Technological and social aspects of EGS development

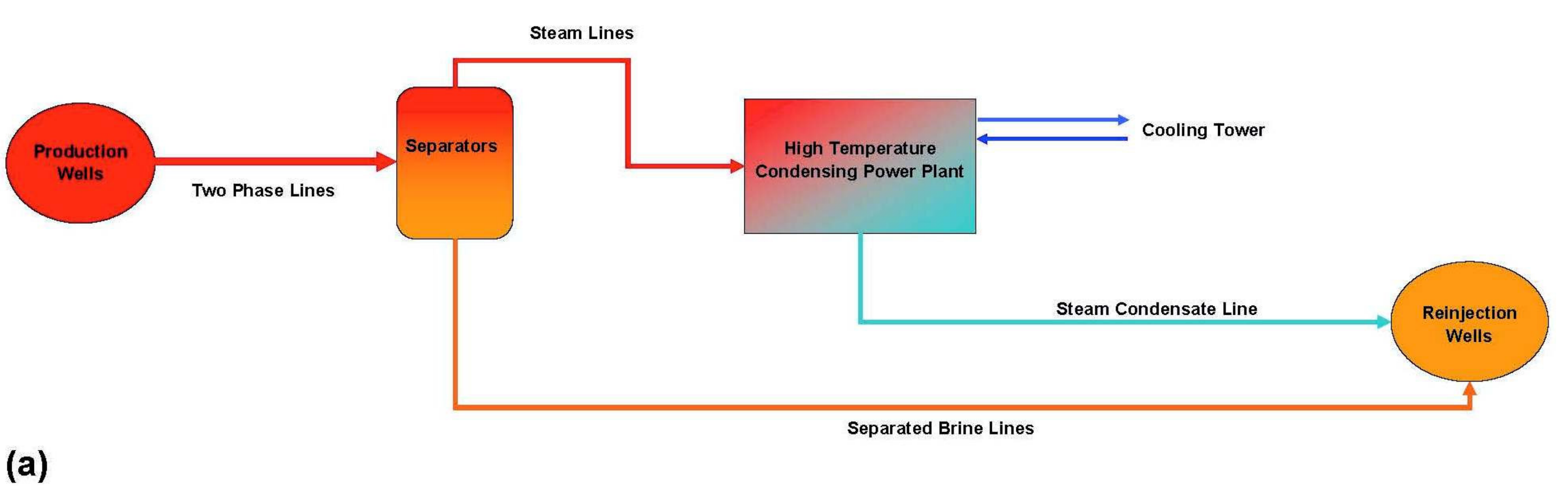
Dr. C. Karytsas and D. Mendrinos

Centre for Renewable Energy Sources

Geothermal Power Generation and/or Heat Supply

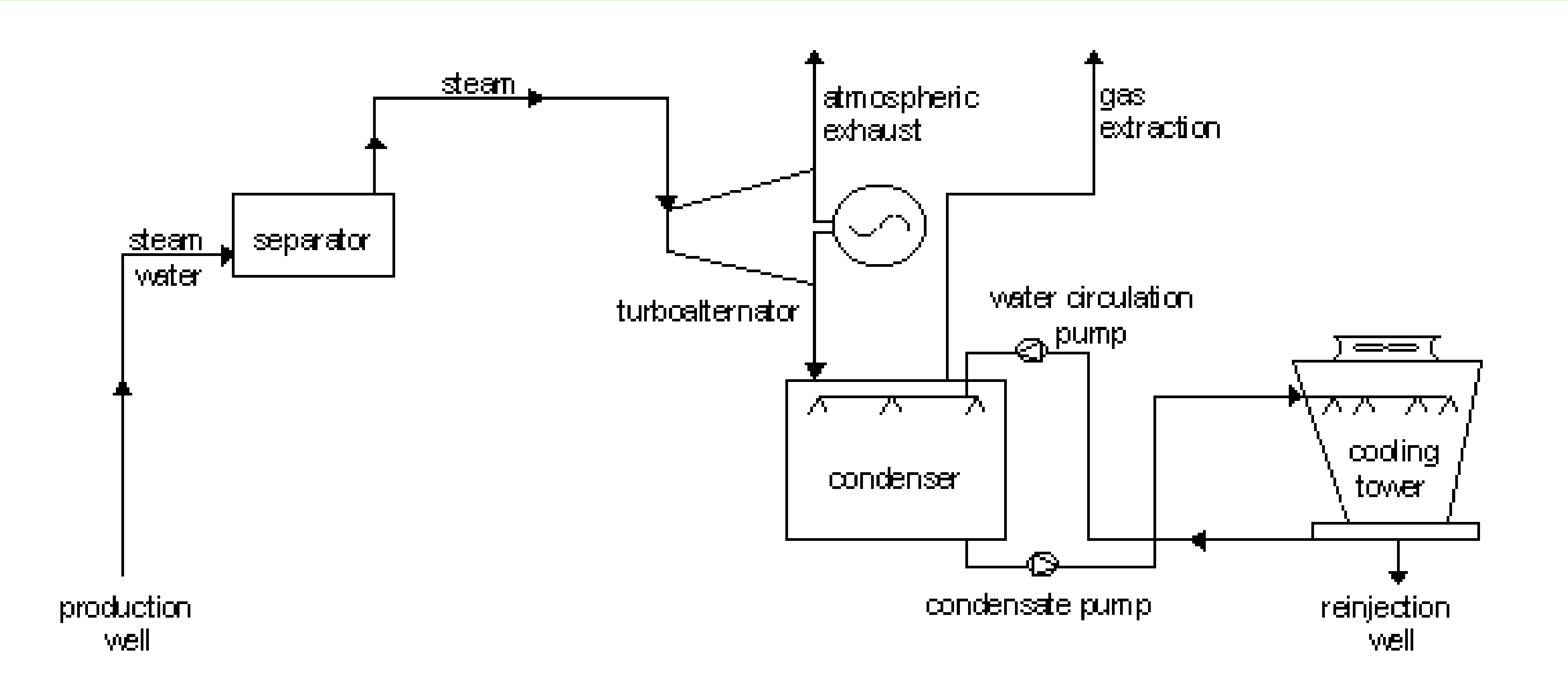
- As the market for power supply is usually available and national regulations usually oblige power utilities to purchase all produced electricity from a geothermal plant at guaranteed fixed tariffs during the entire economic life of plant, power generation is the main option considered for geothermal development.
- Considering that there is 10 times more heat available than electricity for a given subsurface geothermal infrastructure (production and reinjection wells drilling, completion and testing) which accounts for the largest part (60-80%) of the capital costs involved, several geothermal heat supply plants through a district heating system are in operation. Considering however the *low load factor* for heat demand, the *market risks* involved in attracting and keeping customers, and the intense *competition* from low priced diesel oil and natural gas, geothermal heat supply economics are also marginal.
