University of Maribor

Faculty of Energy Technology

Journal of ENERGY TECHNOLOGY

Volume 9 / Issue 3

OCTOBER 2016

www.fe.um.si/en/jet.html

Journal of
ENERGY TECHNOLOGY

VOLUME 9 / Issue 3

Revija Journal of Energy Technology (JET) je indeksirana v bazi INSPEC©.
The Journal of Energy Technology (JET) is indexed and abstracted in database INSPEC©.

JOURNAL OF ENERGY TECHNOLOGY

Izhajanje revije / PUBLISHING

Revija izhaja štirikrat letno v nakladi 150 izvodov. Članki so dostopni na spletni strani revije - www.fe.um.si/si/jet.html / The journal is published four times a year. Articles are available at the journal's home page - www.fe.um.si/en/jet.html.
Cena posameznega izvoda revije (brez DDV) / Price per issue (VAT not included in price): 50,00 EUR
Informacije o naročninah / Subscription information: http://www.fe.um.si/en/jet/subscriptions.html

Lektoriranje / LANGUAGE EDITING

Terry T. JACKSON

Oblikovanje in tisk / DESIGN AND PRINT

Fotografika, Boštjan Colarič s.p.

Naslovna fotografija / COVER PHOTOGRAPH

Jurij AVSEC

Oblikovanje znaka revije / JOURNAL AND LOGO DESIGN

Andrej PREDIN

Ustanovni urednik / FOUNDING EDITOR

Andrej PREDIN

Izdajanje revije JET finančno podpira Javna agencija za raziskovalno dejavnost Republike Slovenije iz sredstev državnega proračuna iz naslova razpisa za sofinanciranje domačih znanstvenih periodičnih publikacij / The Journal of Energy Technology is co-financed by the Slovenian Research Agency.

Spoštovani bralci revije Journal of energy technology (JET)

Gibalo današnjega sveta je energija ogljikovodikov. Transport predstavlja enega izmed pomembnejših porabnikov in onesnaževalcev. Srce vsakega tovornega, osebnega avtomobila, ladje ali vlaka je motor. Bencinski in dizelski motorji spadajo v skupino motorjev z notranjim zgorevanjem. Njihova zgodovina nastanka sega v začetke devetnajstega stoletja. Skozi čas so se motorji izpopolnili in dosegajo vedno boljše izkoristke. Sodobni motorji z notranjim zgorevanjem s pomočjo diagnostike, senzorjev in računalnikov delujejo vedno bolj dovršeno, hkrati imajo vedno več električnih komponent. Zaradi globalnih ekoloških problemov, boljše učinkovitosti in grožnje, da bodo nekega dne določene vrste ogljikovodikov dejansko pošle, se pojavljajo novi tipi pogonov. Mednje vsekakor lahko uvrstimo električne pogone, kakor tudi hibride med električnimi pogoni in motorji z notranjim zgorevanjem. Priča smo velikemu razvoju električnih pogonov in poleg klasičnih se vedno bolj uveljavljajo tudi pogoni z gorivnimi celicami. Trenutno so na trgu trije avtomobili z gorivnimi celicami in neprimerno večje število avtomobilov s klasičnimi električnimi pogoni ali hibridi. Živimo v nepredvidljivem času, kjer poteka razvoj motorjev z veliko hitrostjo z daljnosežnimi posledicami.

Jurij AVSEC
odgovorni urednik revije JET

Dear Readers of the Journal of Energy Technology (JET)

The driving force of the world of today is the energy of hydrocarbons, and transportation is one of the major consumers and polluters. At the heart of each freight vehicle, passenger car, ship and train are engines. Petrol and diesel engines date back to the beginnings of the 19th century. Over time, the engines have been improved, continually achieving great efficiency. Modern internal combustion engines using diagnostics, sensors and computers operate in an increasingly sophisticated manner, having more and more electrical components. Due to global environmental problems, better efficiency, and the threat that certain types of hydrocarbons may actually be close to exhaustion, new types of engines are appearing. We certainly can include electric engines, as well as hybrids between electric engines and internal combustion engines as a promising development. However, classic electric engines are being overtaken by fuel cell drives. Currently on the market are three cars with fuel cells and even much larger number of cars with conventional electrical engines. We live in unpredictable times, in which engines are being developed at high speed with far-reaching consequences.

Jurij AVSEC
Editor-in-chief of JET

Table of Contents / Kazalo

Sustainable energy planning in Slovenian municipalities

Trajnostno energetsko načrtovanje v slovenskih občinah

Rebeka Kovačič Lukman **11**

Energy renovation of the Letuš Cultural Centre

Energetska prenova Kulturnega doma Letuš

Bogdan Trop, Franjo Pranjič, Damjan Konovšek, Zdravko Praunseis **27**

An overview of regulations regarding photovoltaic systems in Slovenia

Pregled fotovoltaičnih sistemov v Sloveniji na podlagi nacionalnih predpisov

Franc Rihl **38**

Ultrasonic detection of defects in steel welds

Ultrazvočno odkrivanje napak v jeklenih zvarih

Marko Pešić, Irena Nikolić, Zdravko Praunseis **53**

Elemental analysis of welds with an X-ray fluorescence analyser

Elementarna analiza zvarnega spoja z rentgentsko fluoroscentnim analizatorjem

Marko Kišek, Zdravko Praunseis **61**

Instructions for authors **79**

JET Journal of Energy Technology

JET Volume 9 (2016) p.p. 11-25
Issue 3, October 2016
Typology of article 1.01
www.fe.um.si/en/jet.html

SUSTAINABLE ENERGY PLANNING IN SLOVENIAN MUNICIPALITIES

TRAJNOSTNO ENERGETSKO NAČRTOVANJE V SLOVENSKIH OBČINAH

Rebeka Kovačič Lukman[ℜ]

Keywords: energy efficiency, energy management, Covenant of Mayors, sustainable energy action plan, Slovenia.

Abstract

One of the European initiatives responding to the global challenges of climate change, on the local level, is the Covenant of Mayors (CoM), a voluntary agreement of cities and municipalities to improve energy efficiency, the usage of renewable resources, and carbon dioxide (CO2) reduction by 2020. Our study represents a process of sustainable energy planning and analyses two Sustainable energy action plans (SEAPs) in Slovenia, offering an in-depth view of the improvements, which are composed of technological measures and "soft" measures, such as education and awareness raising. Further recommendations are made regarding the SEAP preparation, implementation, and monitoring, considering a systematic and holistic approach towards more sustainable local communities.

Povzetek

Ena izmed evropskih iniciativ, ki uresničuje skupne globalne izzive na lokalnem nivoju je t.i. Zaveza županov. Predstavlja prostovoljni dogovor mest in lokalnih skupnosti, z namenom povečati energetsko učinkovitost, uporabo obnovljivih virov in zmanjšanje izpustov ogljikovega dioksida do leta 2020. V našem prispevku predstavljamo proces trajnstnega energetskega načrtovanja in analizo dveh trajnostnih energetskih akcijskih načrtov v Sloveniji. Podrobna analiza ukrepov za izboljšanje prikazuje, da so le-ti sestavljeni iz tehnoloških izboljašav, kot tudi t.i. »mehkih vsebin«, med katere sodita izobraževanje in ozaveščanje.

[ℜ] Corresponding author: Assist. Prof. Rebeka Kovačič Lukman, PhD, University of Maribor, Energy Conversion Laboratory, Hočevarjev trg 1, SI-8720 Krško, Tel.: +386 3 777 0400, E-mail address: rebeka.kovacic@um.si

V zaključkih smo pripravili priporočila za pripravo, implementacijo in spremljanje trajnostnega energetskega načrtovanja, z upoštevanjem sistematičnega in celostnega pristopa k bolj trajnostnim lokalnim skupnstim.

1 INTRODUCTION

The European Union (EU) committed itself to becoming an energy-efficient and low carbon economy, by adopting the Climate and Energy Package in 2008, *[1].* The Energy Efficiency Directive (EED), *[2]*, was approved in 2012 as the most comprehensive directive on energy efficiency. By 2014 all EU member states (MS) had transposed the EED into their national laws. The EED represents the following targets: a) a 20% energy increase regarding the consumption of the EU by 2020; b) MS shall ensure that from 2014 onward, 3% of the total floor area of public buildings owned or occupied by government be renovated each year; c) achieving new savings each year from 2014 to 2020 of 1.5% of the annual energy sales to final customers of all energy distributors, *[3]*. By reviewing the progress, the European Commission has prepared an agreement on new energy efficiency targets for 2030, including 27% of savings compared to the business-as-usual scenario, *[4]*.

To support the implementation of climate and energy policies at the local level, the European Commission has launched a Covenant of Mayors (CoM), representing a voluntary agreement towards increasing energy efficiency and usage of renewable resources at the local level, where local governments play a crucial role. The CoM represents a significant commitment to reach the EU sustainability goals, focusing on a 20% reduction of the EU greenhouse gas (GHG) emissions from the 1990 baseline year, raising the share of renewables by 20% in the energy consumed, and a 20% increase in energy efficiency, *[5]*. The CoM commitment covers the geographical area of the local authority, referring to a town, city, municipality or region, *[6]*.

By September 2016, 6201 mayors had become signatories. As argued by Christoforidis et al., *[7]*, the high number of signatories does not necessarily imply that the goals of CoM will be reached, because the commitment is required by the local authorities and their financial capabilities for investments.

Regarding the CoM initiative in Slovenia, there have been 29 signatures of commitment, and 29 Action Plans submitted to the CoM. Within them, there are 29 commitments to the 2020 targets, one commitment to the 2030 targets, and two adaptations (Idrija and Odranci) of the Action Plans.

This paper represents research work within the Erasmus+ project, Innovative educational tools for Energy Planning, focusing on energy planning and energy efficiency in Slovenian municipalities as the case studies. The paper is organized as follows: Section 2: provides background information on Sustainable energy action plan (SEAP), followed by SEAPs in Slovenia as case studies (Section 3), in which an in-depth review of SEAPs for the Municipality of Velenje and the Municipality of Krško was carried out in order to define the municipalities energy consumption “hot spots” and their measures for improvement. Section 4 analyses sectoral measures of the SEAPs, followed by monitoring activities in Section 5. Section 6 focuses on the results of the emissions reductions needed and discusses the measures to achieve them. Finally, a discussion and conclusions are represented in Section 7.

2 SUSTAINABLE ENERGY ACTION PLAN

The Sustainable Energy Action Plan (SEAP) is the main policy act that local authorities should adopt to reach the EU sustainability goals and reach its CO_2 reduction by 2020, *[8,9]***,** as well as a planning tool to promote the policy strategies, *[10]*. The SEAP illustrates the applicable procedures to achieve the targets in CO_2 emissions reductions, and it is the subject of approval by the CoM office, *[7]*. It defines concrete reduction measures, time frames, and responsibilities to achieve the settled long-term goals, focusing on the reduction of CO_2 emissions and final energy consumption by end users, *[6]*. The SEAP covers areas where local authorities have an influence, such as land use planning, green public procurement, and changes in consumption patterns. According to Corrado et al., *[11]*, the SEAP is a precise operational tool for defining sustainable development strategies, regulations and actions in line with the policy directions defined by the local authorities. It also includes a future vision of the involvement of citizens and other stakeholders.

The preliminary action towards designing an SEAP is to prepare the Baseline Emission Inventory (BEI) data to identify the best fields of action and opportunities to reach the CO_2 reduction targets, *[6, 7]*. The recommended baseline year is 1990, since the Covenant's goal is to reduce the emissions by 20% by 2020 in comparison to the 1990 levels. However, if the data from 1990 are insufficient or unavailable, then a subsequent year must be chosen, *[12]*. The BEI is divided into four parts: the final energy consumption data, the CO_2 emissions, local electricity production and local heat/cold production, *[12]*, and enables the identification of main CO_2 emission sources and their reduction potential, including a preparation of the action plan and describing the actions in a more detailed way, *[11]*. The BEI represents the initial activity for the SEAP, which consists of four phases: Initiation, Planning, Implementation, and Monitoring and Reporting, which described in greater detail in Fig. 1.

Figure 1: *The SEAP process*

Signing the CoM for a municipality means that after formulating a BEI, the municipality must submit the SEAP within one year of being signed, create an internal management structure for implementing the process involving other stakeholders and citizens, carry out monitoring, and communicate and disseminate the activities, *[11]*.

3 SEAPs IN SLOVENIA

In Slovenia, there are currently 29 SEAPs. In our study, two SEAPs are selected, the Municipality of Velenje (VE), and Municipality of Krško (KK) in order to define their principal activities approaching more energy efficient municipalities. The municipalities of Krško and Velenje have joined the CoM, the committing mayors, and other decision-makers on their field to increase energy efficiency and the use of renewable energy sources, and are undertaking to reduce CO_2 emissions by 20% until 2020.

Following the recommendation of the European Commission and Joint Research Centre, *[12]*, the scope of the action plans encompasses energy use in:

a) Buildings
- Municipal building
- Tertiary buildings, the buildings of the service sector that are not owned or operated by local communities
- Residential buildings

b) Transport
- The municipal fleet
- Public transport
- Personal cars and trucks

c) Street lighting.

The SEAPs are dedicated exclusively to the public sector. However, local communities can, with their policies, role models and the sustainable planning, have a positive impact on energy efficiency and sustainable energy usage in other sectors. Industrial sectors are not covered by the SEAPs.

Both SEAPs have identified the main goals, which are in line with the policy directions of the European Commission, *[1]*:

- To reduce CO_2 emissions in all sectors, implementing energy efficiency (EE) measures with further exploitation of renewable energy sources (RES), effective management and energy control, education and other measures,
- To reduce energy consumption in the public sector (public buildings, transport, and public lighting,
- To ensure the security of energy supply and diversity of energy sources.

The process of developing the SEAPs was divided into six steps, which were similar to the proposed methodology (see SEAP process, Fig. 1):

1) Preparation process of the SEAP: political will, coordination, and the scope,
2) Elaboration of the SEAP,
3) Approval of the SEAP as an official document for the municipality,
4) Implementation of the SEAP,
5) Monitoring and control of the implementation of the SEAP,
6) Reporting on the implementation of the SEAP.

Both municipalities (Velenje and Krško) identified the most significant activity in the preparation of the SEAP, which was achieving the political will for its successful implementation, and necessary consensus and support from the mayor and municipal council. Furthermore, the municipalities have identified the tasks of the municipal administration in the implementation of the SEAP:

- To ensure the budget for the implementation of activities and measures,
- To integrate the SEAP objectives in the development strategy of the municipality,
- To support the implementation of measures and activities of the SEAP,
- To ensure tracking and reporting on the implementation of the SEAP,
- To communicate with the general and professional public on the implementation of the SEAP,
- To provide and encourage citizens for the realization of the SEAP.

3.1 Analyses of energy use

In the SEAP for Krško, the reference year was 2005, while it was 2003 for Velenje. For both cases, the CO_2 inventory was based on overall energy consumption, using the standard method from the Intergovernmental Panel on Climate Change (IPCC) for GHG emissions, based on the end-use of energy, and have been classified into several categories (see Table 1), not including industry, and long-distance transport.

Table 1: *Analysis of energy use in the municipalities of Krško (KK) and Velenje (VE), with the reference years 2003 and 2005. Source: SEAP Krško and SEAP Velenje*

Category	VELENJE (VE) Energy used [MW h]	Total CO_2 emissions [t/a] in VE	KRŠKO (KK) Energy used [MW h]	Total CO_2 emissions [t/a] in KK
Buildings	400,302.2	147,488.3	18,935.3	39,045.1
- Public buildings	54,786.3	23,000.7	6,619.3	1,875.1
- Residential buildings	319,113.9	116,303.0	176,316.0	37,170.0
- Other non-residential buildings	26,402.0	8,184.6	n.a.	n.a.
Mobility/Traffic	61,159.0	13,081.0	95,407.2	23,387.2
Public lighting	1,694.5	943.8	3,534.0	1,968.4
TOTAL	463,155.7	161,513.1	281,876.5	64,400.7

Table 1 shows that the higher energy consumption belongs to the building category, which represents more than 86% of consumption in Velenje and 60% in Krško. According to Table 1, buildings present the most energy-consuming sector; thus, most of the attention in the SEAP will be given to energy efficient and sustainable buildings, including energy efficient renovation of public buildings and exploitation of RES. Regarding the traffic sector, use of public transport is to be fostered, including a purchase of environmentally friendly vehicles. Public lighting represents a relatively low proportion of the contribution of the CO_2 emissions to the total balance. However, the measures to improve public lighting will focus on the replacement of the current lamps with more efficient ones.

