COST OF ENERGY TRANSPORT

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Abstract

Deposits of energy products (oil, coal, natural gas, …) are located on various parts of the earth, depending on the conditions taking place during the million years of earth's development. This is why energy or energy products need to be transported to the intermediate or indirectly to the final consumer. The transport can take place in various forms, depending on the energy product and the physical state of this energy product. Solid and liquid energy products (coal, oil) are transported by means of shipping, railway and road transport. Oil is also transported by means of oil pipelines, whereas natural gas is transported in the gaseous state by means of gas pipelines or liquefied on board of special vessels for liquefied natural gas, and less often by means of railway and road transport in thermally insulated tanks. Electricity is a secondary energy product and is the most widely-spread and practical form of energy due to its branched infrastructure all the way to the final consumer. Remote heating covers shortest distances.

Slovenia is small and therefore the analysis of transport costs was performed at the longest possible distance from port in Koper to Lendava. The transport costs mainly depend on the quantity of transported energy products. Therefore, the quantity of 100 tons of lignite, which gives 1000 GJ of energy at average caloric value, was chosen as the reference.

1. Introduction

Generally a network is defined as a unit formed by mutually functionally connected network elements. The definition applies to energy network as well as road, gas and railway networks, through which energy is transported.

When speaking of networks generally, we picture a network of a certain country, for example Slovenian. Such a network is normally connected with the networks of the neighbouring countries.

Due to diversified investments in the near past and a different concept of development in the former common country we can determine that the networks are quite variously constructed or follow the world development in their own way, but momentarily they meet Slovenian demands. Transit is a different story – there are congestions in road transport and transport of electricity.

2. Networks

Slovenia is such a small country that when comparing costs of transport, we compared the costs of energy distribution while the data was mainly collected from the websites of energy suppliers. For a clearer image first individual networks will be presented.

