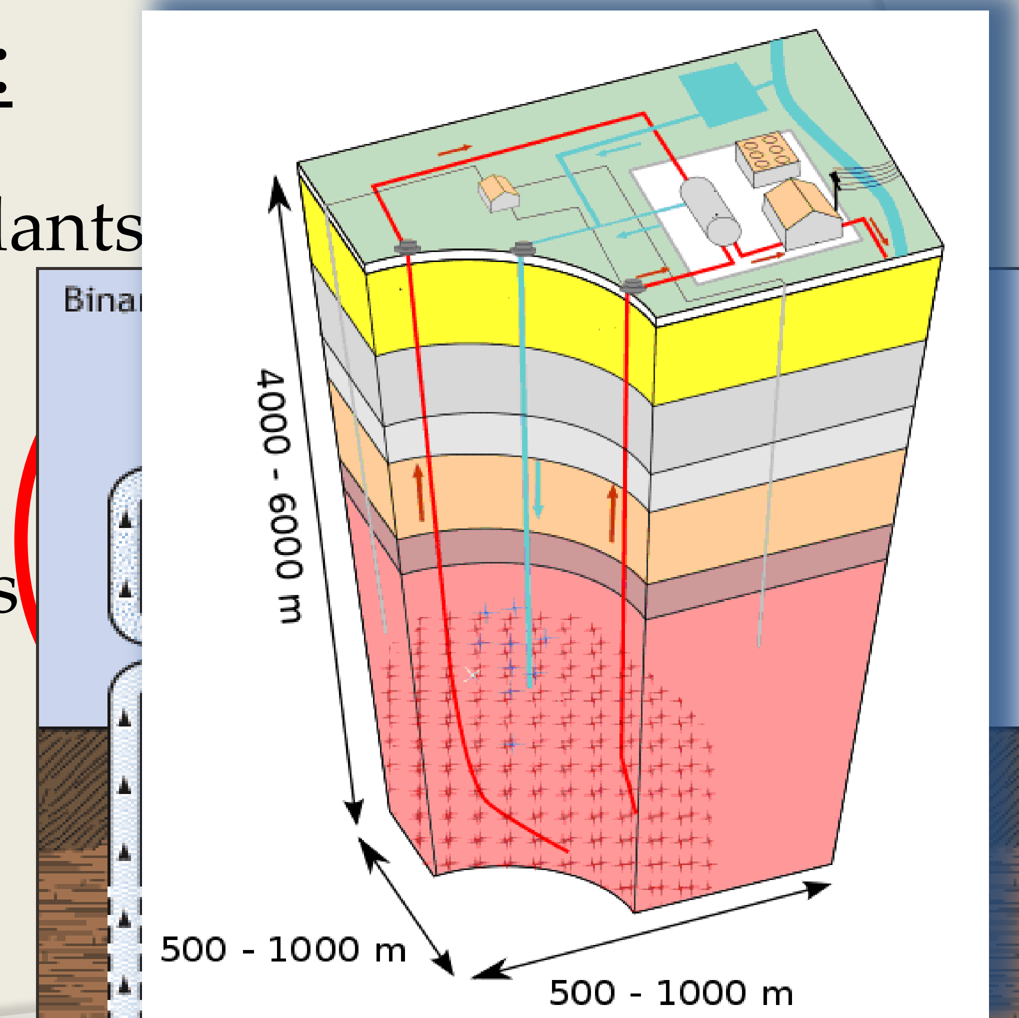


Installed capacity in 2010 worldwide (10,7 GW) ***[R. Bertani]***

Electricity production

<u>Main technolgies:</u>

- Dry steam power plants
- Flash systems
  - *Single flash*
  - *Dual flash*
- Binary power plants
  - *Organic Rankine cycle*
  - *Kalina cycle*
- (EGS systems)



Statistics

Top 15 greatest geothermal power plants

	Country	Plant name	Unit	COD	Capacity	Type
1	Indonesia	Wayang Windu	2	2009	117	Single Flash
2	USA	Socrates	1	1983	113	Dry Steam
3	USA	Quicksilver	1	1985	113	Dry Steam
4	USA	Lake View	1	1985	113	Dry Steam
5	USA	Grant	1	1985	113	Dry Steam
6	Mexico	Cerro Prieto III.	1	1986	110	Double Flash
7	USA	Cobb Creek	1	1979	110	Dry Steam
8	USA	Eagle Rock	1	1975	110	Dry Steam
9	Mexico	Cerro Prieto II.	2	1987	110	Double Flash
10	Mexico	Cerro Prieto II.	1	1986	110	Double Flash
11	Indonesia	Darajat	3	2008	110	Dry Steam
12	Indonesia	Wayang Windu	1	2000	110	Single Flash
13	Mexico	Cerro Prieto III.	2	1986	110	Double Flash
14	USA	Sulphur Spring	1	1980	109	Dry Steam
15	New Zealand	Kawerau	1	2008	100	Double Flash

