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Harmonized Resource Assessment for selected Hydrogeothermal Plays in the Transenergy Pilot Areas

Authors:	Goetzl, G. with contributions by MFGI, SGUDS & GeoZS
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5.3.2 Summary report of the scenario modelling

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1 Introduction

The assessment of resources is an essential step towards a future thermal water management. During the decades of geothermal research various definitions and workflows have been developed in order to quantify available geothermal resources. However, globally agreed standards for the qualification and quantification of geothermal resources are still missing.

A recent attempt for standardized codes for reporting of geothermal resources has been published by the Canadian Geothermal Energy Association – CanGEA (http://www.cangea.ca), which is strongly related to "The Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves", published by the Australian Geothermal Energy Group – AGEG (http://www.pir.sa.gov.au/geothermal/ageg/geothermal_reporting_code).

The Transenergy working group decided to establish a harmonized terminology and assessment workflow relying on the above mentioned public reporting codes.

In the following section of this report the underlying terms and definitions of the different levels of hydrogeothermal potential, resources and reserves will be described.

In general it has to be distinguished between 3 different main levels of hydrogeothermal assessment:

The most general level covers the **hydrogeothermal potential**, which delimits the theoretically available heat content in a specific subsurface volume. The **resource** level confines the share of stored heat, which can be extracted by known technical measures, irrespective of economic constraints. The **reserve** level in turn also considers economic constraints and therefore delimits the economically feasible share of resources.

The term "**Hydrogeothermal Play**" covers a distinctive subsurface rock volume (in this case a geological reservoir complex) where natural thermal water is supposed to be occurring and may be utilized in at least one distinctive reservoir.

The table shown below is giving an overview on the different levels of hydrogeothermal assessment considered at Transenergy. It does not cover all levels of resource assessment described at the above mentioned reporting codes. However, the chosen selection covers all aspects, which are needed to fulfill the goals of Transenergy and should be seen as a first attempt towards a future joint resource management. Further diversifications of levels of hydrogeothermal assessment can be realized on demand.

Table 1: Overview of the different levels of hydrogeothermal assessment considered at Transenergy

Potential	Resource	Reserve	Definition used at Transenergy
Heat in Place			*Heat stored in a subsurface volume. This term delimits the theoretically available geothermal potential, which could only be utilized by*

			cooling down the entire rock volume of the specific Hydrogeothermal Play. In practice it won't be possible to extract the entire amount of heat stored by technical measures.
	Inferred Resources		*Technically extractable amount of Heat in Place at a low level of confidence. The assessment of Inferred Resources mainly bases on modelling results and simplified assumptions at a regional scale.*
		Probable Reserves	*Share of Inferred Resources, which can be developed in an economic way (e.g. considering maximum drilling depths or maximum distances to areas of settlement).*
	Measured Resources		*Technically extractable amount of Heat in Place at a high level of confidence by relying on direct measurements at wells.*
		Installed Capacities	*Already installed hydrogeothermal power.*