- In order *to improve geothermal plant economics*, there is the need to utilize the heat of the produced fluid together with electricity generation, and hence operate a geothermal heat and power cogeneration plant. At present geothermal cogeneration plants use heat extracted either upstream, or downstream, or in parallel to the power plant, and generate electricity at times where there is limited or no demand for the heat load. In essence heat is supplied when needed, usually during 30% of the time and power during the remaining 70%.

Geothermal Power Plant: Condensing



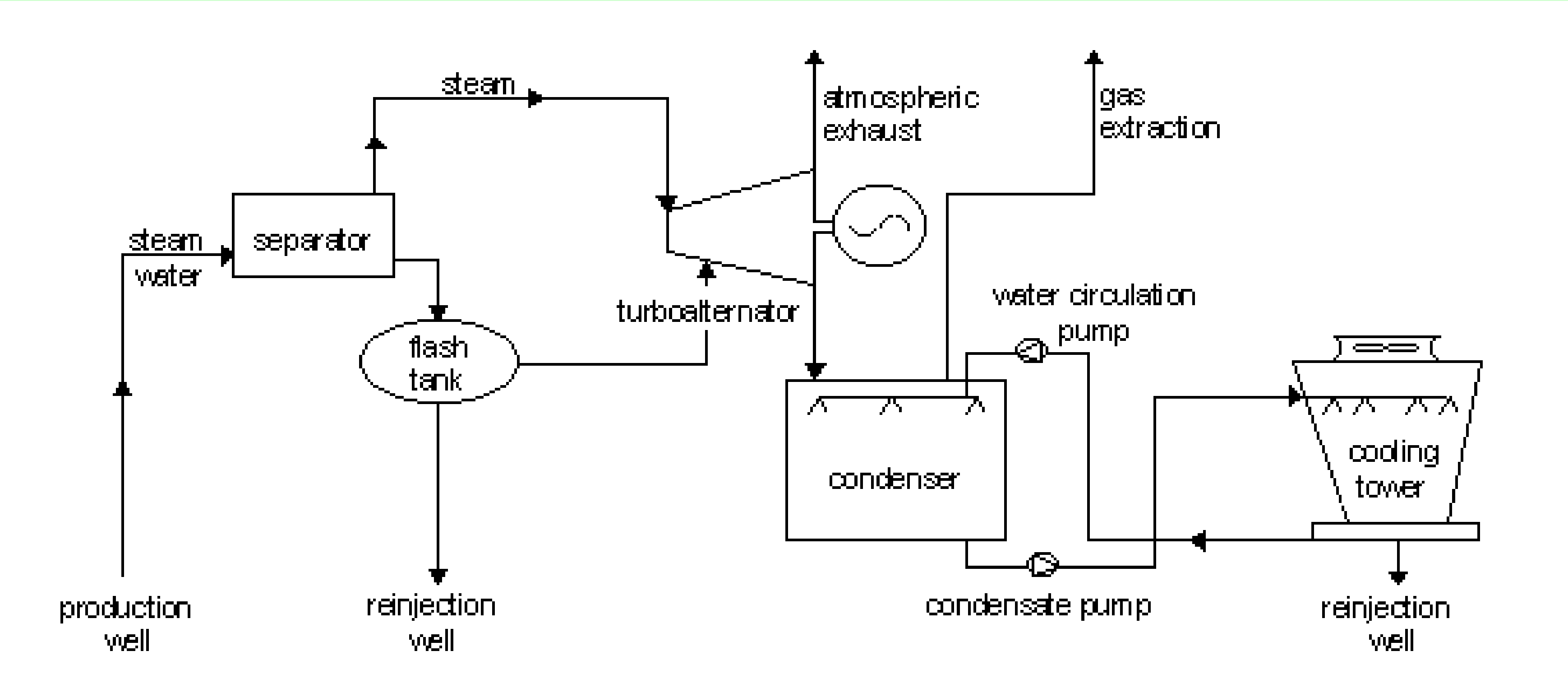
- **Steam condensing plants are traditionally used when the geothermal temperature exceeds 150°C.**
- **94% of the total generated power globally is derived by steam flash plants, the majority of which use condensing turbines, which in practice yield twice as much power output than the atmospheric exhaust ones. In a condensing plant the steam is condensed at the turbine outlet, at exhaust pressure of 0.10-0.12 bar, which results in improved cycle efficiency. Specific steam consumption of 7-8 kg/kWhe is typical for non condensable gases content of 1%.**

