



# Water filled underground oil shale mines as heat source

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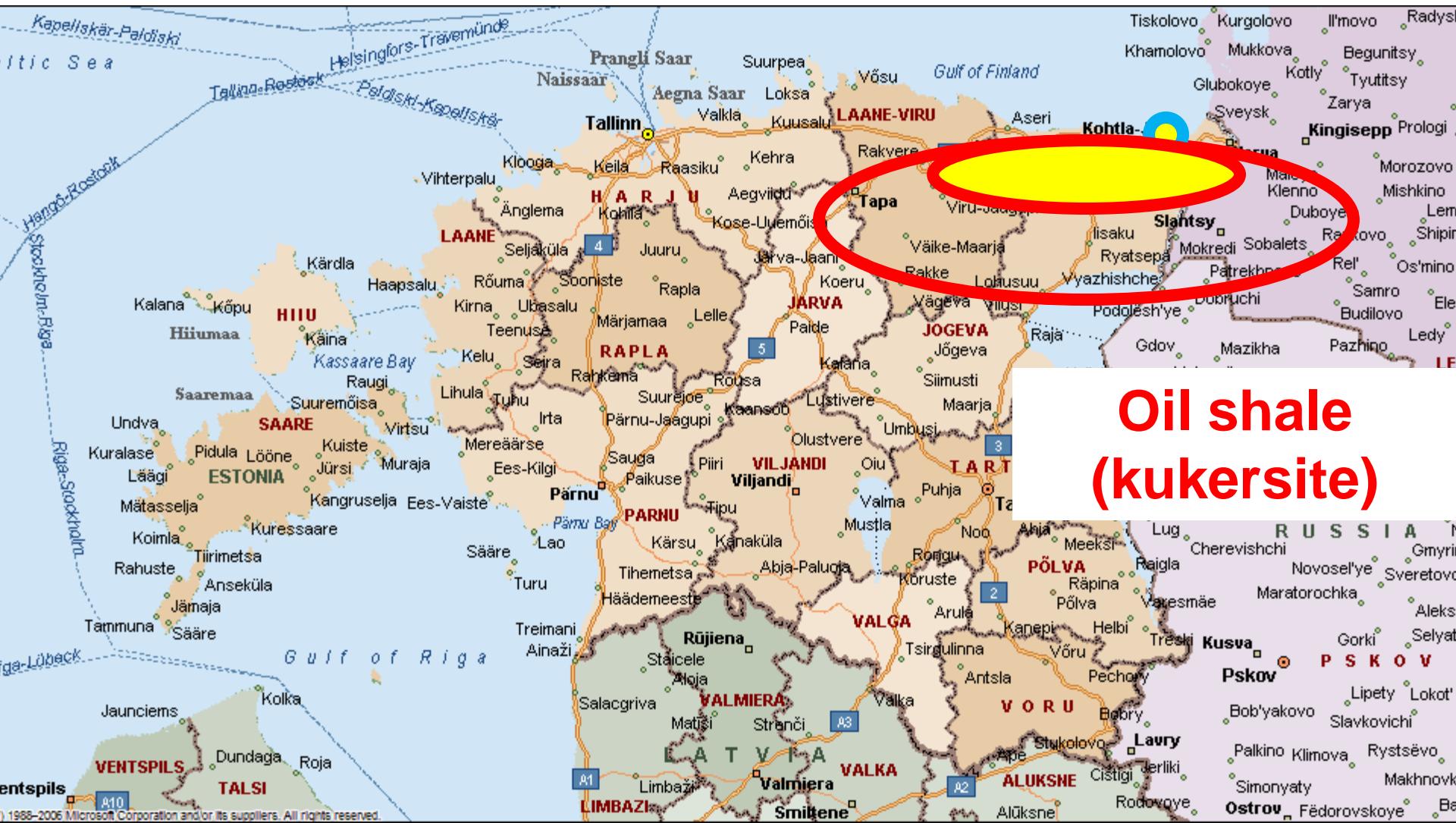


# Introduction

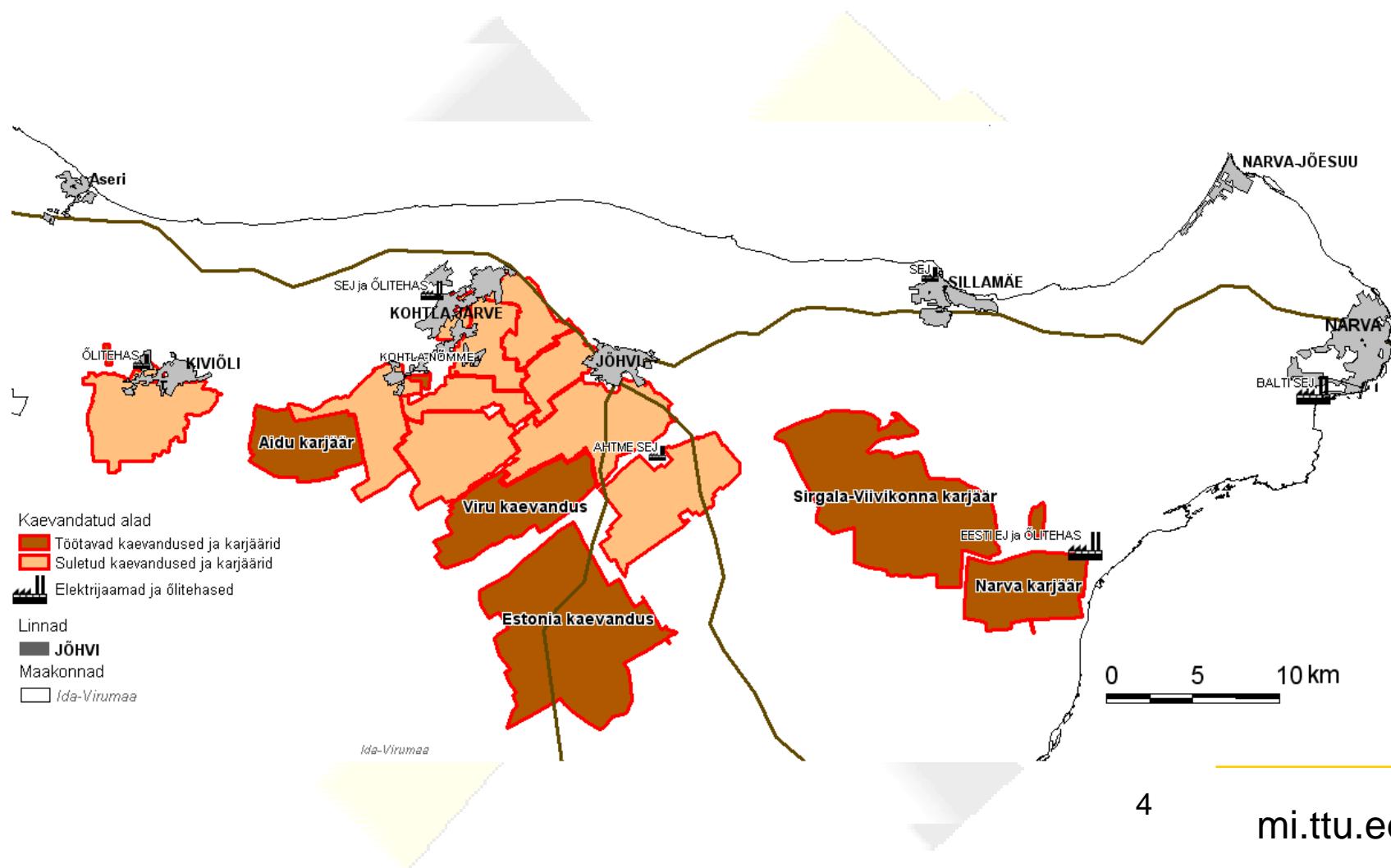
- Oil shale deposit is located East-Estonia
- In Estonia have mined oil shale more than 90 years
- There are nine closed mines and two working mines.
- Undermined area is nearly 250km<sup>2</sup>
- Electricity is mostly produced with oil shale in Estonia