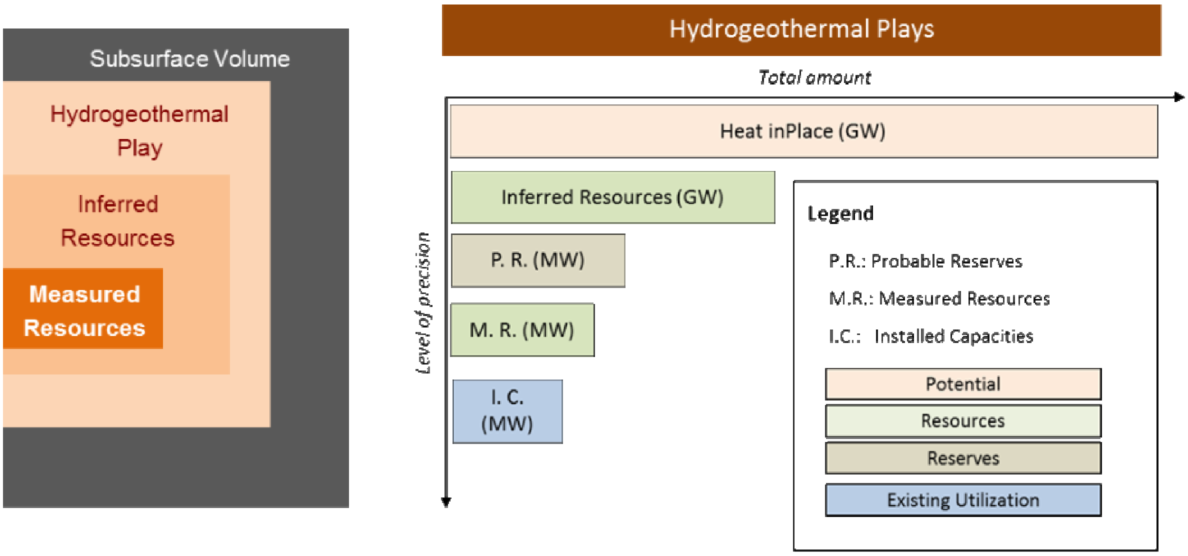

Figure 1: General scheme of the resource assessment scheme applied at Transenergy

It has to be considered, that the amount of assessed energy available for utilization is in general attenuating towards a higher confidence of the assessment level. As shown in Figure 1 the lowest level of confidence is provided by “Heat in Place” (potential) and in contrast the highest level of confidence provided by “Measured Resources” and already “Installed Capacities”.

At Transenergy the harmonized hydrogeothermal assessment has been achieved for relevant Hydrogeothermal Plays at the selected pilot areas only. All calculations are basing on the data acquired and models developed during Transenergy. The assessment is limited to a regional scale (maximum resolution 1:100.000).

The assessment of resources is strongly depending on the technical utilization scheme chosen. In this context the controlling technical parameters are constituted by:

- Single well or doublet use
- The required minimum reservoir temperature
- The temperature of the injected water
- The maximum yield

In order to assess the hydrogeothermal potential (Heat in Place) the operational lifetime of all chosen technical utilization scheme was set to 50 years of full annual load. The technical utilization schemes applied for the hydrogeothermal resource and reserve assessment are listed below:

Table 2: Overview of the utilization schemes selected for hydrogeothermal resource assessment

ID	Title	Required minimum temperature	Reference temperature (discharge, re-injection)	Type of scheme	Constraints
		°C	°C	-	-
1	**Balneology** (energetic use of water for local heating)	30	10*	Single Well	None
2	**Heat Supply** (district heating as well as individual heating)	40	25	Doublet (2 wells)	Maximum flow rate 100 l/s or max. drawdown of 100 meters**
3	**Electric Power Generation** (combined with heat supply)	105	55	Doublet (2 wells)	Maximum flow rate 200 l/s or max. drawdown of 200 meters**

The selected technical utilization schemes intend to cover the most important or already widely spread utilizations.

2 Investigated Hydrogeothermal Plays

In total 9 different Hydrogeothermal Plays located in the 5 different pilot areas have been identified for the harmonized hydrogeothermal assessment. Except for the Vienna Basin pilot area only 1 Hydrogeothermal Play has been identified for each pilot area.

Table 3: Overview on the Hydrogeothermal Plays selected for the hydrogeothermal assessment

ID	Name	Pilot Area	Description
VB1	*Aderklaa Conglomerate*	Vienna Basin	Conglomerates of the Miocene basin fillings (Lower Badenian)
VB2	*Deltafront Sediments (Eggenburgian - Ottnangian)*	Vienna Basin	Sandstones and sands of the Miocene basin fillings
VB3	*Tirolic Nappe System*	Vienna Basin	Dolomites and limestones of the Triassic basement of the Vienna Basin (Norian - Anisian)
VB4	*Juvavic Nappe System*	Vienna Basin	Dolomites and limestones of the Triassic basement of the Vienna Basin (Ladinian - Anisian)
VB5	*Central Alpine & Tatric Carbonates*	Vienna Basin	Dolomites and limestones of the Triassic basement of the Vienna Basin (Ladinian - Anisian)
TWB1	*Upper Triassic karbonate reservoir*	Komarno - Sturovo Area	Limestones and dolomites of the Upper Triassic basement
LZ1	*Devonian dolomite*	Lutzmannsburg - Zsira Area	Limestones and dolomites of the Paleozoic basement
DB1	*Upper Pannonian formation*	Danube Basin	Interchange of clays, marls and sands/sanstones of the Miocene basin fillings
BRH1	*Bad Radkersburg – Hodoš pilot area / Raba fault zone*	Bad Radkersburg - Hodoš Area	Carbonates and metamorphic rocks of the Pre-Tertiary basement (Triassic & Paleozoic)