Geothermal Power Plant: Single Flash



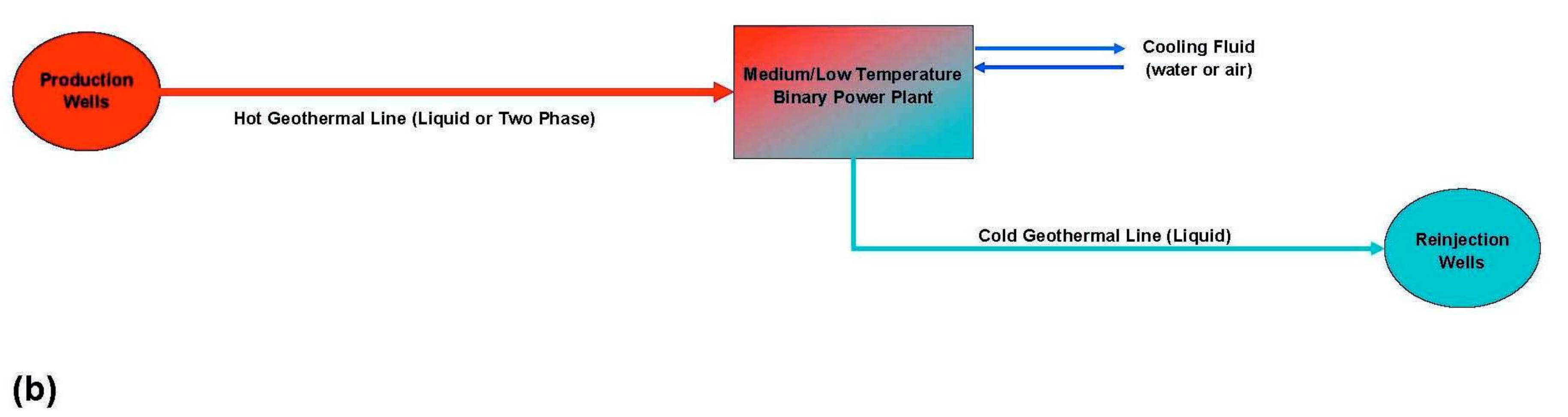
- In single flash plants, typical separation pressures are 5-7 bars optimizing the inlet pressure to the turbine.
- higher separation pressures may be necessary in order to control silica or calcite scaling in the separator and brine lines.

