Catalogue of monitoring and reporting measures

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Work package WP6 Implementation tools for transboundary geothermal resource Management

6.3.1. Catalogue of monitoring and reporting measures

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1. Introduction

TRANSENERGY targets the enhanced and sustainable utilization of hydrogeothermal resources, where the carrying medium of subsurface heat is groundwater. Therefore management and monitoring issues are two-folded: on one hand they are strongly linked to the related questions of groundwater management, and as such are rather focussing on the fulfilment of environmental targets (sustainable satisfaction of water demands without causing long-lasting qualitative and quantitative changes in the aquifers). On the other hand measurements have to provide reliable data on energy contribution of geothermal installations, such as mass flow and temperature, which require different concepts and other types of parameters to be measured.

Monitoring activity includes planned, regularly repeated measurements covering quantitative and qualitative features. The appropriate network infrastructure, data quality, data management and reporting are also parts of the monitoring activity. Monitoring programs have to be specifically designed for each geothermal reservoir because of their individual characteristics. Monitoring programs may be revised as time progresses, which may apply for monitoring frequency of different parameters.

The aim of the present report is to summarize monitoring and reporting concepts of both aspects. Based on these principles the detailed monitoring plan of the 5 pilot areas will be elaborated and discussed in a separate report (6.3.2. Detailed cross-border monitoring and reporting assessment of pilot areas).

2. What and how often should be measured

Measurements have to provide reliable data on energy contribution of the geothermal installation and on achieving environmental objectives. All measurements described in this report refer to deep geothermal applications excluding ground-source heat-pumps.

2.1. Energy contribution measurements

Monitoring the physical changes in a geothermal reservoir involves measurements of (1) mass and heat transport, (2) pressure, and (3) energy content (temperature in most situations). As these measurements must be done at high temperatures and pressures in most cases, in practice this is highly complicated. Measurements are generally limited to a few boreholes. Methods of monitoring as well as monitoring frequency may vary in different geothermal systems. Conventional geothermal monitoring programs cover the following direct observations:

- Mass discharge history of production wells
- Enthalpy or temperature of fluid produced
- Wellhead pressure (water level) of production wells
- Chemical content of water and steam produced
- Injection rate histories of injection wells
- Temperature of injected water
- Wellhead pressure (water level) of injection wells
- Reservoir pressure (water level) in observation wells
- Reservoir temperature through temperature logs in observation wells
- Well status through caliper logs, injectivity tests and other methods

2.1.1. *Levels of monitoring of hydrogeothermal reservoirs*

Different intensity of thermal water utility requires different level of monitoring. Three levels of monitoring can be distinguished: baseline monitoring, active monitoring and passive monitoring (Table 1).

Table 1: General monitoring concept on different levels

Level of Utilization (Exploitation)	Data Acquisition (Surveys / Monitoring)	Data Management
1 – No utilization	Closed aquifers: Interpretation of existing exploration data (baseline estimation) Open systems: baseline monitoring	Bilateral numeric, regional scale steady state models for identified hydrogeothermal plays; reporting of resources; bilateral database
2 – Moderate utilization, no interference or regional scale changes	Interpretation of exploration data Active Monitoring	Bilateral database of baseline and production data; evaluated and calibrated bilateral numerical models for allowance and permissions
3 – Intense utilization, interferences and regional scale changes evident	Active Monitoring Passive Monitoring Evaluation of existing permission based on numerical modelling	Bilateral database of passive monitoring; evaluation of numerical models for history matching ➔ adaption of models; evaluation of existing utilizations based on adapted numerical models;

2.1.1.1. Baseline Monitoring (Baseline Estimation)

Baseline monitoring also comprehends baseline estimation and intends to summarize the initial (or steady state) hydraulic, thermal and hydrochemical conditions in a specific hydrogeothermal play. In case that no hydrogeothermal use is existing available exploration data (e.g. from the hydrocarbon industry) can be interpreted. In case of open loop hydrodynamic plays baseline monitoring should also focus on the estimation of recharge and discharge. Table 2 gives an overview on aimed parameters to be investigated for baseline monitoring.

