Tolmin – expectations for the first geothermal electric power plant in the Alps

PETER KRALJ

GEJZIR CONSULTING, EON Research Centre, 1113 Ljubljana, Turnerjeva 17, SLOVENIA, e-mail: peter.kralj@siol.net

Abstract

The town of Tolmin, W Slovenia, is situated in the southern ending of the Julian Alps near Slovenian – Italian border. There is no utilisation of geothermal energy in this area any more. Before the First World War, there was a small spa in the vicinity of Tolmin, which was renown for healing thermal water. In the thirthies of the past century, the spa was closed. There is also another natural spring of low temperature (22°C) thermal water NW of Tolmin.

With planned deep drilling, we intend to tap one of several carbonate aquifers. Expected temperature is 109°C and the outflow 45 l/s. Geothermal gradient is lower in western Slovenia than in the Mura basin in the East, and for this reason, drilling costs will strongly control the economy of the project. Energy, produced from the captured water will be sufficient for electricity production, district heating of the Tolmin downtown area and for the planned spa and recreation center. Estimated drilling costs for a doublette and district heating amount to 7,5 million euro.

Keywords: geothermal energy, cascade utilisation, electric power production, district heating, Slovenia

Introduction

Near the town of Tolmin, at the Volče village, a small spa already existed before the First World War. Owing to the war devastation and the following recession, the spa was abandoned. Natural spring of thermal water having the temperature of 22°C occurs in the channel of the Tolminka river, immediately under Hudičev most (Devil's bridge), in a distance of 1,6 km from the foreseen well location.

The fundation of independent Republic of Slovenia and its economic transformation created favourable conditions for intensive developmentof tourism in the Tolmin area, including the idea of restoration of thermal water utilisation.

Geology

In a broader Tolmin area, three large tectonic units meet – the Dinaric Alps, Slovenian Trench (westernmost part of the Inner Dinaric Unit) and the Overthrust of Southern Alps, which underwent extensive tectonic deformations (Fig. 1). The area is cut by several faults, the most important being the Idria Fault. Carbonate rocks ranging in age from Triassic to Upper Cretaceous prevail. They are characterised by shallow water environment on the Dinaric platform, and deep water environment in the Slovenian Trench. Carbonate sedimentation was accompanied by sedimentation of clastic, pyroclastic and flysch deposits. The uppermost sediments in the Tolmin valley are Quaternary alluvial sediments and glacial deposits (moraine and lake chalk). The thickness of Triassic to Upper Cretaceous deposits amounts to 3000 – 3500 m in the Dinaric Alps South of Tolmin, and to about 1500 m in Slovenian Trench.