Geothermal Power Plant: Double Flash



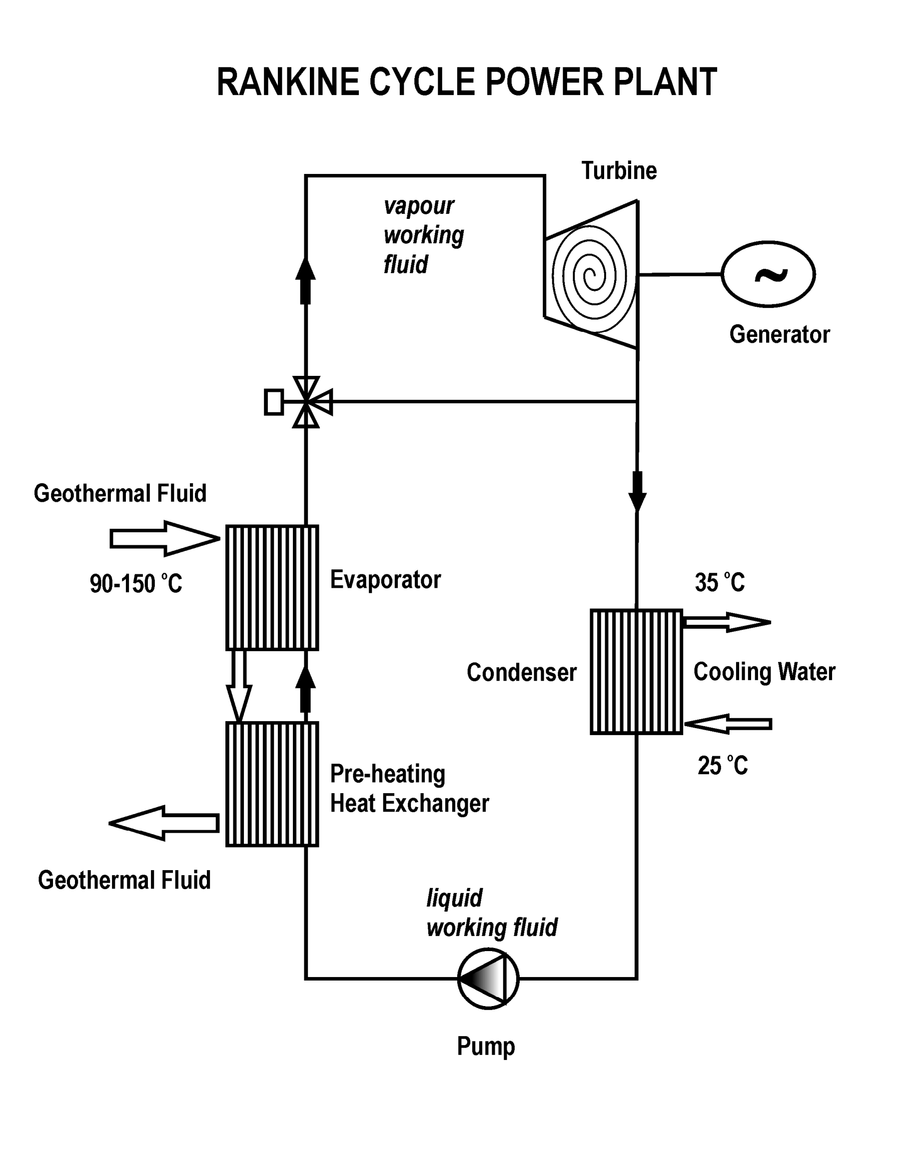
As the separated water is of 150-170°C temperature and has high energy content, it can be flashed further at a lower pressure of 2-2.5 bars and either supply the second stage of the turbine or feed a second turbine operating at lower pressure.

Geothermal Power Plant: Binary



- Binary plants are used for geothermal supply temperatures of 90-180°C.
- ORC or Kalina cycles.
- 100% computer controlled with automatic start-up. They require no supervision during operation, can be monitored and controlled remotely through a telephone line, or operated by part time semi-skilled personnel.
- They operate in a variety of load conditions, such as base load, peek load, fluctuating load, low load down to 0-25% of rate power.
- Conversion efficiency depends on both heat supply temperature and load, usually varying from 6.5%-15%