Table 2: Main parameters of baseline monitoring

Parameter group	Parameter (Minimum resolution in space)
Reservoir characterisitcs	Temperature (x,y,z) Pressure (x,y) Hydraulic Gradient (x,y) Thermal rock parameters (x) Hydraulic Rock Parameters (x,y)
Hydrochemistry	Main Ions (x) Salinity (x,y) Isotopes (x)
Recharge, Discharge	Infiltration Rate (x,y) Exfiltration Rate (x,y)

Note: »x« stands for scalar characteristic values

The baseline monitoring / estimation can also be compiled of reported explorative data by users. In order to guarantee a harmonized data-acquisition a bilateral explorative catalogue of measurements should be implemented in the national licensing and permitting procedures.

2.1.1.2. Active Monitoring (production)

Operative monitoring can be separated into (1) Qualitative Monitoring and (2) Quantitative Monitoring. The active monitoring should be performed by users based on automatical digital recording at different frequencies as well as on effective date surveys, which can be performed by either the user himself or competent public agencies (Table 3).

To get relevant information about the reservoir it is necessary to implement pressure and temperature measurements in the centre of the "production" layer. Recently there are several instruments available from different producers ('Methodology for joint groundwater management' Annex II. edited by Prestor et al 2012). The electronic data loggers can be equipped with GSM/GPRS modem. Data from loggers are transmitted via modem to the data management centre (e.g. Geological Survey's server) daily and stored in the data base. Such transfer allows regular inspection of each measurement location and fast reaction in the occasion.

In every 5 years temperature- and inflow log measurements are recommended in the selected wells. The measurements supply information the changes went on within the well and in the productive layer direct neighbouring of the well.

Table 3: Parameters of active monitoring

Type	Parameter (Unit), [Accuracy]	Frequency	Operated by
Qualitative Monitoring	Electric Conductivity (µS/cm), [1µS/cm]	60 min	User (automatic registration)
	Comprehensive Hydrochemical Analyses including isotopes, trace elements and biological activity	5 years	User
	Basic Hydrochemical Analyses: Main Ions	1 year	Public Agency / Institute
Quantitative Monitoring	Flow Rate (l/s), [0.1 l/s]	60 min	User (automatic registration)
	Water level during operation (m), [0.1 – 1m] or Operational Pressure (bar), [0.1 bar]	60 min	User (automatic registration)
	Flow Temperature (°C), [0.1°C]	60 min	User (automatic registration)
	Water meter (total extraction) (m^3), [1m^3]	1 day	User (automatic registration), weekly manual check
	Closing pressure (bar) or Static water level (m) after shutdown of well	3 months	Public Agency / Institute

Note: all the reporting of monitoring (either performed by the user or an public agency or institute) should be addressed to the competent public authorities.

2.1.1.3. Passive Monitoring (observative monitoring)

Passive monitoring collects information about the regional effect of thermal water pumping such as decreasing in regional groundwater heads. These measurements are done in monitoring wells situated at different distance from the production wells. Furthermore it has to be kept in mind, that most reservoirs are situated in great depths, > 1000 meters below surface. Solely observation wells have to be financed by public authorities and are therefore not likely to be realized for the above mentioned reservoir depths. Synergies for cost reduction may in turn be given at abandoned hydrocarbon wells and non-prospective exploration drillings (hydrogeothermal, hydrocarbons).

The main parameters to be monitored are listed in Table 4. The data-acquisition as well as maintenance of both well and monitoring probes have to be realized by public authorities and associated agencies / institutes. All quantitative monitoring should be realized by automatic devices equipped with GSM unit to ensure on-line data management.

Table 4: Parameters of passive monitoring

Type	Parameter (Unit), [Accuracy]	Frequency
Qualitative Monitoring	Electric Conductivity (µS/cm), [1µS/cm]	6 hours
	Comprehensive Hydrochemical Analyses including isotopes, trace elements and biological activity	5 years
	Basic Hydrochemical Analyses: Main Ions	1 year
Quantitative Monitoring	Temperature (°C), [0.1°C]	6 hours
	Static pressure (bar) or Static water level (m)	6 hours

2.2. Environmental measurements

Measurements have to be provided that enable to control:

– the response of the natural system to the stress of abstraction and emission,

– the efficiency of utilization.

