# The OpERA Magna Carta

## ITALY

| | solved | | unsolved |
|---|---|---|---|
| | Issue | Solution | |
| **Scaling** | *Deposit from single flushing fluids, deposit on reinjection wells, pipelines, separators* | *Monitoring systems* | *Improvement of actual technology for chemical or physical treatment and for monitoring systems (including cost reduction)* |
| | | *Chemical treatment (e.g., fluids washing)* | |
| | | *Temperature dejection management (i.e. mantain the temperature above the scaling limit. Linked to reinjection constraints)* | |
| **Corrosion** | *Corrosion of casing, pipes and turbine* | *Monitoring systems* | *Improvement of actual technology* |
| | | *Steam washing to break down the pH of the fluid* | |
| | | *Special coating/material* | *New materials* |
| | | *Avoid condensation by pressure/temperature management* | *Improvement of actual technology* |
| **Gas content** | *Natural gases and associated minerals.* | *Abatement systems* | *Better economics of abatement systems* |
| | *- Large CO2 content - Reduce production (parasitic losses for gas extraction)* | *CO2 extraction/sequestration (it is economical only when used for chemical industry)* | *CO2 sequestration and capture technology at economic price* |
| | *power plant outage gas emission* | *Minimization of outage time, harmonization of gathering system to avoid "island" power plant* | *Total reinjection technology* |
| **Re-injection** | *Scaling due to cooling of separeted fluid in liquid dominated reservoirs* | *Reinjection at high temperature* | *Improved utilization of thermal energy* |
| **Plant Performance** | *To increase plant performance and availability* | *Advanced diagnostic – plant automation with sensors, industrial automation technology* | |
| **Geothermal System Management** | *Depletion of reservoir* | *Data acquisition and monitoring, resource management* | *Integrated model of geothermal system (from well to plant)* |
| **Auxiliary management** | *Submersible pump failure* | *Replacement of pumps every 4 years* | *Long-living pumps* |

## FRANCE

| | solved | | unsolved |
|---|---|---|---|
| | Issue | Solution | |
| **Scaling & Corrosion** | *Internal scaling and corrosion* | *Remediation by jetting during workover* | |
| | | *Remediation by smooth acidizing* | |
| | | *Installation of downhole chemical treatment at the bottom of the production well with continous injection (some ppm)* | |
| | | *Re-lining old wells with iron or composite casing* | |
| | | *Composite casing in new wells* | |
| **Scaling & Corrosion** | *External scaling and corrosion* | *Composite casings in new wells (first test in 2015 for re-vamping of old wells completed sucessfully)* | |
| | | *New logging tools for measurement of casing thickness at the extrados (new promising tool tested in 2015)* | |
| **Gas content** | | | |
| **Re-injection** | *Reinjection in sandstones* | *Use of triplet scheme with one production and two injection wells* | |
| | *Reinjection in poorly cemented sands or sand interbedded with clays* | *Drilling of extra-large diameter in reservoir and setting pre-packed gravel screens (Johnson type)* | |
| **General technological issue** | *Lifetime of geothermal doublet* | *Enlarging the spacing between doublet wells to > 1500 m* | |
| **General technological issue** | *Increase of well productivity* | *Drilling large diameter wells, hoizontal drilling in order to increase flowrates* | |
| **General technological issue** | *Lifetime of down-hole pumping equipment* | | *ESPs with short duration in very hot geothermal water above 120C* |

## SLOVENIA

| | solved | | unsolved |
|---|---|---|---|
| | Issue | Solution | |
| **Scaling** | *Carbonate scaling* | *Inhibitors* | *Improvement of treatment or use in the closed system* |
| **Corrosion** | *Casing corrosion* | *Re-lining of old wells* | |
| **Gas content** | *CO2 – safety* | *Gas separator* | *Use in the closed system* |
| | *CH4 – safety* | *EX-Zones, Gas separator* | |
| **Re-injection** | *Re-injection in poorly cemented sands or sand interbedded with clays* | *Proper well design, microfiltration, backwashing* | *Further RD&D needed* |
| | *High temperature of re-injected water* | | *Lower injectibility due to lack of end user* |
| **High investment cost of drilling of reinjection boreholes** | | | |
| **Lack of financing for RD&D because of very weak investment sector and absent political support.** | | | |