Statistics

Top 15 latest geothermal power plants

	Country	Plant name	Unit	COD	Capacity	Type
1	Indonesia	Wayang Windu	2	2009	117	Single Flash
2	USA	Faulkner	1	2009	50	**Binary**
3	Turkey	Germencik	1	2009	47	Double Flash
4	Italy	Sasso 2	1	2009	20	Dry Steam
5	Italy	Nouva Lagoni R.	1	2009	20	Dry Steam
6	Indonesia	Lahendong	3	2009	20	Single Flash
7	USA	Sillwater	1-2	2009	48	**Binary**
8	USA	Salt Wells	1	2009	24	**Binary**
9	USA	North Brawley	1-7	2009	49	**Binary**
10	USA	Thermo Hot Spring	1-50	2009	10	**Binary**
11	Indonesia	Darajat	3	2008	110	Dry Steam
12	New Zealand	Kawerau	1	2008	100	Double Flash
13	Iceland	Hellisheidi III.	1-2	2008	90	Single Flash
14	Kenya	Olkaira III.	3	2008	36	Single Flash
15	USA	Galena III.	1	2008	30	**Binary**

Domestic opportunities

Key facts:

- Hungary has good geothermal potential
  - Thick Earth's crust
  - Good reservoirs
- Hungary is a well-researched country (more than 8000 drillings)
- There is no goethermal based electricity generation
- The entire geothermal energy utilised directly

Examination of geothermal based electricity production

Main steps of the quick calculation

1. Collecting the data of the observed wells
2. Determining the aims
3. Model building
4. Calculating the output parameters of all wells
5. Ranking the wells
6. Fitting a power plant onto the best well
7. Cycle optimization
8. Improving the system

Examination of geothermal based electricity production

1. **<u>Collecting well data</u>**

- It is neccessary to have as many as possible
- Needed details
  - Depth
  - Wellhead pressure
  - Wellhead temperature
  - Productivity
  - Existing heat demand (consumer) and it's distance
  - (Location)

Examination of geothermal based electricity production

2. Determining the aims of the project

- Highest efficiency
- Highest electric power output
- Fully sastisfy the consumers heat demand
- Lowest costs
- Shortest payback period
- Shortest installation time
- (Mixture of them)