3.2 Sustainable energy action planning

The results of the BEI are followed by the identification of the categories consuming the most energy and thus producing more CO_2 emissions, and where the improvements should be made. The Joint Research Centre, *[12]*, argues that the improvement measures must be defined with various criteria (quality and quantity), cover objectives, expected savings, and emission reduction, including timetables, deadlines, budget and risk analyses. Both municipalities plan on achieving 20% CO_2 emissions reduction by 2020 according to their baseline years. The SEAPs considered in the case studies were prepared by the local energy agencies (e.g. Local energy Agency Dolenjska and Energy Agency for Savinjska, Šaleška, and Koroška) in collaboration with the municipalities. Several experts from the agencies and municipalities have been included in the preparation of the SEAP from various fields, such as economic mechanical engineering, chemical engineering, etc.

Table 2 shows that the intention of both municipalities is to reduce the CO_2 emissions by more than 20%, as suggested. Thus, SEAPs for Velenje and Krško define several key actions to achieve their goals in three different sectors.

Table 2: *Expected CO_2 emissions reduction for various sectors. Source: SEAP Velenje and SEAP Krško*

Category	CO_2 reduction target per sector (VE) (in tons)	Contribution of action to the overall emissions reduction target (%) for VE	CO_2 reduction target per sector (KK) (in tons)	Contribution of action to the overall emissions reduction target (%) for KK
Buildings	31,392.0	19.4	11,177.8	17.4
Mobility/Traffic	5,444.4	3.4	4,700.6	7.3
Public lighting	505.0	0.3	1,004.1	1.6
TOTAL	37,341.4	23.1	16,882.5	26.2

4 SECTORAL ANALYSES OF MEASURES FOR VELENJE'S AND KRŠKO'S SEAPs

Within the sectors of buildings, traffic/mobility and public lighting Velenje proposed 31 and Krško 24 measures.

4.1 Buildings

The BEIs for both municipalities show that the building category (public buildings, residential buildings, and other non-residential buildings) is very energy consuming and consequently producing over 90% of the total CO_2 emissions in Velenje and nearly 65% of the emissions in Krško.

In the case of Velenje, 57 buildings of different typologies were considered for the analysis, including kindergartens, schools, dormitories, sport facilities and buildings of local communities). The majority of buildings are heated with the Šaleška Valley district heating system, which is the second largest district heating system in Slovenia, *[14]*, providing energy from a thermal plant, which is a non-renewable energy source. The Krško municipality included 32 buildings in their analysis, mostly primary schools and kindergartens. The analysis shows that the public buildings are mostly heated with natural gas (57%), heating oil (30%), and district heating (13%), while residential buildings use solid fuels (54%) and heating oil (27%). The reasons for low energy efficiency under the building category are not defined in the SEAPs. Corrado et al., *[11]*, argue that factors influencing high energy consumption in the building sector are construction and the limited use of insulating materials for outer walls, one-family heating plants (often oversized and inefficient), and cooling systems.

In Velenje's SEAP*, [14]*, 18 measures for public and residential buildings are identified, which consist of 14 "technology/equipment" measures and four "soft" measures. Under the "technology/equipment" measures, such as thermal solar collector systems, the optimization of district heating, the co-financing of energy efficient appliances for households, updating the boiler technology, installation of micro-photovoltaic systems on private buildings, etc., see Table 3. "Soft" measures cover awareness raising.

***Table 3**: Measures, costs, estimated CO_2 reduction and assessment of energy savings for Municipality of Velenje, [14]*

No.	Measure	Sector	Costs [in EUR]	Estimated CO_2 reduction [t/a]	Assessment of energy savings [MWh/a]
1	Educational events, awareness raising about EE and RES in public buildings	Public buildings	4,000/a	93	300
2	PV power plants on public buildings	Public buildings	2,500,000	55.7	100
3	5 thermal solar collector systems for public buildings	Public buildings	60,000	27.1	49
4	Optimization of district heating	Public buildings	1,000,000	7,579	24,447

5	Utilization of district cooling absorption system	Public buildings	1,000,000	848	1,523
6	Optimization of lighting in public buildings	Public buildings	500,000	1,628	2,923
7	Change of electric appliances with more efficient ones	Public buildings	500,000	678	1,218
8	Updating technology in boiler rooms of public buildings	Public buildings	1,000,000	283	913
9	Replacement of building doors, windows, etc.	Public buildings	696,486	287	927
10	Supporting the energy /passive construction	Public buildings	5,000		
11	Educational events, awareness raising about EE and RES in residential buildings	Residential buildings	2,000,000	3,856	12,438
12	Installation of heat dividers	Residential buildings	1,000,000	8,328	29,851
13	Change of non-energy efficient home appliances	Residential buildings	11,697,000	2,646	4,752
14	Installation of systems for the exploitation of thermal solar energy for private houses	Residential buildings	1,000,000	87	280
15	Change of lighting (bulbs) in residential buildings	Residential buildings	300,000	1,959	3,518
16	Replacement of doors, windows and improving the facade	Residential buildings	2,500,000	2,313	7,463
17	Installation of micro PV systems on private buildings	Residential buildings	1,200,000	223	400
18	Supporting the low energy /passive construction – private houses	Residential buildings	5,000		
19	Change of bulbs to more efficient ones	Public lighting	14,000	126	226.3
20	Change of lamps	Public lighting	73,000	126	226.3
21	Change of lamps with power of 200-500 W	Public lighting	201,240	113	203
22	Change of lamps with power of 100-199 W	Public lighting	569,908	125	225
23	Change of lamps with power of 1-99 W	Public lighting	338,576	64	115
24	Regulation for public lighting	Public lighting	221,416	216	388
25	Self-sufficient street lighting	Public lighting	250,000	0.2	0.4
26	Increasing biofuels (7,5 % until 2020)	Traffic		981.1	

27	Restriction of parking in the city centre	Traffic			
28	Education and awareness raising	Traffic	108,000		
29	Improvement of municipality fleet	Traffic	90,000		
30	Supporting car sharing	Traffic			
31	Free public transport	Traffic	4.500.000	2.500	

The SEAP of Krško *[13]* introduces 16 public and residential building measures, consisting of 13 technology/equipment measures, such as energy restoration of buildings, co-financing energy efficient appliances for households, installation of biomass boilers, co-generation in public schools, installation of PV power plants, and three soft measures, which are awareness raising, employment of energy manager, and promotion of low-energy construction; see Table 4.

***Table 4**: Measures, costs, estimated CO_2 reduction and assessment of energy savings for municipality of Krško, [13]*

No.	Measure	Sector	Costs [in EUR]	Estimated CO_2 reduction [t/a]	Assessment of energy savings [MWh/a]
1	Educational events, awareness raising about EE and RES in public buildings	Public buildings	24,000	98 [total]	331 [total]
2	Energy renovation of public buildings	Public buildings	3,598,534	218	1.088
3	Energy renovation of public buildings	Public buildings	5,766,120	46	109
4	Solar systems for hot water	Public buildings	200,000	46	82
5	Change of electric appliances with more efficient ones	Public buildings	50,000	34 [total]	61 [total]
6	Installation of biomass boilers (wood)	Public buildings	363,000	367	874
7	Co-generation in the public school	Public buildings	94,270	5,5	27
8	Supporting low energy, passive construction	Public buildings	5,000		
9	Installation of PV power plants	Public buildings	2,000,000	468	840
10	Installation of heat dividers	Residential buildings	5,000	153	759
11	Change of non energy efficient home appliances	Residential buildings	230,000	1,105 [total]	1,984 [total]
12	Replacement of doors, windows, etc.	Public buildings	2,990,700	452 [total]	1,888 [total]
13	Replacement of bulbs in households	Residential buildings	30,000	737	1,323
14	Employment of a manager of boilers in public buildings	Public buildings	90,000	53 [total]	236 [total]

15	Energy renovation of residential buildings	Residential buildings	131,555	5.2	10-15%
16	Energy renovation of PGE Krško	Public buildings	193,950	19	82
17	Renovation of public lighting	Public lighting	299,602	538 [total]	965 [total]
18	Exchange of bulbs with more efficient ones	Public lighting	14,000 + 73,000	126 [total]	226 [total]
19	Increasing biofuels (7.5% until 2020)	Traffic		483	
20	Parking restriction in the centre	Traffic			
21	Education, awareness raising – public transport and mobility	Traffic	12,000/a		
22	Improving the municipal fleet	Traffic	35,000/car	0.8	
23	5 stations for electric vehicles	Traffic	25,000		
24	New vehicle for fire-fighters	Traffic	25,000	0.2	

4.2 Public lighting and local transport/mobility

Regarding public lighting, the BEIs for both municipalities show that their public lighting is not efficient, consisting of mostly high-pressure mercury lamps, which could be replaced by highly efficient LED lamps. The improvement measures of the public lighting thus focus on technology/equipment, such as change of bulbs, and regulation and control of public lighting.

To reduce the urban GHG emissions from transport/mobility, all the parameters contributing to the emissions need to be examined and are related to the city (municipality) shape and settlement location, *[15]*. Regarding the CO_2 emissions, the municipality fleet, public transport, and personal vehicles have been considered. In both municipalities, personal vehicles represent over 95% of all the CO_2 emissions. Velenje's and Krško's SEAPs propose six transport-related measures, consisting of soft measures (e.g. awareness raising, car sharing, parking restriction in the city centre) and improving the municipal fleet (new, more efficient vehicles and usage of biofuels).

5 SEAP MONITORING

Continuous control of the implemented measures and reporting the results is an important part of the implementation process of the SEAP. At the beginning SEAP guidelines forecast biennial monitoring, assessing the implemented activities and propose goals. Furthermore, the BEI should be updated with the current CO_2 emissions. The four-year monitoring report is called the Monitoring Emission Inventory (MEI), which is a substantially updated version of BEI, not based on CO_2 emissions reduction, but on the re-calculation of the BEI, *[11]*. Regarding the monitoring process of SEAPs in Velenje and Krško, it could be perceived that in 2016 Krško prepared an updated version of their SEAP, which could be in line with the MEI, while for Velenje, no information regarding the annual and/or biennial achievements was reported, based on the indicators settled.

6 RESULTS AND DISCUSSION

When municipalities committed to the voluntary agreement of the CoM, they agreed to reduce their CO_2 emissions by at least 20%. In our cases, Velenje suggested cutting their emissions by 23.1% and Krško even my 26.2%, compared to the BEI, see Fig. 2. Thus, Krško needs to reduce the CO_2 emissions by almost 17 k tonnes, while Velenje by around 37 k tonnes.

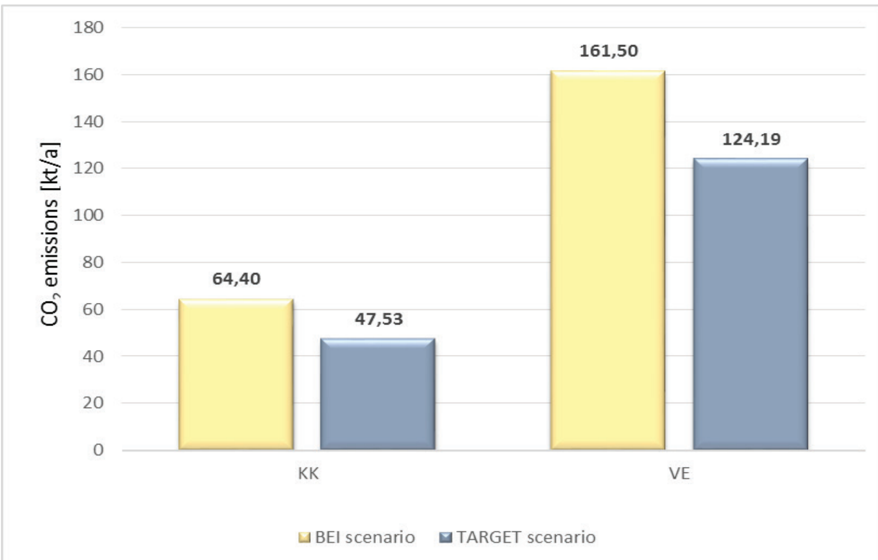


***Figure 2**: The 2020 Baseline Emissions Inventory (BEI) and targets*

Based on the data in the SEAPs of the municipalities Krško and Velenje, calculations have been made regarding the annual CO_2 emissions targets until 2020, see Table 5. The greatest CO_2 emissions reductions in both municipalities are expected in the building sector, followed by mobility, and public lighting.

***Table 5**: Annual average reduction of CO_2 emissions (in k tonnes) needed per category in VE and KK*

Year	Krško			Velenje		
	Buildings	Mobility	Public lighting	Buildings	Mobility	Public lighting
2003				147.5	13	0.9
2005	39	23.4	1.9			
2012				144.01	12.40	0.85
2013				140.52	11.80	0.79
2014	37.41	22.73	1.76	137.03	11.20	0.74
2015	35.81	22.06	1.62	133.54	10.60	0.69
2016	34.22	21.38	1.48	130.05	10.00	0.63
2017	32.63	20.71	1.35	126.56	9.39	0.58
2018	31.03	20.04	1.21	123.06	8.79	0.53
2019	29.44	19.37	1.07	119.57	8.19	0.47
2020	27.85	18.70	0.93	116.08	7.59	0.42

Considering the measures to achieve the 2020 SEAP targets, both municipalities will use a combination of technological improvements and "soft" measures; technological improvements are prevailing in all the measures introduced, and require substantial investments, see Section 4. Furthermore, the expected investment costs for technological improvements regarding the SEAP in Velenje are around 31 million euros and in Krško around 16 million euros. The annual municipality budgets include the investment costs (e.g. Velenje for the year 2015 around 15 million euros); however, the investment budget lines are not specified for the energy efficiency or activities related to the SEAPs. Therefore, the data for SEAPs investments from the municipalities' budgets and potential CO_2 reductions cannot be obtained.

Both municipalities have made public information regarding their energy efficiency projects, e.g. Velenje's energy renovation of the health centre or Krško's energy renovation of elementary schools, which nevertheless represent too little information in order to make a correlation between the investments made and annual achievements of the CO_2 emissions targets. Based on the public information obtained, CO_2 emissions reduction under the category of public lighting seems attainable, after the investments made, because LED lighting produces around 80% less CO_2 emissions than commonly used high-pressure sodium lamps do, *[16]*.

The building category requires huge investment costs, mostly depending on the municipalities' budget priorities, capabilities to attract investments, especially in the form of public-private partnership, and gaining EU funding. The municipalities are proposing some private-public partnerships and co-financing from EU funds, but unfortunately, information about how many measures were realized through these instruments or how many private investments have been made is not available. Even greater vagueness exists in the mobility category. Measures targeting this category are focusing on parking restrictions, supporting car sharing and public transport. According to the data obtained from the Statistical Office of the Republic of Slovenia, in both municipalities there is around 0.5 car per capita, meaning that on average every person above 18 owns a car, *[17, 18]*. Thus, changes in mobility patterns will be needed, including the behaviour of inhabitants. As argued by Louf and Barthelemy, *[19]*, cities are not defined only by spatial and functional issues (e.g. shops, hospitals, etc.), but also by the individuals commuting between places.

7 CONCLUSIONS

Urban areas represent a challenge regarding the reduction of CO_2 emissions; thus, the CoM represent a valuable and reasonable initiative towards more sustainable city living when implementing SEAPs in the local area. The cases in Slovenia have shown that room for improvement still exists in terms of preparation, implementation, and monitoring, such as considering social aspects, especially planning in a line of the economic situation of the particular local community, selecting measures in the SEAP that improve the condition of the local economy (indirect employment and green jobs). In terms of preparation, the SEAP needs to be designed based on the improvements and measures that are feasible to realize, and not as wish list of actions of the local community, since the planned of implemented measures are not corresponding with the municipalities' existing budgets.

Our study has shown that the municipalities are primarily focusing on the building category and its measures, which is the most extensive from the costs perspective but bringing the most positive impacts on the emissions reduction from the quantity perspective. SEAPs also need to be coherent with the priorities of the European Commission to obtain the funding (e.g. improving the public lighting is not a priority within the 2014–2020, but it was in a previous period). This survey also illustrates that, within the implementation phase, municipalities need to appoint an expert, an energy manager with the responsibility to carry out continuous monitoring. An educated energy manager should be a prerequisite and a good solution regarding SEAP implementation and follow-up. SEAPs are also lacking integrated and holistic approaches, and interdisciplinarity regarding the measures, e.g. sustainable urban mobility merges spatial, energy, environmental and social features of the urban area. Furthermore, the implementation needs to be followed by detailed reporting, where investments were made and emissions reduced should be correlated with the municipality budget, public-private partnerships and EU funding, preferably on an annual or biannual basis. Energy planning is an important instrument, although maybe all the emissions reductions of both municipalities would not be achieved until 2020, but with SEAPs municipalities have set goals and made commitments, including political and stakeholders' supports towards more competitive, secure and sustainable energy systems, and GHG reduction targets, representing long-term goals.