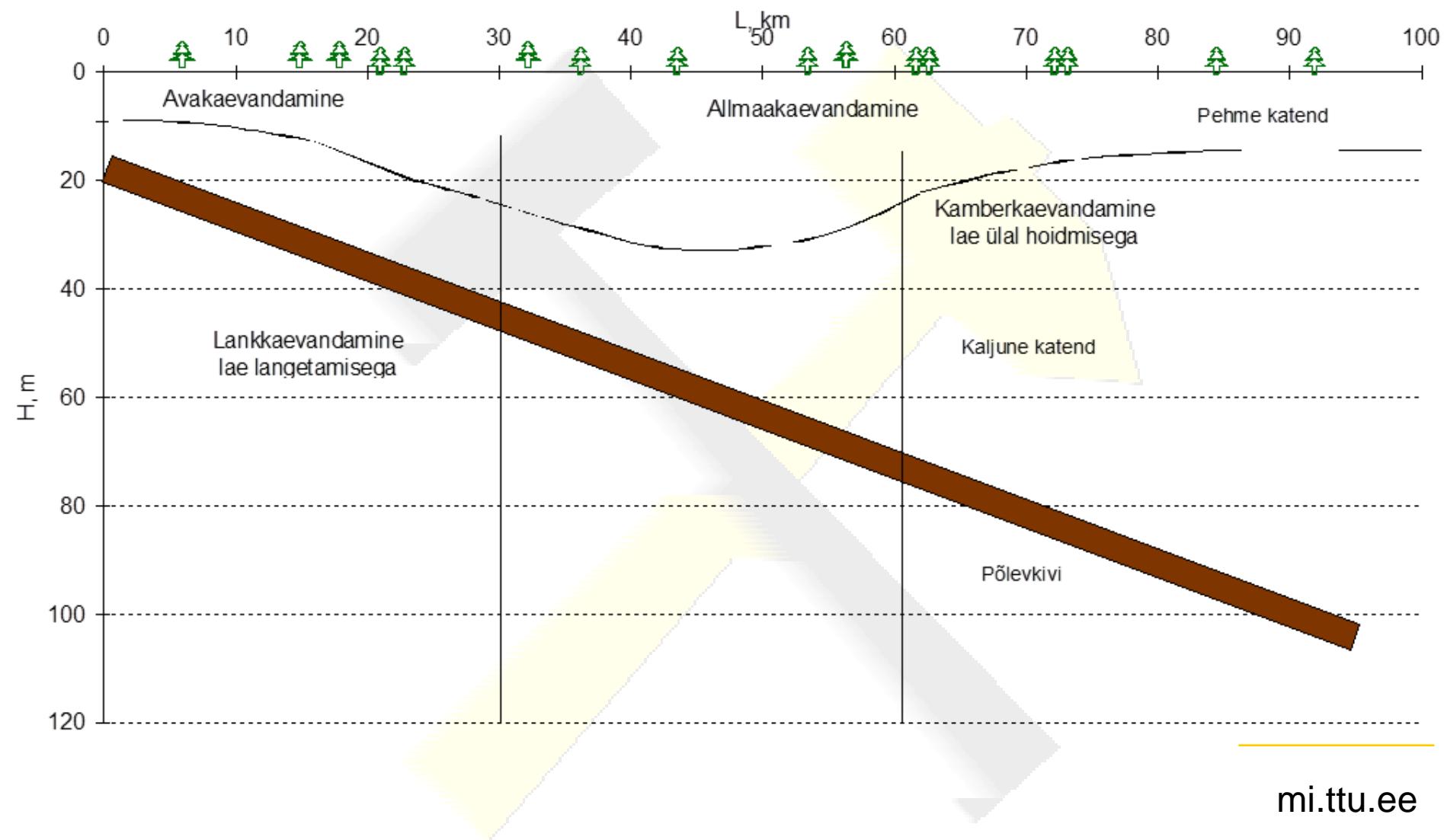
# Oil Shale mining areas



# Oil Shale Mining fields in East-Estonia

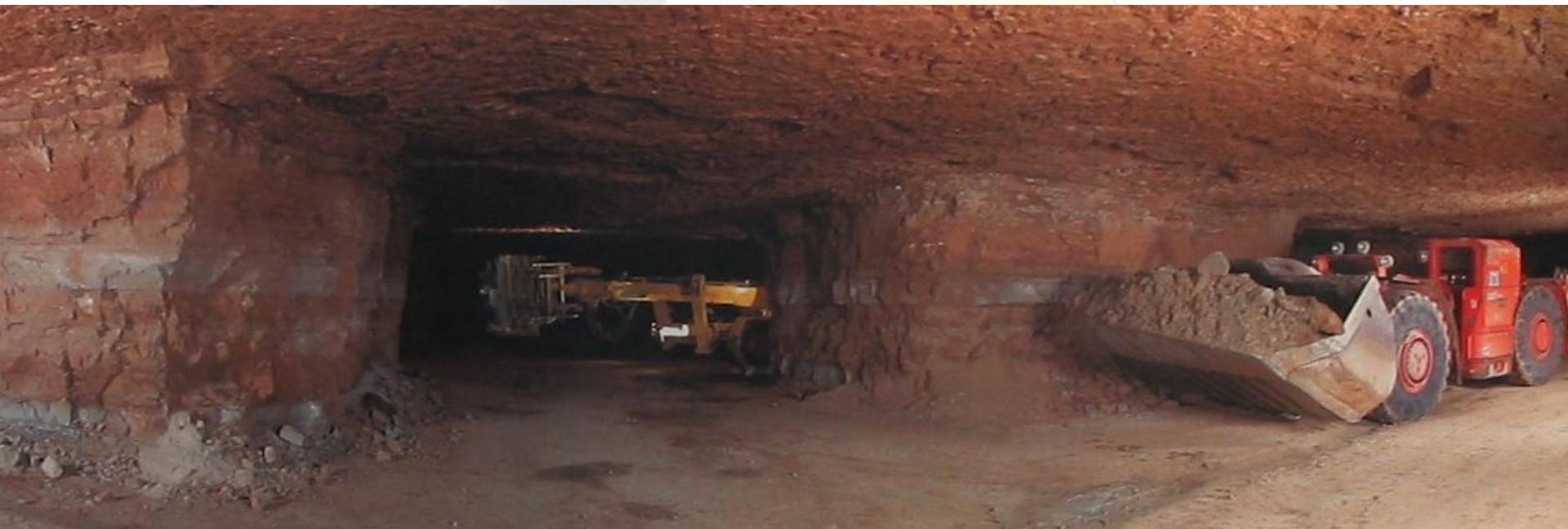


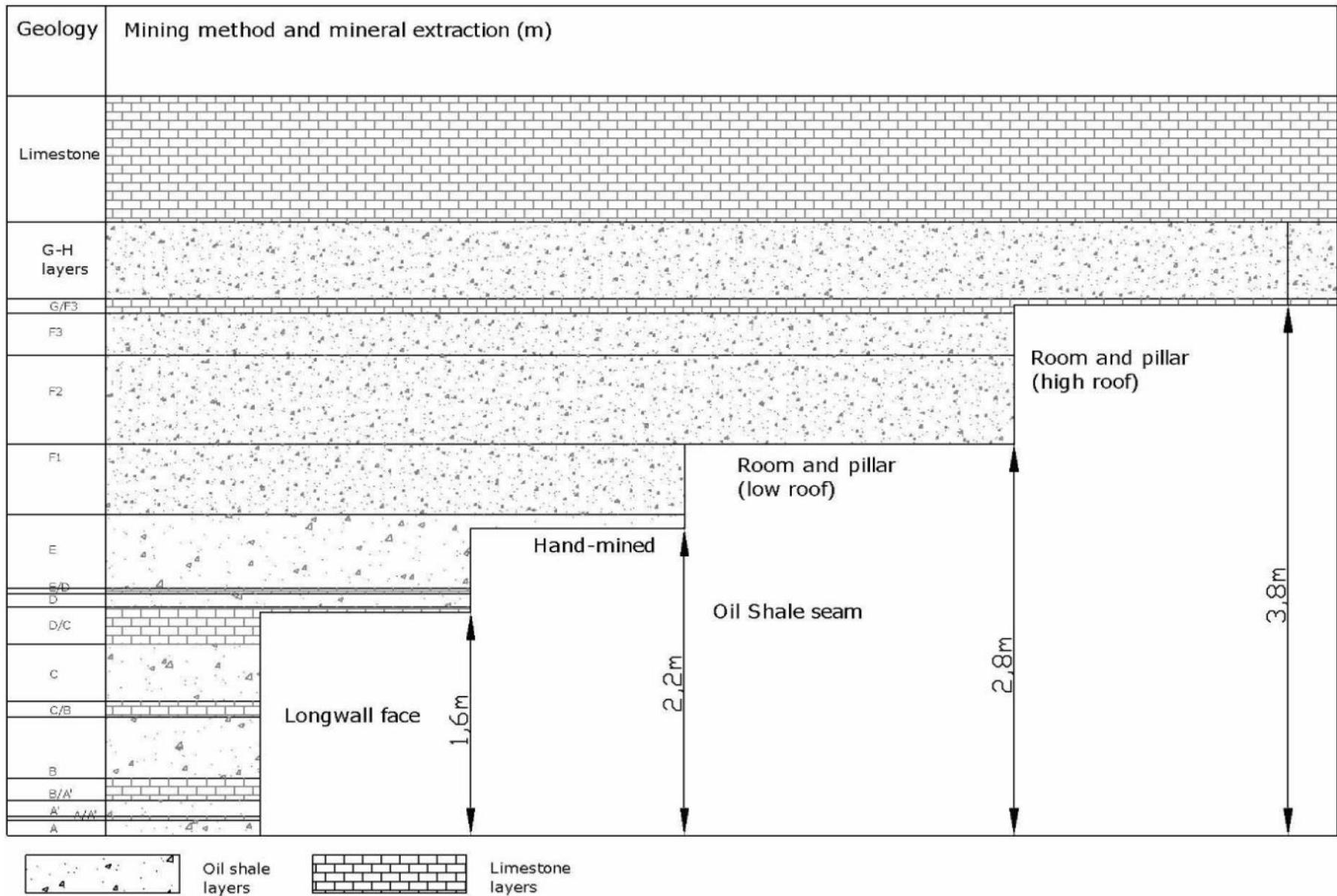