## NETHERLANDS

| | solved | | unsolved |
|---|---|---|---|
| | Issue | Solution | |
| **Scaling** | *Pb* | *Inhibitor* | *Selection, content, monitoring and dosage of inhibitor, Costs, sustainability and optimization* |
| | | *Remove galvanic cells* | *Optimal material selection in pumps, pipework, screens Focus to one alloy, lowest diversity* |
| | | *Prevent corrosion, because of redox reactions* | *NORM/LSA: contamination…* |
| | | *No ungassing and high pressure over surface* | *Relation pressure / system / temperature / injection* |
| | *Ca CO3 + some others* | *Cleaning of pipes, degasser etc.* | *Dosage of CO2 for injector Inhibitor selection Effect injector* |
| **Corrosion** | *Hypothese decline coupling* | *Repairments No galvanic cells: one alloy Set up monitoring programm Well integrity management 1. Selection casing logging tools Use inhibitor* | *Evolution completion Execution monitoring plan and evolution 2. Detailed selection monitoring tools Determine critical factors & parameters flow velocity Upgrade new projects in alloy casing Install packers safety ESP Composite material GRE use Optimization inhibitor dosage* |
| | *Erosion/cavitation* | | |
| | *Surface installation* | *No galvanic cells Cleaning and testing protocol before start Proper monitoring Inhibitor* | *Proper specification description surface installation Leakage seals at pumps* |
| **Gas content** | *Surface installation* | *Optimization modulair Timing, planning, extensive testing programm* | *Development criteria can be set up after drilling and testing: time squeeze* |
| | *Pressure optimization* | *Only in respect to realized installation* | *Overall concept optimization complex due to multi-phenomena* |
| **Re-injection** | *High pressure 40-60 bar needed* | *Not yet executed Thermal fraccing* | *Stimulation by: soft acidization, radial drilling,* |
| | *High power costs and low COP* | | *Quantitative Risk Assessments for stimulation Social acceptance* |

## ICELAND

| | solved | | unsolved |
|---|---|---|---|
| | Issue | Solution | |
| **Scaling** | *Scaling in Low temp fields* | *Various ways, depending on the site and situation http://www.lagnaval.is* | *Silica precipitation in ultra high temp fields - IDDP wells* |
| **Corrosion** | *Corrosion in low temp fields* | *Various ways, depending on the site and situation http://www.lagnaval.is* | *Develop materials that can withstand superheated and supercritical conditions* |
| | *Acid scrubbing* | *Wet Scrubbing Low cost and robust, but reduces energy output of plant* | *Find more energy efficient ways to remove acid components from the geothermal steam* |
| **Gas content** | *Gas emissions from geothermal plans* | *Carbfix and Sulfix* | *Cost reduction on gas separation and reinjection* |
| | *CO2 content in low temp field* | *Harness it and sell it (Hæðarendi)* | *Value creation from the separated gases (an alternative to reinjection)* |
| **Re-injection** | *Triggered seismic events* | *Start injection slowly Keep flow steady Inform and educate the public* | *Clogging of injection wells due to scaling* |
| **High emphasis on developing material to withstand the conditions of a supercritical steam and power output of up to 10 time normal output.** | | | |

# The OpERA Magna Carta

## DENMARK

| | solved | | unsolved |
|---|---|---|---|
| | Issue | Solution | |
| **Scaling** | *Carbonate scaling* | *Soft acidizing* | *Lead precipitation* |
| | | | *Unidentified precipitations?* |
| **Corrosion** | *Base corrosion* | *Keep air out* | |
| **Gas content** | *Methane* | *Keep pressure above bubble point* | *Use in the closed system* |
| | *CO2* | | |
| **Re-injection** | *Calcite and corrosion products* | *Soft acidizing* | *Particles clog up screens with base pipe* |

**Integration with heat pumps gives a more efficient but also more complex system**

## HUNGARY

| | solved | | unsolved |
|---|---|---|---|
| | Issue | Solution | |
| **Scaling** | *Carbonate scaling* | *Inhibitors (acids)* | |
| | | | *Barite scale removal* |
| **Corrosion** | | | |
| **Gas content** | *CH4 – safety* | *Gas separator* | *Separated gas treatment or utilisation* |
| **Re-injection** | *Re-injection in poorly cemented sands or sand interbedded with clays* | *Proper well design, microfiltration, backwashing* | *Further RD&D needed* |
| | *Surface disposal of waste water* | *Thermal lakes* | *High temperature and high TDS of waste water* |