Acknowledgement

The author of this paper would like to thank anonymous reviewers and the Editor-in-Chief, Prof. Jurij Avsec, Phd, for their in-depth comments and advice on improving the quality of the manuscript. The work presented in this paper has been partially financed by the ERASMUS+ Programme, project KA2-HE-17/15.

References

[1] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - 20 20 by 2020 - Europe's climate change opportunity COM/2008/0030 final

[2] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency

[3] European Council for an energy efficient economy (ECEEE): Understanding the energy efficiency directive – A guide from eceee, Stockholm, Sweden, 2013

[4] Communication from the Commission to the European Parliament and the Council: *Energy efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy*, COM(2014)520 final, Brussels

[5] **F. Famoso, R. Lanzafame, P. Monforte, P.F. Scandura***: Analysis of the Covenant of Mayors Initiative in Sicily*, Energy Procedia, Vol. 81, p.p. 482–492, 2015

[6] **N. Kontinakis:** *Drafting of BEI and SEAP*, TCG-DIBA 2nd twinning visit, 21–23 January, Athens, 2013

[7] **C. G.Christoforidis, K. C. Chatzisavvas, S. Lazarou, C. Parisses:** *Covenant of Mayors initiative – Public perception issues and barriers in Greece*, Energy Policy, Vol. 60, p.p. 643–655, 2013

[8] **Covenant of Mayors** [online], Available: http://www.covenantofmayors.eu/index en.html (12. 10. 2016)

[9] **M. Beccali, M. Bonomolo, G. Ciulla, A. Galatioto, V. Lo Brano**: *Improvement of energy efficiency and quality of street lighting in South Italy as an action of Sustainable Energy Action Plans*, The case study of Comiso (RG), Energy, Vol. 92, p.p. 394–408, 2015

[10] **G. Dall'O', M. F. Norese, A. Galante, C. Novello:** *A multi-criteria methodology to support public administration decision making concerning Sustainable Energy Action Plans*, Energies, Vol. 6, p.p. 4308–4330, 2013

[11] **C. Schenone, I. Delponte, I. Pittaluga**: *The preparation of the Sustainable Energy Action Plan as a city-level tool for sustainability: The case of Genoa,* Journal of Renewable and sustainable energy, Vol. 7, 033126, 2015

[12] **Joint Research Centre** (JCR): *Existing methodologies and tools for the development and implementation of sustainable energy action plans*, Office for Official publications of European Communities, Luxembourg, 2010

[13] **D. Šoštaršič, J. Uršič, Lisac I, M. Pirc**: *Sustainable Energy Action Plan for Krško Municipality*, Krško, 2013. (in Slovene), 2013

[14] **B. Krajnc, G. Tepež, S. Mozgan, L. Stvarnik, U. Cerkovnik**: *Sustainable Energy Action Plan for Velenje,* Velenje, 2011 (in Slovene)

[15] **C. Kennedy, J. Steinberger, B. Gasson, Y. Hensen, T. Hillman, M. Havranek, D. Pataki, A. Phdungsilp, A. Ramaswami, G. V. Mendez**: *Greenhouse gas emissions from global cities*, Environmental Science and Technology, Vol. 43, p.p. 7297–7302, 2009

[16] **R. Kovačič Lukman, and D. Krajnc**: *Environmental impact assessment of two different streetlight technologies,* In: KUNGOLOS, Athanassios (ed.), et al. Proceedings of the Third International Conference on Environmental Management, Engineering, Planning and Economics (CEMEPE 2011) & SECOTOX Conference, Skiathos, June 19–24, Thessaloniki, 2011

[17] Statistical office of Republic of Slovenia: *Municipality of Velenje* [online], Available: http://www.stat.si/obcine/sl/2010/Municip/Index/190 (25. 10. 2016)

[18] Statistical office of Republic of Slovenia: *Municipality of Krško* [online], Available: http://www.stat.si/obcine/sl/2010/Municip/Index/75 (25. 10. 2016)

[19] **R. Louf and M. Barthelemy**: *How congestion shapes cities: from mobility patterns to scaling*, Scientific Reports, Nature Publishing Group 4, 5561, DOI: 10.1038/srep05561, 2014

Journal of Energy Technology

JET Volume 9 (2016) p.p. 27-37
Issue 3, October 2016
Typology of article 1.01
www.fe.um.si/en/jet.html

ENERGY RENOVATION OF THE LETUŠ CULTURAL CENTRE

ENERGETSKA PRENOVA KULTURNEGA DOMA LETUŠ

Bogdan Trop[1], Franjo Pranjič[2], Damjan Konovšek[3], Zdravko Praunseis[ℜ]

Keywords: efficient use of energy, energy renovation of building, energy indicators, required heat for heating, thermal conductivity

Abstract

This paper describes the energy status of the Letuš Cultural Centre, which is an older and energy-wasteful building. The paper also describes the guidelines and regulations concerning the efficient use of energy in buildings, both for Europe and Slovenia. With the help of KI Energy software, energy indicators for the building were calculated, and it was placed in energy class G. Actions for energy renovation of the building are proposed and described. In order to determine the effectiveness of the proposed measures, recalculation of energy indicators was performed. Economic analysis of the efficiency of the actions proposed is also presented.

Povzetek

V predstavljenem delu smo opisali energetsko stanje stavbe – Kulturni dom Letuš. Stavba je starejše izdelave in je energijsko potratna. Opisane so smernice in podlage v zakonodaji, tako v evropski kakor slovenski, za učinkovito rabo energije v stavbah.

ℜ Corresponding author: Zdravko Praunseis, Faculty of Energy Technology, University of Maribor, Tel.: +386 31 743 753, Fax: +386 7 620 2222, Mailing address: Hočevarjev trg 1, Krško, Slovenia, E-mail address: zdravko.praunseis@um.si

[1] Elektro Trop & Trop d.o.o., Letuš 56c, Šmartno ob Paki, Slovenia

[2] University of Maribor, Faculty of Energy Technology, Hočevarjev trg 1, Krško, Slovenia

[3] Petrol d.o.o, Ljubljanska 12, Ljubljana, Slovenia

Za stavbo smo z računalniškim programom KI Energija izračunali energijske kazalnike, kateri uvrščajo stavbo v energijski razred G. Predlagali in opisali smo ukrepe energetske prenove stavbe. Za ugotovitev učinkovitosti predlaganih ukrepov smo izvedli ponoven izračun energijskih kazalnikov. Na koncu je predstavljena še analiza ekonomske učinkovitosti ukrepov. Naloga ima uporabno vrednost, saj se bo lahko lastnik na podlagi izsledkov naloge lažje odločil za nujno potrebne ukrepe prenove. V sklopu naloge je izdelana tudi Energetska izkaznica.

1 INTRODUCTION

Energy renovation of buildings is one of the key challenges and opportunities for economic recovery in our country. The Republic of Slovenia is a member of the European Union and thus is committed to the implementation of European legislation into its national legal systems. The key interconnected objectives are pursued within the regulatory framework: efficient use of energy, protecting the environment and saving money in energy use.

A long-term strategy to promote investment in the energy renovation of buildings was made for Slovenia. The strategic objective of this document is carbon-free energy use in buildings by the year 2050, *[1]*.

The current housing fund has the greatest potential to generate savings in energy use in buildings. If the Republic of Slovenia's objectives are to be achieved, a quarter of all buildings must be renovated by 2020, which represents over 20 million square metres of building space. With this, the energy use in buildings will be decreased by about 10%. These measures will revive economic growth as they create opportunities for new investments of approximately €500 million in one year. These investments show the possibility of significant savings in energy consumption. By reducing energy imports and lower prices, the contribution may also be in an estimated 10,000 new jobs, *[3].*

The energy performance certificate was designed under the "Energy Performance of Buildings Directive", *[2].* Its primary purpose is to give information about the energy consumption of the building; it includes proposals for recommended energy efficient measures.

The purpose of this research is to present the possibilities for the energy renovation of a public building: the Letuš Cultural Centre. The research will show the current status of energy supply of the building, its shortcomings, the possibility of implementing the measures and economic efficiency of the investment in renovation. Energy indicators of the building before and after renovation will be calculated. The owner and manager of the building will be presented with the findings and suggestions about the measures (organizational and investment) that need to be taken.

This work does not include a complete renovation of the building; the emphasis is solely on measures to improve the building shell. The matter of renewable energy sources remains open; this must be resolved in accordance with the relevant legislation regarding the energy supply of the building. The building has great energy potential because it is situated along the Savinja River. Decades ago, a part of this building was used for a hydroelectric power plant, which is currently being renovated.

2 GENERAL FACILITY INFORMATION

The Letuš Cultural Centre is located in the village of Letuš by the Savinja River. The building was erected in 1927, and renovated and upgraded in the present form in 1976. It is owned by the Municipality of Braslovče and managed by a local committee. In addition to the implementation of cultural activities and events, the purpose of the cultural centre is socializing villagers and youth, and it serves for different associations' activities of local communities and the municipality.

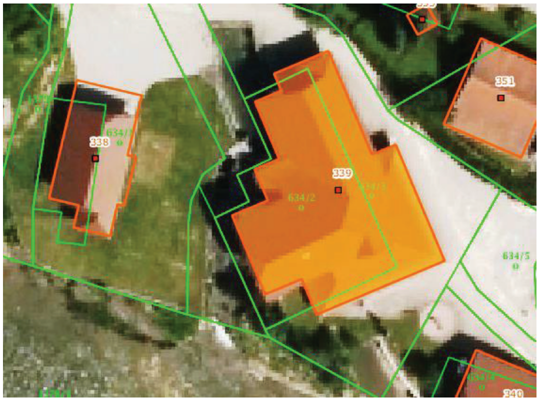


Figure 1: *Object location – ARSO [12]*

The building was built in an L-shape with external layout dimensions of 22.25 m × 25.30 m and a ridge height of 10.3 m (Figure 1). In the NW-SE direction of the ridge, the building contains the main room, which is a one-floor hall. In the direction of the NE-SW ridge in the second part of the building is a two-floor hall. The ground floor contains an office, meeting room, handy kitchen, wardrobe, utility cleaning room, an archive and a hallway that connects all of these areas. On the first floor of this building, there are a museum and cultural society rooms. On the ground floor, there is a large glass-enclosed hall, which is not heated. Figure 2 shows the building from the front to show the architectural diversity of the building.

Figure 2: *Front side of the Letuš Cultural Centre*

2.1 Building envelope

The building envelope consists of outer walls, building elements (windows, doors, floor, and roof). External walls throughout the house differ in thickness, from 24 cm to 65 cm. The walls are of solid red brick, on the outside treated with a conventional plaster, which is worn out in many places to such an extent that it falls off the building. In addition to the exterior walls not having any thermal insulation, there is also a significant problem with moisture. This is especially seen on the walls near the floor.

Windows are wooden with single or double glazing. Window frames are rotten and worn out, window sashes are twisted, without gaskets and leaking very badly. Because of this, there are large heat losses accompanied by significantly increased convection or ventilation losses. Like the windows, the entry gates are wooden and 6 cm thick; due to age and twisted closing mechanisms, many leaks are present.

The floors of the ground floor are partly restored due to a partial renovation in 2010. Weathered and worn wooden parquet floors were completely removed. A floor with a new concrete screed was built and waterproofed, and Thermodur thermal insulation was laid. The rest of the ground floor is not repaired and remains with clinker ceramic plates without any thermal insulation. The roof of the building was restored in 2005 but is not a part of the thermal envelope of the heating zone. Both in the hall and on the first floor, the zone is concluded by the ceiling against the unheated attic. In the hall, the ceiling is made up of panels and foil, between the rafters (from the upper side) thermal insulation had been placed, but it is damaged and destroyed to the extent that it does not function as intended. Insulation from the upper side is not protected by wooden planks; before it was repaired, it was repeatedly soaked, and mechanically damaged during the roof replacement. Ceilings in another part of the building have a thickness of 28 cm; the structure consists of lime plaster and wooden boards. In some places, the ceiling is lowered and treated with wood panelling, with the presence of an air gap.

2.2 Technical system of the building

For heating the ground floor and the halls of the Letuš Cultural Centre, a heating system with an ELFO (Extra Light Fuel Oil) 85,000 kcal/h boiler is used (shown in Figure 3), and the heat transfer is conducted via an air-air heat exchanger. Blowing of the heated air is carried out with ducts (80 cm × 20 cm), which are routed into the hall and hallway. The water system is designed with a central air duct, which runs from the boiler room to the multipurpose hall. Air duct distribution pipes were originally not built for heating auxiliary rooms, but later an additional channel for heating of the meeting room was constructed. Control of the volume of blowing air is not carried out; in addition, steering hatches to make a selection of the heated rooms have not been installed. Hall temperature control is two-point, conducted by a room thermostat that is placed on the wall in the hall. The temperature mode of functioning is set. Other rooms have no temperature control. The ELFO system heats the hall and the ground floor. First floor rooms are not heated with this system; portable radiators are used for heating. The temperature is set manually with thermostats on eight different radiators.

Figure 3: *Boiler room with ELFO boiler*

3 BUILDING'S ENERGY SITUATION BEFORE AND AFTER THE RENOVATION

After the calculation of the energy indicators, the building was placed in the high energy class G, which is the highest grade on the colour strip. This class is determined by the energy indicator QNH/Ak, "the annual heat required for heating the building on one unit of heated area of the building", *[7].* Within one year of measurements, the Letuš Cultural Centre needs QNH = 226 kWh of thermal energy per square metre of heated surface. The total energy supplied to the building is Q = 302 kWh of energy per year per square meter. Together, this amounts to Qp = 428 kWh/m²a of primary energy for which the calculated emissions are CO_2 = 102 kg/m²a. Figure 4 shows the indicators of the energy characteristics of the building on the colour strip, which is an integral part of EPC (energy performance certificate).

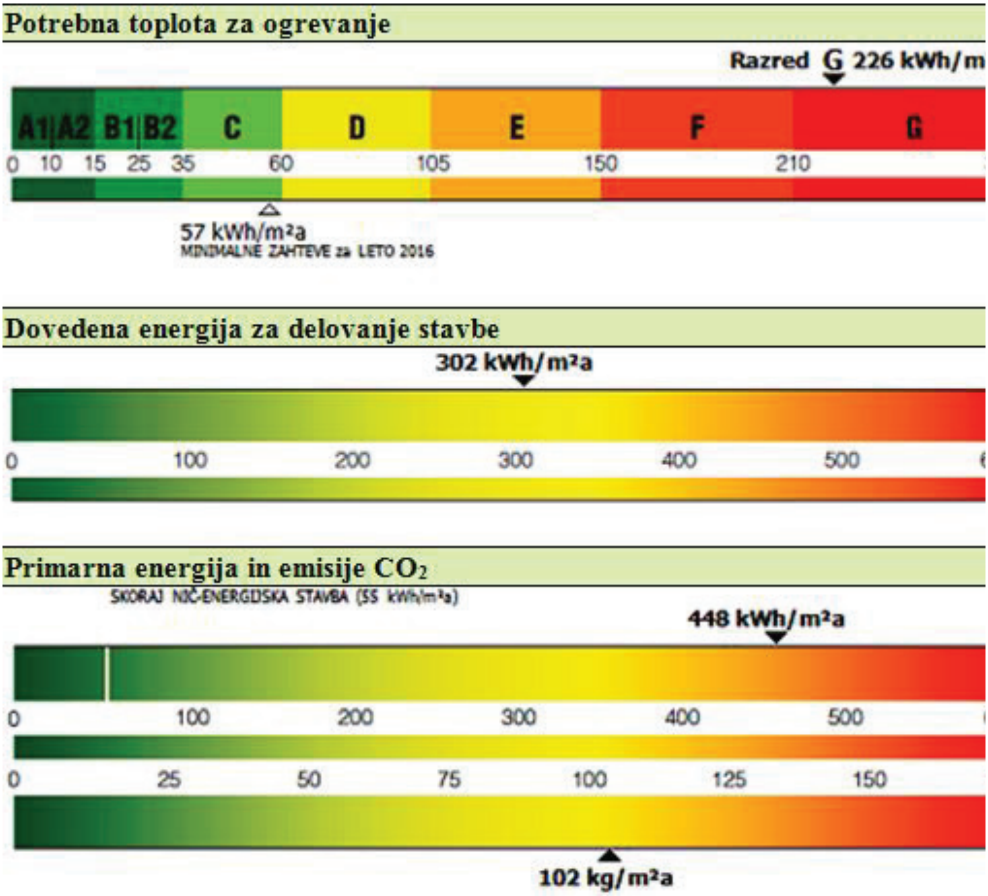


Figure 4: *Energy indicators before renovation*

The program in which the energy indicators were calculated also includes an analysis of the entry structures of individual zones and the building as a whole. From the calculated indicators, we find that the building is energy inefficient. There are high energy losses due to the envelope of the building. Based on the collected data which describe the energy consumption and on the basis of current energy prices, we calculated the annual energy costs for the building. Energy input of the building in one year is 131,909 kWh, of which 36,252 kWh of electricity and energy from ELFO at 95,657 kWh. An infrared camera was used for further analysis of the transmission and convection losses from the building shell. With thermal imaging, we found that windows and doors sealed very poorly. Ventilation losses are significant and may determine that it is necessary to replace the windows (Figure 5).