# Oil Shale seam



# Oil shale underground mining

- Room and pillar mining



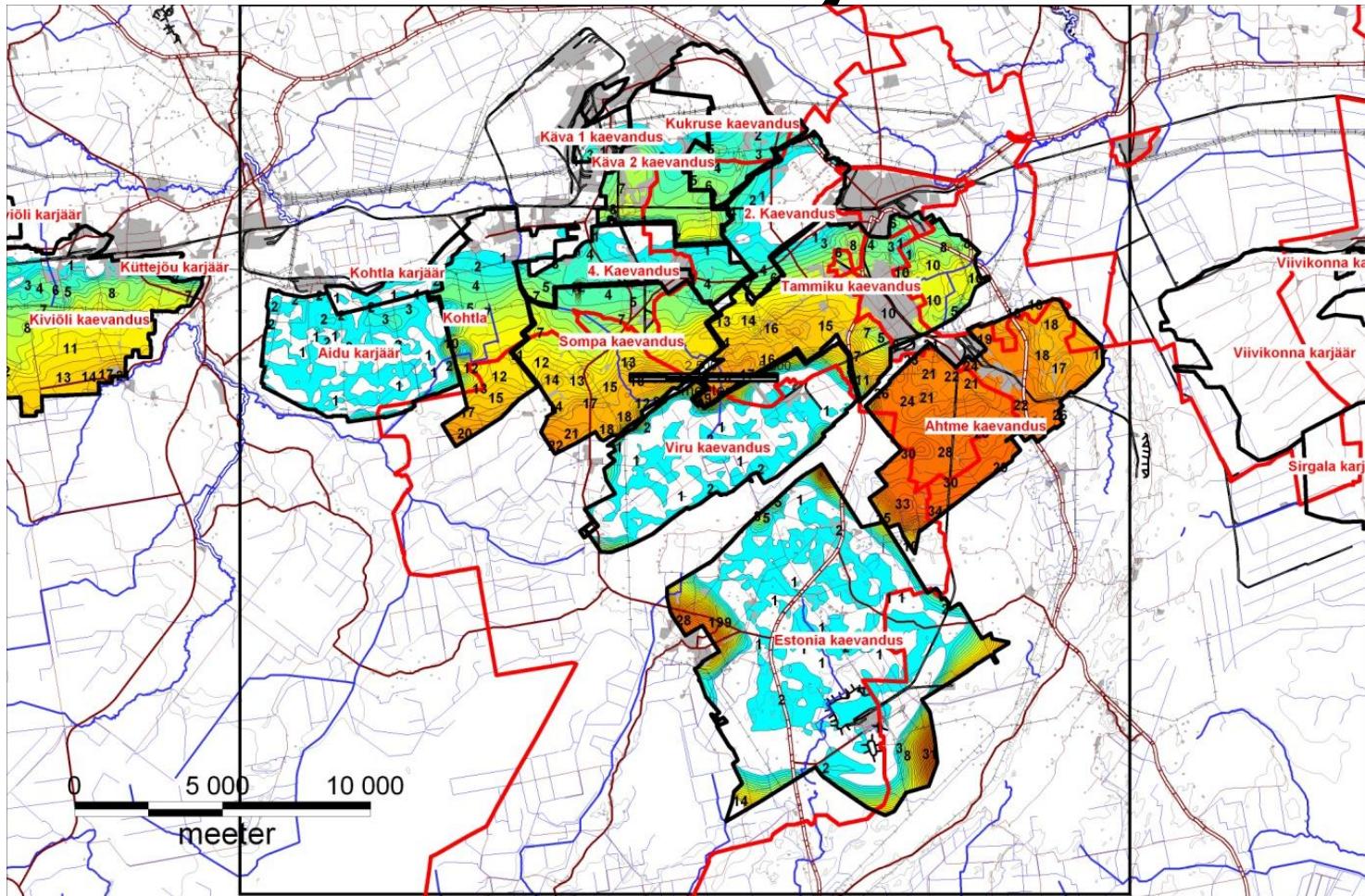


# Methods

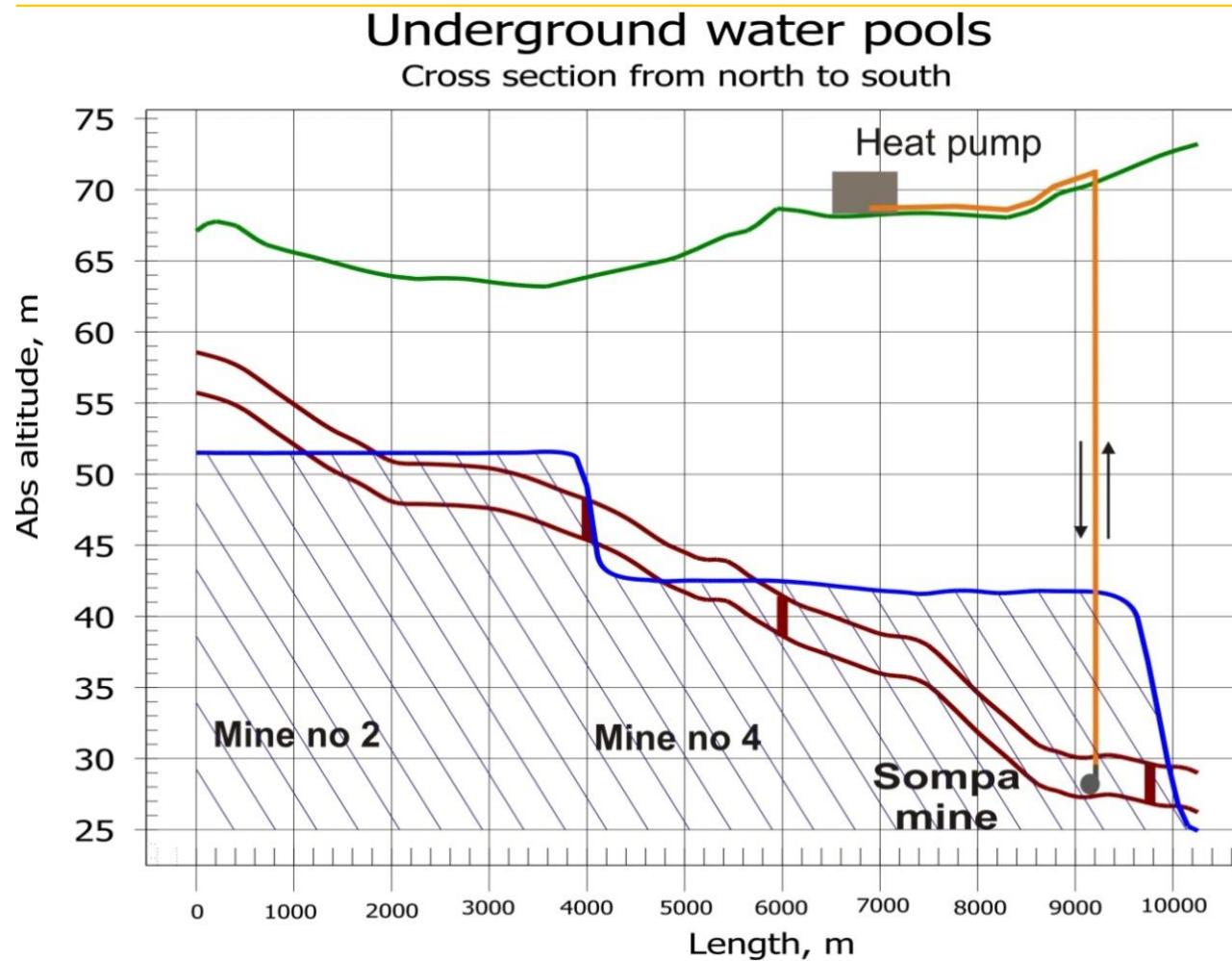
- Main tools for analysis
  - mapping
  - amount of water in abandoned oil shale mines is computational modeling with spreadsheet models
  - designing the water flow with ModFlow