Geothermal Power Plant: Organic Rankine Cycle

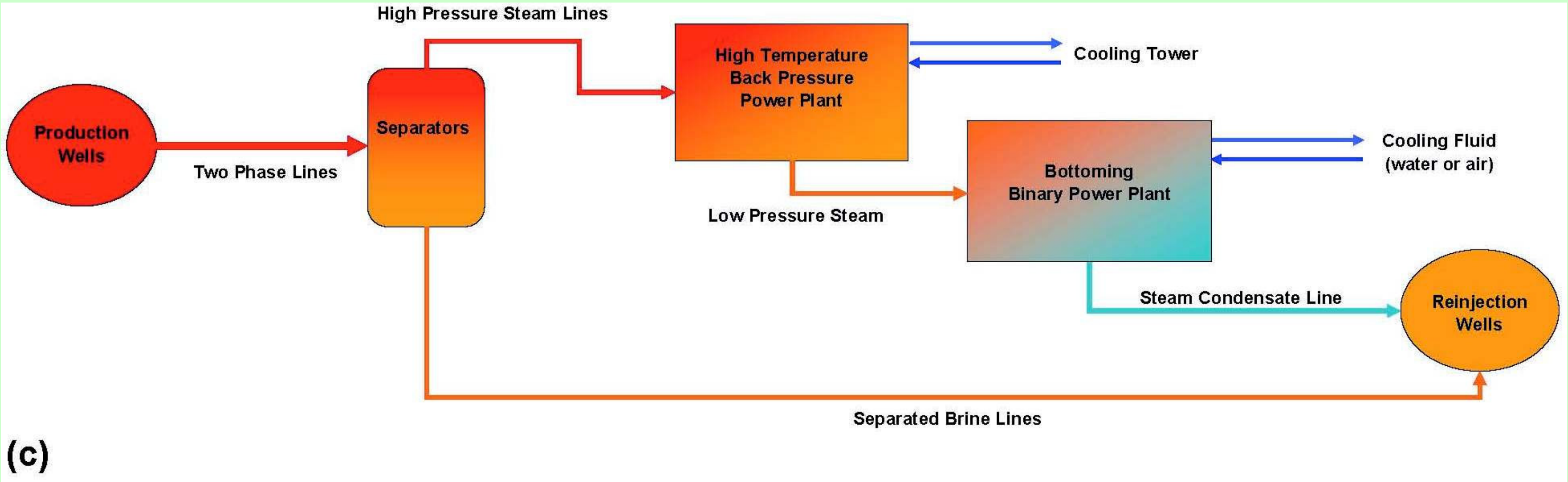


In an ORC machine, the geothermal fluid transfers thermal energy to a closed loop of circulating fluid, or working fluid, through a heat exchanger.

Typical working fluids used in ORC machines are either hydrocarbons (isobutane or isopentane) or fluoro-hydrocarbons, which operate at relatively low pressures or R134a.

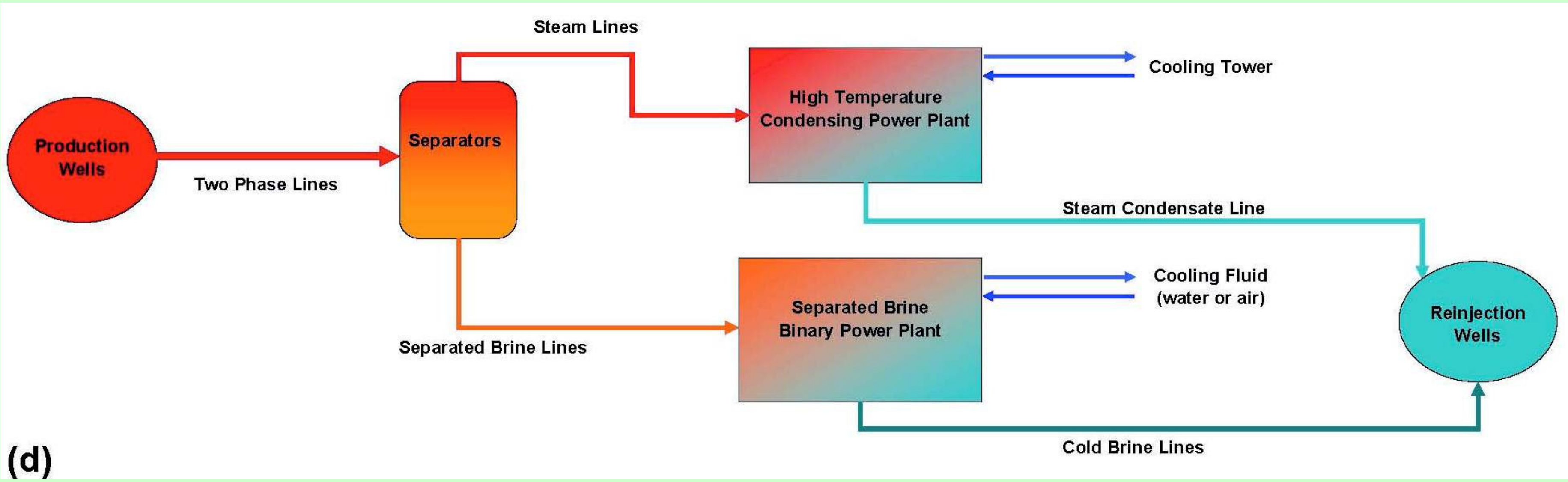
The circulating fluid evaporates within the geothermal heat exchanger, and from there its vapour is conveyed into a condensing turbine for power generation. The condenser, can either be water cooled (cooled by surface water or by water from a cooling tower), or air cooled. Then, the liquid working fluid is pumped to the geothermal heat exchanger and the cycle is repeated.