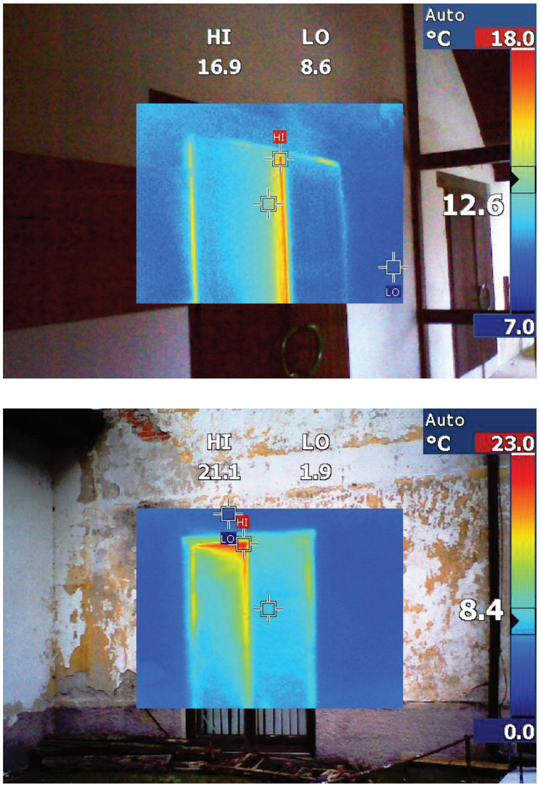


Figure 5: *Sealing of the side doors*

The balance of energy indicators for the building after the renovation is shown in Figure 6.

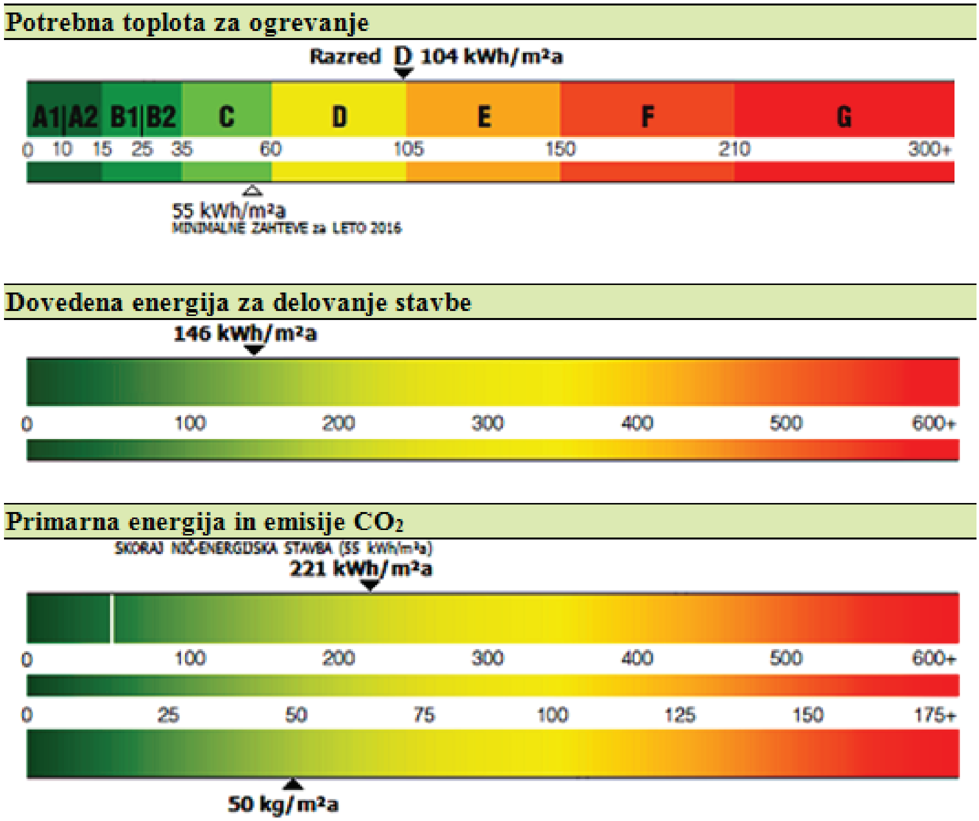


Figure 6: *Primary energy and CO2 emissions after implementation of the measures*

Figure 7 shows energy indicators before and after the renovation of the Letuš Cultural Centre. It was found that the consumption of the energy by the building was reduced by more than one half after the proposed measures were implemented. On closer examination, the smallest contribution to the reduction of used energy is contributed by Measure A: replacement of the external building materials. This is due to a very low "z" factor of windows and doors against the surface of the entire building envelope. The proposed Measure B represents a greater contribution to reducing energy consumption via the additional insulation of ceiling structures. The maximum reduction of the energy consumption can be achieved with Measure C: the renovation of the facade with the installation of thermal insulation materials.

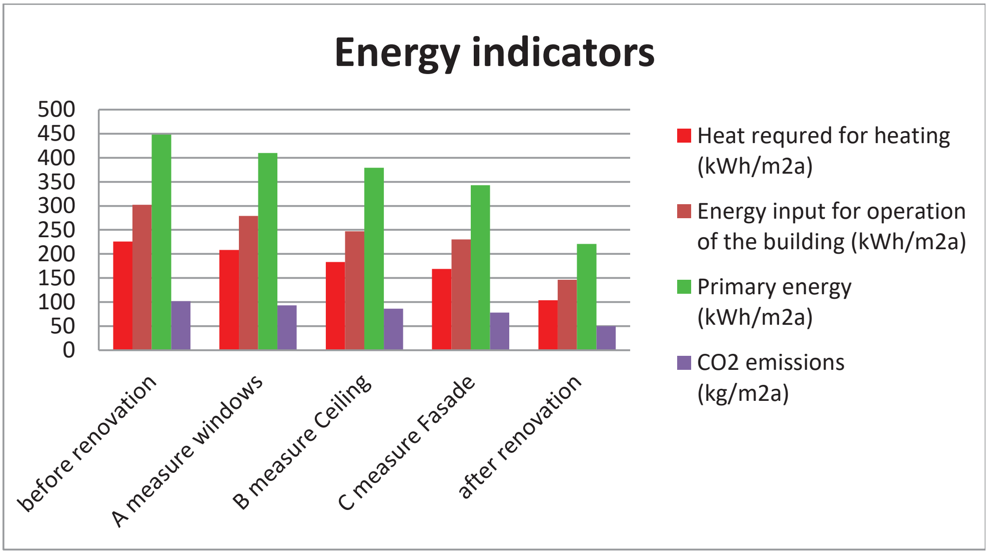


Figure 7: *Energy indicators*

The ratio between the energy products is about the same before the renovation of a building; more precisely, the proportion of ELFO decreased by 4% after the renovation (Figure 8).

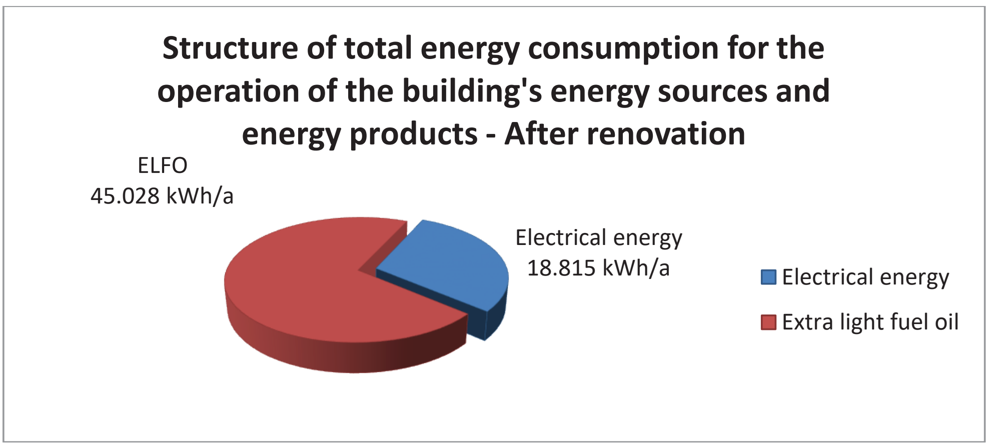


Figure 8: *Energy for the building after renovation*

Energy renovation of a building is an investment. We have calculated the economic viability of the project over the life cycle of the building envelope (i.e. 20 years). This economic analysis was performed in accordance with the LCC (Life Cycle Cost) analysis.

Economic analysis was performed using the following financial ratios:

- Payback period of the investment,
- Net present value (NPV),
- The internal rate of return (IRR).

To assess the cost effectiveness of the measures in the renovation of a building, it is advisable to use the payback period. The payback period is both a static method and a very simple method that defines the rationality of the investment. The payback period is calculated by dividing the value of an investment (the cost of renovation) by the annual return; in our case, this is an annual saving on energy costs for the building. If the annual income or savings are the same, then this method is quite acceptable. The disadvantage of the payback period is ignorance of the time component (i.e. the loss of money at the time). In most cases, the unit for the payback period is expressed in years.

4 CONCLUSION

Energy is an asset of extraordinary proportions and the foundation and driving force for economic development. The supply of cost-effective and environmentally acceptable energy is the foundation for a good and efficient economy. The global trend is to reduce energy consumption with the emphasis on maximizing the use of renewable energy sources. About 40% of all consumed energy is used for the normal operation of buildings. This area is most certainly a major challenge for savings. With the right approach and awareness, we can make great strides in reducing negative impacts on the environment, while providing a great opportunity for the recovery and growth of the economy. The Letuš Cultural Centre is a public building; consequently, it must be a particularly good example of a correct approach to energy management. The building is old and is placed in the energy class G, which is a very bad grade.

After a thorough analysis and applied calculations, we proposed a variety of measures. In addition to organizational measures, there are also three proposed investments: window replacement, renovation of the ceiling with additional thermal insulation, and facade renovation with the installation of thermal insulation. With these renovation measures, the energy needed for the building will be reduced by half, and so the operating costs will be lower. The payback period of the investment costs has been calculated, according to the static method, as a little over eight years, which is a good indicator for this type of investment. With the dynamic method, the calculated time to restore the investment is a little longer, just slightly above 13 years. Energy savings from these actions are subject to the conditions of continuous heating and other reference conditions. If the building is to function with interrupted operation, the annual energy savings is reduced, and the will also relatively prolong the period of reparability. The measures do not represent a comprehensive energy reform: such renovation should also include solutions and measures for the installed technical systems, such as the heating system. The current system is most definitely in need of a renovation, but there are many alternative solutions. It should also be noted that the use of renewable energy sources remains under consideration since the location of the building of the Letuš Cultural Centre is suitable for exploitation of the hydro-electricity, due to its location by the Savinja River.

References

[1] Dolgoročna strategija za spodbujanje naložb energetske prenove stavb, [online]. Avalible:http://www.mzi.gov.si/si/delovna_podrocja/energetika/ucinkovita_raba_energije/ (21. 2. 2016)

[2] Direktiva 2010/31/eu evropskega parlamenta o energetski učinkovitosti stavb. Ur. l. EU, št. 153, 18/06/2010 str. 0013 – 0035

[3] Pravni red, [online]. Avalible: http://www.arhiv.evropa.ukom.gov.si/si/pravni-red/ (27. 2 2016)

[4] Zakon o graditvi objektov, Ur. l. RS, št. 102-4398/20004- uradno prečiščeno besedilo, 14/05 - popr., 92/05 - ZJC-B, 93/05 - ZVMS, 111/05 - odl. US, 126/07, 108/09, 61/10 - ZRud-1, 20/11 - odl. US, 57/12, 101/13 - ZDavNepr in 110/13

[5] Pravilnik o učinkoviti rabi energije v stavbah PURES, Ur. l. RS, št. 52/2010, z dne 30.06.2010

[6] Direktiva 2012/27/eu evropskega parlamenta o energetski učinkovitosti stavb, Uradni list EU, 14/11/202, str. 315/1 – 315/56

[7] TSG-1-004:2010 Učinkovita raba energije, Ur. l. RS, št. 51/10

[8] ARSO: Atlas okolja, [online]. Avalible: http://gis.arso.gov.si/atlasokolja/profile.aspx?id=Atlas_Okolja_AXL@Arso (4. 1. 2016)

[9] **S. Medved**: *Gradbena fizika*, Fakulteta za arhitekturo, Ljubljana, 2010

[10] Toplotna energija in prenos toplote, [online]. Avalible: http://smarteco.wix.com/intermatics#!prihranki/cfmh (11. 3. 2016)

[11] **D. Goričanec:** *Prenos toplote*, [online]. Avalible: http://www.fkkt.um.si/egradiva/fajli/prenos_toplote.pdf (20. 2. 2016)

[12] Prenos toplote, [online]. Avalible: http://les.bf.unilj.si/uploads/media/5_PRENOS__TOPLOTE.pdf (20. 2 2016)

[13] ISO 6946:2007, Building components and building elements. Thermal resistance and Thermal transmittance, [online]. Avalible: http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=40968 (20. 2. 2016)

[14] Računalniški program KI Energija, verzija 4.2.7.3. [online]. Avalible: http://www.knaufinsulation.si/ (4. 1. 2016)

[15] Pravilnik o metodologiji izdelave in izdaji energetskih izkaznic stavb, Ur. l. RS, št. 92-3699/2014

[16] Arhiv Občine Braslovče

[17] **Š. Bojnec:** *Ekonomika podjetja*, Fakulteta za management, Koper, 2007

[18] **B. Trop:** *Energy renovation of cultural center Letuš*, Master Thesis, Faculty of Energy technology, Krško, 2016

[19] **Z. Praunseis:** *Energetska oskrba objektov*, Univerzitetni učbenik, Fakulteta za energetiko, Krško, 2013

Journal of Energy Technology

JET Volume 9 (2016) p.p. 39-51
Issue 3, October 2016
Typology of article 1.04
www.fe.um.si/en/jet.html

AN OVERVIEW OF REGULATIONS REGARDING PHOTOVOLTAIC SYSTEMS IN SLOVENIA

PREGLED FOTOVOLTAIČNIH SISTEMOV V SLOVENIJI NA PODLAGI NACIONALNIH PREDPISOV

Franc Rihl[ℜ]

Keywords: photovoltaic systems, subsidized prices, feed-in tariff and operative support, LCOE, net metering

Abstract

As a member of the EU, Slovenia has followed European trends encouraging the growth of renewable energy sources and, consequently, photovoltaic systems. Based on the Energy Law and several acts, two kinds of support schemes for PV systems were implemented.

This paper focuses on an overview of this support schemes for the electricity produced, their impact on the spread of production, and analyses the transition to net metering for PV systems in Slovenia.

Povzetek

Slovenija je kot članica Evropske Unije sledila evropskim trendom za spodbujanje rasti obnovljivih virov energije, med njih tudi spada spodbujanje in razvoj fotovoltaičnih sistemov. Na podlagi Energetskega zakona in sprejetih uredb se je v Sloveniji implementiralo dve vrsti finančnih podpor.

Članek se osredotoča na pregled finančnih podpor, njihov vpliv na širjenje PV sistemov in analizo prehoda na neto merjenje električne energije v Sloveniji.

ℜ Corresponding author: Franc Rihl, University of Maribor, Energy Conversion Laboratory, Hočevarjev trg 1, SI-8720 Krško, Tel.: +386 40 792 479, E-mail address: franc.rihl1@um.si

1 INTRODUCTION

Photovoltaics is a young scientific discipline, and a younger industry, which is already proving to be a significant contribution to the sustainable supply of electricity, the operation of which does not burden the environment. Photovoltaics is developing into a comprehensive, sustainable, and innovative economic sector, which also offers an excellent opportunity to develop and run advanced RES technologies in Slovenia.

Support schemes were implemented as a result of the sufficient spread of this technology in Slovenia. The main reasons for implementation were high production costs and low electricity prices on the market. Under the schemes, the resulting differences are regulated, so the technology can have a chance to compete with conventional production sources. In 2009, the first national regulation describing support schemes for RES in Slovenia was published. Before that, over 70 PV systems had already been connected to the grid in Slovenia. The values of schemes have been changing recently due to market conditions. In 2016, due to current stagnation, Slovenia introduced a net metering policy, which should result in fostering RES and PV systems.