Parameters to be measured:

- Mass discharge history of production wells
- Enthalpy or temperature of fluid produced
- Wellhead pressure (water level) of production wells
- Chemical and isotope content of water and steam produced
- Injection rate histories of injection wells
- Temperature of injected water
- Wellhead pressure (water level) of injection wells
- Reservoir pressure (water level) in observation wells
- Reservoir temperature through temperature logs in observation wells
- Well status through caliper logs
- Specific yield / injectivity of abstraction / reinjection well
- Chemical content of fluid reinjected
- Temperature of fluid reinjected

Monitoring in observation wells is highly recommended if observation well exists. In special cases, where observation wells are located not within the direct depression cone of the abstraction / reinjection wells, they could be of outstanding high value to monitor background conditions at a regional scale. In such a case, these observation wells could be monitored by the state's agency responsible for state monitoring activities.

Frequency of measurements:

Sufficient to reveal significant oscillation of values and to statistically assess the standard deviation and error.

Sufficient to reveal any eventual significant trend.

Sufficient to forecast any eventual need to implement on time additional measures for safe operation and not to increase costs.

Good practice example of TAT project for a qualitative and quantitative monitoring concept is shown on Tables 5 and 6.

Table 5. Required continuous measurements at current usages (Goldbrunner et al., 2007, p. 244-245/276)

Parameter	*Interval*	*Accuracy*
Flow rate Q [l/s]	15 min	0.1 l/s
○ operating pressure [bar] or ○ Water level during operation [m]	15 min	0.1 bar or 0,1-1 m
Flow temperature T [°C]	15 min	0,1 °C
Elec. Conductivity Lf [µS/cm]	15 min	1 µS/cm
Water meter (total extraction)	Once a day	1 m³, weekly manual check

Table 6. Required periodic measurements at current usages (Goldbrunner et al., 2007, p. 245/276).

parameter	*interval*
○ Closing pressure **or** ○ Static water level	Closing pressure and temperature trend: every Tuesday 16:00 there is a production stop followed by pressure and temperature measurements within a 15 min interval in 5 sec increments
Hydrochemical analysis	○ Basic observation: every 5 years ○ Repeated observation: annually

3. How and whom to report

3.1. Energy contribution

Geothermal energy (GE) contribution is regarded as a share to renewable energy sources in the National Renewable Energy Action Plan - NREAP (Table 11 in every country's NREAP).

Within the NREAP, the yearly abstracted geothermal energy from the geothermal resources has to be reported (Tables 7,8) (http://ec.europa.eu/energy/renewables/action_plan_en.htm).

Total actual contribution from GE is to be reported to the authority responsible for the energy and the implementation of *Article 22 of Directive 2009/28/EC*. This directive requires Member States to submit a report to the Commission on progress in the promotion and use of energy from renewable sources by 31 December 2011, and every two years thereafter. The sixth report, to be submitted by 31 December 2021, shall be the last report required.

Table 7. Reporting total actual contribution (installed capacity, gross electricity generation) from GE in electricity (indirect use)

	Year n-2		**Year n-1**	
	MW	**GWh**	**MW**	**GWh**
Geothermal				
of which in CHP				

Table 8. Reporting total actual contribution from GE (direct use) in heating and cooling (ktoe).

	Year n-2	**Year n-1**
Geothermal (excluding low temperature geothermal heat in heat pump applications)		
Renewable energy from heat pumps: - of which geothermal - of which hydrothermal		
TOTAL		
Of which DH (district heating)		

http://ec.europa.eu/energy/renewables/transparency_platform/doc/article_22_progress_reports/template_progress_reports__article_22.zip

3.1.1. Australian / Canadian Geothermal Code for Public Reporting

Concerning the reporting of geothermal resources at different levels of confidentiality is well described at the so called »Australian / Canadian Geothermal Code for Public Reporting« (AGC 2009, CGCC 2010). These codes comprehend mandatory reporting prescriptions from both private as well as public enterprises to the governing authorities with respect to geothermal exploration and resource assessment.