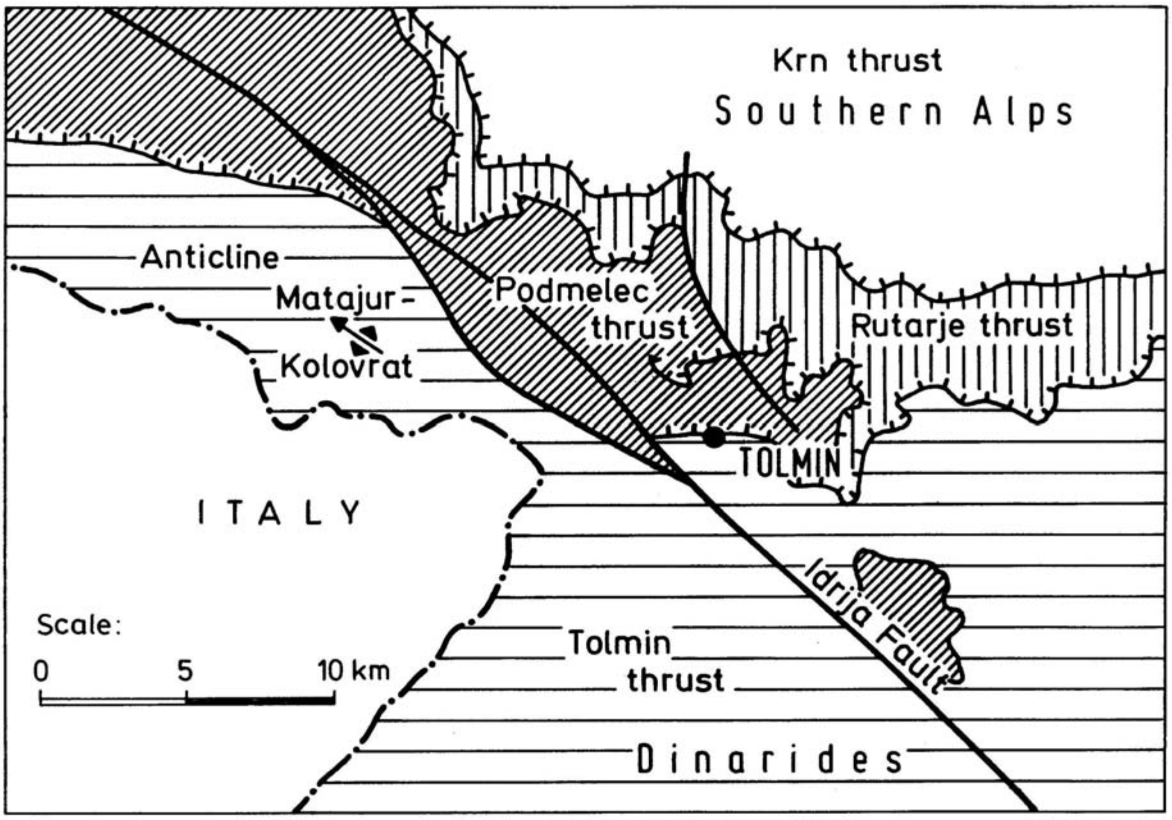

Fig. 1. Tectonic sketch map of broader Tolmin area (adapted after [1, 2]). The Podmelec and Rutarje thrusts belong to Inner Dinarides.

The territory of broader Tolmin area is composed of several overthrusts developed from a large broken fold developed in Early Tertiary [3] during Late Alpine orogeny. The thrusts are directed from the North and North-East [4] towards the South-West having rectangular orientation with respect to Dinaric direction of geological structures. To capture thermal water with expected temperature of over 80 °C, the Tolmin Thrust and the underlying flysch, Cretaceous and Jurrasic impermeable to poorly permeable strata must be drilled throughout to reach the desired thermal aquifer in Upper Triassic dolomites. The Tolmin thrust is composed of an up to 3000 m thick succession of Mesozoic carbonate and clastic rocks (Fig. 2).