This article presents the transition from support schemes to net metering for PV systems in Slovenia.

2 NATIONAL REGULATIONS, SUPPORT SCHEMES

In Slovenia, electricity production was supported via two basic supports. According to Article 372 of the Energy Act (EZ-1), support is provided in case the costs of electricity production from RES, including normal market return on invested assets, exceeds the electricity price that can be obtained on the electricity market, *[1]*.

Two types of support were introduced:

- Feed-in tariff – guaranteed purchase of produced and supplied electricity into the public grid electricity at a price set by the government;
- Operational support – support for the real-time operation of the system, *[1]*.

Borzen is a Slovenian electricity market operator. Its principal activity is the implementation of public service obligations relating to the organization of the electricity market, which includes both the organization of the electricity market and the activities of the Centre for RES/CHP Support. The centre administers the electricity feed-in support scheme for RES (renewable energy source) and CHP (high-efficiency cogeneration) power plants, *[2]*.

2.2 Feed-in tariff

In the case of the guaranteed purchase, the Centre for Support assumes the produced electricity from renewable power plants for the price determined in accordance with the decision granting assistance issued by the Energy Agency. Therefore, it is not possible to sell this electricity on the market, and a commercial contract for the sale of this electricity may not be concluded. The renewable power plant is placed in a special balancing group or sub-group established by the Centre for Support (Eco-balance group). The centre regulates the balance of the differences between the forecasted and realized production (i.e. cover deviations) and pays electricity that is produced and delivered into the public network, *[3]*.

For the feed-in tariff, renewable power plants with installed capacities of less than 1 MW are eligible. All producers of renewable energy are usually deemed to have the declaration as long as they use any of the listed RES technologies. The period of eligibility for this support is no more than 15 years, *[3]*.

2.2 Operational support

The producers of renewable energy may decide to directly sell produced electricity on the electricity market, in this case, they are eligible for so-called “Operational support”. The Centre for Support will not assume or pay for the produced electricity but only disburse operational support.

The support is intended to replace the difference between the production costs of the renewable power plant and the electricity price on the open market. The suppliers for purchasing electricity produced from renewable energy sources in Slovenia are the following:

- E 3, energetika, ekologija, ekonomija d. o. o.,
- ECE d. o. o.,
- Elektro energija d. o. o.,
- Energija plus d. o. o.,
- GEN-I d. o. o.,
- HSE d. o. o.,
- Petrol d. d.and
- Termoelektrarna Toplarna Ljubljana, [4].

Renewable power plants with installed capacities of less than 125 MW are eligible for operational support. The age of the plant should not exceed 15 years. If a power plant entered the support scheme when it was already in operation, then the duration of the support is reduced by the previous operational time of this power plant, *[1]*, *[3]*.

2.3 The relation between reference costs and subsidized prices for PV systems

The reference costs are the basis for determining the prices for feed-in tariff and operational support in contracts for the provision of support. Slovenia has divided the power plants into three categories:

- up to 50 kWp,
- from 50 kWp to 1 MWp, and
- 1 MWp from up to 10 MWp, *[4]*.

Purchase prices for feed-in tariffs are identical to the reference cost for renewable power plants, and they consist of two parts:

- The fixed part, which is equal to the fixed part of reference costs and does not change throughout the duration of the contract;
- The variable part, which is equal to the variable part of the reference cost, if it is defined. This part is annually or more frequently set according to the published reference price of the fuel used, *[4].*

For renewable power plants for which the variable part of the feed-in tariff is not defined or depends on the amount of electricity produced, just the fixed part should be indicated; the variable part should be ignored, *[4]*. PV systems are an example of this.

Operational support is determined with Equation 2.1, which consists of reference costs minus the reference price of electricity multiplied by factor B, *[4]*.

$$OS = RC - MP \cdot factor\ B \tag{2.1}$$

The reference price of electricity is expected to be the market price of electricity from the Energy Agency's forecast reference market prices of electricity. Factor B reflects the operating characteristics of individual types of renewable power plants, and thereby the quality of the electricity produced, which affects the achieved price of electricity from these production facilities on the electricity market, *[4].*

Reference costs were determined in relation to the competitiveness of electricity production from renewable power plants and their competitiveness on the electricity market, such as production spread, production costs, and efficiency.

Supports have affected the growth in demand and the decrease in production costs for RES systems, especially PV systems, which has led to the reference cost reduction and, consequently, to the downturn of supports. The first announcement of the reference costs reduction for PV systems was made in 2009. In Table 1, the reference cost reductions for PV systems between 2009 and 2014 are shown. The same data are also shown in Figure 1.

Table 1: *Reference cost reductions for PV systems between 2009 and 2014, [4], [5], [6], [7]*

Announced year	**Starting year**	**Reference costs reduction [%]**	**Regulation**
2009	2010	7	Official Gazette of the Republic of Slovenia Act Nr. 37/2009
	2011	14	
	2012	21	
	2013	28	
2010	2011	20	Official Journal of the Republic of Slovenia Act Nr. 94/2009
	2012	30	
	2013	40	
2011	1. 1. 2012 - 30. 6. 2012	30	Official Journal of the Republic of Slovenia Act Nr. 105/2011
	1. 7. 2012 - 31. 12. 2012	40	
2012	1. December 2012	2 (each first of the month)	Official Journal of the Republic of Slovenia Act Nr. 90/2012

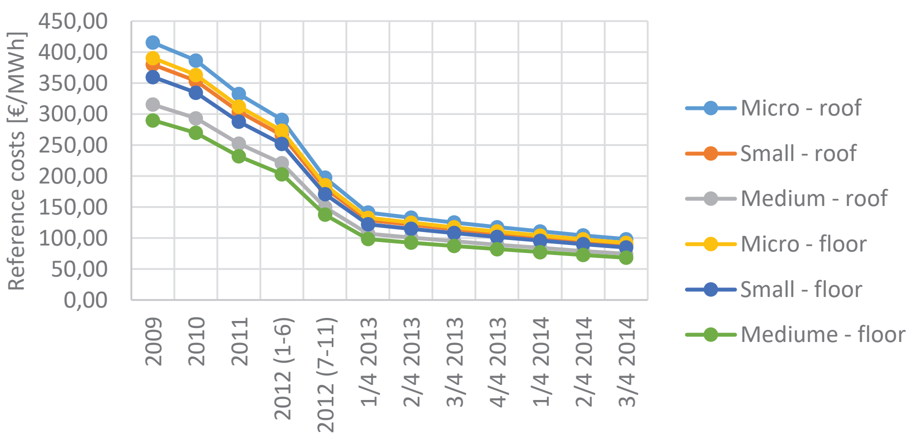


Figure 1: *Reference costs for PV systems in Slovenia,* [3]

3 SPREAD OF PV SYSTEMS REGARDING SUBSIDIZED PRICES

Despite the fact that the first supports were paid in 2009, 73 PV power plants were already operating in Slovenia. From Figure 2, we can observe that the first payoff of supports led to a steep increase in PV power plant construction. This mainly happened because reference costs were at their peak value that year, and the relation between them and production costs was extremely high; this presented a business opportunity. The spread of PV systems continued until 2012, when the yearly installed capacity was at peak value. After that it began to decline, *[8]*. The main reason for this decline was the adoption of regulations that contained the reference costs reduction (Table 1).

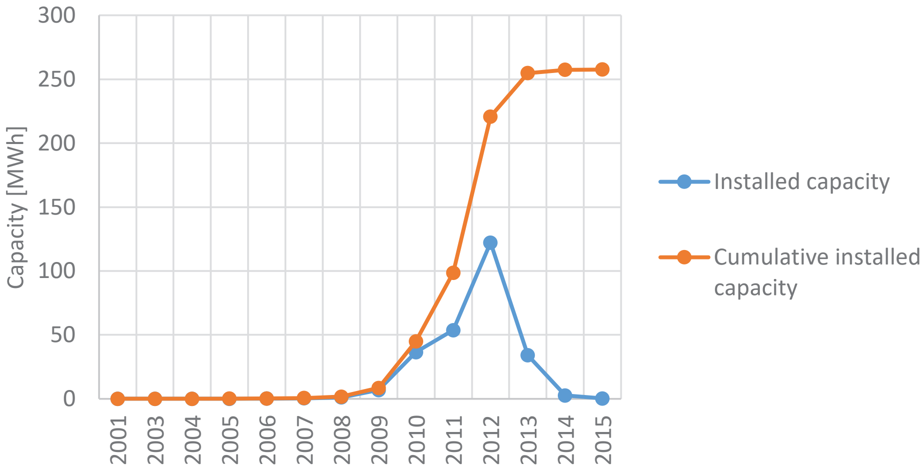


Figure 2: *Installed and cumulative installed capacity of PV systems in Slovenia, [8]*

In 2015, 3,367 PV power plants with a total installed capacity of just over 250 MW were in operation. Small PV power plants dominated with a share of over 83%, which can be seen from Table 2, *[8].*

Table 2: *Number of installed PV systems by categories for 2015, [8]*

Category	Micro	Small	Medium	Total
Number of PV systems	2798	569	0	3367
Percentage share	83.10	16.90	0	100

As shown in Figure 2, photovoltaics in Slovenia is nearly in stagnation, as support schemes are at their lowest value, or they are not in use anymore because of low production costs and electricity price on the electricity market. This depends on the RES used.

Perhaps the proper solution for this stagnation phase is properly set net metering regulation. With this, the re-growth of PV systems can be achieved.

4 NET METERING

Net metering (or net energy metering (NEM)) allows consumers that generate some or all of their own electricity to use that electricity anytime, instead of when it is generated. This is particularly important for wind and solar energy production, which are non-dispatchable. Net metering policies can vary significantly by country and by state or province. Most net metering laws involve monthly or annual roll over of kWh credits, a small connection fee, require payment of deficits (i.e. normal electric bill), and settlement of any residual credit. Thus, a net metering policy involves the electrical grid being used as a type of virtual accumulation pool, which is used for storing the generated electricity. Unlike a feed-in tariff, which requires two meters, net metering uses a single, bi-directional meter and can measure the current flowing in two directions. Net metering can be implemented solely as an accounting procedure, and requires no special metering, or even any prior arrangement or notification. Net metering is an enabling policy designed to foster private investment in renewable energy, *[9].*

Net metering usually becomes effective when electricity prices on the market are higher than the production costs of electricity from solar energy. For that reason, the movement of electricity prices on the market must be known, and the production cost of electricity produced by a power plant must be evaluated. To do this properly, the "Levelized Cost of Energy" (LCOE), which is one of the utility industry’s primary metrics for the cost of electricity produced by a generator, is calculated.

4.1 LCOE

The LCOE is the price at which electricity must be generated from a specific source to break even over the lifetime of the project. It is an economic assessment of the cost of the energy-generating system, including all the costs over its lifetime: initial investment, operations, and maintenance, the cost of fuel, and the cost of capital. It can be calculated with a single formula. There are many different formulas for calculating LCOE, and one of them is shown in Equation 4.1, *[10].*

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \tag{4.1}$$

where I_t are investment expenditures in year t, M_t are the operations and maintenance expenditures in year t, F_t are fuel expenditures in year t (zero for PV systems), E_t is electricity generation in year t, r is discount rate, and n is investment period considered in years.

It is an economic assessment of the cost of the energy-generating system including all costs over its lifetime:

- initial investment,
- operations and maintenance,
- cost of fuel,
- cost of capital, *[14].*

Typically, LCOE is calculated over 20 to 40 years of the project's lifetime. It is given in the units of currency per kilowatt-hour (€/kWh).

The biggest impact on the calculation of LCOE for PV systems are from the investment costs. Operating and maintenance costs are much lower in comparison to investment costs; fuel costs practically do not exist. This means that the LCOE depends essentially on the investment costs, which are mostly the costs of purchasing solar modules.

The PV industry has experienced a compound annual growth rate of over 50% over the last 10 years, accompanied by a four-fold reduction of costs. This is directly linked to solar module prices which are shown in Figure 3. It is noteworthy that prices have practically halved in the last five years. The price decrease has influenced high demand and enlarging the production capability of solar modules in various markets, which resulted in increased competitiveness, *[8]*, *[13]*.

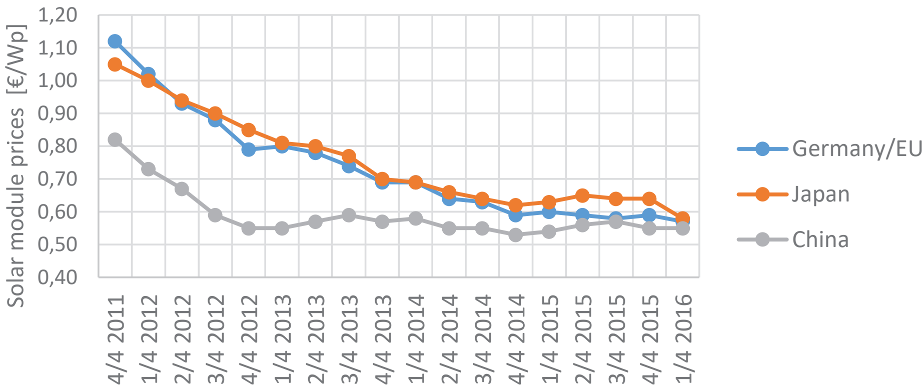


Figure 3: *Average net prices for crystalline modules, [13]*

JRC has produced a series of PV electricity price maps, which combine a standard model for the leveled cost of electricity (LCOE) with the geographically dependent PV performance data from its PVGIS software system *[3, 4]*. The calculated LCOE values are then compared with the retail electricity prices in the Member States, of which Slovenia is one, *[10].* Table 3 summarizes the parameter values used in 2012, 2013 and 2014 for LCOE calculations.

Table 3: *Parameter values used in the LCOE calculation, [10]*

Parameter	**Values**		
	2012	**2013**	**2014**
I_t	2300	1700	1400
r	5%	5%	5%
n	20	20	20
M_t	1%	1%	1%
E_t	From JRC's PV-GIS on-line tool	From JRC's PV-GIS on-line tool	From JRC's PV-GIS on-line tool

According to the calculated LCOE data from 2013, Slovenia has already reached grid parity. This is shown in Figure 5.

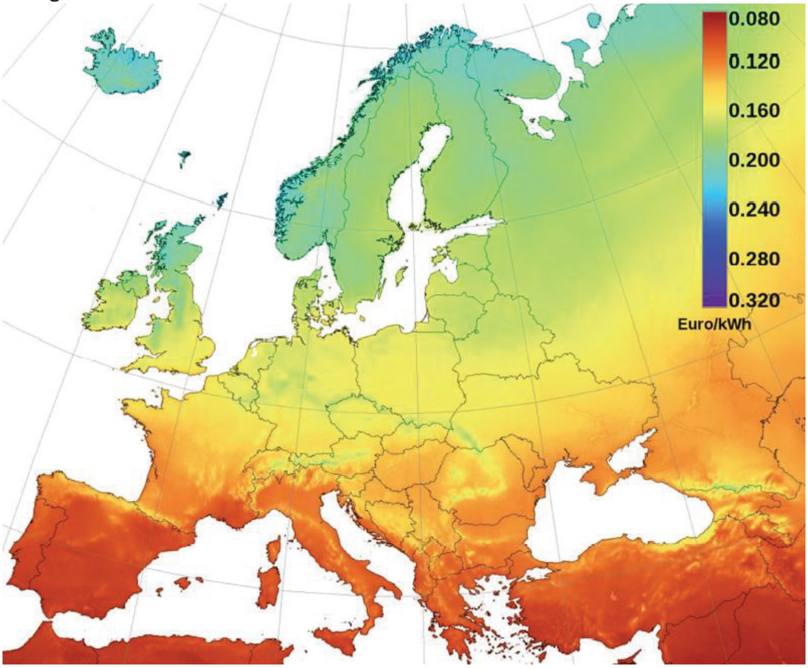


Figure 4: *Distribution of the leveled cost of PV electricity in Europe for 2013, [10]*

4.2 Electricity market prices

As already stated, the prices of electricity have a key role in achieving the proper environment for the successful integration of net metering; they must be below the calculated LCOE.

Electricity market prices in Slovenia have been practically constant over the previous seven years, which can be observed from Figure 4. The increase in prices was just a few percentage points, so it can be concluded that electricity prices in the future will not affect the net metering, as much as the prices of solar modules will.