Railway network

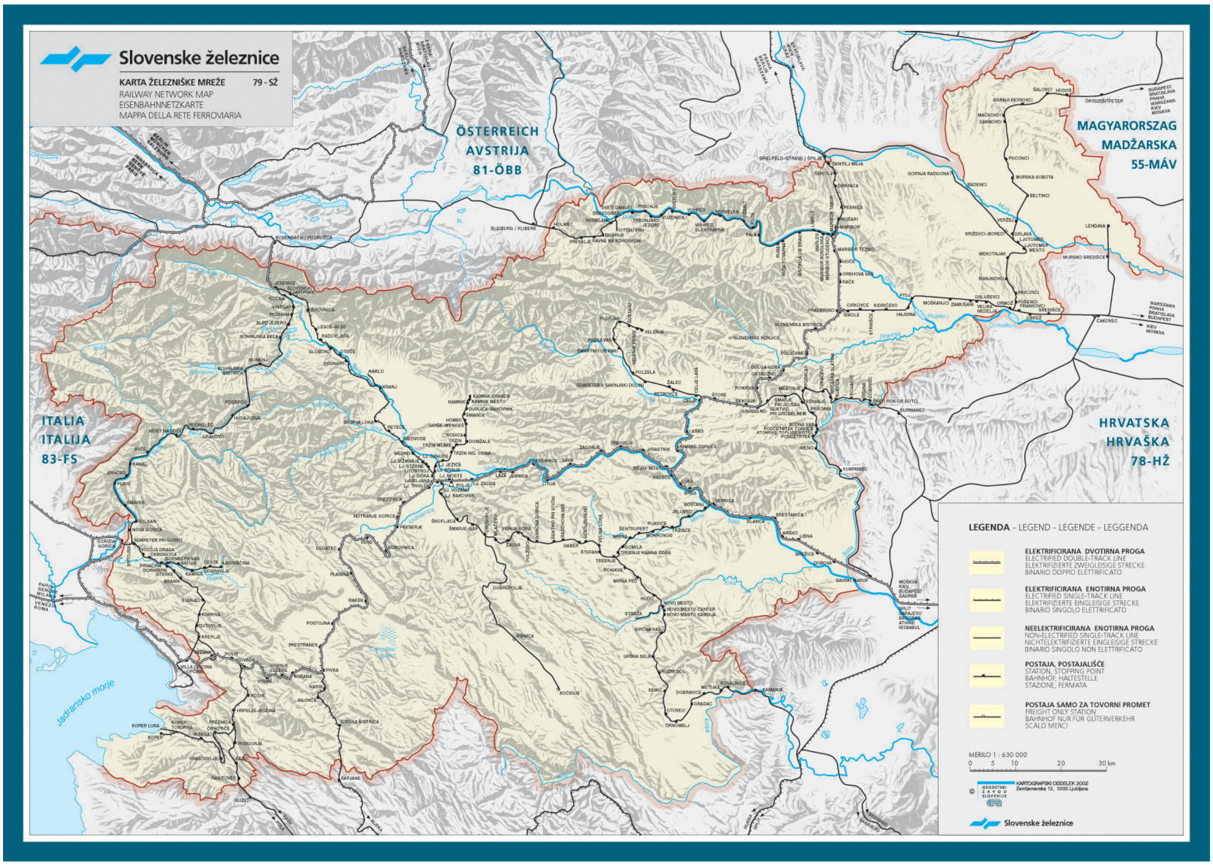

Figure 1: Railway network in Republic of Slovenia

Table 1: Statistical data on railway lines in Republic of Slovenia

statistical data	**km**
overall length of lines	1228,6
dual-track line	330,9
single-track line	897,7
for freight transport	101,5
for passenger transport	2,2
for combined transport	1124,9
electro traction	
length of electrified lines	503,5
length of tracks	1.559,6
all bridges, viaducts and culverts (number)	3.181,0
all bridges, viaducts and culverts (km)	13,1
tunnels and galleries (number)	94

Road network

Figure 2: Road network in Republic of Slovenia

In Slovenia there are 6,253 km of categorized state roads altogether. These are, according to traffic and connection functions in space, categorized in: motorways, high-speed roads, main roads of 1st class, main roads of 2nd class, and regional roads of 1st class, regional roads of 2nd class and regional roads of 3rd class. Management, maintenance and development of motorways and some four-lane high-speed roads is in the jurisdiction of DARS, d.d., the Motorway company of the Republic of Slovenia. Management, maintenance and development of the remaining state road transport – main and regional roads – are under the authority of the Directorate of the Republic of Slovenia for Roads.

Table 2: Lengths of roads

road category	**length in km**
motorways	417
high-speed roads	60
two-lane high-speed roads	82
main roads	972
regional roads	4.810
local roads	13.814
public paths	18.245