The main criteria for the selection of Hydrogeothermal Plays are:

- Coverage of at least one aquifer

- Relevance for present or future hydrogeothermal use
- Minimum average temperature level above 30°C

Three of the nine identified Hydrogeothermal Plays are located at the Miocene basin fillings of the Pannonian- and the Vienna Basin. They mainly constitute porous aquifers belonging to a single stratigraphic horizon. The remaining 6 Hydrogeothermal Plays are located at the pre-Miocene basement of the basins and are represented by fractured carbonate reservoirs, which are partly consisting of several different tectonic and stratigraphic structures.

Table 4: Geometrical attributes of the investigated Hydrogeothermal Plays

ID	Name	Gross Volume (km³)	Aquifer Volume (km³)	Average Thickness (m)
VB1	*Aderklaa Conglomerate*	249	37	199
VB2	*Deltafront Sediments (Eggenburgian - Ottnangian)*	124	21	182
VB3	*Tirolic Nappe System*	4,495	265	2,239
VB4	*Juvavic Nappe System*	900	31	1,937
VB5	*Central Alpine & Tatric Carbonates*	3,220	103	1,930
TWB1	*Upper Triassic karbonate reservoir*	164	2	200
LZ1	*Devonian dolomite*	120	6	600
DB1	*Upper Pannonian formation*	9,127	1,278	985
BRH1	*Bad Radkersburg – Hodoš pilot area / Raba fault zone*	1,779	356	3,100

The geometrical attributes of the investigated Hydrogeothermal Plays have been derived from the steady-state 3D modelling executed at the different pilot areas. The largest reservoir complexes exist in the Danube Basin (DB1) and the Vienna Basin (VB3 and VB5). While the gross- and estimated aquifer volume in the Play DB1 is resulting from the vast surface, the volumes of the Plays in the Vienna Basin are resulting from the great thickness of the reservoir complexes. The smallest Hydrogeothermal Play is located at the Lutzmannsburg – Zsira pilot area (Play LZ1). The total estimated gross aquifer volume is at 2100 km³. It has to be kept in mind that this estimation bases on the simplifying assumption of a homogeneous reservoir.

Table 5: Range of the estimated reservoir temperatures of the investigated Hydrogeothermal Plays

ID	Name	Estimated Reservoir Temperature (°C)		
		Min	*Max*	*Average*
VB1	*Aderklaa Conglomerate*	26	114	80
VB2	*Deltafront Sediments (Eggenburgian - Ottnangian)*	10	155	58
VB3	*Tirolic Nappe System*	8	239	118
VB4	*Juvavic Nappe System*	58	193	129
VB5	*Central Alpine & Taric Carbonates*	9	282	134
TWB1	*Upper Triassic karbonate reservoir*	20	152	86
LZ1	*Devonian dolomite*	n. a.	n. a.	n. a.
DB1	*Upper Pannonian formation*	10	136	46
BRH1	*Bad Radkersburg – Hodoš pilot area / Raba fault zone*	45	243	148

The estimated range of reservoir temperatures has been derived from the achieved steady-state thermal models covering the pilot areas. High temperatures of more than 200°C have therefore not been proofed by direct measurements. However, the estimated maximum temperatures vary between 114°C (VB1) and 282°C (VB5). The average reservoir temperatures, which have been used for the hydrogeothermal resource assessment, are varying between 46°C (DB1) and 148°C (BRH1).

The hydraulic transmissivity was used to calculate the Inferred- and Measured Resources, as this parameter controls the maximum yield of an individual geothermal doublet. It was calculated by combining the modelled thickness of a Hydrogeothermal Play with an averaged hydraulic conductivity, once again assuming isotropic and homogeneous conditions at the Play.