Examination of geothermal based electricity production

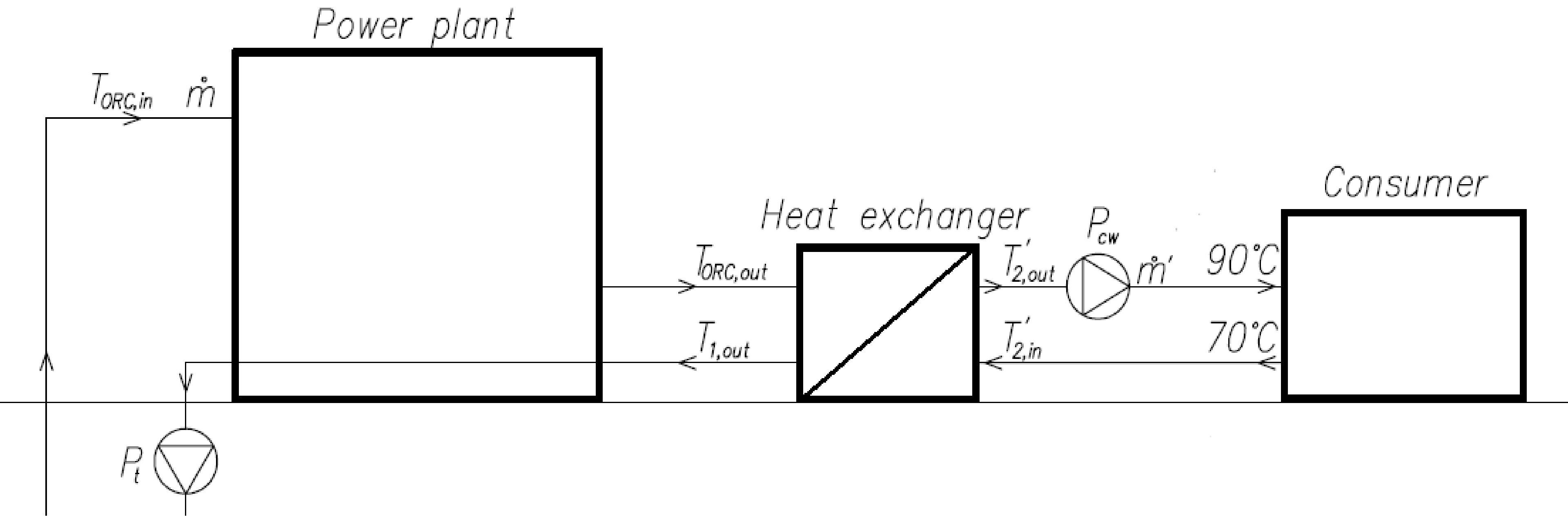
2. Determining the aims of the project

In Hungary:

- Only electricity production is not profitable currently (flow rates are not high enough)
- Neccessary to have a heat consumer relatively close to the thermal well → combined utilization

Examination of geothermal based electricity production

3. The observed model



Examination of geothermal based electricity production

3. The observed model

The main properties of the built model:

- Optimal power plant type for domestic reservoirs: ORC
- Heat exchanger: Regular shell-tube heat exhanger (ϕ=0,85)
- Consumers heat demand
  - Temperature: 90/70 ^oC
  - Constant during the year

Examination of geothermal based electricity production

4. Calculation

- Determine the neccessary mass flows in the secondary cycle

$$Q = c_w \cdot \dot{m}' \cdot \Delta T_{\sec} \cdot \tau = c_w \cdot \dot{m}' \cdot (90 - 70) \cdot \tau \Rightarrow \dot{m}' = \frac{Q}{c_w \cdot 20 \cdot \tau}$$

- Calculate the diameter of the pipes

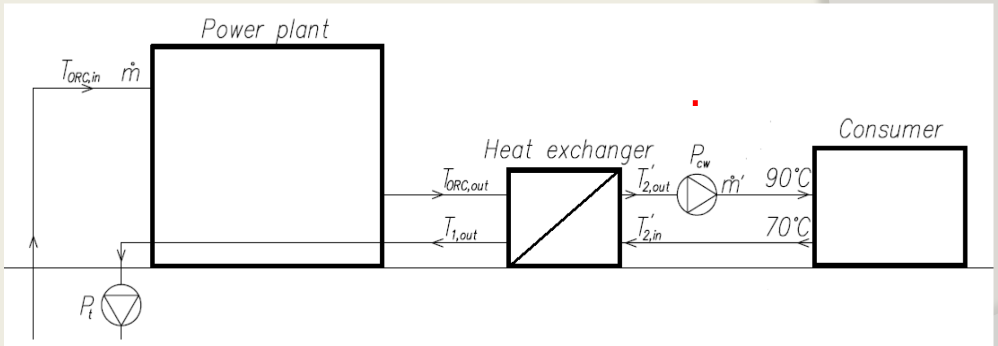
$$d_{\min} = \sqrt{\frac{4 \cdot \dot{m}'}{\pi \cdot w \cdot \rho}} = \sqrt{\frac{4 \cdot \dot{V}}{\pi \cdot w}}$$

Examination of geothermal based electricity production

4. Calculation

- Calculate the heat losses on pipes
- Determine the temperatures of the primary side of the heat exchanger