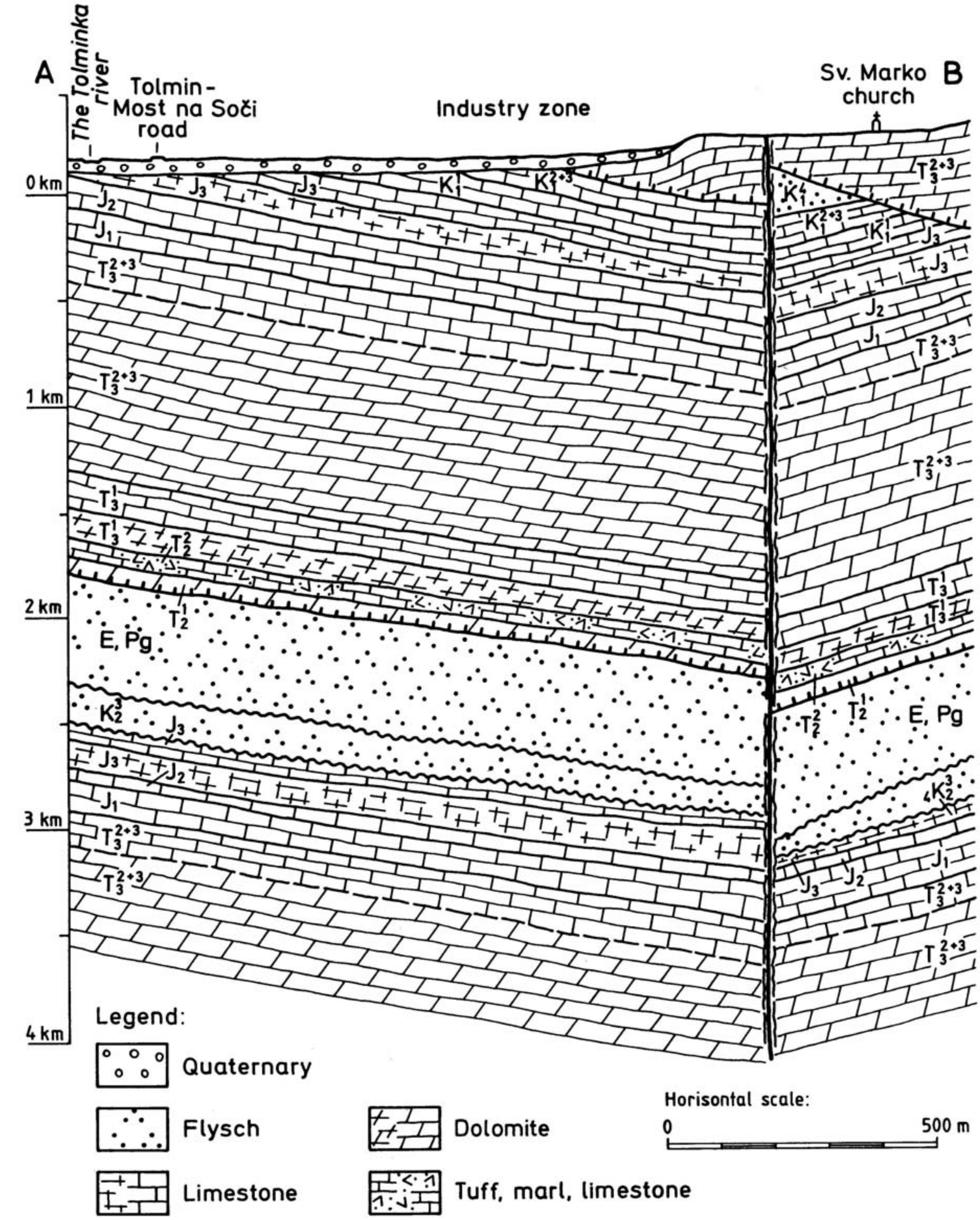

Fig. 2: Geological cross-section A-B (see also Fig.3) through the planned drilling area.

With respect to petrological parameters of rocks [5, 6] (intergranular porosity and permeability, fracture porosity) and the formation thickness, an about 1000 m thick layer of Upper Triassic Main Dolomite and an up to 150 m thick layer of Cordevolian limestone are assumed to be the most favourable thermal aquifers. According to our up to date experience, Jurrasic and Createaceous limestones are far less porous and permeable except for paleokarstic porosity.

Upper Cretaceous flysch sediments and Carnian limestones interlayered with schistous marls and tuffs can act as good aquiclude horizons.

For deep structure interpretation of the Tolmin area, fault systems are of great importance, too. Particularly outstanding are the Idria and Tolmin faults. The Idria fault is encountered as a broad tectonic zone trending in the Dinaric direction along the Soča valley. The fault is a combination of vertical and horizontal displacement in some kilometre distance. The Tolmin fault has the Dinaric trending, too. Particularly important are vertical displacements in the western fault flank which brought into contact Triassic and Jurrasic sequences with Upper Cretaceous flysch.

Hydrogeology

Chemical composition of thermal water can be predicted from the analyses of nearby springs which probably have deep circulation. Particularly important are two springs, named Bele and Črne vode at the village Volče. As mentioned before, there used to be a thermal spa »I bagni« over 80 years ago, but unfortunately, the spring is not accesable any more owing to the creek channel regulations. As a comparison, thermal spring from abandoned spa at the Hotavlje village, about 30 km from Tolmin has been analysed, too (Table 1).