Table 6: Estimated transmissivity of the investigated Hydrogeothermal Plays

ID	Name	Estimated Transmissivity 10^{-3} (m²/s)		
		Min	*Max*	*Estimated*
VB1	*Aderklaa Conglomerate*	0.002	1.219	0.325
VB2	*Deltafront Sediments (Eggenburgian - Ottnangian)*	0.020	1.305	0.356
VB3	*Tirolic Nappe System*	0.000	3.426	1.159
VB4	*Juvavic Nappe System*	0.003	2.416	1.010

VB5	*Central Alpine & Taric Carbonates*	0.274	3.328	1.006
TWB1	*Upper Triassic karbonate reservoir*	n. a.	n. a.	42.000
LZ1	*Devonian dolomite*	n. a.	n. a.	0.480
DB1	*Upper Pannonian formation*	0.072	1.544	0.423
BRH1	*Bad Radkersburg – Hodoš pilot area / Raba fault zone*	0.755	4.700	3.120

Except for the Hydrogeothermal Play TWB1, which exhibits a very high level, all estimated transmissivities vary in the range of 10^{-4} to 10^{-3} m^2/s.

The heat exchange between the surrounding rock matrix and the circulating thermal water is controlled by the rock parameters (i) Heat Capacity, (ii) Density and (iii) Porosity as well as by the same parameters of the fluid itself. The thermal rock parameters have been generalized based on measurements done by or available at the involved geological surveys. Due to the lack of data once again simple isotropic and homogeneous reservoirs had to be assumed.

Table 7: Thermal rock parameters of the investigated Hydrogeothermal Plays

ID	Name	Bulk Heat Capacity (J/(m^{3x}K)	Bulk Density (kg/m^3)	Porosity (%)
VB1	*Aderklaa Conglomerate*	1380	2273	15.0
VB2	*Deltafront Sediments (Eggenburgian - Ottnangian)*	1154	2370	17.2
VB3	*Tirolic Nappe System*	1126	2681	5.9
VB4	*Juvavic Nappe System*	1028	2735	3.4
VB5	*Central Alpine & Taric Carbonates*	897	2860	3.2
TWB1	*Upper Triassic karbonate reservoir*	914	2650	3.0
LZ1	*Devonian dolomite*	1380	2273	15.0
DB1	*Upper Pannonian formation*	n. a.	n. a.	14.0
BRH1	*Bad Radkersburg – Hodoš pilot area / Raba fault zone*	1000	2850	20.0

3 Methodology and workflow

The assessment of hydrogeothermal potentials, resources and reserves follows a workflow developed in the frame of Transenergy. All processing steps have been in a MS Excel worksheet, which has been sent out to all partners for individual calculations. The chosen approach bases on the previously elaborated steady state models and have been performed based on 2D raster analyses using the software package Esri ArcGIS.

Doing so the entire Hydrogeothermal Play was covered with a 1 km x 1 km raster putting on individual geothermal doublet (1 production well + 1 injection well) at each cell in order to consider the utilization schemes 2 (heat supply) and 3 (electric power generation). Considering scheme 1 (balneological use) only 1 single well was put at each cell.

The assessment of hydrogeothermal resources is consisting of the following processing steps (see nomenclature at the end of this chapter):

(1) <u>Preparation of input data</u>

- Define the outline of each Hydrogeothermal play and cut out all relevant input data from the elaborated steady-state 3D models.
- Calculate a raster of the gross thickness of each Hydrogeothermal Play (HP).
- Calculate the gross volume of each HP by summing up the thickness of all cells.
- Calculate the average (midpoint) temperature for each cell by: $T_i = \frac{T_{Top,i} + T_{Base,i}}{2}$.
- Assign uniform Heat Capacity, Bulk Densities and Porosities (total, effective) to each HP.
- Calculate the transmissivity of each HP:
    - If no direct measurements of the hydraulic conductivity are available then transform hydraulic permeabilities into hydraulic conductivities using: $kf = \frac{K \cdot g \cdot \rho_f}{\eta_f}$.
    - Calculate the hydraulic transmissivity by combining the hydraulic conductivity with the gross thickness for each cell.
- Calculate the gross aquifer volume by multiplying the gross volume with the effective porosity.
- Create filter considering the minimum reservoir temperature requirement for the schemes 1 to 3: Each utilization scheme has a minimum reservoir temperature required. In order to avoid negative capacities all cells, which don’t fulfil the requirements, have been excluded from the calculations.