$$\Phi = \frac{T_{2,out} - T_{2,in}}{T_{ORC,out} - T_{2,in}}$$



- Calculate the gross thermal input of the power plants

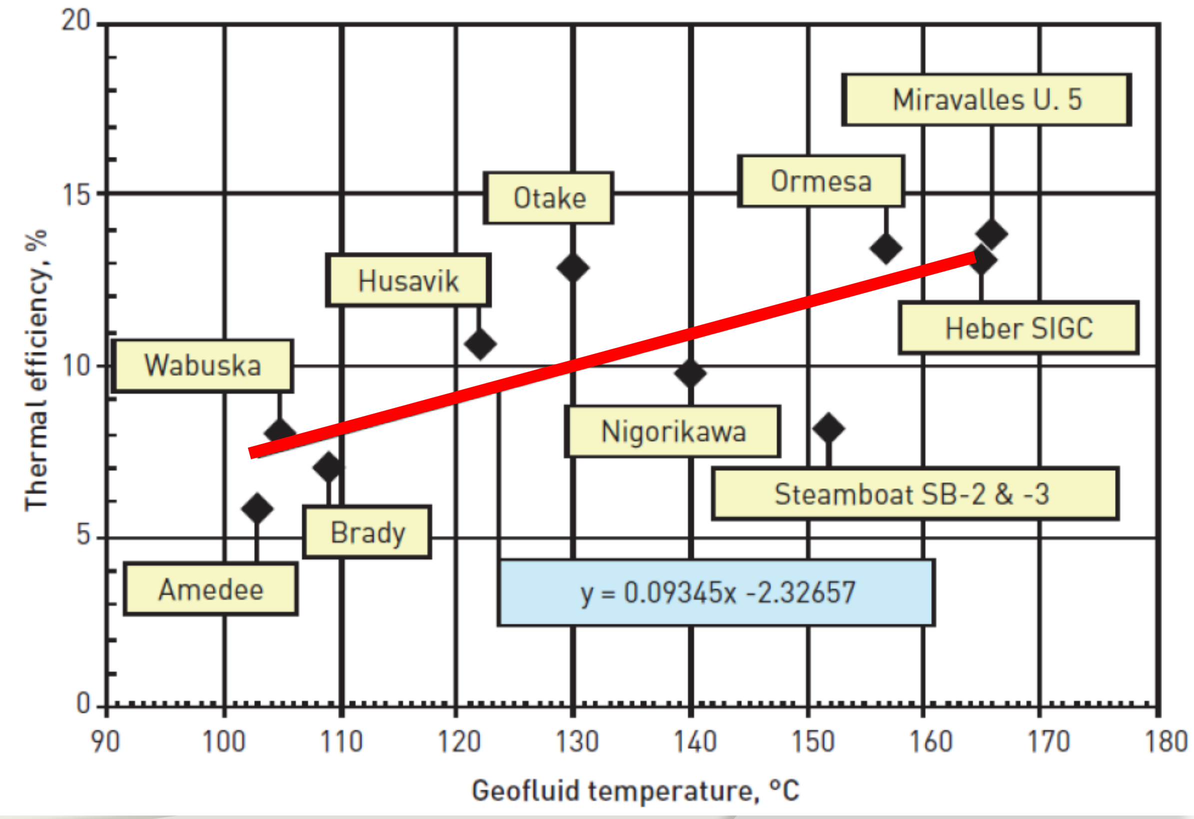
$$\dot{Q}_{in} = c_v \cdot \dot{m} \cdot (T_{ORC,in} - T_{ORC,out})$$

Examination of geothermal based electricity production

4. Calculation

$$\eta_{ORC} = 0,0935 \cdot T_{ORC,in} - 2,3266$$

Estimate the efficiency of each ORC power plant

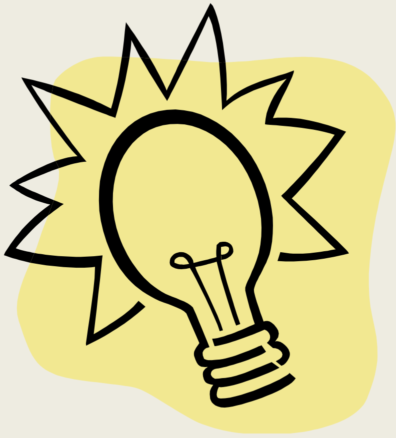


Determine the net power outputs of the power plants!