Mineralisation of water in the springs Črne and Bele vode is relatively low, attaining in average 246,85 mg/l, and 302,95 mg/l. The water is dominated by calcium and bicarbonate ions. Thermal water from Hotavlje has low mineralisation too, attaining 280,4 mg/l. The composition is dominated by calcium, magnesium and bicarbonate ions. In all analysed samples, chloride amount is insignificant. Sulfate is very low, although in the sample from Hotavlje its amount is twice as high as in the samples from Črne and Bele vode.

For thermal water, which is to be captured by the planned welling, low mineralisation is foreseen too, and the composition dominated by sodium, calcium and bicarbonate ions. The presence of sulfate is possible and its amount will be strongly dependent on local rock composition. The expected mineralisation and composition is in accordance with observations in Slovenian spa resorts producing thermal water from lithologically and stratigraphically similar, although shallower carbonate aquifers, i.e. Dolenjske Spa (T = 36,2 °C, TDS = 292 mg/l) or Čatež Spa (T = 57,2 °C, TDS = 335 mg/l)

Intensive tectonic activity and long-scale displacements in the Alpine region removed geothermal aquifers into different depths. For this reason, the temperature calculation in geothermal aquifer bases on the present position relying on geothermal gradient.

Geothermal gradient was determined on data basis obtained from wells, which tapped the same or similar lithologic units. In carbonate rocks, geothermal gradient is relatively low and attains to about 20 ^{o}C/km. In impermeable flysch layers, which act as hydrogeological barrier, the gradient is much higher, about 37 ^{o}C/km.

Table 1. Major ions and parameters determined in the analysed spring and captured waters. ČV – Črne vode, BV – Bele vode and Ho – Hotavlje.

Ion/gas/ parameter	**Unit**	**ČV-1**	**ČV-2**	**BV-1**	**Ho-1**
NH_4^+	mg/l	<0,01	<0,01	<0,01	<0,01
Na^+	mg/l	2,1	1,4	4,2	1,6
K^+	mg/l	0,4	0,4	1	1,1
Ca^{2+}	mg/l	55	62	72	39
Mg^{2+}	mg/l	<1	2	1	22
Cl^-	mg/l	1,1	1,1	1,4	1,0
Br^-	mg/l	0,011	0,007	0,014	0,009
J^-,	mg/l	<0,05	<0,05	<0,05	<0,05
F^-	mg/l	<0,02	<0,02	<0,02	0,024
SO_4^{2-}	mg/l	7,9	6,5	6,9	17
NO_2^-	mg/l	<0,007	<0,007	<0,007	<0,007
NO_3^-	mg/l	3,5	3,1	3,5	2,2
HCO_3^-	mg/l	162	183	212	195
CO_2	mg/l	20	29	22	7
H_2S	mg/l	<0,05	<0,05	<0,05	<0,05
COD	mg/l	0,6	0,6	0,4	0,4
TOC	mg/l	0,7	1,3	0,9	1,2
SH	N^o	7,8	9,2	10,3	10,6
CH	N^o	7,4	8,4	9,7	8,9
m-alkalinity	Mekv/l	2,6	3	3,5	1,7
Conductivity	µS/cm	257	314	322	318
TDI	mg/l	232,77	260,84	302,95	280,4
T	^{o}C	12,1	11,7	11,8	20,3
pH	N^o	8,93	7,99	8,37	7,72