Gas pipeline network

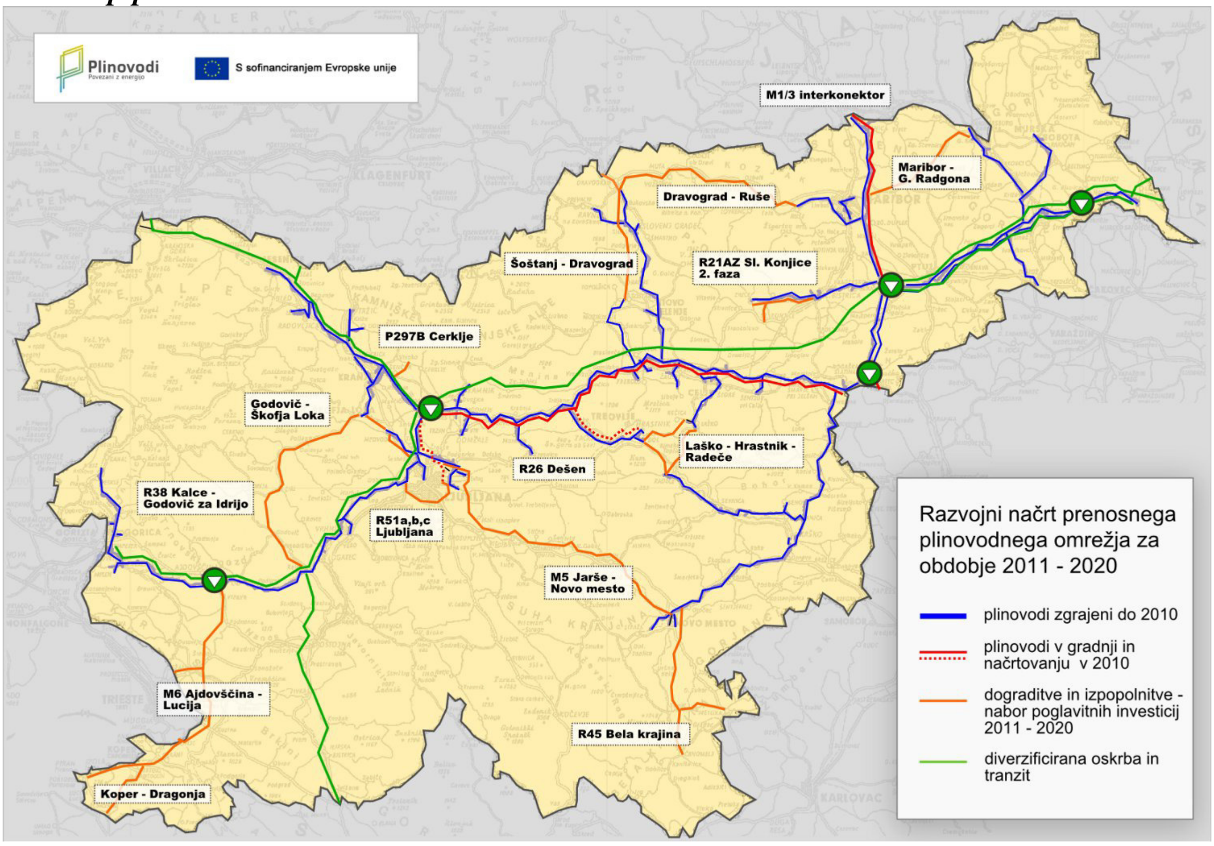

Figure 3: Transmission gas pipeline network of natural gas in Republic of Slovenia

Transmission gas pipeline network in the Republic of Slovenia covers approximately 957 km of gas pipelines, a compressor station in Kidričevo, over 300 measuring regulating, measuring and sectional stations. Devices which enable the control and maintenance of the network are built on the crucial places of the transmission gas pipeline network. An aid in realization of the control and maintenance is the informative and telemetric control system, which is used to monitor and manage the operation of the gas pipeline network. The transmission gas pipeline network is entirely cathodic protected for the purposes of anti-corrosive protection.

The development plan for the period of 2005 – 2014 anticipates, within the framework of the existing transmission gas pipeline network, the construction of the following new transmission gas pipelines:

The basic backbone of the new gas pipeline network will be built for the working pressure of 70 bars. The overall length of all planned new transmission gas pipelines is 450 km. The present capacity of the system will with the anticipated investment increase by more than 100%. For a medium-term period this signifies a sufficient capacity of the transmission gas pipeline network, which will serve the needs for the transmission of natural gas for the planned thermo – energetic objects, the development in the field of wide consumerism and industry as well as enable certain free capacities for a further development.