(2) Calculation of the Heat in Place

All calculations are basing on a volumetric approach assuming to cool down the entire volume of the HP to the level of the reference temperature.

- Utilization scheme 1: $HIP = \sum_{i=1}^{n} \left(6.2420E - 10 \cdot (cp \cdot \rho)_f \cdot \theta \cdot (T_i - T_{Ref})\right)$, unit [MW].
- Utilization scheme 2,3: $HIP = \sum_{i=1}^{n} \left(6.2420E - 10 \cdot (cp \cdot \rho)_a \cdot (T_i - T_{Ref})\right)$, unit [MW].

(3) Calculation of the Inferred Resources

- Scheme 1 (balneology, single well use): Follows an approach presented by Gringarten (1978): $H = (cp \cdot \rho)_f \cdot Q \cdot v_{heat}$, where v_{heat} is representing the heat transfer velocity between the rock matrix and the circulating fluid: $v_{heat} = \frac{(cp \cdot \rho)_f}{(cp \cdot \rho)_a}$. For calculating the Inferred Resources a constant yield of 10 l/s (0.01 m^3/s) was assumed. The output unit is [MW].

- Schemes 2, 3: The inferred resources have been assessed using a multiplet-scheme approach (1 individual doublet per cell) based on a correlation between the maximum yield of an individual doublet and the transmissivity at the affected cell:

    - Calculate the maximum allowed yield: $Q = 150.816 \cdot \tau$. This equation also follows an approach by Gringarten (1978). A maximum yield of 100 l/s (0.1 m^3/s) was set as a general constraint for each cell.

    - Calculate the thermal capacity of each individual doublet: $H = (cp \cdot \rho)_f \cdot Q \cdot (T_i - T_{Ref})$, afterwards the unit is transformed from [W] into [MW].

    - Sum-up all cells in order to get the total Inferred Resources.

(4) Calculation of the Measured Resources

The calculation of Measured Resources follows the methodologies for calculating the Inferred Resources. Instead of using modelled reservoir temperatures the thermal capacity of a single well or a hydrogeothermal doublet was calculated using direct measurements at hydrocarbon wells and geothermal wells only. That means only those cells have been considered, where wells with direct temperature measurements were available.

(5) Calculation of the Probable Reserves

The calculation of probable reserves has been experimentally applied on the utilization scheme 2 (heat supply) for the HPs in the Vienna Basin only. For that purpose the Inferred Resources have been calculated only for cells showing a maximum distance of 1000 meters to settlement areas. The information about settlement areas have been derived from a Corrine Landsat dataset (Eurosat©, Corrine Landcover, 2006).

(6) Calculation of already Installed Capacites

Considering the utilization schemes 1 to 3 the already Installed Capacities have been assessed based on production data: $H = (cp \cdot \rho)_f \cdot Q \cdot (T_i - T_{Ref})$.

Nomenclature

Symbol	Name	Unit
K	(Hydraulic) Permeability	m^2 (Darcy)
g	Gravity	m/s^2
η	Dynamic Viscosity	Ns/m^3
ρ	Density	Kg/m^3
cp	Heat Capacity	J/(kg·K)
θ	Porosity	-
τ	Transmissivity	m^2/s
Q	Yield	m^3/s
H	Heat (Resources)	MW, (W)
T	Reservoir Temperature	°C
T_{Ref}	Reference Temperature (Injection Temperature)	°C
$_f$	Subscript: Fluid (Water)	

a	Subscript: Aquifer (rock matrix and fluid filled pores)
i	Subscript: Cell

4 Results

The Heat in Place, assessed for the investigated Hydrogeothermal Plays is shown in the table below:

Table 8: Estimated Heat in Place for the investigated Hydrogeothermal Plays

ID	Name	Heat in Place ($MW_{Th,\ 50\ years}$)		
		Scheme: Single well	*Scheme: Heat Supply*	*Scheme: Electric Power*
VB1	*Aderklaa Conglomerate*	5,449	28,794	454
VB2	*Deltafront Sediments (Eggenburgian - Ottnangian)*	1,153	7,422	1,289
VB3	*Tirolic Nappe System*	52,998	858,027	587,344
VB4	*Juvavic Nappe System*	6,533	194,102	122,013
VB5	*Central Alpine & Taric Carbonates*	12,628	557,686	380,336
TWB1	*Upper Triassic karbonate reservoir*	235	15,731	3,896
LZ1	*Devonian dolomite*	412	7,014	3,603
DB1	*Upper Pannonian formation*	34,325	176,868	0
BRH1	*Bad Radkersburg – Hodoš pilot area / Raba fault zone*	29,945	374,354	250,455

In general the greatest potential has been calculated for the Heat Supply scheme, as this scheme is affected by a moderate minimum temperature required (40°C). In this context the highest amount of Heat in Place was calculated for the HP VB3 (approx. 860 GW_{Th}) assuming an operational lifetime of 50 years for cooling down the reservoir. This high amount of the Heat in Place is strongly related to the vast volume of this Hydrogoethermal Play and therefore calculated high temperature levels in the basal sections of the Play. However, it has to be kept in mind, that this is only a hypothetical potential, which will never been realized in practice. Nevertheless using the Heat in Place we can summarize, that the maximum amount of heat stored in all investigated HPs.

A first estimation of the technically realizable share of the stored Heat in Place is given by the Inferred Resources:

Table 9: Estimated Inferred Resources for the investigated Hydrogeothermal Plays

ID	Name	Inferred Resources (MW_{Th})		
		Scheme: Single well	*Scheme: Heat Supply*	*Scheme: Electric Power*
VB1	*Aderklaa Conglomerate*	636	14,285	229
VB2	*Deltafront Sediments (Eggenburgian - Ottnangian)*	199	4,455	835
VB3	*Tirolic Nappe System*	459	66,624	46,242
VB4	*Juvavic Nappe System*	72	15,567	10,945
VB5	*Central Alpine & Taric Carbonates*	264	60,547	41,756
TWB1	*Upper Triassic karbonate reservoir*	51	5,327	1,319
LZ1	*Devonian dolomite*	22	1,809	919
DB1	*Upper Pannonian formation*	1,075	6,205	0
BRH1	*Bad Radkersburg – Hodoš pilot area / Raba fault zone*	846	122,253	81,791
	SUM	**3,624**	**297,072**	**184,036**

The assessed Inferred Resources show an average share of the stored Heat in Place in the range of 10% considering the different technical utilization schemes. Except for the HP DB1 (Upper Pannonian formation) each investigated Hydrogeothermal Play shows resources for the generation of electric power. Considering a technical conversion factor of around 10% total resource for the generation of around 1.8 GW_{El} are available in 8 Hydrogeothermal Plays in the 5 different pilot areas. However, this is only a technical potential, which does not respect any economic constraints. The by far greatest amount of Inferred Resources is, once again, evident for the Heat Supply technical scheme (297 GW_{Th}). In contrast, the single well use (Single well or Balneology Scheme) only offers limited resources. Irrespective of the environmental consequences of only using a single well for hydrogeothermal utilization only a by far smaller amount of the heat stored in a subsurface rock volume can be technically extracted by a single well in comparison to a doublet use.

The already proven resources are represented by the Measured Resources:

Table 10: Calculated Measured Resources for the investigated Hydrogeothermal Plays

ID	Name	Measured Resources (MW_{Th})		
		Scheme: Single well	*Scheme: Heat Supply*	*Scheme: Electric Power*
VB1	*Aderklaa Conglomerate*	7	114	0
VB2	*Deltafront Sediments (Eggenburgian - Ottnangian)*	1	28	0
VB3	*Tirolic Nappe System*	36	1,007	349
VB4	*Juvavic Nappe System*	10	461	102
VB5	*Central Alpine & Taric Carbonates*	5.4	20	0
TWB1	*Upper Triassic karbonate reservoir*	0.2	17.2	0
LZ1	*Devonian dolomite*	22	434	39
DB1	*Upper Pannonian formation*	24	137	0
BRH1	*Bad Radkersburg – Hodoš pilot area / Raba fault zone*	n. a.	n. a.	n. a.
	SUM	**105**	**2,218**	**490**

The already proven resources constitute only a small share of the Inferred Resources (<1%). It has to be pointed out, that the Measured Resources do not include already Installed Capacities. Nevertheless, total Measured Resources of more than 2 GW_{Th} (Heat Supply scheme) and around 500 MW_{Th} (Electric Power scheme) are already verified for the Transenergy project area. In this context a great share of the Measured Resources have been identified for the Vienna Basin pilot areas, where lots of hydrocarbon wells exist.