Geothermal Power Plant: Hybrid (Back-Pressure + Binary)



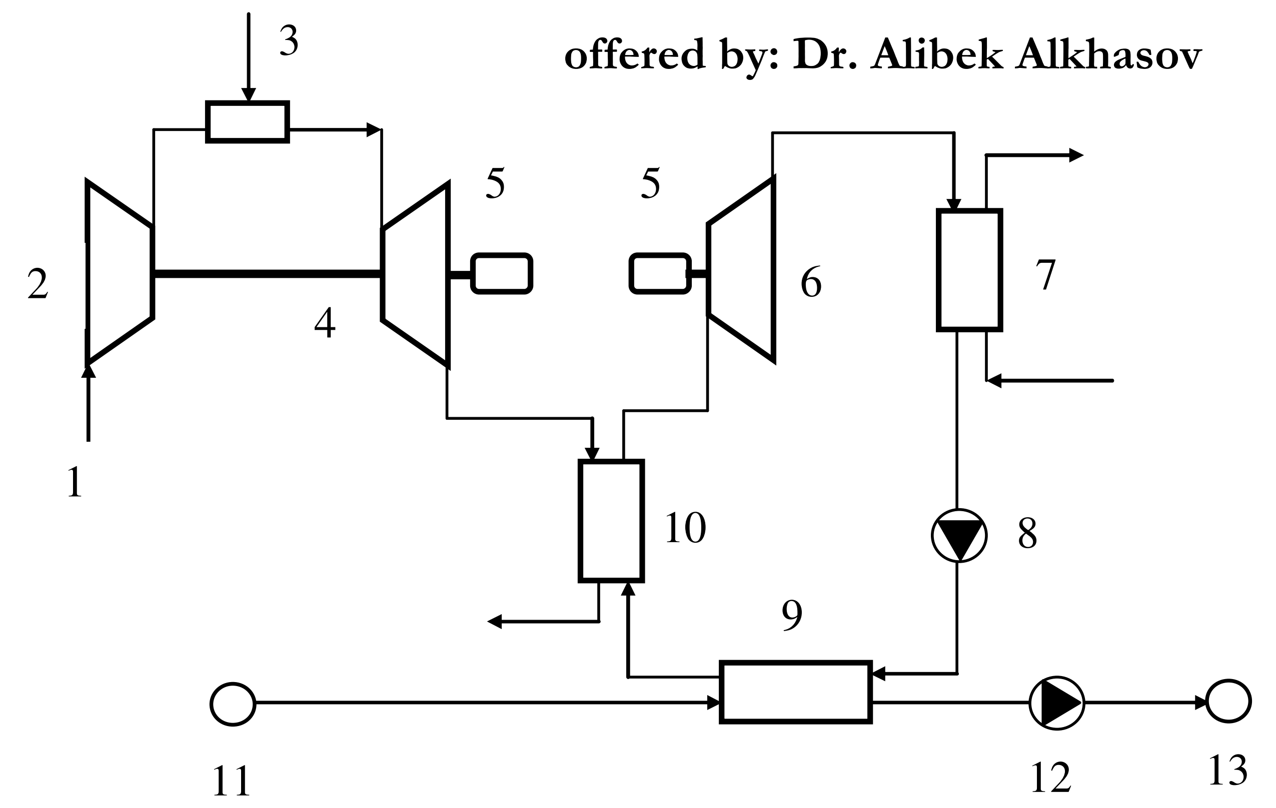
Site specific optimization in terms of energy use can lead to Hybrid plants combining back-pressured turbines as topping plants for the condensing turbines, and bottoming binary plants for secondary flash steam.

Geothermal Power Plant: Hybrid (Condensing + Binary)



Site specific optimization in terms of energy use can lead to Hybrid plants combining a steam condensing plant with binary units at the separated brine line.

Combined geothermal and gas turbine plant



1 - inflow of air
2 – compressor
3 – combustor
4 – gas turbine
5 – generator
6 – steam turbine
7 – condenser
8 – circulating pump
9 – heat exchanger
10 – evaporator
11 – production well
12 - circulating pump of geothermal fluid
13 – injection well

In such a plant, the working fluid of a Rankine cycle is pre-heated and partially/ totally evaporated by the geothermal water, and afterwards it is further evaporated and superheated by the waste gases of a gas turbine.

Heating applications

Geothermal heating applications include:

- **space and district heating**
- **heating of soil and greenhouses**
- **sea farming and heating of low temperature**
- **industrial processes such as drying and washing**
- **seawater desalination**

energy output of a geothermal low temperature heating plant can be improved further by water source heat pumps.

Geothermal fluid supply and disposal

- The fluid supply and disposal system includes production wells, fluid pipelines and reinjection wells.
- Well locations, paths and specifications (depth, hole-diameters, casing string, downhole pumps if any) are based on the results of the exploration works taking also into consideration new information acquired from subsequent well drilling and testing.
- A thorough well testing program is necessary to identify well production characteristics and reservoir properties. It includes production tests, injection tests, interference tests and tracers.
- The number of production wells depends upon the necessary geothermal fluid mass flow rate output, and on the need to tap enough proven stored heat resources, for a given plant size.
- A reservoir engineering study is necessary in order to predict well output behaviour during long term exploitation (pressure, temperature and chemistry transients), which is updated as new data comes in.
- Depending on the plant design, main equipment used may include downhole pumps, well-head assembly with valves and controls, sand/particles removal equipment, silencers, separators, steam moisture separators, two phase pipelines, steam lines, hot water (brine) lines, main heat exchanger, brine booster pumps, reinjection pumps as well as scale/corrosion inhibitors injection equipment.