| Options  | Kukruse | Mine no 2 | Käva | Käva 2 | Mine no 4 | Tammiku | Sompa | Kohtla | Ahtme | Viru  | Estonia |
|--|---------|-----------|------|--------|-----------|---------|-------|--------|-------|-------|---------|
| Mine opening   | 1921    | 1949      | 1924 | 1924   | 1953      | 1951    | 1948  | 1937   | 1948  | 1964  | 1972    |
| Mine closing   | 1967    | 1973      | 1972 | 1972   | 1975      | 1999    | 1999  | 2001   | 2001  |       |         |
| Working time, year                                     | 46      | 24        | 48   | 48     | 22        | 48      | 51    | 64     | 53    |       |         |
| Field area, km <sup>2</sup>                            | 13.20   | 12.30     | 3.47 | 14.05  | 12.70     | 40.00   | 33.60 | 18.30  | 43.30 | 41.70 | 141.10  |
| Mined field area, km <sup>2</sup>                      | 15.13   | 8.57      | 1.84 | 11.72  | 10.43     | 19.26   | 18.14 | 12.14  | 26.36 | 25.49 | 62.77   |
| Not mined area, km <sup>2</sup>                        | -1.93   | 3.73      | 1.63 | 2.33   | 2.27      | 20.74   | 15.46 | 6.16   | 16.94 | 16.21 | 78.33   |
| Thickness of overburden, m                             | 11      | 13        | 21   | 10     | 12        | 23      | 23    | 15     | 37    | 42    | 57      |
| Thickness of oil shale seam, m                         | 2.83    | 2.81      | 2.83 | 2.82   | 2.8       | 2.8     | 2.77  | 2.76   | 2.79  | 2.75  | 2.71    |
| Geological space in oil shale seam, mln m <sup>3</sup> | 42.82   | 24.08     | 5.22 | 33.05  | 29.20     | 53.92   | 50.24 | 33.52  | 73.53 | 70.09 | 170.11  |
| <b>Mined oil shale seam thickness, m</b>               |         |           |      |        |           |         |       |        |       |       |         |
| Hand-mined face  | 2.2     | 2.2       | 2.2  | 2.2    | 2.2       | 2.2     | 2.2   | 2.2    | 2.2   | 2.2   | 2.2     |
| Hand- mined rooms                                      | 2.2     | 2.2       | 2.2  | 2.2    | 2.2       | 2.2     | 2.2   | 2.2    | 2.2   | 2.2   | 2.2     |
| Room and pillar  | 2.83    | 2.81      | 2.83 | 2.82   | 2.8       | 2.8     | 2.77  | 2.76   | 2.79  | 2.75  | 2.71    |
| Drifts   | 2.83    | 2.81      | 2.83 | 2.82   | 2.8       | 2.8     | 2.77  | 2.76   | 2.79  | 2.75  | 2.71    |
| Longwall face  | 1.5     | 1.5       | 1.5  | 1.5    | 1.5       | 1.5     | 1.5   | 1.5    | 1.5   | 1.5   | 1.5     |
| <b>Mined field area, km<sup>2</sup></b>                |         |           |      |        |           |         |       |        |       |       |         |
| Hand-mined face  | 11.28   | 6.87      |      | 9.16   | 7.71      | 4.36    | 12.70 | 3.80   | 6.33  | 0     | 0       |
| Hand- mined rooms                                      | 3.50    | 0.00      | 1.84 | 1.73   | 0         | 0       | 0.06  | 1.36   | 0.05  | 0     | 0       |
| Room and pillar  | 0.29    | 1.70      |      | 0.79   | 1.08      | 11.81   | 1.86  | 0.55   | 19.22 | 25.38 | 61.49   |
| Drifts   | 0.06    | 0.00      | 0.00 | 0.04   | 0.69      | 0.36    | 0.00  | 0.02   | 0.30  | 0.11  | 1.26    |
| Longwall face  | 0       | 0         |      | 0      | 0.95      | 2.74    | 3.52  | 6.41   | 0.46  | 0     | 0.02    |
| <b>Total mined area</b>                                | 15.13   | 8.57      | 1.84 | 11.72  | 10.43     | 19.26   | 18.14 | 12.14  | 26.36 | 25.49 | 62.77   |