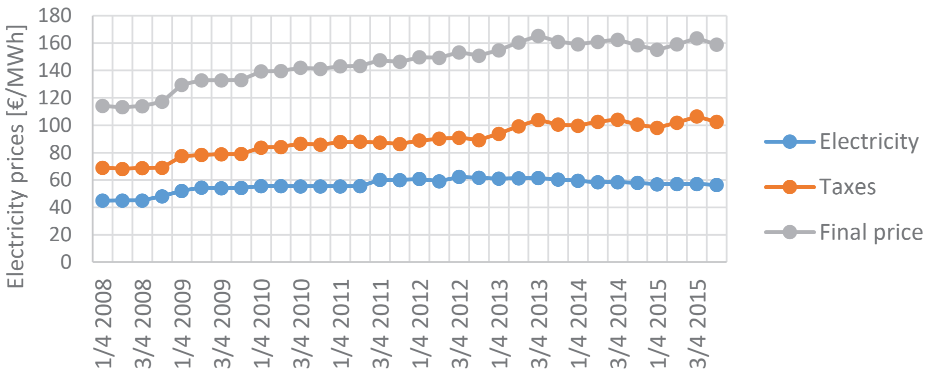


Figure 5: *Average electricity prices for households,* [12]

4.3 The net metering regulation in Slovenia

In January 2016, net metering regulation was adopted for the electricity produced from RES. The regulation sets out the conditions for self-sufficiency, the accounting method, the annual limit of renewable power plants, the way of reporting on the measures implementation and the method for calculating the electricity produced from renewable power plants, *[14], [15].* The conditions under which devices are eligible for net metering regulation are the same as they were in the feed-in tariff and operational support with one exception: net metering uses a single, bi-directional meter for measuring the power.

The maximum installed capacity for power plants is 11 kVA; it means that apparent power has to be considered in planning, so active and reactive power also have to be taken into consideration. For the calculation of the electricity consumption, the difference between the used and produced active power in a given billing period (normally the current calendar year) is taken into account. If a power plant has a positive balance at the end of the period, then the difference is transferred free of charge to the ownership of the power supplier. Otherwise, when the electricity consumed is greater than that produced, the difference is accounted at current electricity prices on the market. Therefore, the best option is to plan the size of the renewable power plant as close to the predicted household electricity consumption or just a little lower, in addition to not having any costs with the free transferring of extra produced electricity to the power supplier.

The maximum total rated power of connected devices for self-sufficiency to the grid in the calendar year is 7 MVA for households and 3 MVA for SMEs. The amount of the network charges for using the electrical network is determined when signing the contract with the selected system operators. The user of the net metering device must pay to the system operator for the following items for the usage of the electrical network on a monthly basis:

- Network charge,
- The contribution of RES and CHP, *[14], [15].*

For the implementation of the net metering in Slovenia, the following distribution system operators are eligible:

- Elektro Ljubljana,
- Elektro Maribor,
- Elektro Gorenjska,
- Elektro Primorska, and
- Elektro Celje, [3].

5 CONCLUSION

Slovenia has followed European trends for encouraging the spread of RES and especially PV systems by introducing financial support schemes. In the beginning, supports were extremely high due to high production costs from RES in comparison to conventional sources. These grants were quickly utilized, which has led to the great annual growth of PV systems as shown in Figure 2.

Decreasing solar module prices on the global market, due to the massive enlargement of demand and consequently, production facilities, resulted in a decrease of supports. The decrease was happening until production costs from renewable power plants became level with the price of electricity on the market. This meant that the withdrawal of supports slowed the spread of PV systems and that a new way had to be found to again encourage the spread of such systems. The adopted net metering regulation was found to be a good solution for this matter.

According to the content of the adopted regulation, restriction of the size and the annual number of connected PV systems, we cannot expect a major change in the spread of such systems in Slovenia. The ratio between the price of electricity and the production cost is still too low to expect that the regulation would drastically affect the spread of PV systems.

One disadvantage is that fees for using the electrical network as an “accumulation pool” are not clearly set; consequently, distribution system operators are at least partially adversely affected. In contrast, electric utilities are required to buy produced power, even though it generally would cost them less to produce the electricity themselves or to buy the power on the wholesale market from other electricity providers, *[16].*

In the end, we can say that this regulation is set without taking into account the knowledge of electrical providers and operators of PV systems. Furthermore, the maximum total rated power of connected devices for self-sufficiency to the grid in the calendar year is too limited in regards to what potential owners of PV systems could contribute in the field of RES.

References

[1] **Government of the Republic of Slovenia:** *Official Journal of the Republic of Slovenia, Act Nr. 17/2014,* Energy Act – Slovenia, Ljubljana 2014

[2] **F. Pranjić**: *Review of energy regulations on solar energy (pv) in Slovenia and Austria*, JET volume 7, 2014

[3] Borzen, organizator trga z električno energijo, d.o.o.

[4] **Government of the Republic of Slovenia:** *Official Journal of the Republic of Slovenia Act Nr. 37-2009*, Ljubljana 2009

[5] **Government of the Republic of Slovenia:** *Official Journal of the Republic of Slovenia Act Nr. 94/2010,* Ljubljana 2010

[6] **Government of the Republic of Slovenia:** *Official Journal of the Republic of Slovenia Act Nr. 105/2011,* Ljubljana 2011

[7] **Government of the Republic of Slovenia:** *Official Journal of the Republic of Slovenia Act Nr. 90/2012,* Government of the Republic of Slovenia, Ljubljana 2012

[8] **UL FE, LPVO:** *PV portal, Slovenski portal za fotovoltaiko* [online]. Available: http://pv.fe.uni-lj.si/Welcome.aspx (10. 8. 2016)

[9] **Wikipedia:** *Net metering*, The Free Encyclopedia [online]. Available at: https: // en.wikipedia.org/wiki/Net_metering (15. 8. 2016)

[10] **H. Ossenbrink, T. Huld, A. Jäger Waldau, N. Taylor**: *Photovoltaic Electricity Cost Maps*, Annual Report 2013, Joint Research Centre (JRC), 2013

[11] **Wikipedia:** *Capital recovery factor*, The Free Encyclopedia [online]. Available: https://en.wikipedia.org/w/index.php?title=Levelised_energy_cost&oldid=365220846 (15. 8. 2016)

[12] **Ministry of Infrastructure, Government of the Republic of Slovenia, The Energy Directorate:** *Electricity prices* [online]. Available at: http://www.energetika-portal.si/statistika/statisticna-podrocja/elektricna-energija-cene/ (30. 7. 2016)

[13] **Pv magazine:** *pvXchange module price index* [online]. Available: http://www.pv-magazine.com/investors/module-price-index/#axzz49Jp3NaVt (20. 8. 2016)

[14] **Public Hearing Notice:** *Net metering regulation for RES* [online]. Available: http://www.enerson.si/scripts/download.php?file=/data/upload/Predlog_uredbe_samooskrba_z_EE_jun_2015.pdf (18. 8. 2016)

[15] **Government of the Republic of Slovenia:** *Official Journal of the Republic of Slovenia Act Nr. 97/2015*, Ljubljana 2015

[16] **Edison Electric Institute (EEI):** *Solar Energy and Net metering* [online]. Available: http://www.eei.org/issuesandpolicy/generation/NetMetering/Documents/Straight%20Talk%20About%20Net%20Metering.pdf (22. 8. 2016)

Nomenclature

(Symbols)	(Symbol meaning)
PV	Photovoltaic
RES	Renewable Energy Sources
OS	Operational support
RC	Reference costs
MP	The reference price of electricity
LCOE	Levelized Cost of Energy
I_t	Investment expenditures in year t
M_t	Operations and maintenance expenditures in year t
F_t	Fuel expenditures in year t, which is zero for photovoltaic electricity
E_t	Electricity generation in the year t
r	Discount rate
n	Investment period considered in years
r	discount rate (cost of capital)
CHP	Combined Heat and Power

Journal of Energy Technology

JET Volume 9 (2016) p.p. 53-60
Issue 3, October 2016
Typology of article 1.01
www.fe.um.si/en/jet.html

ULTRASONIC DETECTION OF DEFECTS IN STEEL WELDS

ULTRAZVOČNO ODKRIVANJE NAPAK V JEKLENIH ZVARIH

Marko Pešić[ℜ], Irena Nikolić[1], Zdravko Praunseis[2]

Keywords: HSLA steel, welded joints, defects, ultrasound

Abstract

High-strength micro-steels(VTML) are often used in the modern steel construction of multi-bead welds. Given the effectiveness and efficiency, welding is one of the main technological processes in the production of metal parts to manufacture complex forms.

In this paper, the ultrasonic detection of defects in steel welds is presented. The first part of the paper deals with the problem of the occurrence of defects in steel welds and how to determine them. The next part describes the ultrasonic detection of defects with a *Krautkrämer* device.

Povzetek

Visokotrdna mikrolegirana (VTML) jekla so pogosto uporabljena kot moderna jekla za gradnjo večvarkovnih zvarnih spojev. Glede učinkovitosti in ekonomičnosti je varjenje eden od glavnih tehnoloških postopkov pri proizvodnji kovinskih delov, ki nam omogoča izdelavo kompliciranih oblik.

ℜ Corresponding author: Graduate student, Marko Pešić, Faculty of Energy Technology, University of Maribor, Tel.: +386 70 286 719, Mailing address: Hočevarjev trg 1, Krško, Slovenia, E-mail address: marko.pesic@student.um.si

[1] School Center of Velenje, Trg mladosti 3, Velenje, Slovenia

[2] University of Maribor, Faculty of Energy technology, Hočevarjev trg 1, Krško, Slovenia

V članku je predstavljena detekcija napak v jeklenih zvarih z ultrazvokom. V prvem delu raziskave je opisana problematika pojava napak v jeklenih zvarih in kvalifikacija nastalih napak. V nadaljevanju je opisana detekcija napak v zvarih z ultrazvočno napravo *Krautkrämer*.

1 INTRODUCTION

Welding is the joining of two or more parts of a base material into an indivisible whole *[1]*. Regarding effectiveness and efficiency, welding is one of the main technological processes in the production of metal parts to manufacture complex forms. For effective welding, the knowledge of welding structure design, metallurgical welding, the weldability of materials, and the different technological processes of welding are necessary.

Chemical reactions are not desirable; they enter the weld melt from the atmosphere and base material. The best properties of welded joints are achieved by a very expensive welding process the takes place in a vacuum, for the military and aerospace industries. Structural stresses occur in metal when the crystal structure is modified and as a result of warming or cooling. In the case of Y-α in the iron, the consequence is a change in volume. Furthermore, the rate of change in the material causes elasticity or plasticity of the tested material, *[2-4]*.

Therefore, it is necessary to search and classify the defects in welds. This study presents the most commonly used non-destructive method of finding defects: the ultrasonic method.

2 EXPERIMENT AND RESULTS

The sound field of ultrasonic probes can be divided into the near and far fields. The focusing of the sound is called the *Frasne* zone or a near field. Due to the overlapping and aggregating of individual wavefronts, the impact of the scope is robust and rapid, preventing a reliable assessment of echo heights. In the *Fraunhofer* zone or far field, the sound path increases due to the divergence of the ultrasonic beam split into a rising curve. The impact of the loss of divergence means that the distance of the sound pressure decreases (Figure 1).

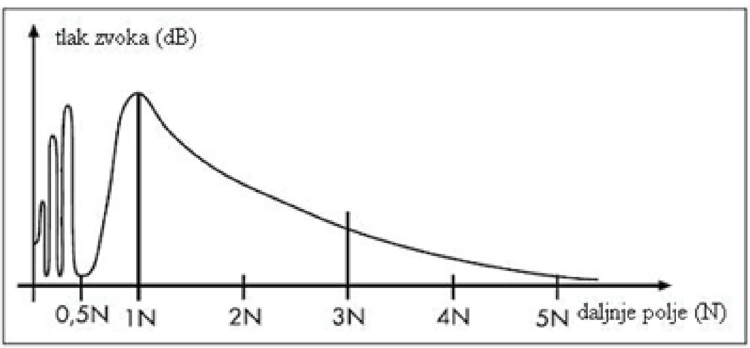
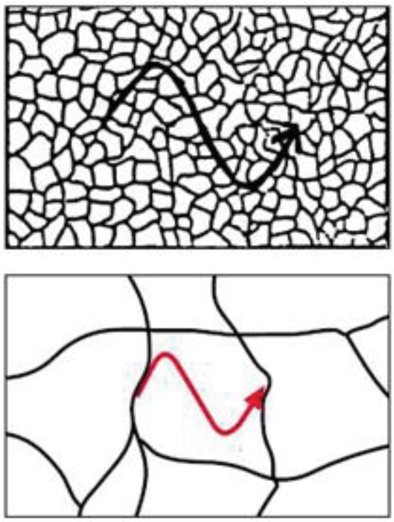


Figure 1: *Sound field (Faculty of Energy Technology archive)*

We assumed that the validity of ultrasound is treated as a deduction of acoustically ideal substances. So, the sound pressure decreases due to spreading of the sound beam travelling through a specimen. Other materials have additional sonic insulation, which can be divided into absorption and scattering.

Absorption represents the conversion of sound energy into heat, *[5-8]*. Such throttling reduces the intensity of waves, but it does not increase the noise in the received signal. The echo height is reduced and can be levelled by increasing the transmission power and the repeater. In *damping* or *scattering*, this cannot be performed because it would lead to an increase in the base noise and would not improve the signal/noise ratio. Scattering represents the parts of the sonic waves that bounce in straight lines and spread when deducted against the inverter. They can be seen on the screen as noise. Due to this phenomenon, the suitability of the materials is reduced in two different ways:

- The intensity of the sound field is decreased, thereby reducing the height of the indications being the result of searching for defects in the material.
- Background jamming occurs because of which the indication of interruption is covered.



–

Figure 2: *Fr Damping of ultrasound (Faculty of Energy Technology archive)*

Very fine grains do not cause scattering since the wavelength is relatively large in comparison to the grain size. If the grain size reaches that of the wavelength, a part of the sound wave is declined from its direction (Figure 2).

Damping of the ultrasound depends on the type of material, the size of specimen grains, and the size of the wavelength. The ultrasonic *Krautkrämer* USM 36 is a device for the non-destructive debugging of steel welds. (Figure 3).

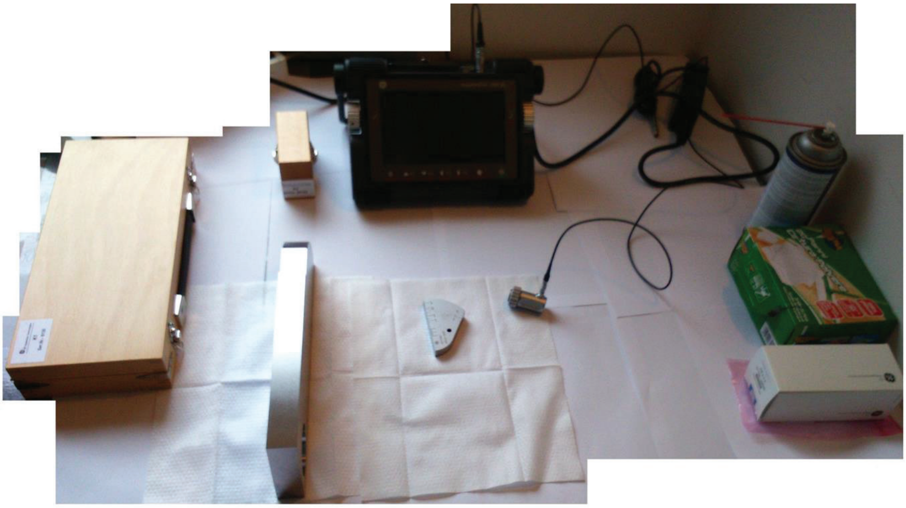


Figure 3: Preparations before testing with an ultrasonic method (Faculty of Energy Technology archive)

The flat head probe sends the sound into the object. The device automatically detects defects on the basis of the data, height, thickness and length of the transmitted signal (Figure 4).

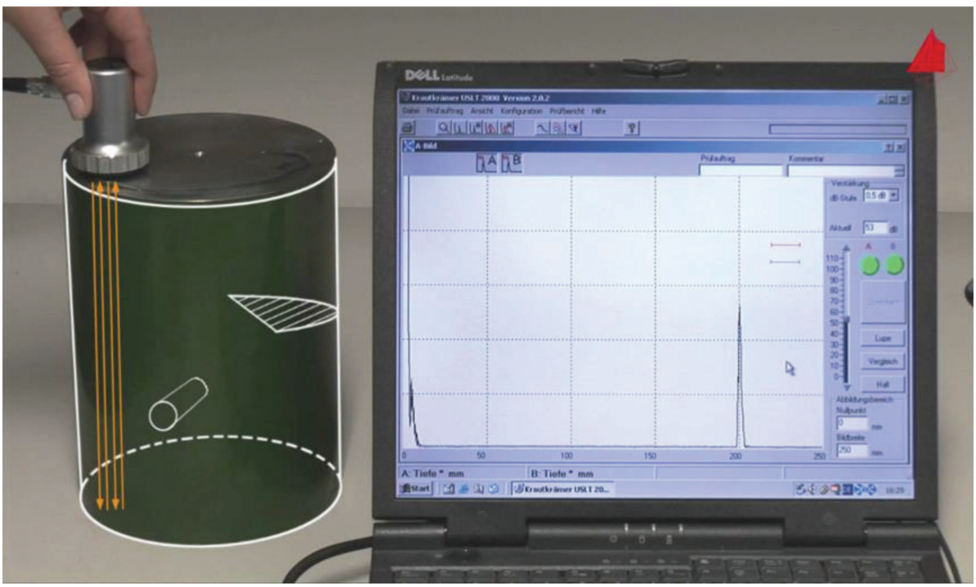


Figure 4: Operation of a flat head probe and the readings on the computer monitor, *[3]*

The device is activated by pressing the start button. Then it has to be connected to the straight probe. To start the measurement, the probe is lubricated with a water-based gel, in a portion the size of a bean. Then the calibrations for each standard or material are made separately.