Electricity network

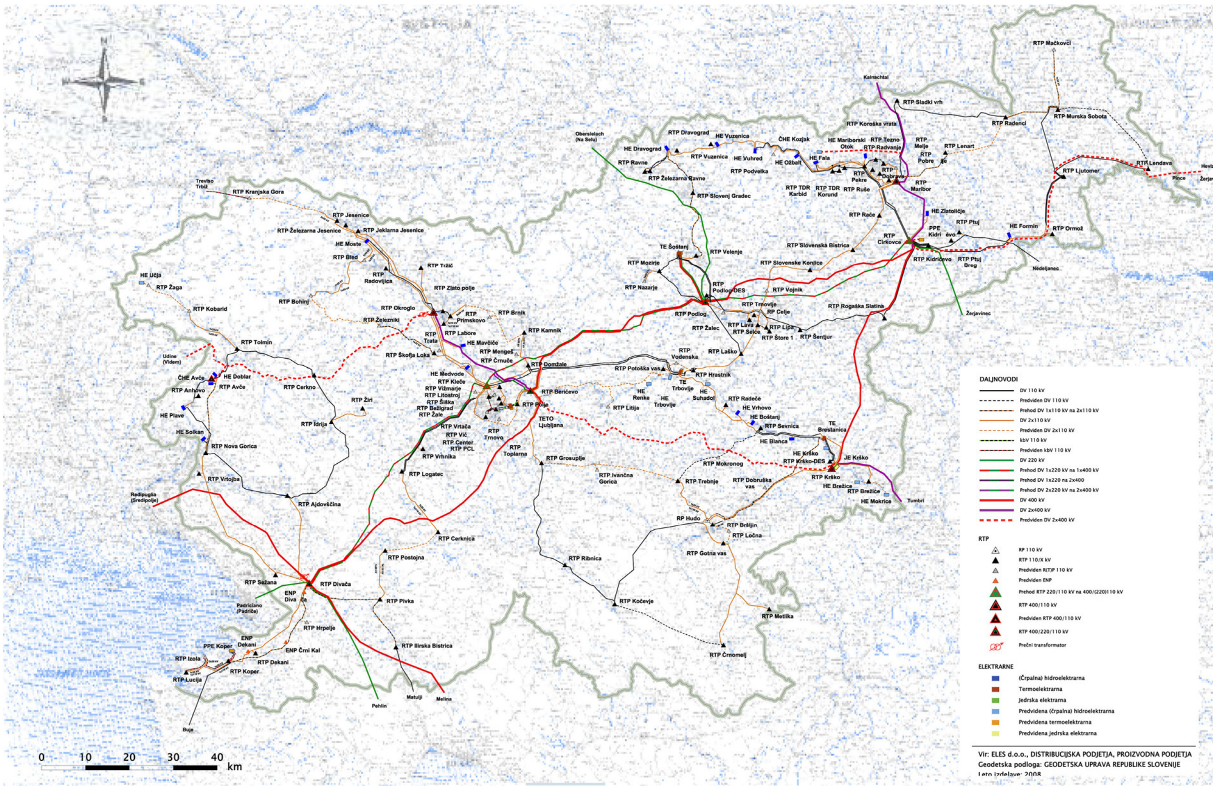

Figure 4: Transmission electricity network in Republic of Slovenia

Table 4: Transmission lines and electric generating stations according to voltage levels

Voltage / **Element**		**110 kV**	**220 kV**	**400 kV**	**overall**
transmission lines	[km]	1667	328	508	2503
energy transformer	number	11	15	8	34
interrupter	number	193	30	28	251
isolating switch	number	1652	240	281	2173
instrument transformer	number	1139	136	180	1455
arrester	number	435	72	38	545

Table 5: Distribution lines and electric generating stations

Voltage / Company/ surface area/ number of consumers		110 kV	35/20/10 kV	0,4 kV	overall
Elektro Celje 4.345 km^2 155.460	transmission lines [km]	102	3.232	14.972	18.306
	transformers [number]	14	16	2.992	3.022
Elektro Gorenjska 2.091 km^2 82.000	transmission lines [km]	99	1429	3717	5244
	transformers [number]	17	16	1569	1602
Elektro Ljubljana 5.231 km^2 306.027	transmission lines [km]	279	5.202	12.399	17.601
	transformers [number]	23	30	4.892	4.945
Elektro Maribor 3.992 km^2	transmission lines [km]	165	3.630	11.400	15.195
	transformers [number]	17	2	3.200	3.219
Elektro Primorska 4.335 km^2 119.322	transmission lines [km]	57	2.067	5.731	8.318
	transformers [number]	25	12 (+16 reserve)	2.561	2.598 (2.614)

Our transmission lines of voltage levels of 400 and 220 kV are connected with the interconnection UCTE which helps its members in the event of difficulties. Our transmission lines are full due to trading and do not serve a connection purpose which is why they were built.

The majority of energy consumption is currently in the western part of Slovenia, together with the transmission from Eastern Europe towards Italy. Half of this energy runs through the Podlog switchyard. According to the size of some units in comparison with the overall installed capacity, dissolution of this part of the interconnection is possible.