According to the Codes Geothermal resources and geothermal reserves must only be reported in units of Recoverable Thermal Energy i.e. as Petajoules (PJth) or Megawattthermal-years (MWth-years) relative to defined Base and Cut-off Temperatures. If the thermal energy is envisioned to be converted into electricity, then an estimate of the Recoverable Electrical Energy may additionally be stated using units of PJe or MWe-years. In all cases the subscript 'thermal' / 'th' or 'electrical' / 'e' must be used to distinguish thermal from converted electricity energy. Furthermore all recovery and conversion factors used must be stated separately.

The Geothermal Reporting Codes of the Australian Geothermal Energy Association (AGEA) and the Canadian Geothermal Energy Association (CanGEA) (AGRCC 2009, CGCC 2010) aimed to produce and maintain a methodology and provide a minimum, mandatory set of requirements for public reporting of exploration results and the assessment of geothermal resources and reserves to inform existing and potential investors, their advisors, as well as governmental geo-scientific agencies. The codes give provisions on the entire life-cycle of a geothermal project, applicable also in other countries, therefore they became internationally accepted. The Geothermal Reporting Codes are relevant to all forms of geothermal energy (including naturally permeable aquifers, engineered geothermal systems and both magmatic and non-magmatic heat sources) and all forms of end-use applications of geothermal energy (including both electricity generation and direct use projects) except for ground source heat pumps operating at low source temperatures.

The Codes provide a detailed list of parameters which have to be assessed during various phases of a geothermal project such as the following:

<u>Pre-drilling exploration technical data:</u> geological maps and interpretations, data location and spacing, evidence for past/present rock-water interaction, hydrology, sampling techniques, analytical techniques, temperature measurements and geothermometry (nature and quality of techniques used), temperature gradient, thermal conductivity (K), heat flow, heat generation determination, geophysical techniques, data integrity and verification.

<u>Tenement, environmental and infrastructure data:</u> permit and land tenure status (ownerships, royalties, historical sites, national parks, etc.), terrain, geotechnical issues and access (geotechnical and geohazard which could affect future drilling), environmental issues (e.g. water requirement), land-use issues (potential conflicts affecting future drilling), infrastructure (e.g. water supply, transmission lines for electricity), exploration by other parties.

<u>Subsurface and well-discharge data:</u> drilling data (technical specifications of drilling), sample recovery (e.g. cuttings, core, fluid, sampling intervals), geological log (qualitative vs. quantitative logs, lithology, paleontology, mineralogy, fluid inclusions, vitrinite reflectance, etc.), downhole temperature pressure and flow logs (types and quality of measurements), other downhole logging, aquifers (location of permeable zones), depth of reservoir, injection tests, multi-well tests, well-discharge testing.

<u>Naturally convective systems and hot sedimentary aquifer resource parameters</u>: flow-rate (well-tests: individual vs. interference, duration, depth, etc), pressure data, recharge, water saturation and enthalpy, reservoir fluid chemistry (scaling, gas content and acidity), reservoir properties (rock types, porosity, permeability, anisotropy, etc), conceptual model on the nature of the system (integrated geo-hydrogeological reservoir model including analogies used and key-assumptions made, interpretation of physico-chemical reservoir processes), numerical modeling (model structure, key parameters, boundaries and relationship to conceptual model, results of nature-state modeling, history matching and forecast runs), data interpolation/extrapolation.

<u>Estimation and reporting of geothermal resources</u>: expected use (nature of anticipated exploitation), data integrity (source and reliability of relevant data, data validation), data interpretation (certainty of interpretation of geological, geophysical and geochemical data), well deliverability (pumping or self-discharging wells, expected power requirement for production or injection wells), estimation and modeling techniques (e.g. previous production records), cut-off parameters (cut-off temperatures, flow rates, quality parameters), recovery factors, conversion efficiency (heat into electricity), dimensions (expressed as surface area and depth below, reservoir geometry), geothermal resource life, classification (into confidence categories), third party involvement, audits or reviews, accuracy/confidence (sensitivity analysis, probabilistic analysis, scenario trees, discussion of factors which could affect the relative accuracy and confidence of the estimate).