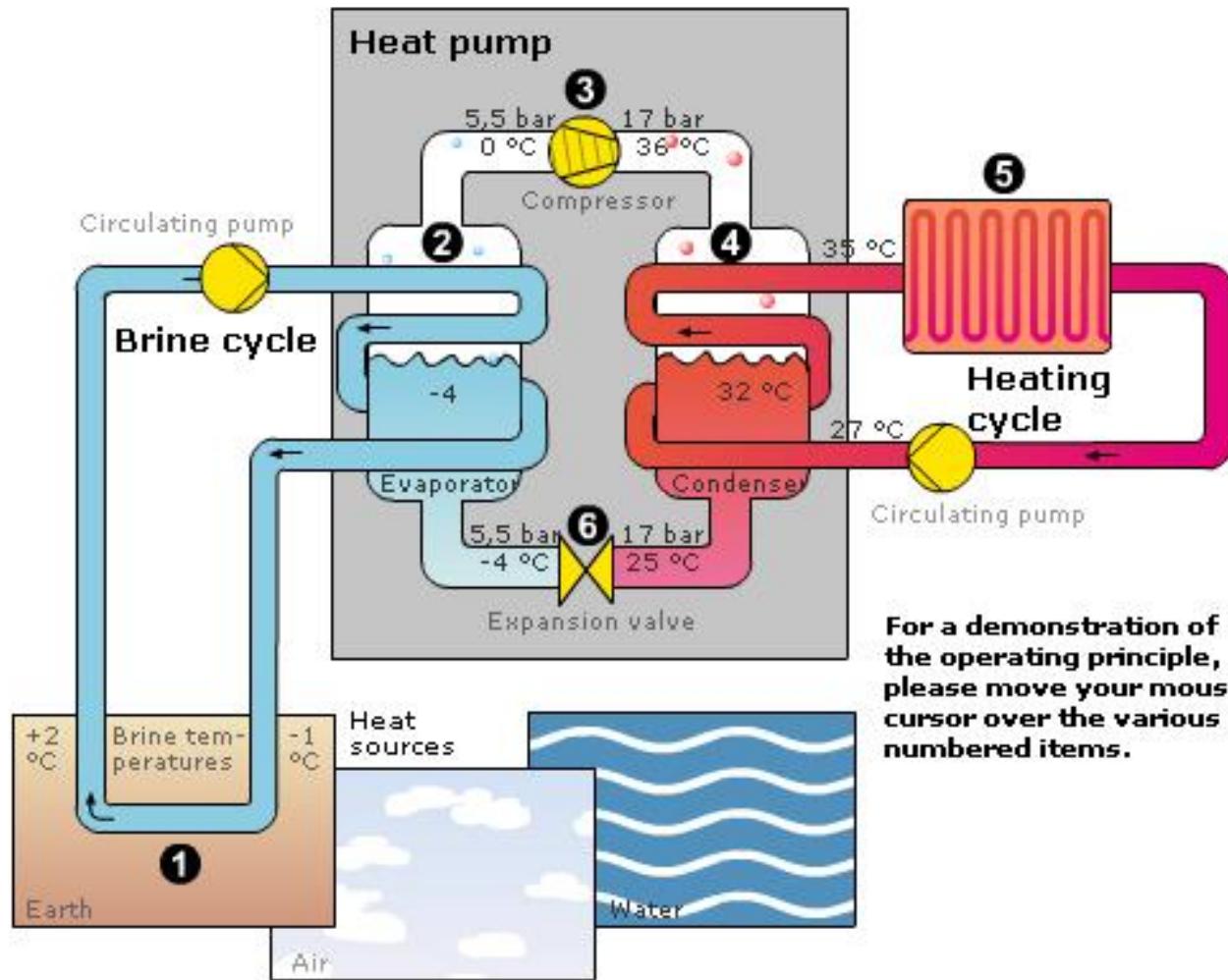
# Potential of water usage in study area