A bigger priority than the construction of transmission lines for the transport across Slovenia is the construction of connecting transmission lines which will ensure a self-sufficient supply of the Republic of Slovenia with energy, provided that the production facilities are constructed simultaneously. The priorities on the highest voltage level are:

- Transmission line Krško - Ljubljana, unfortunately not intended past Novo mesto.
- Transmission line Šoštanj – Podlog; urgent due to the construction of a new block (VI)
- Looping of the pumping water station Avče into the 400 kV network (from Nova Gorica or from Okroglo)
- Looping of the pumping water station Kozjak into the 400 kV network (opening of the west system Maribor – Kainachtal).

Due to the dissatisfaction of people in cases of constructions of high-voltage overhead lines throughout Europe, the solution is in underground cables.

3. Energy consumption

As soon as we want to determine cost of energy transport we need to know the quantity of energy and the level of transport (voltage, pressure). Energy consumption in Slovenia has not change significantly in the last few years – it has risen and dropped. Figure 5 shows consumption and production of energy from own sources for period from 1990 to 2010.

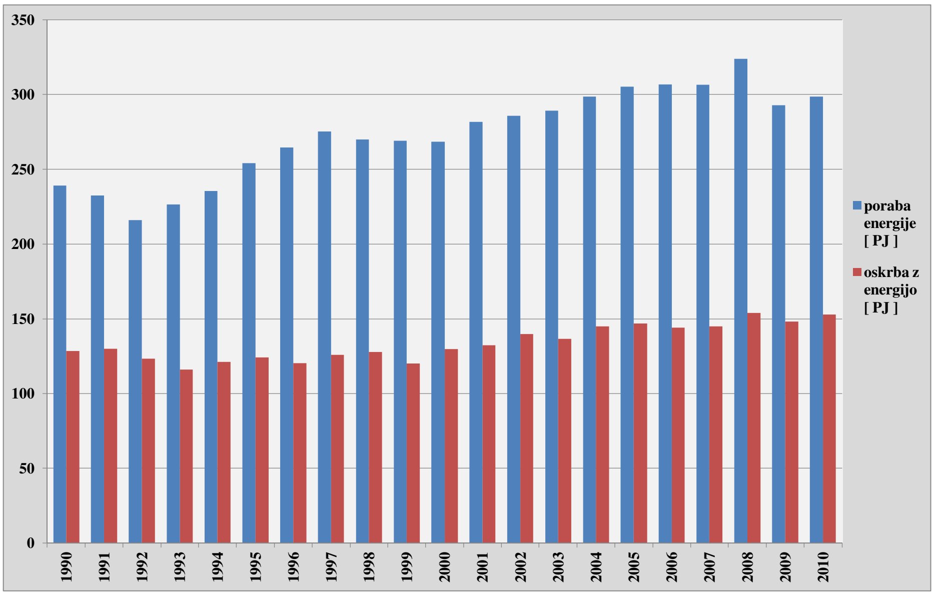

Figure 5: Energy self-sufficiency in Republic of Slovenia

Data review shows that energy production in the Republic of Slovenia stays at approximately the same level through whole period shown in figure 5. Its amount is around 50 % of the total energy consumption in the year 2010. That means that deficit must be imported. The Republic of Slovenia imports mainly driving fuel, natural gas and electric energy which loads the transport systems and raises energy price.