Finally, the assessed already Installed Capacities are shown in the table below:

Table 11: Assessed already Installed Capacities at the investigated Hydrogeothermal Plays

ID	Name	Installed Capacities (MW_{Th})		
		Scheme: Single well	*Scheme: Heat Supply*	*Scheme: Electric Power*
VB1	*Aderklaa Conglomerate*	0	0	0
VB2	*Deltafront Sediments (Eggenburgian - Ottnangian)*	0	0	0
VB3	*Tirolic Nappe System*	0	0	0
VB4	*Juvavic Nappe System*	0	0	0

VB5	*Central Alpine & Taric Carbonates*	4.9	0	0
TWB1	*Upper Triassic karbonate reservoir*	12.8	2.5	0
LZ1	*Devonian dolomite*	4.0	0	0
DB1	*Upper Pannonian formation*	36.7	23.9	6.8
BRH1	*Bad Radkersburg – Hodoš pilot area / Raba fault zone*	10	0	0
	SUM	**68.0**	**26.4**	**6.8**

The Installed Capacities have been assigned to the 3 different utilization schemes in order to opposite them to Measured Resources in order to estimate the degree of utilization. Of course this is a very pessimistic or conservative statement, as the Measured Resources only reflect the already proven hydrogeothermal resources. As the already Installed Capacities have been excluded from the assessment of Measured Resources and therefore reflect the remaining known resources, the following total degree of utilization (DoU) can be reported for the 3 different technical utilization schemes:

- Balneological- (single well) scheme: DoU ~39%
- Heat Supply Scheme: ~1%
- Electric Power Generation scheme: ~1%.

The term Reserves describes both the technical as well as economical extractable amount of heat stored in the subsurface. Probable Reserves correspond to Inferred Resources by outlining the share, which can be developed in an economically feasible way. There are various economic constraints controlling the feasibility of hydrogeothermal utilizations. Most of them are very site specific and are difficult to generalize (e.g. the load profile of local users). However general constraints are given by the maximum drilling depth and the distance to existing settlement zones. In order to give a rough estimation about Probable Reserves we have considered the limitations given by the distance to existing settlement areas. By assuming a maximum distance of 1,000 meters to settlements the Probable Reserves have been assessed for the heat supply utilization scheme. This assessment has only been executed in an experimentally way for the Hydrogeothermal Play VB03 Tirolic Nappe System, located at the Vienna Basin pilot area.

The table below shows the achieved results:

Table 12: Probable Reserves calculated for the identified Hydrogeothermal Plays considering the heat supply utilization scheme.

ID	Title	Probable Reserves (MW_{Th})

		Heat supply scheme
VB 01	Aderklaa Conglomerate	816
VB 02	Deltafront Sediments	87
VB 03	Tirolic Nappe System	22,688
VB 04	Juvavic Nappe System	5,292
VB 05	Central Alpine & Tatric Units	20,391
	TOTAL SUM	**49,273**