# Underground water pools

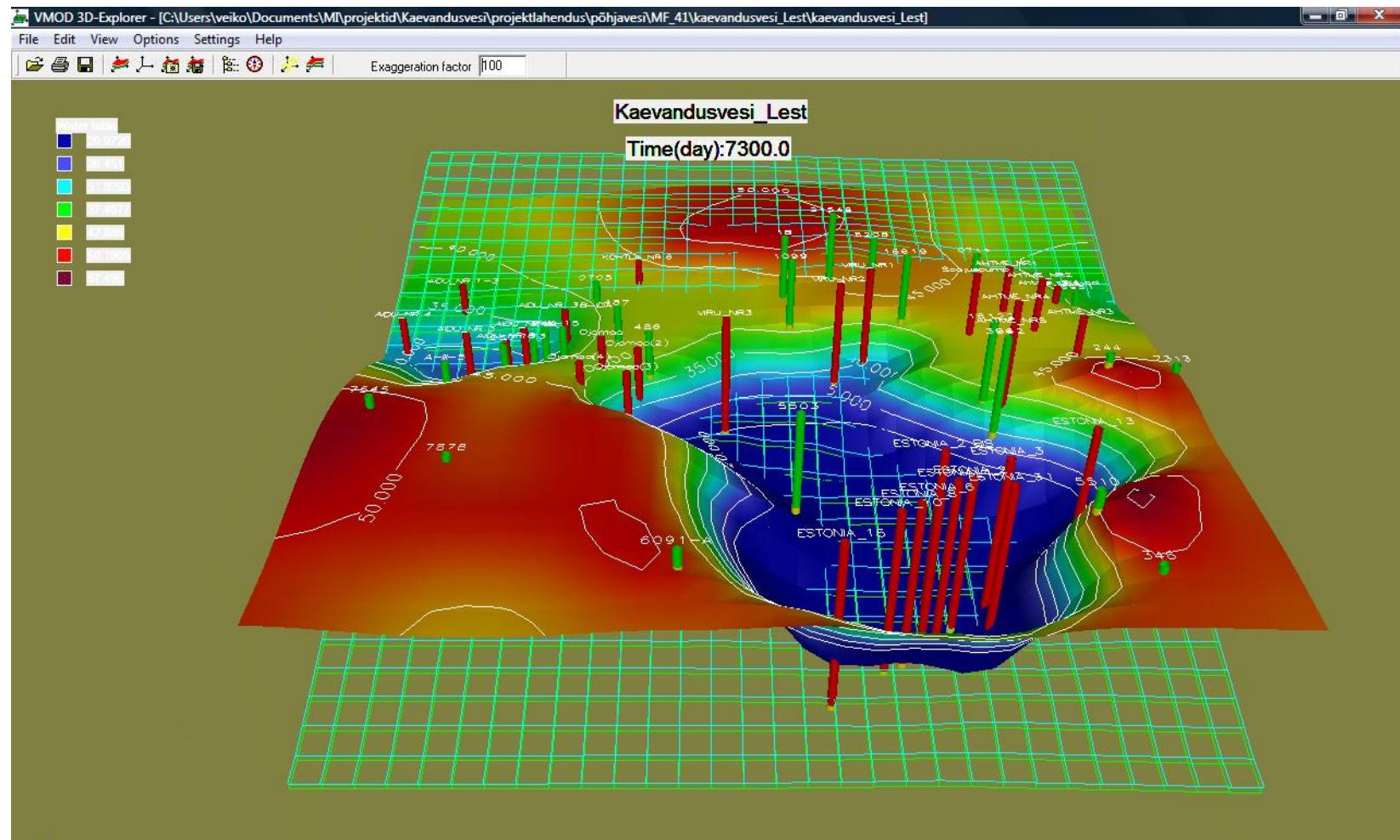


# Heat pump

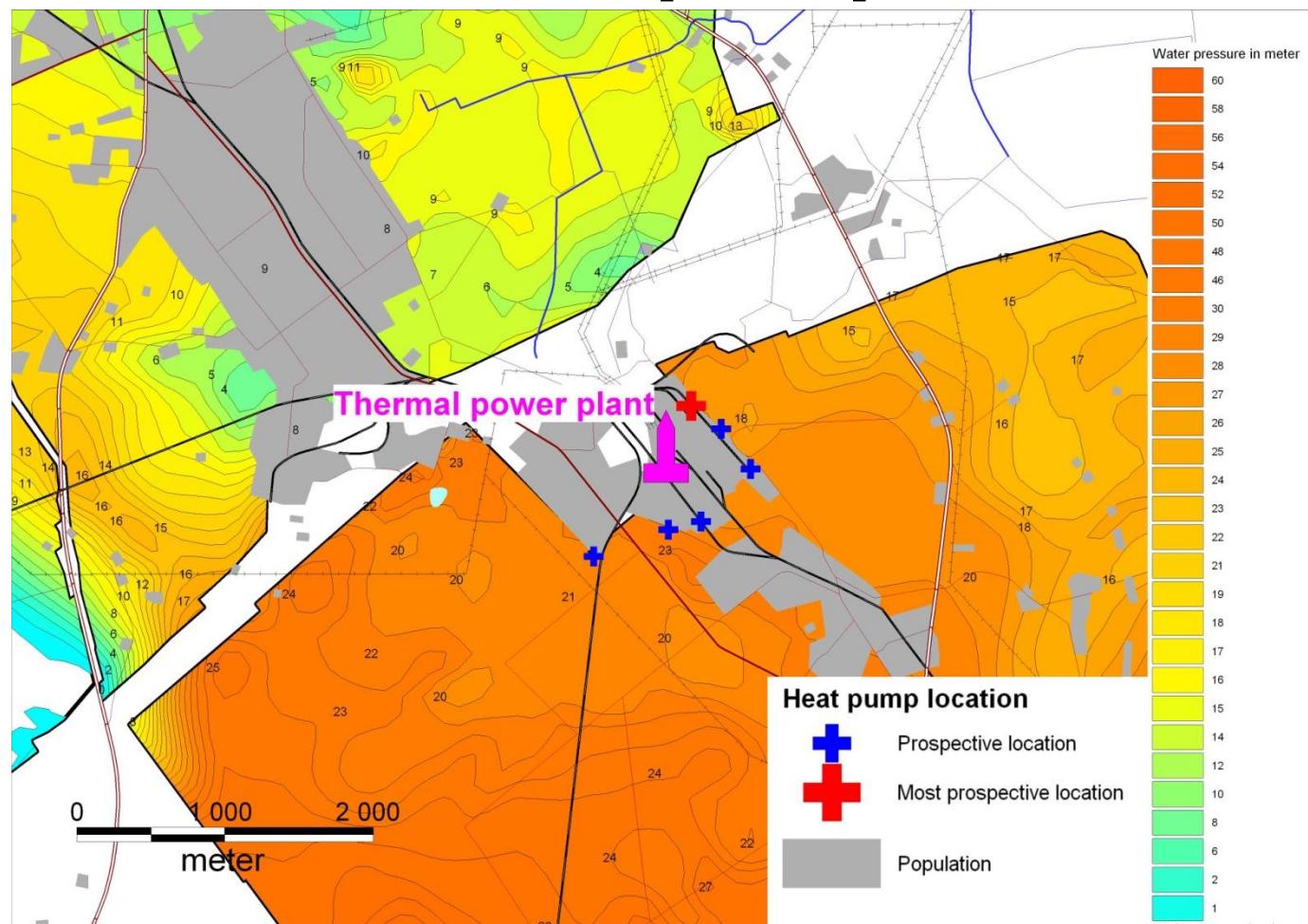


For a demonstration of the operating principle, please move your mouse cursor over the various numbered items.