CH, carbonate hardness
SH, silicate hardness

Average depth of the uppermost parts of the desired geothermal aquifer (Haupt Dolomite) is 4100 m (3400 m and 5500 m), thickness of flysch sediments amounts to 450 m, and the rest are carbonate rocks. Multiplying the expected thickness with the geothermal gradient, the value of 89.65 ^{o}C is obtained. If annual average temperature in the area amounting to 10.5 ^{o}C is added, and the temperature elevation owing to thermal convection in the aquifer (approx. 9 ^{o}C), the temperature of 109 ^{o}C is obtained (from 100 ^{o}C to 115 ^{o}C). Owing to the expected aquifer thickness ranging from 800 m to 1000 m, the aquifer must be hydraulically interconnected in the whole Tolmin area, so that the temperature of captured water is expected to be more or less independent of the well location. The yield of the planned research well can be estimated on the basis of the aquifer thickness. Dolomite layers are well permeable, although the coefficient of permeability »k« is expected to be somewhat lower owing to an appreciable aquifer depth amounting to about 10^{-6} m/s. Hydrodynamic calculation of the well yield having final drilling diameter of 8.5`` indicates that about 45 l/s of thermal water is the expected production. Foreseen energy potential of geothermal well amounts to 14 MW_t.

The concept of energy use

Cascade utilisation of geothermal energy potential of 14 MW_t is planned for:

- Electricity production (300 kW_e) in the temperature range of 109-93 ºC,
- District heating of a part of the town of Tolmin (7 MW_t) in the temperature range of 93-56 ºC,
- Heat demand for Spa resort (3 MW_t) in the temperature range of 56-35 ºC, and
- Other users with the emphasis on the lower cascade part, mainly agriculture and aquaculture (Fig. 3).