The ultrasound examination has a tendency in which the natural reflectivity of reflectors is compared with the reflectance of artificial reflectors; the comparisons may be direct or indirect. In the direct mode, a comparator block, which is in accordance with the regulations for comparative reflectors, has to be available, *[9-11].*

In the indirect comparison, the comparative reflectivity of the reflector is determined. The direct comparison, to be a valid method of the comparative block, the AVG indirect method or the ultrasonic device, called DGS, is used.

The advantage of the DGS method is that it does not require comparative blocks to reduce costs when changing the tasks, while other advantages include the testing of small batches and maintenance. According to the geometry and damping properties of the experimental equipment, the DGS method is more limited than that of the comparative block (Figure 5).

The use of the comparative block requires such blocks with similar acoustic properties of a specimen. Regarding finances, this method is useful for testing large batches.

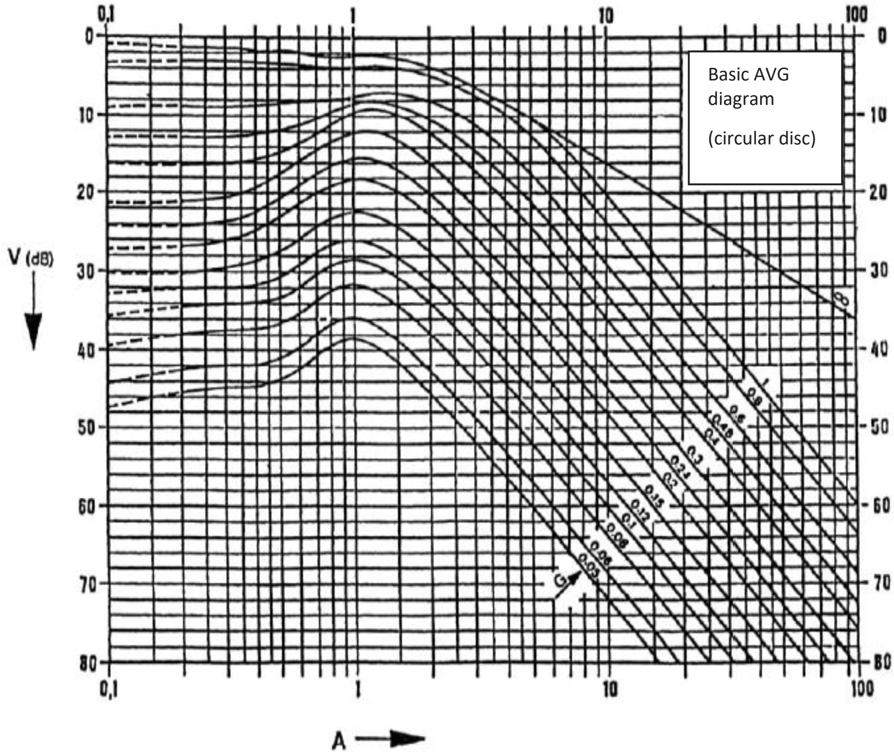


Figure 5: *General AVG or DGS diagram*

The code ˝AVG˝ is an abbreviation of the German words *Abstand*, *Verstärkung*, and *Groß* (distance, amplification, size). The method uses a relative difference attenuator for perfectly circular reflectors of different diameters to increase the distances away from the vibrator. In the diagram of the differential attenuator, the difference in the attenuation setting on the machine is provided due to the need to achieve a signal, both compared with the same reflectors arranged at the height of the screen.

The horizontal axis represents the distance from the reflector vibrator, while the decreasing and increasing of the vertical axis needs amplification. The diagram reflector with different diameters belongs to one of the curves to obtain a group of curves. If the associated reflectors are smaller, more lines run low, and more of them are highly amplified.

The KSR curve of the rear wall is seen just for a limited period, having a lower slope of decline in dependence with the distance. The size and distance are given as quantity norms so that the general DGS diagram can be used for all normal and angle probes.

The protective boxes of probes have ready-made special diagrams valid only for the types of probes. The AVG diagram does not apply to the SE-focused and highly damped probe (Figure 6).

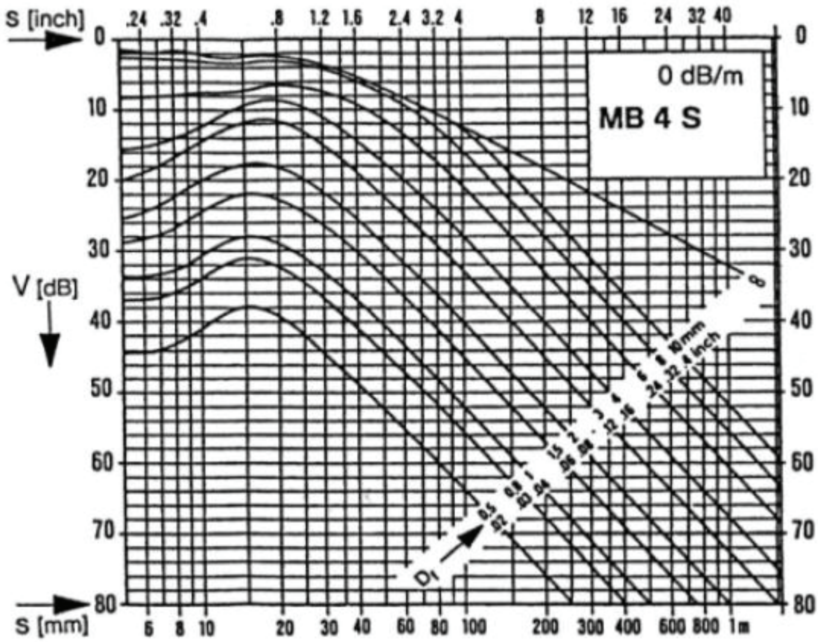


Figure 6: *Diagram only applies to the flat probe MB 4 S*

3 CONCLUSION

Steel welds are an integral part of steel structures. Welded joints are typically characterized by the heterogeneity of chemical and mechanical properties. The welds develop different defects that detrimentally affect the carrying capacity of welded structures. In some cases, a sudden collapse of the structures may occur.

Therefore, it is crucial that the presence of errors is detected in due time. One of the most effective methods of testing is the ultrasonic method. When handling the USM ultrasonic device 36, it is important to properly calibrate it to measurement standards K1 and K2 and to select the corresponding measurement probe with which the defects will be sought.

The defects are classified according to the standard classification, while the size is read through the AVG rocks. This makes it vital to detect defects in due time. One of the most effective methods of testing is the ultrasonic method.

References

[1] **I. Rak**: *Tehnologija varjenja*, Modrijan, 2008

[2] **Z. Praunseis**: *Ultrazvočna defektoskopija*, Fakulteta za strojništvo Maribor, 1999

[3] **J. Strnad**: *Fizika*, Univerzitetni učbenik, Fakulteta za naravoslovje in tehnologijo, Ljubljana, 2000

[4] **M. Tušek**: *Tehnika spajanja*, Univerzitetni učbenik, Fakulteta za strojništvo, Ljubljana, 2003

[5] **J. Puhar**: *Mehanska tehnologija*, Univerzitetni učbenik, Fakulteta za strojništvo, Ljubljana, 1990

[6] **Z. Ren**: *Strojni elementi 1.del*, Univerzitetni učbenik, Fakulteta za strojništvo, Maribor, 2005

[7] **R. Schwalbe**: Welding of Passat cars, Handbook, Hamburg, 2001.[8] M. Šolar: Dodajni materiali in varjenje, SŽ-elektrode Jesenice, d.o.o., 2003

[9] **M. Kovač**: *Gradiva*, Zapiski predavanj, Fakulteta za strojništvo, Ljubljana, 2001

[10] **I. Anžel**: *Gradiva*, Univerzitetni učbenik, Fakulteta za strojništvo, Maribor, 2007

[11] **Z. Praunseis, J. Avsec**: *Gradniki v energetiki*, Univerzitetni učbenik, Fakulteta za energetiko Krško, 2012

Journal of Energy Technology

JET Volume 9 (2016) p.p. 61-77
Issue 3, October 2016
Typology of article 1.01
www.fe.um.si/en/jet.html

ELEMENTAL ANALYSIS OF WELDS WITH AN X-RAY FLUORESCENCE ANALYSER

ELEMENTARNA ANALIZA ZVARNEGA SPOJA Z RENTGENSKO FLUOROSCENTNIM ANALIZATORJEM

Marko Kišek[ℜ], Zdravko Praunseis[1]

Keywords: HSLA steel, elemental analysis, welds, x-ray fluorescence analyser

Abstract

High-strength low-alloyed (HSLA) steels are often used as an advanced material for the construction of multi-pass welded joints. Chemical analyses of welds are performed with X-ray fluorescence spectrometry (XRF) using an X-ray fluorescence spectrometer (Thermo Scientific Niton XL3t GOLD+).

The aim of this paper is to design a measuring table for the x-ray fluorescence analyser. At the end of the research, the experimental results measured with the table are compared with the values obtained from manual measurements.

Povzetek

Visokotrdnostna mikrolegirana (VTML) jekla so pogosto uporabljena kot moderna jekla za gradnjo večvarkovnih zvarnih spojev. Kemijska analiza zvarov je izvedena z rentgenskim fluoroscentnim analizatorjem XRF (Thermo Scientific Niton XL3t GOLDD+).

Namen članka je konstrukcija merilne mizice za rentgenski fluoroscentni analizator. Na koncu raziskave so eksperimentalni rezultati, izmerjeni na mizici, primerjani z vrednostmi, ki so bile izmerjene ročno.

ℜ Corresponding author: Master student, Marko Kišek, Faculty of Energy Technology, University of Maribor, Tel.: +386 70 827 672, Mailing address: Hočevarjev trg 1, Krško, Slovenia, E-mail address: marko.kisek@gmail.com

[1] University of Maribor, Faculty of Energy technology, Hočevarjev trg 1, Krško, Slovenia

1 INTRODUCTION

Welding is a process in which two or more pieces of material are joined and is achieved by pressure, heat, with a combination of both, with or without added material, *[1-8]*.

During the process of welding, various problems occur due to weather and mechanical influences. Due to the growing needs and requirements of the market, improvements and the provision of perfect welds are constantly needed, *[8-16]*.

To ensure complete welds, the x-ray fluorescent analyser can be used, which also aids in the analysis of welds. In the survey, the Niton Gold+ analyser will be used, which is a manual, compact, high-performing, portable device for the x-ray analysis of elements. With the help of the device, the welds will be analysed with two procedures. One is that the device is handheld; the second procedure is the creation of a small support panel installed in the device, thus enabling the performance of the measurements. After completion of the measurement, the results of the chemical analysis will be compared.

2 EXPERIMENTAL PROCEDURE

Our goal was to make the product (support panel or table) for the Niton device so that we would be able to make hands-free measurements. The idea was to make the product more useful and as reliable as possible so that it could be used by anyone. We also wanted the panel to have a benchmark so that measurements could be performed several times, ensuring minor deviations. Our purpose was that with the help of a panel we could control the device with a PC, which would be significantly easier for the user and for the subsequent processing of the results.

To make this product, we first needed the dimensions of the Niton apparatus. With the help of clay and the case of the apparatus (Figure 1), we attempted to obtain the shape of the device, but it turned out that the case was bigger and of a different shape than the device, so this approach was unhelpful.

Figure 1: *Model obtained by using the clay*

Next, we obtained the dimensions directly from the device, using a calliper (Figure 2). Due to the unusual shape of the device, we had difficulties obtaining measurements. Next, we copied the shape of the device. Initially, the idea was to make a stand, following the idea from Figure 3. After a couple of considerations, this concept turned out to be inappropriate, since the device would be attached to only one side, and therefore would not be sufficiently stable. After consultation, we had the idea of making the product similar to as shown in Figure 4. Thus, we have achieved greater stability of the device, since the device was attached to two sides. We had to take additional measurements for brackets for a perfect fitting of the device (Figure 5).

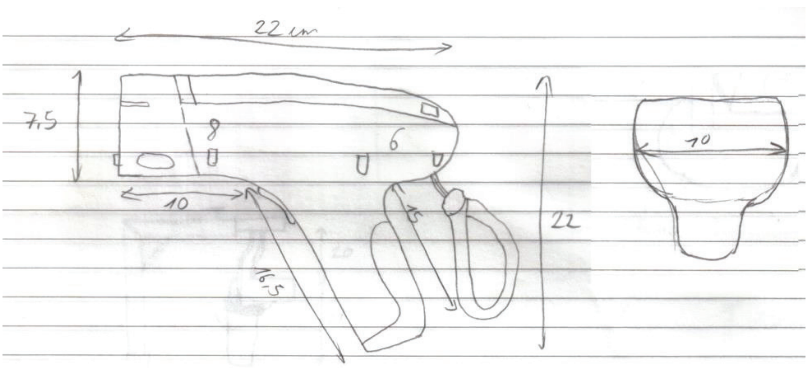


Figure 2: *Sketch of dimensions of the Niton apparatus*

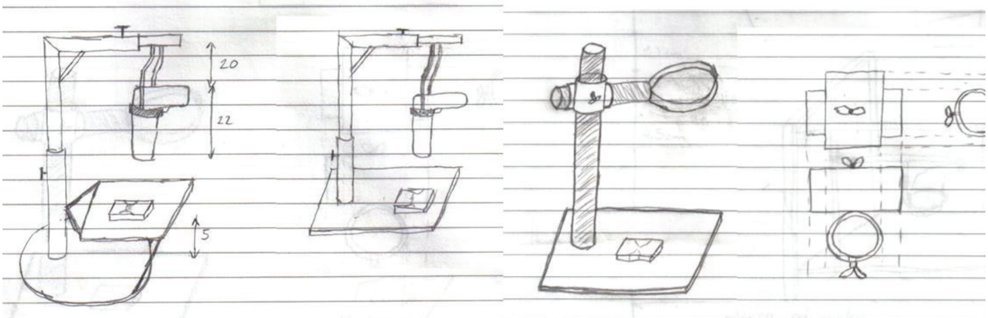


Figure 3: *Sketch of the stand*

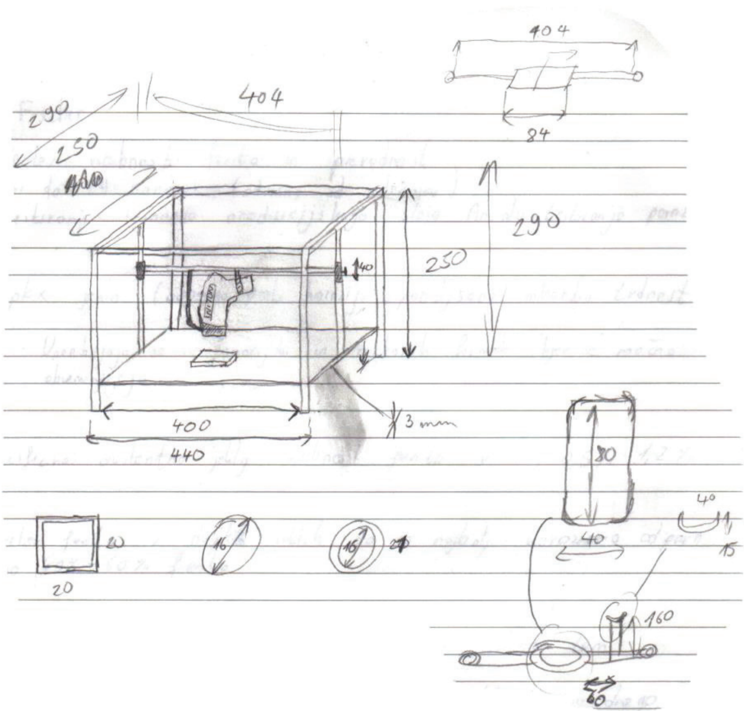


Figure 4: *Sketch of the support panel with dimensions*

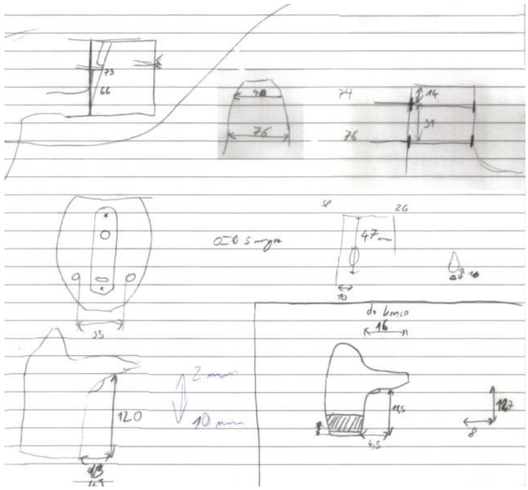


Figure 5: *Dimensions of the device where it is attached to the stand*

Our technological requirements were that the support panel should be stable and rigid and perfectly fit the device. We also wanted it to be as easy as possible to use. In choosing the material, we focused on strength. We opted for stainless steel, because it is solid and does not require additional protection against oxidation. Parts of the support panel, where the device and bracket are in contact, were cushioned for the device to fit better into the panel. Thus, the device was also protected against unwanted abrasions. On the bottom of the panel is a 3-mm-thick plate of stainless steel, with an attached benchmark that enables more accurate positioning of the measured object.