Examination of geothermal based electricity production

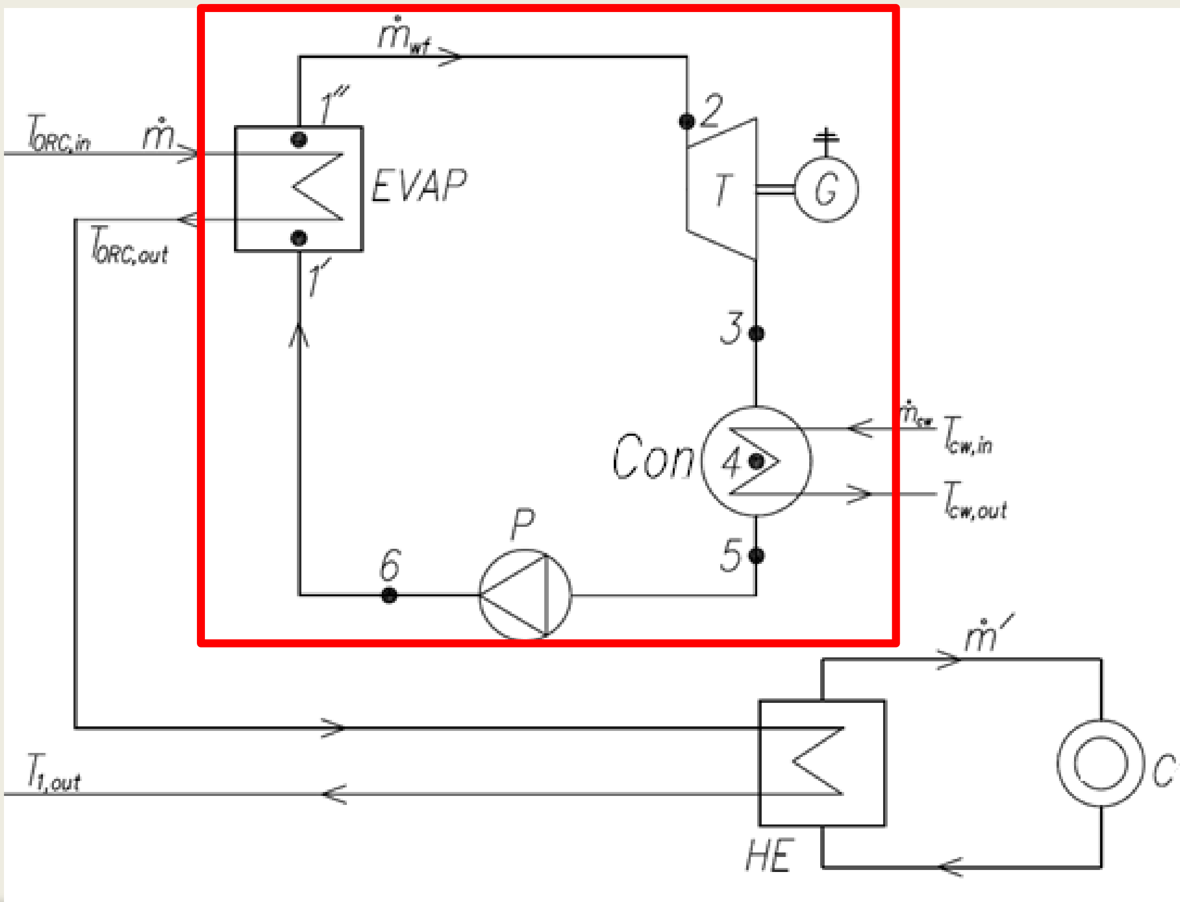
5. Ranking the wells

Choose the best → Observe, optimize and improve it!



Examination of geothermal based electricity production

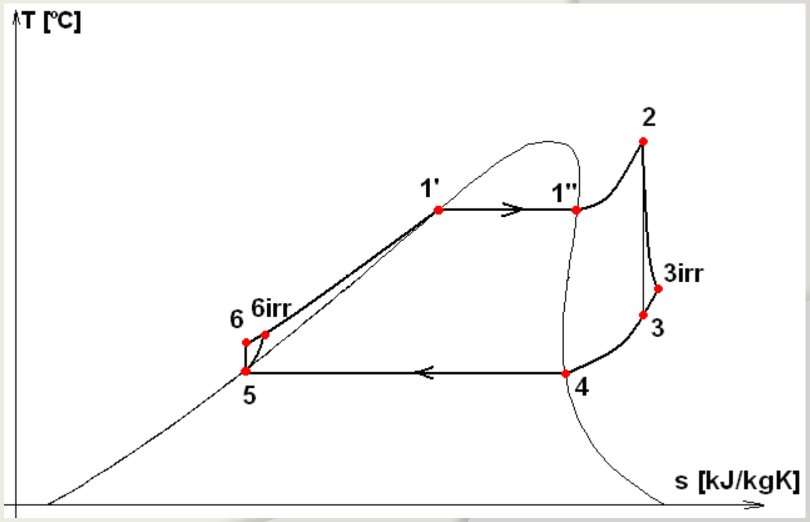
6. Fitting a power plant onto the best well