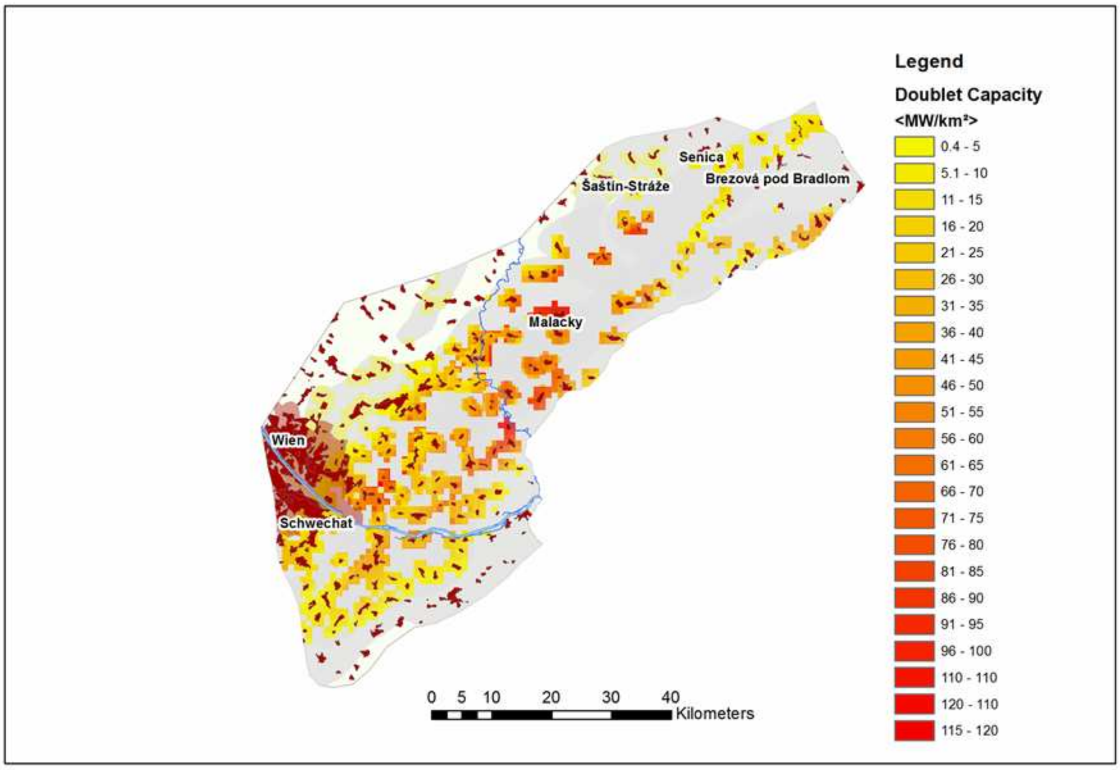

Figure 2: Probable Reserves: Hydrogeothermal doublet capacity per km² combined for all investigated Hydrogeothermal Plays. Settlement Areas: Eurosat©, Corrine Landcover (2006)

Considering a maximum distance of 1.000 meters the estimated Probable Reserves associated to the heat supply scheme are in the range of 49 GW_{Th}. The resulting hot spots for hydrogeothermal heat supply are located at the surrounding of the capital city Vienna and at the Austrian – Slovakian border region between Malacky and Schoenkirchen / Aderklaa.

5 Summary and Conclusions

Following the Canadian Geothermal Code for Public Reporting (CanGEA) we have assessed different levels of geothermal potential and resources for 9 selected Hydrogeothermal Plays (reservoir complexes) at the 5 pilot areas. The general aim of this task was to give an overview about the limitations and opportunities for different schemes of hydrogeothermal utilization in the Transenergy pilot areas.

The maximum level of hydrogeothermal potential is given by the calculated Heat in Place, which is in the range of several Terawatts. The assessed Inferred Resources can be seen as an upper technical limit for hydrogeothermal utilizations neglecting any economic constraints. Taking into account the different utilization schemes Inferred Resources between 4 GW_{Th} (Single Well use) and 300 GW_{Th} (Heat Supply scheme) could be assessed for the selected Hydrogeothermal Plays. In practice these resources are not likely to be realized by technical measures, as all the available surface space would be systematically covered by geothermal doublets in a so called multiplet scheme. In contrast the already proven resources, described by the term Measured Resources, only represent a small share of the realizable resources, as they have been derived from already drilled wells and boreholes, which have shown a significant inflow of natural thermal water. However, taking into account the already Installed Capacities only a very small share of the proven resources (less than 1%) are already realized leaving great opportunities for future development.

The realized assessment of resources at the different levels of confidence and resolution has shown that the Balneological- or Single Well scheme is the least efficient way to extract geothermal heat from the subsurface. Taking also into account environmental aspects, such as the pollution of surface streams or the attenuation of pressure in the exploited aquifers, the Transenergy group strongly advises against a single well scheme for pure energetic use of natural thermal water.

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