Protecting local environment

Standard practices for protecting local environment are:

- **reinjecting 100% of produced fluid**
- **use of noise barriers**
- **plant design in order to eliminate steam losses: steam is never allowed to escape to the atmosphere with the exception of safety valves**
- **installing hydrogen sulphide and mercury abatement equipment**

Field management practices

The main objective of field management is to sustain production at desired levels and include:

- periodic maintenance work in order to eliminate scale and recondition the boreholes (mechanical cleaning with a scraping tricone tool hanging from a rod assembly, hydraulic jetting with a coil-tubing unit of small diameter, and combined hydraulic-mechanical processes)
- drilling additional production wells in new areas to offset the generation loss from dying wells due to cold surface water inflow or reinjection returns,
- casing-off acid zones or establishing downhole corrosion mitigation to eliminate problems associated with inflow of cold acid fluids,
- moving injection wells or limiting injection rate in order to minimize injection breakthrough,
- work-over drilling and acidizing to dissolve silica scales encountered in the injection wells,
- installation of calcite inhibition system whereby inhibitors are injected to slow down calcite deposition in production wells

Field management practices (continued)

- convert injection from cold to hot, in order to minimize scaling in the injection lines, wellbore and reservoir,
- perforation of cased-off permeable zones for additional production,
- upgrade production facilities to address changing reservoir conditions by including "brine-scrubbing" of steam, and by improving brine separation efficiency,
- installation of steam washing and solids removal trapping facilities along the steamline to catch the fine solids carryover from drying steam reservoirs.
- optimizing the use of thermal energy by modifying or updating the equipment parts in order to adapt them to new exploitation conditions (ejectors, large pressure loss in the pipes, etc.)

Monitoring and control

The objectives of a monitoring program during exploitation is to study the evolution of reservoir and fluid parameters over time, and further decide on the exploitation strategy of the geothermal field, e.g. increase or decrease production rates, change the location of reinjection wells, drilling additional wells, treating the fluid with chemical agents in order to prevent scaling or corrosion, etc.

Geophysical parameters monitored should include micro-earthquakes, resistivity and gravity data with the aim to predict possible future environmental impact (micro-earthquakes evolution and subsidence if any).

Geochemical parameters include chemistry transients of the produced geo-fluids, aiming in predicting future evolution of its scaling or corrosion tendency.

In addition pressure, flow rate, temperature/enthalpy transients at the production and reinjection wells should be monitored. The data collected should feed the integrated reservoir engineering and computer simulation model of the field.

Other parameters include the evolution of hot springs and fumaroles, steaming ground, hydrothermal evidence, as well as the chemistry of nearby water streams or rivers, the air quality around the wells and plants, and the noise level.

Economic considerations - costs

Type of Resources	Hydrothermal Fields	Enhanced Geothermal Systems	Supercritical Reservoirs & Magma Chambers
Location	Volcanic areas, Deep Sedimentary Basins	Everywhere	Volcanic areas only
Commercially Available	Yes	No	No
Power Plant Range	0.3 – 133 MWe	1 – 6 MWe	40 – 100 MWe
Heat carrier	Natural Steam, Two Phase or Liquid Water	Injected water	Supercritical water
Heat-to-Power Efficiency	7% - 20%	7% - 12%	30%
Environmental aspects	chemistry, H_2S & salts in the steam	Micro-seismic activity	unknown
Other Features	Cogeneration, >90% capacity factor	Cogeneration, >90% capacity factor	Cogeneration, >90% capacity factor
Costs, power generation	1000 – 3000 €/kW(e) 0,04-0,07 €/kWh(e)	10000 - 26000 €/kW(e) 0,17-0,35 €/kWh(e)	unknown
Costs, heat supply	100 – 300 €/kW(th) 0,004-0,007 €/kWh(th)	1000 - 2600 €/kW(th) 0,017-0,035 €/kWh(th)	unknown
Commercial Status	well deployed	Experimental Plants	Basic Research

Research and Development Needs

As the technical feasibility for EGS exploitation has been proven by the Soultz European Hot Dry Rock project, further research should focus towards reducing the output unit energy costs from EGS plants, as this is the main barrier towards their large scale exploitation.

A European research and demonstration project with high replication potential proving the economical feasibility of EGS plants is necessary in order to stimulate large scale development and effectively contribute to the EU renewable energy objectives of 2020.