# Water level



# Prospective locations of heat pump





# Technical solution

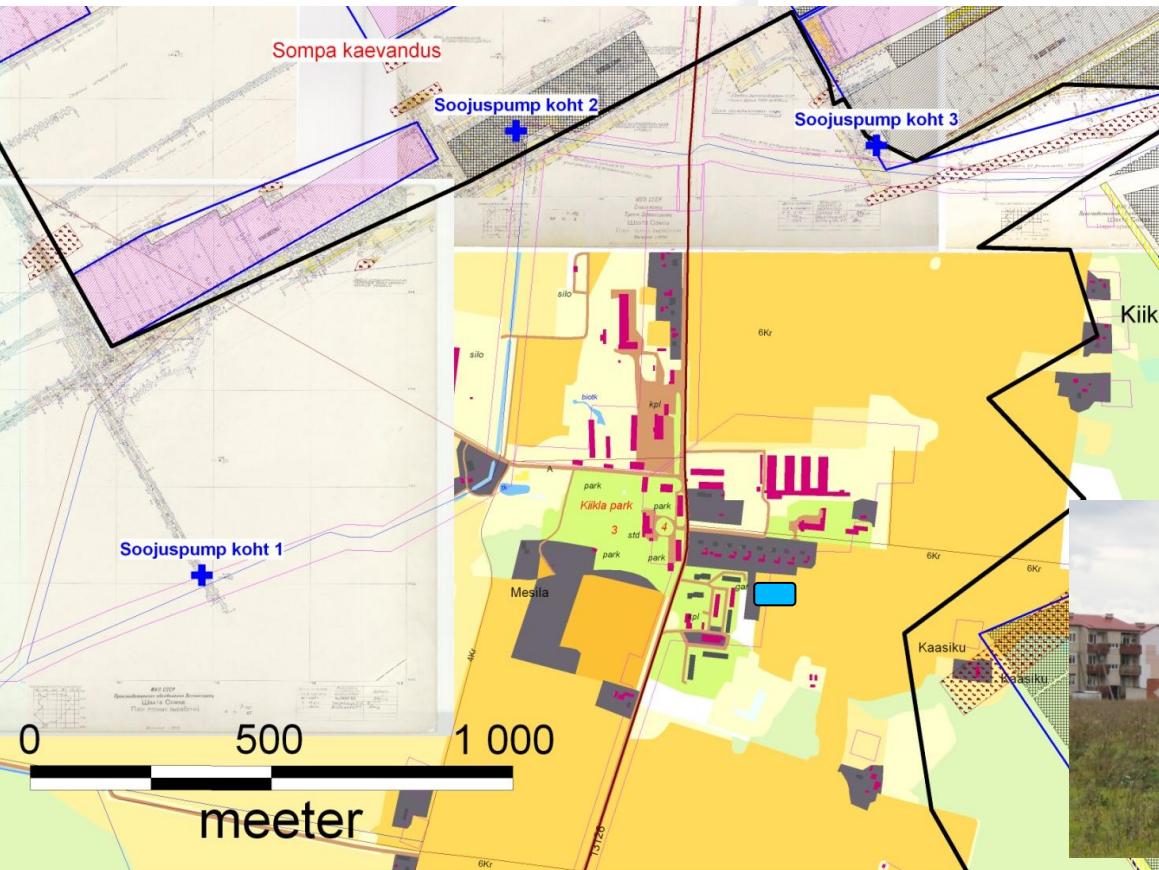
- 1) pumping the water through drillhole onto the ground surface
- 2) water goes to heat exchanger unit
- 3) minewater temperature will be lowered in heat pump heat exchanger about 1...4 degrees,
- 4) after that minewater is directed back to the mine.

# Pilot project

- First heat pump, based on minewater starts working in Kiikla settlement in 2011.
- If the pilot project is successful, there could be invested to others heat pump plants too.



# Pilot project





# Kiikla 500kW heat pump

Pilot project in Kiikla 500kW heat production unit

| Date   | Heat production, MWh | Electricity for heat pump, kWh | Electricity for pumps, kWh | Summary of electricity, kWh | Pumped amount of water, m³ | Water from mine, °C | Water to mine, °C | ΔT  | COP  |
|--------|----------------------|--------------------------------|----------------------------|-----------------------------|----------------------------|---------------------|-------------------|-----|------|
| 20.04. | 3.559                | 1415                           | 341                        | 1756                        | 1488                       | 6.4                 | 5.7               | 0.7 | 2.03 |
| 21.04. | 2.104                | 655                            | 268                        | 923                         | 1534                       | 6.1                 | 4.9               | 1.2 | 2.28 |
| 25.04. | 8.381                | 2749                           | 1245                       | 3994                        | 6852                       | 6.4                 | 5.1               | 1.3 | 2.10 |
| 29.04. | 3.321                | 1131                           | 632                        | 1763                        | 3151                       | 5.9                 | 4.6               | 1.3 | 1.88 |
| 02.05. | 6.97                 | 2421                           | 893                        | 3314                        | 4671                       | 6.2                 | 5.2               | 1   | 2.10 |
| 04.05. | 4.954                | 1743                           | 558                        | 2301                        | 2856                       | 6.1                 | 5.2               | 0.9 | 2.15 |
| 06.05. | 4.82                 | 1649                           | 599                        | 2248                        | 2978                       | 6.6                 | 5.2               | 1.4 | 2.14 |
| 18.10. | 45.684               | 15600                          | 3468                       | 19068                       | 24673                      | 0                   | 0                 | 0   | 2.40 |
| 27.10. | 29.015               | 9671                           | 1800                       | 11471                       | 10498                      | 0                   | 0                 | 0   | 2.53 |
| 31.10. | 11.828               | 4299                           | 842                        | 5141                        | 4753                       | 0                   | 0                 | 0   | 2.30 |
| 08.11. | 20.068               | 6081                           | 1538                       | 7619                        | 8688                       | 0                   | 0                 | 0   | 2.63 |

# Conclusion

- Closed oil shale mines have been filled with groundwater, it would be useful to get one part heat production from water through heat pumps.
- Water has a certain temperature all year round ( $7\ldots 9^{\circ}\text{C}$ ).



# Mining and Mineral Processing Waste Management Innovation Network

- ① AGH University of Science and Technology
- ② Upper Silesian Agency for Enterprise Restructuring
- ③ Foundation for Lower Silesian Mineral Resources Cluster
- ④ University of Örebro
- ⑤ Örebro Regional Development Council
- ⑥ Tallinn University of Technology
- ⑧ Kainuun Etu Ltd.
- ⑨ University of Oulu
- ⑩ Educational Institution of Employers Association Saxony - Anhalt
- ⑪ European Institute for Innovation
- ⑫ University of Stavanger





# Thank You!

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Estonia