Estimation and reporting of geothermal reserves: description of geothermal resource for conversion to a geothermal reserve, plant when related to electricity generation (technology to be used, expected capacity, etc.), environmental and land-use factors (third party development, emissions to air or water, subsidence, effects on groundwater and ecosystems, changes in surface heat flow, induced hydrothermal eruptions, seismicity, effect on tourism bathing and other land use, etc.), costs and revenue factors (project capital and operating costs, revenue, royalties), market assessment (market capacity vs. price), other (effects of any natural risk, infrastructure, legal, social or governmental factors), classification (into confidence categories), audits or reviews, accuracy/confidence (sensitivity analysis, probabilistic analysis, scenario trees, discussion of factors which could affect the relative accuracy and confidence of the estimate).

Additional factors: existing developments: production data (past total heat and fluid extraction and reinjection, pressure, temperature, enthalpy and chemical historical trends, assessments on heat and fluid recharge), reservoir monitoring (surface and downhole pressure and temperature, fluid flow and enthalpy measurements, tracer tests well output tests, thermal activity and heat-flow monitoring, ground deformation, microgravity, environmental monitoring), production history, numerical modeling (simulation modeling with history matching for credibility, scenario models), future development scenarios.

Transenergy project – by its nature and goals – cannot and will not cover all the above listed aspects, especially those ones which are related to drilling, tenement and infrastructure data, developments, however tries to cover as many of the above listed criteria related to exploration data and naturally convective systems and hot sedimentary aquifer resource parameters as possible (available).

3.1.2. EGEC / IGA view on statistics and reporting

According to EGEC view on statistics regarding the Directive on Promotion of Renewable Energy Sources, geothermal energy exists and shall be counted in the following forms:

1. Electric power generated from geothermal sources (indirect use),
2. Heat (mainly deep geothermal heat – direct use)
    a. swimming, bathing and balneology,
    b. space heating including district heating,
    c. agriculture applications,
    d. aquaculture applications and
    e. industrial processes produced directly from geothermal sources,
3. Heat (mainly shallow geothermal) used as input to geothermal heat pumps,
4. Cooling (mainly in geothermal heat pump plants).

Good practice for reporting (related only to deep geothermal) is represented by a set of suitable tables has been prepared by J.W. Lund and co-authors. The tables are dedicated for indirect use reporting (Table 9) direct use reporting (Tables 10,11) **Table** and for and are sent one year before each World Geothermal Congress (organized every 5 years) to all the countries that exhibit any category of utilization of geothermal energy for direct use (for example Lund et al., 2010).

Table 10 is aimed for reporting data, which are useful and required to be reported by all direct heat users. Data shall be presented for all the users only in total. Data which are useful to be reported are: flow rate, inlet and outlet temperatures at maximum utilization and resulting capacity. Data which are required to be reported: average flow rate during annual utilization, inlet and outlet temperatures if different than those at maximum utilization. Table 11 is aimed for reporting summary data on geothermal direct heat use for the country where the installed capacity and annual energy use for each category of direct heat use is presented.

Table 9. Utilization of geothermal energy for electric power generation as of, for example, 31 December 2009.

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash; 2F = Double Flash; 3F = Triple Flash; D = Dry Steam; B = Binary (Rankine Cycle); H = Hybrid (explain); O = Other (please specify)

3) Data for 2009 if available, otherwise for 2008. Please specify which.

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MW_e*	Total Running Capacity MW_e*	Annual Energy Produced 2009[3)] GWh/yr	Total under Constr. or Planned MW_e
Total									

* Installed capacity is maximum gross output of the plant; running capacity is the actual gross being produced.

Table 10. Utilization of geothermal energy for direct heat as of, for example, 31 December 2009.

I = Industrial process heat
H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling)
D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables)
B = Bathing and swimming (including balneology)
F = Fish farming
G = Greenhouse and soil heating
K = Animal farming
O = Other (please specify by footnote)
S = Snow melting

Enthalpy information is given only if there is steam or two-phase flow

Capacity (MW_t) = Max. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184 ($MW = 10^6$ W)
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 ($TJ = 10^{12}$ J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (^oC)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MW_t)	(kg/s)	(TJ/yr)	Factor[5)]
TOTAL										

Table 11. Summary table of geothermal direct heat uses as of, for example, 31 December 2009.