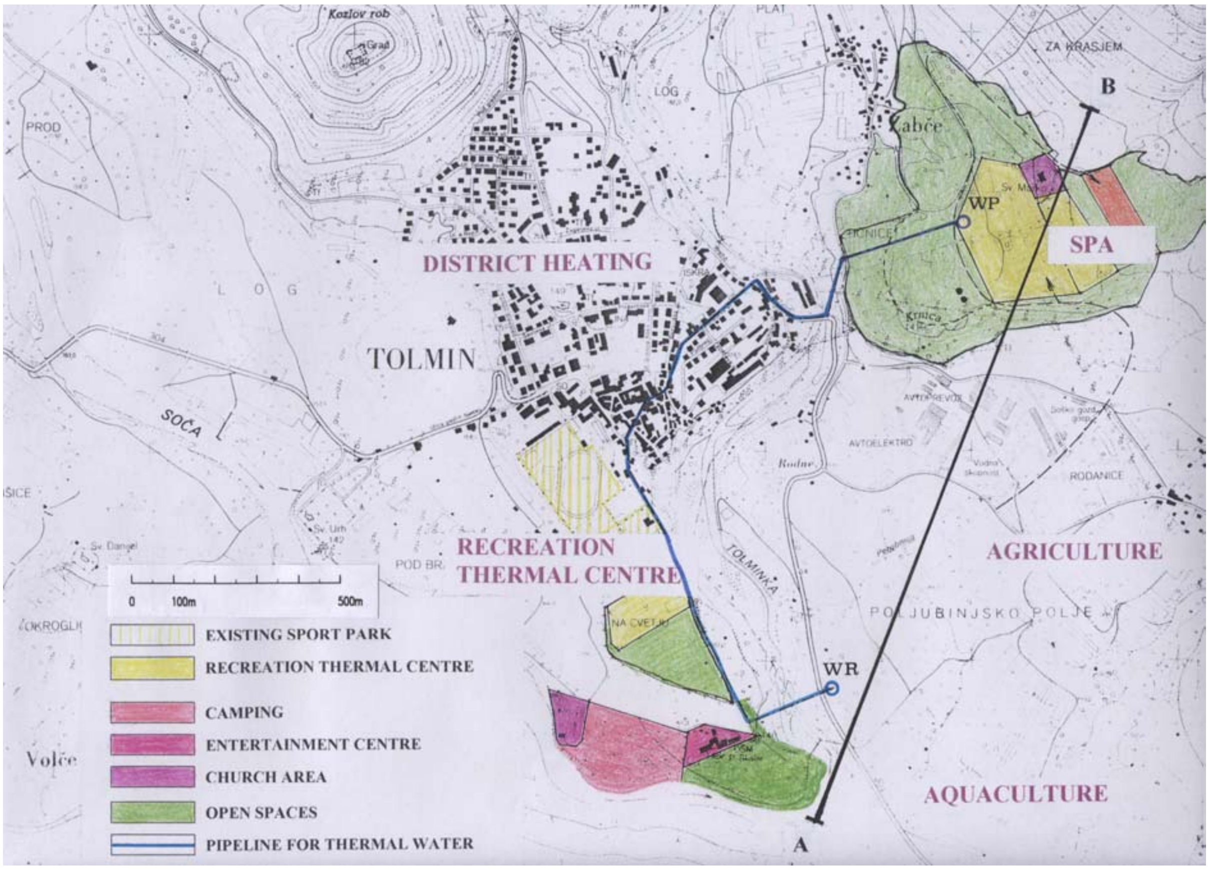

Fig. 3: Planned doublet system and users of geothermal energy.

The town of Tolmin is the centre of the Tolmin municipality. It is situated on a natural terrase, developed by the rivers Soča in Tolminka, which join in the southern part of the town. In the northern part of the town, there is a hill with the remains of a midevial castle. The number of inhabitants amounts to 3718. According to the data from November 2001, there are 604 individual houses, 976 apartments in 84 apartment buildings and 181 business premises occupying 79.728, 46.619 and 62.996 sq. m respectively. Idustrial zone consists of 9 building complexes having 27.274 sq.m, and the majority of them is under than 25 years old. Energy consumption is estimated to 38.375,64 MWh/year (individual houses and apartments buildings 209 kWh/m^2 per year and business premises to 132,3 kWh/m^2 per year). Annual oil and liquified natural gas consumption for heating and preparation of sanitary water amounts to 1.894.780 l and 41.974 m^3, respectively [7]. The consumption of electric power for heating purposes can not be specified. Overall annual consumption (in the year 1999), however, amounts to 12.640.279 kWh. For the next ten years, the town spreading for additional 65.300 m^2 heating surfaces is foreseen. Annual heat demand will increase for 11.733 MWh.

The planned geothermal project will provide annually:

- 2.400.000 kWh/year of electric power (20 % of the total need of the town of Tolmin), and
- 27.628 MWh/year of heat for district heating and preparation of sanitary water (72 % of the total need of the town of Tolmin).

Conclusions

In the north, the town of Tolmin borders with the Triglav National Park, and along with exceptional beauty of the Soča river, it forms a pristine Alpine environment. There`s no need to emphasise what means the replacement 72 % of classic energy resources used for heating purposes and production of 20 % of total demand for electric power with an environment friendly, renewable and sustainable geothermal energy. Economy calculation elaborated in the year 2001 has shown that the project is economically justified at the annual sale of 13.340 MWh of heat at the price of 31,10 €/MWh.

References

1. S. Buser, Basic geological map of SFRJ, scale 1:100.000 – Sheet Tolmin and Udine, Zvezni geološki zavod, (1986a)
2. S. Buser, Comment to Sheet Tolmin and Udine, Basic geological map of SFRJ, scale 1:100.000, Zvezni geološki zavod, (1986b), p. 103
3. D. Roeder and D. Lindsey, Barcis area (Veneto, Friuli, Slovenia): Architecture and geodynamics. *Nafta*, **43**,11 509-548 (1992)
4. L. Placer, Geološka zgradba jugozahodne Slovenije, *Geologija*, **16**, 27-60 (1981)
5. S. Buser, 1989: Development of the Dinaric and the Julian carbonate platforms and of the intermediate Slovenian basin (NW Yugoslavia). *Mem. Soc. Geol. Ital.* **40**, 313-320 (1987)
6. D. Kuščer, K. Grad, A. Nosan and B. Ogorelec, Geološke raziskave soške doline med Bovcem in Kobaridom. *Geologija*, **17**, 425-476 (1974)
7. M. Drole, M. Sekavčnik and M. Tuma, The Energy Balance of the Tolmin Municipality, *Journal of Mechanical Engineering*, **6**, 355-360 (2002)