Increasing policy makers' awareness and public acceptance

• Geothermal energy is a versatile renewable energy source that is among the cleanest of the commercially viable technologies available today.

• However there has not been the predictable development in this field as it is for most other "alternative" energy sources.

• An important reason is that many geothermal projects face strong opposition from politicians, neighbouring communities or environmental pressure groups. This is why there is a global tendency for geothermal companies to develop their policy and their social responsibility.

• The goal of the geothermal community is to make policy makers' aware of the need of a strategy by examining the policy that should be followed in order to eliminate any social opposition, analyzing the reasons for the generally weak social acceptance, and identifying possible solutions for changing the situation.

Reasons for weak social acceptance of geothermal projects

The main aspects that affect the success of the geothermal projects and should be taken into account during the process of geothermal energy development in a specific environment are :

1. **The initial phase of project development**

2. **The environmental impact**

3. **The public acceptance**

4. **The political acceptance**

The initial phase of project development

KAΠE
CRES

The initial phases of development of a geothermal project often includes test drillings with dirty, noisy equipment and without contact with, or involvement of the local people.

↓

After the initial completion of a geothermal system, local people and politicians have, in front of their eyes, a system of irregularly located boreholes, pipelines passing through properties in a "strange" way. Therefore, in the initial phase of development, benefits are not obvious, and appear to be outweighed by negative changes to the surroundings.

↓

It was found that many elements of the complex nature of geothermal energy can be the reason for weak public support in some areas. A lot of work is necessary to change the resistance by spreading honest information in an understandable way, accommodated to the culture and cultural level in question.

The environmental impact

When news spreads about the possibility of having a geothermal project initiated in a given area, many residents eulogize natural heat. Individual and collective attitudes towards geothermal development usually change with time as the project reaches the drilling stage, and work begins for plant construction.

Reaction often grows against landscape modifications and alteration of natural features of cultural or religious interest, caused by civil and industrial works and by changes in the use of public areas resulting from project activities.

The elements of the environmental impact can contribute positively if the focus will be on :

1. the quality of the organizational approach of project development,
2. the quality of project design,
3. the organization of work during construction and completion,
4. the quality of the operations.

Social Acceptance

• Social acceptability is one of the most important parts of the process of geothermal energy development in a specific environment and should be taken into account.

• In order to attain social acceptability, the project activities should not result in drastic changes from the regular conditions of the area, and the affected sectors should be able to see some advantages issuing from the project.

•Social acceptability is the condition upon which the technical and economic objectives of the project may be pursued in due time and with the consensus of the local communities (in the respect of the people's health, welfare, and culture).

•It is not possible to complete a successful project if initially not identifying the elements of the local environment, which can influence its social acceptance and not designing honest organizational, technical, economic, and other solutions in order to prevent the development of negative opinions.

Measures that have been successfully applied

1. **Enforcing legislation separating geothermal resources from the mining code**

   Geothermal regulation should be also taken into account. The present lack of regulation for geothermal energy exploitation over most of the EU is inhibiting the effective exploitation of this underutilized resource. The process is planned to outline and encourage investment in geothermal energy by private and public sector partnerships.

2. **Demonstration of very small scale geothermal pilot power plants (a few kWe)**

3. **Providing strong incentives to investors**

4. **Communicating positive impact of geothermal development through independent experts**

5. **Educating local society and company staff**

   Education programs can be really helpful in order to make geothermal energy more friendly and accepted by children and their communities in general. Educative materials can be prepared for students and professors with suitable style.

6. **Communication best practices by inviting local journalists to foreign geothermal power plants**

A Successful case

Geothermal Projects in El Salvador

BASELINE STUDIES

ENVIRONMENTAL IMPACT ASSESSMENT

QUALITY AIR, WATER, AND SOIL MONITORING PROGRAMME

References

C. Karytsas, D. Mendrinos, Mr. Z. Sarmiento, K. Povarov, A. Alkhasov, O. Mertoglu, L. Le Bel, D. Tournaye, P. Ungemach, O. Flovenz, J. Goldbrunner, P. Seibt, J. Van Wees, M. Monterrosa 2008: ENGINE Best Practice Handbook, chapter 3 "Exploitation: Best Practices and Innovation Needs".

C. Karytsas, D. Mendrinos, Mr. Z. Sarmiento, K. Povarov, A. Alkhasov, O. Mertoglu, L. Le Bel, D. Tournaye, P. Ungemach, O. Flovenz, J. Goldbrunner, P. Seibt, J. Van Wees 2008: ENGINE Best Practice Handbook, chapter 4 "Environmetnal and Socioeconomic Impact".

C. Karytsas 2007: "Increasing policy makers awareness and public acceptance", presented during the ENGINE workshop 7 on "risk analysis for development of geothermal energy", Leiden, Netehrlands, 7-9 November 2007.

Thank you for your attention