1) Installed Capacity (thermal power) (MW_t) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MW_t)] x 0.03171 (MW = 10^6 W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1] (MW_t)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]			
District Heating [4]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]			
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps			
TOTAL			

4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

Remark: spas and pools are difficult to estimate and are often over estimated. Be sure to use the inflow and outflow temperature and not the spring or well temperature (unless it is the same as the inflow temperature) for calculating the energy parameters, as some pool need to have the geothermal water cooled before using it in the pools.

3.2. Environmental objectives

The main legal framework for a trans-national monitoring and reporting is given by the Water Framework Directive (WFD - Directive 2000/60/EC of the European parliament and of the council) for the time period 2009 - 2015.

Basic premises from Water Framework Directive (Anonymous, 2000):

»…Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such.

Further integration of protection and sustainable management of water into other Community policy areas such as energy, transport, agriculture, fisheries, regional policy and tourism is necessary. This Directive should provide a basis for a continued dialogue and for the development of strategies towards a further integration of policy areas. This Directive can also make an important contribution to other areas of cooperation between Member States, inter alia, the European spatial development perspective (ESDP).

Within a river basin where use of water may have trans-boundary effects, the requirements for the achievement of the environmental objectives established under this Directive, and in particular all programmes of measures, should be coordinated for the whole of the river basin district. This Directive is to contribute to the implementation of Community obligations under international conventions on water protection and management, notably the United Nations Convention on the protection and use of trans-boundary water courses and international lakes, approved by Council Decision 95/308/EC(15) and any succeeding agreements on its application.

It is necessary to undertake analyses of the characteristics of a river basin and the impacts of human activity as well as an economic analysis of water use. The development in water status should be monitored by Member States on a systematic and comparable basis throughout the Community. This information is necessary in order to provide a sound basis for Member States to develop programmes of measures aimed at achieving the objectives established under this Directive.

To ensure the participation of the general public including users of water in the establishment and updating of river basin management plans, it is necessary to provide proper information of planned measures and to report on progress with their implementation with a view to the involvement of the general public before final decisions on the necessary measures are adopted….«

According to Water Framework Directive, Article 4: In making operational the programmes of measures specified in the river basin management plans, Member States shall:

1) implement the necessary measures to
   i. prevent deterioration of the status of all bodies of surface and groundwater
   ii. progressively reducing pollution from priority substances and ceasing or phasing out emissions, discharges and losses of priority hazardous substances to surface water bodies
   iii. to prevent or limit the input of pollutants into groundwater and to prevent the deterioration of the status of all bodies of groundwater
   iv. to reverse any significant and sustained upward trend in the concentration of any pollutant resulting from the impact of human activity in order progressively to reduce pollution of groundwater.

2) at the latest till 2015 (by protecting, enhancing and restoring all bodies of surface and groundwater bodies and by ensuring a balance between abstraction and recharge of groundwater) achieve

i. good status of surface and groundwater bodies,
ii. good ecological potential and good surface water chemical status of all artificial and heavily modified bodies of water,
iii. compliance with any standards and objectives for water bodies in protected areas.

The required reporting of thermal groundwater status to the authority responsible for water management is shown in Tables 12 and 13.

Table 12. Reporting quantitative status of groundwater body

The level of groundwater in the groundwater body is such that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction.	y/n/uncertain
Accordingly, the level of groundwater is not subject to anthropogenic alterations such as would result in: – failure to achieve the environmental objectives for associated surface waters,	y/n/uncertain
– any significant diminution in the status of such waters,	y/n/uncertain
– any significant damage to terrestrial ecosystems which depend directly on the groundwater body,	y/n/uncertain
Alterations to flow direction resulting from level changes may occur temporarily, or continuously in a spatially limited area, but such reversals do not cause saltwater or other intrusion, and do not indicate a sustained and clearly identified man induced trend in flow direction likely to result in such intrusions.	y/n/uncertain

Table 13. Reporting chemical status of groundwater body

The chemical composition of the groundwater body is such that:	
– does not exhibit the effects of saline or other intrusions or trends that could exhibit unstable conditions and uncertain prediction,	y/n/uncertain
– not result in failure to achieve the environmental objectives for associated surface waters nor any significant diminution of the ecological or chemical quality of such bodies nor in any significant damage to terrestrial ecosystems which depend directly on the groundwater body.	y/n/uncertain

Furthermore three of the pilot areas (Vienna Basin, Danube Basin and Komarno area) are also affected by the Danube River Management Plan coordinated by the International Commission for the Protection of the Danube River (ICPDR), which is of course focussing on the surface near water bodies.