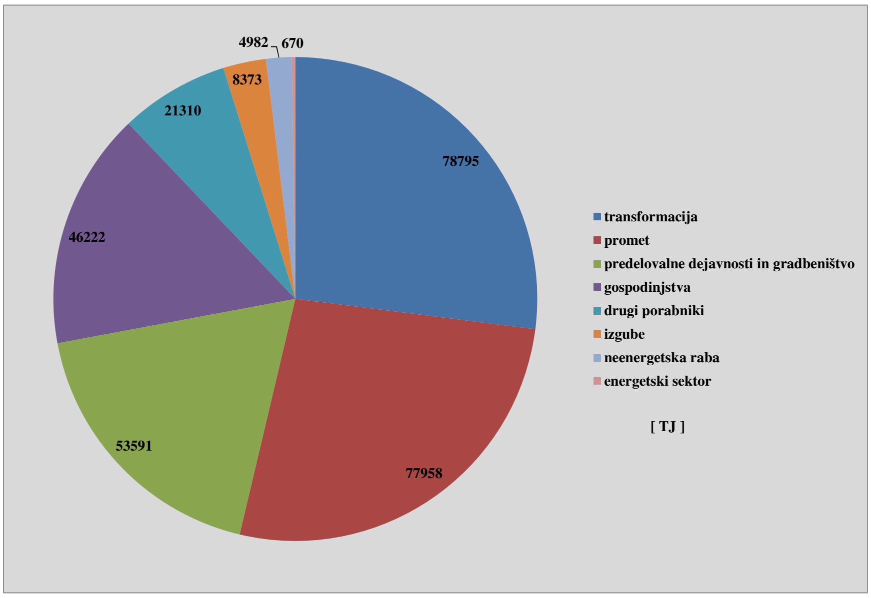

Figure 6: Energy consumption in Republic of Slovenia by sectors

4. Comparison of costs of energy product transport

Our basis for comparison was a composition of a train and 10 railway carriages of Velenje lignite, respectively, which equals 1,100 GJ of energy or 305.5 MWh of electricity or 32,281 Sm^3 of natural gas or 30,387 l of heating gas oil. Since we concentrated on the energy supply of the Slovenian people, we took into account only LV and MV electricity networks when considering electricity transmission.

Table 6: Comparison of costs of energy product transport

	Quantity	Transport mode	Energy price [EUR/MJ]	Transport price [EUR/MJ]	Transport cost and energy cost ratio		Transport cost and energy cost [EUR/MJ]
coal	100 t	railway	0,0025	0,00172	0,408	0,592	0,00422
coal	100 t	road	0,0025	0,00204	0,449	0,551	0,00454
ELKO	30 387 l	railway	0,01619	0,00041	0,025	0,975	0,0166
ELKO	30 387 l	road	0,01619	0,00045	0,027	0,973	0,01664
diesel	32 350 l	road	0,02767	0,00213	0,071	0,929	0,0298
natural gas	32 281 Sm^3	gas pipeline, transmission network	0,01767	0,00192	0,098	0,902	0,01959
natural gas	32 281 Sm^3	gas pipeline, distribution network	0,01767	0,00331	0,158	0,842	0,02098
UN		road	0,02941	0,00000	0,000	1,000	0,02941
electricity	305,5 MWh	MV network (t>2500 ur)	0,01502	0,00457	0,233	0,767	0,01959
electricity	305,5 MWh	MV network (t<2500 ur)	0,01502	0,00716	0,323	0,677	0,02218
electricity	305,5 MWh	LV network (t>2500 ur)	0,01522	0,01047	0,408	0,592	0,02569
electricity	305,5 MWh	LV network (t<2500 ur)	0,01522	0,01680	0,525	0,475	0,03202
district heating	1100 GJ	household	0,00546	0,00017	0,030	0,970	0,005627
district heating	1100 GJ	industry	0,00596	0,00052	0,080	0,920	0,006476

5. Conclusion

A true comparison among various energy products is possible only when comparing the acquired useful amount of energy per cost unit and therefore prior to the comparison we need to be acquainted with much more data than merely selling cost of the energy product, energy. Extra costs need to be considered too, caused by individual fuels, e.g. manipulation costs, warehousing costs, maintenance of energy device costs, amortization of devices,…

By means of comparison of the costs of energy product transport we can reach interesting conclusions.

The comparison indicates that energy is not transported in the cheapest manner. Energy concentration per unit, which is normal for transmission calculation, is the highest in liquid fuels. Therefore also the overall expense of energy and transmission is the lowest as regards consumers. The exception is coal which is cheap but with high transport costs due to low caloric value. The second exception is remote heating with low transport cost which probably does not include all costs – owners are municipalities and they desire lowest possible air pollution.

According to the low recovery in cases of transformation from primary sources, electricity should be three times more expensive, which is not the case. The cost differs in relation to the voltage level of the consumer. Larger energy consumers have the lowest transport costs. The transport cost is relatively high on a low voltage level, and when taking into consideration the construction of electricity system, its maintenance as well as constant upgrading and improvement we can see that the cost in the same quantity class as the energy price is realistic.

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