## AUSTRIA

| | solved | | unsolved |
|---|---|---|---|
| | Issue | Solution | |
| **Scaling** | *Carbonate pecipitation in pipes, heat-exchangers, stripper* | *Stripper, regular cleaning with acids, use of inhibitors* | |
| | *Fe-oxides/hydroxides at wellhead* | *Regular cleaning, precipitation* | |
| | *Sulfur/Sulfates at heat-exchangers* | *Regular cleaning* | |
| | *Fe-silfides at heat-exchangers, pipes, valve flaps* | *Regular cleaning, exchange of parts* | |
| **Corrosion** | | | *High NaCl content* |
| **Gas content** | | | *High concentration of CH4 and H2S* |
| **Re-injection** | | | *Clogging of well because of skin effects* |

**High content of H2S in potential thermal reservoirs near and inside Vienna -> future challenge**

## GERMANY

| | solved | | unsolved |
|---|---|---|---|
| | Issue | Solution | |
| **Scaling** | *URV: Ba- and Sr-Sulphate scalings in rising pipes and surface pipes and devices* | *Application of inhibitors* | |
| | | | *No inhibitors for radioactive Pb210* |
| | *URV: Enhanced radioactivity in sulphate scalings* | *Application of inhibitors* | *BMB: Carbonate- and sulphide scalings<br>- in and on the pumps<br>- in the rising pipe<br>- in filter systems<br>- in entrance heat exchanger<br>Possible solutions:<br>- Application of inhibitors<br>Problem: federal regulations<br>- Development of new filter systems<br>- Usage of coated rising pipes<br>-> Ongoing research projects and active discussions between the individual operating companies* |
| | *NGB: NaCl scalings in production well* | *Pressure- and temperature keeping during drilling and borehole development* | |
| | *NGB: Formation of Pb- and Cu bearing scalings in the rising pipe and borehole close area of the production well* | *Prevention of electrochemical corrosion by application of adequate materials (higher alloyed steels)* | *Removal of Cu above ground* |
| | | | *NGB, URV: Metalsulphide scalings* |
| **Corrosion** | *Corrosion induced by oxygen* | *Pressure keeping* | *Corrosion induced by H2S -> ongoing and planned research projects* |
| | | *Application of inert gas* | |
| | | *Adjusted design of surface devices* | |
| **Gas content** | *Formation of free gas phases during production (and injection)* | *URV: Controlled degassing and appli-cation of inhibitors* | *GB: potentially high amounts of free gas (N2 and CH4) and formation of gas bubbles reduce productivity* |
| | | *Adequate pressure maintenance in the production well, surface devices and injection well* | |
| **Re-injection** | *Formation of scalings due to pressure release in the upper meters of the injection well* | *Adequate pressure maintenance* | *Potential decrease of injectivity due to a decrease of the permeability of water-conducting fractures by the formation of scalings<br>-> ongoing and planned research projects* |
| **Induced Seismicity** | *URV: Induced seismicity due to fluid injection during operation* | *Seismic monitoring; Graduated scheme, developed with mining authorities, to follow when microseismicity accumulates; adjustment of reinjection volumes & pressures: run power plant as stable and smooth as possible* | *still large debate about the main driving parameter (flow rate, injected volume, injection pressure?) of induced seismicity* |
| | *URV Triggered and induced seismicity due to drilling and stimulation* | *- detailed characterisation of the tension regimes in the planning and exploration phase [but hard to derive, in-situ only possible in and in the very vicinity of the borehole (HTPF, borehole break-outs, ...), Fault Plane Solution from microseismicity is unreliable]<br>- Seismicity monitoring before and during drilling, stimulation and borhehole development phase)<br>- Rapid adjustment of the parameters during these phases (Reaction is necessary, but careful! Example Soultz: experience from stimulation is that largest events occured during shut-in, therefore practise of ‚step wise shut-in' )* | |

**Public acceptance and dialogue with citizens movements**

**Increasing investment costs**

**Pump technology**

**Success Insurances**

**Improvement of the effectiveness in the generation of electricity of geothermal power plants**

## TURKEY

| | solved | | unsolved |
|---|---|---|---|
| | Issue | Solution | |
| **Scaling** | *Calcite Scaling* | *Use of anti-scalants* | |
| **Corrosion** | | | |
| **Gas content** | *Handling of non-condensable gas content* | *Use of hybrid extraction system with first stage steam-jet ejectors followed by liquid-ring vacuum pumps* | *Develop materials that can withstand superheated and supercritical conditions* |
| **Re-Injection (Environm. Impact)** | *Disposal of Waste Brine* | *Reinjection, removal of Boron, disposal of brine into Aegean sea* | *Reinjection is chosen as the realistic option whereas removal of Boron is most promising* |
| **Induced Seismicity** | *Active fault zones* | | *Main parameter of induced seismicity should be found out* |