3.2.1. Basic principles of tans-boundary monitoring according to UNECE, WFD, ICPDR

Within a river basin where use of water may have trans-boundary effects, the requirements for the achievement of the environmental objectives established under WFD, and in particular all programmes of measures, should be coordinated for the whole of the river basin district. For river basins extending beyond the boundaries of the Community, Member States should endeavour to ensure the appropriate coordination with the relevant non-member States. WFD is to contribute to the implementation of Community obligations under international conventions on water protection and management, notably the United Nations Convention on the protection and use of trans-boundary water courses and international lakes, approved by Council Decision 95/308/EC (1) and any succeeding agreements on its application.

The trans-boundary management has to include provisions on monitoring, research and development, consultations, warning and alarm systems, mutual assistance, exchange of information, and access to information by the public. Trans-boundary water bodies shall also be monitored for those parameters which are relevant for the protection of all of the uses supported by the groundwater flow (WFD L327/63).

The network shall include sufficient representative monitoring points and monitoring frequency to estimate the groundwater level in each groundwater body or group of bodies taking into account short and long-term variations in recharge and in particular for groundwater bodies within which groundwater flows across a Member State boundary, ensure sufficient monitoring points are provided to estimate the direction and rate of groundwater flow across the Member State boundary (L 327/60).

Programme of measures could be established specifically for each individual groundwater body, including thermal groundwater bodies. It has to include both quantitative and chemical (quality) monitoring and shall provide the necessary information to:

- assess groundwater status,
- identify trends in pollutant concentrations,
- support GW-body characterization and the validation of the risk assessment,
- assess whether water protection area objectives are achieved,
- support the establishment and assessment of programmes of measures, and
- effective targeting of economic resources.

Steps of monitoring design:

- development of conceptual models of GW-bodies;
- achievement of harmonized monitoring networks; and
- establishing of criteria for the selection of parameters.

The task of ensuring good status of groundwater requires early action and stable long-term planning of protective measures, owing to the natural time lag in its formation and renewal.

Results of the observations are common directions to coordinate expert activities of neighbouring countries and theirs reporting to the trans-boundary organization.

We recommend to fully report the sustainability of thermal resource management in the form of benchmarking as it was developed in the frame of "Methodology for joint groundwater management" report (Chapter 5: Benchmarking / indicators of sustainability of thermal groundwater management). (Table 14)

Table 14. Example for reporting the sustainability of geothermal resources management

	Ptuj-Grad+Mura Fm. in SI	points %	
1	Monitoring status	0	Very bad
2	Best available technology	50	Medium
3	Thermal efficiency	75	Good
4	Utilization efficiency	100	Very good
5	Balneological efficiency	100	Very good
6	Reinjection rate	25	Bad
7	Recharge of thermal aquifers	0	Very bad
8	Overexploitation	25	Bad
9	Quality of discharged waste thermal water	?	
10	Public awareness	0	Very bad

4. Conclusions

Catalogue of monitoring and reporting measures gives a summary of what are the obligations to report to follow the renewable energy and environmental objectives. There are also recommendations added how to get full and integrated control and reporting for the status of the resource and its sustainable management.

For each individual trans-boundary geothermal system the exact monitoring procedure should be negotiated / optimized between users and management authorities from all neighbouring countries (e.g. Austria-Bavaria Malm – good practice example). The process of monitoring implementation should be supervised and controlled by intermediate bodies such as the bilateral water commissions. Tangible recommendations for cross-border monitoring stations in the pilot areas are provided in report 6.3.2. Detailed cross-border monitoring and reporting assessment of pilot areas.

5. Literature

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