Examination of geothermal based electricity production

7. Optimization of the cycle

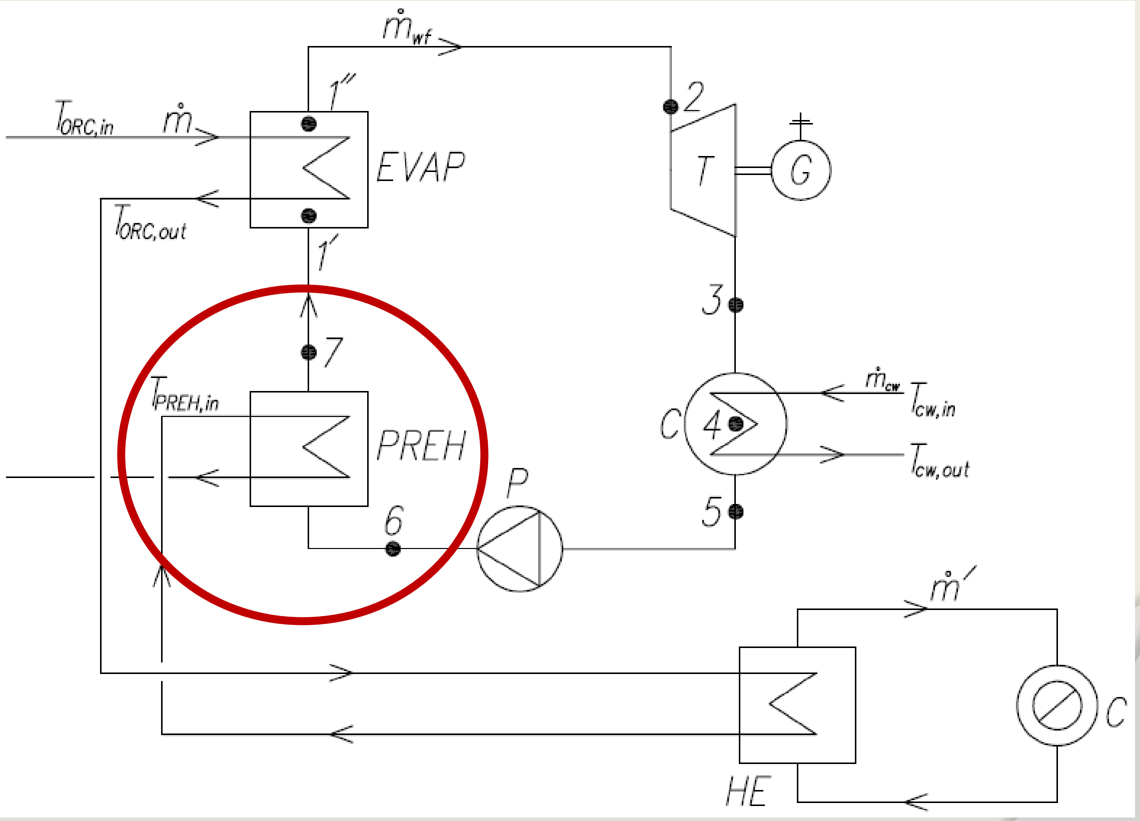
- Calculate the flow rate of the working fluid
- Optimize:
  - Type of working fluid
  - Evaporation temperatue
  - Superheating temperature
  - Condensation temperature



Examination of geothermal based electricity production

8. Improving the system

- Using a preheater, etc.



Costs

Investment costs

- Seismic research: ~200 million HUF
- ORC power plant: ~1500 EUR/kW
- Well renewal: ~200 million HUF/well
- Well drilling: ~600-1000 million HUF/well
- Surface technology costs: ~290-410 million HUF (pipes, injection well, chemicals, remote control,etc.)
- Enginnering and management costs: ~12% of the whole project costs

Costs

<u>Operational expenditure</u>

- Constant operational costs: 25-30 million HUF/a
- Injetion pump operating costs: ~20-25 million HUF/a
- Well reparation: 5 million HUF/a
  (+ 60-80 million HUF in every 5 year term)

Costs

<u>Prices:</u>

- Electricity generation: ~29 Ft/kWh
- Heat production: ~3000 Ft/GJ

Thank you for your kind attention!

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