When the support panel was complete, welds were cleaned with Antox 71 E acid and rinsed with water. In the end, the panel was polished with polish paste. At the bottom of the panel, we attached an A4 millimetre scale with printed units, which was protected with self-adhesive foil. The complete panel is shown in Figure 8.

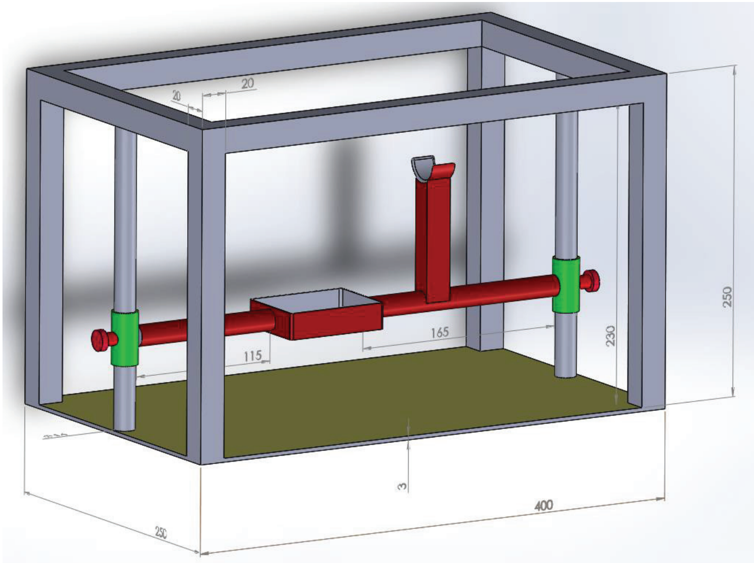


Figure 6: *Plan of the panel made with the program SolidWorks*

Figure 7: *Welded panel*

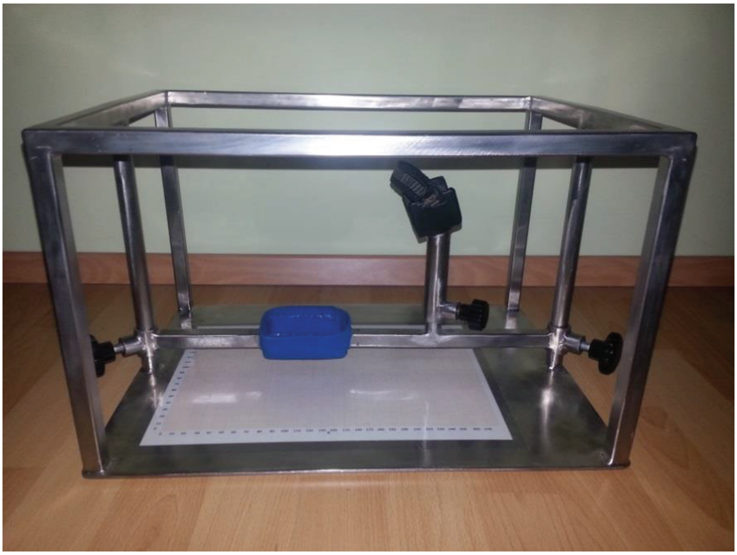


Figure 8: *Completed panel*

3 RESULTS AND DISCUSSION

In the research, we used two different measurement procedures. Measurements were carried out manually and with the use of the support panel presented in the previous chapter. Each measurement was repeated three times, and later the average value calculated. Each measurement was done for one minute. The manual measurement is shown in Figure 9, and the measurement with the help of the support panel is shown in Figure 10.

Figure 9: *Manual measurement*

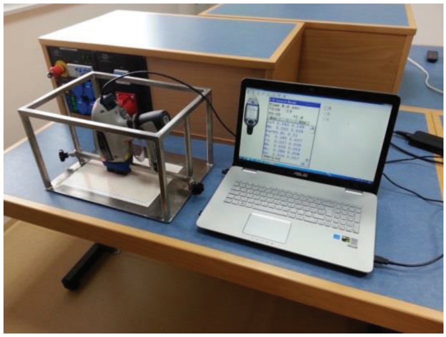


Figure 10: *Measurement with the help of the panel*

Figure 11 shows the weld and location of the first measurement, designated with a black dot. The first measurements were done on basic material, which did not change its properties after welding. Points A and B represent the location of the measured object on the instrument when measuring with the aid of a panel. With the help of these points, we can later duplicate the measurements. Point A has coordinates (80 mm, 85 mm), and Point B (147 mm, 85 mm).

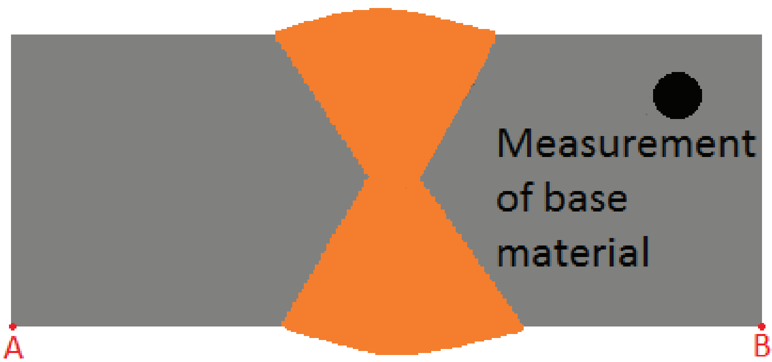


Figure 11: *Measurement of base material*

Tables 1 and 2 show the results of the first measurements of the basic material. Table 1 shows the results obtained with the help of the panel; the results in Table 2 were obtained with manual measurements. Each measurement was repeated three times in a row. We made excerpts from both tables and presented them as a percentage. From all three measurements, we then calculated the average of each element and the maximum and minimum deviation from those values. In Table 3, we copied the deviated values for a better overview. Thus, it is clearly shown with which measurement technique the deviations were smaller. Those deviations that were smaller in the manual mode of measurement have been tagged in red.

Table 1: *Results of measurements of the basic material obtained with the panel*

With the panel	Mo (%)	Nb (%)	Cu (%)	Ni (%)	Fe (%)	Mn (%)	Cr (%)	Si (%)
Measurement 1	0.2730	0.0300	0.2220	0.1450	97.7240	0.4960	0.5530	0.3820
Measurement 2	0.2720	0.0300	0.2410	0.1250	97.8570	0.5140	0.5460	0.3960
Measurement 3	0.2710	0.0280	0.2430	0.1710	97.8810	0.4440	0.5480	0.4010
Average	0.2720	0.0293	0.2353	0.1470	97.8207	0.4847	0.5490	0.3930
Deviations +	0.0010	0.0007	0.0077	0.0240	0.0603	0.0293	0.0040	0.0080
Deviations -	0.0010	0.0013	0.0133	0.0220	0.0967	0.0407	0.0030	0.0110

Table 2: *Results of measurements of the basic material obtained by manual measurements*

Manually	Mo (%)	Nb (%)	Cu (%)	Ni (%)	Fe (%)	Mn (%)	Cr (%)	Si (%)
Measurement 1	0.2770	0.0280	0.2260	0.1700	97.7230	0.4870	0.5520	0.3660
Measurement 2	0.2750	0.0300	0.2410	0.1450	97.8470	0.5350	0.5230	0.3910
Measurement 3	0.2680	0.0290	0.2320	0.1670	97.8690	0.5060	0.5220	0.3760
Average	0.2733	0.0290	0.2330	0.1607	97.8130	0.5093	0.5323	0.3777
Deviations +	0.0037	0.0010	0.0080	0.0063	0.0560	0.0257	0.0197	0.0133
Deviations -	0.0053	0.0010	0.0070	0.0157	0.0900	0.0223	0.0103	0.0117

Table 3: *Deviations of measurements of the basic material*

		Mo (%)	Nb (%)	Cu (%)	Ni (%)	Fe (%)	Mn (%)	Cr (%)	Si (%)
With the panel	Deviat +	0.0010	0.0007	0.0077	0.0240	0.0603	0.0293	0.0040	0.0080
	Deviat -	0.0010	0.0013	0.0133	0.0220	0.0967	0.0407	0.0030	0.0110
Manually	Deviat +	0.0037	0.0010	0.0080	0.0063	0.0560	0.0257	0.0197	0.0133
	Deviat -	0.0053	0.0010	0.0070	0.0157	0.0900	0.0223	0.0103	0.0117

Figure 12 shows the weld and the location of the second measurement marked with a black dot. Other measurements were performed at the edge of the weld where basic and added material are blended and are thermally treated. Points A and B represent the location of measurement with the use of the panel. With the help of these points, we were able to repeat the measurements. Point A coordinates are (68 mm, 78 mm), Point B (135 mm, 78 mm).

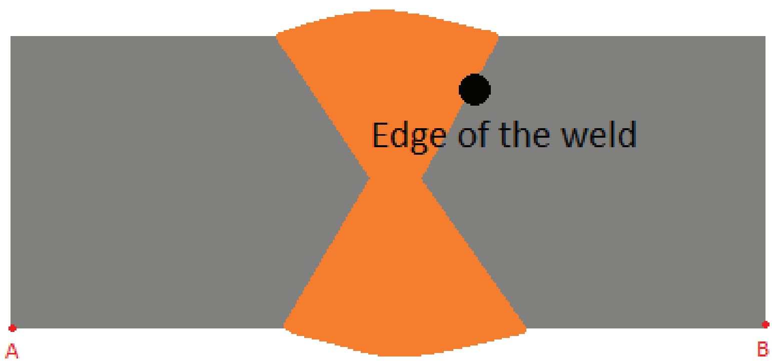


Figure 12: *Measurement at the edge of the weld*

In Tables 4 and 5, the results of measurements on the edge of the weld are shown. In Table 4, the results are obtained with the help of the panel; in Table 5, the results are obtained by manual measurements. Each measurement was repeated three times in a row. From both tables, we excerpted the results of the measured elements that are presented as a percentage. From all three measurements, we then calculated the average of each element and the maximum and minimum deviations from those values. In Table 6, we copied deviated values for a better overview. Thus, it is clearly shown at which measurement technique deviations were smaller. We have tagged those deviations that were smaller in the manual mode of measurement in red.

Table 4: *Results of measurements on the edge of the weld obtained with the panel*

With the panel	Mo (%)	Nb (%)	Cu (%)	Ni (%)	Fe (%)	Mn (%)	Cr (%)	Si (%)
Measurement 1	0.1680	0.0180	0.1650	0.1290	97.3930	0.9630	0.3440	0.4140
Measurement 2	0.1680	0.0200	0.1570	0.1470	97.7240	0.9490	0.3490	0.4620
Measurement 3	0.1650	0.0180	0.1470	0.1230	97.3870	0.9660	0.3430	0.4370
Average	0.1670	0.0187	0.1563	0.1330	97.5013	0.9593	0.3453	0.4377
Deviations +	0.0010	0.0013	0.0087	0.0140	0.2227	0.0067	0.0037	0.0243
Deviations -	0.0020	0.0007	0.0093	0.0100	0.1143	0.0103	0.0023	0.0237

Table 5: *Results of measurements on the edge of the weld obtained by manual measurements*

Manually	Mo (%)	Nb (%)	Cu (%)	Ni (%)	Fe (%)	Mn (%)	Cr (%)	Si (%)
Measurement 1	0.1680	0.0180	0.1600	0.1640	97.3390	0.9860	0.3290	0.4160
Measurement 2	0.1840	0.0180	0.1760	0.1550	97.3280	0.8990	0.3730	0.4360
Measurement 3	0.1770	0.0180	0.1820	0.1570	97.3200	0.9150	0.3670	0.4330
Average	0.1763	0.0180	0.1727	0.1587	97.3290	0.9333	0.3563	0.4283
Deviations +	0.0077	0.0000	0.0093	0.0053	0.0100	0.0527	0.0167	0.0077
Deviations -	0.0083	0.0000	0.0127	0.0037	0.0090	0.0343	0.0273	0.0123

Table 6: *Deviations of measurements on the edge of the weld*

		Mo (%)	Nb (%)	Cu (%)	Ni (%)	Fe (%)	Mn (%)	Cr (%)	Si (%)
With the panel	deviat +	0.0010	0.0013	0.0087	0.0140	0.2227	0.0067	0.0037	0.0243
	deviat -	0.0020	0.0007	0.0093	0.0100	0.1143	0.0103	0.0023	0.0237
Manually	deviat +	0.0077	0.0000	0.0093	0.0053	0.0100	0.0527	0.0167	0.0077
	deviat -	0.0083	0.0000	0.0127	0.0037	0.0090	0.0343	0.0273	0.0123

Figure 13 shows the weld and the location of the third measurement marked with a black dot. The third measurements were performed in the middle of the weld. Points A and B represent the location of the measurement with the use of the panel. With the help of these points, we were able to repeat the measurements. Point A coordinates are (64 mm, 84 mm) and Point B coordinates are (131 mm, 84 mm).

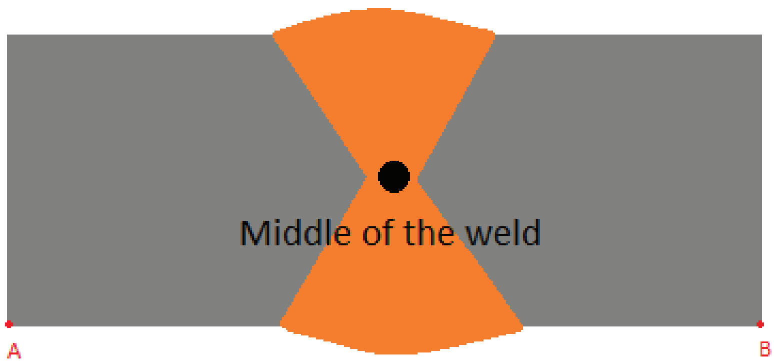


Figure 13: *Measurement in the middle of the weld*

In Tables 7 and 8, the results of the third measurement in the middle of the weld are shown. In Table 7, the results obtained with the help of the panel are shown; in Table 8, the results obtained with manual measurements are shown. Each measurement was repeated three times in a row. From both tables, we excerpted the results of the measured elements that are presented as a percentage. From all three measurements, we then calculated the average of each element and the maximum and minimum deviations from those values. In Table 9, we copied deviated values for a better overview. Thus, it is clearly shown at which measurement technique deviations were smaller. In red, we have tagged those deviations that were smaller in the manual mode of measurement.

Table 7: Results of measurements in the middle of the weld obtained with the panel

With the panel	Mo (%)	Nb (%)	Cu (%)	Fe (%)	Mn (%)	Cr (%)	Si (%)
Measurement 1	0.0210	0.0030	0.0670	97.1730	1.7270	0.0660	0.4050
Measurement 2	0.0190	0.0040	0.0430	97.2700	1.7150	0.0650	0.4310
Measurement 3	0.0210	0.0030	0.0460	97.2230	1.7420	0.0660	0.4100
Average	0.0203	0.0033	0.0520	97.2220	1.7280	0.0657	0.4153
Deviations +	0.0007	0.0007	0.0150	0.0480	0.0140	0.0003	0.0157
Deviations -	0.0013	0.0003	0.0090	0.0490	0.0130	0.0007	0.0103

Table 8: Results of measurements in the middle of the weld obtained by manual measurements

Manually	Mo (%)	Nb (%)	Cu (%)	Fe (%)	Mn (%)	Cr (%)	Si (%)
Measurement 1	0.0130	0.0030	0.0660	97.1890	1.8040	0.0610	0.4310
Measurement 2	0.0140	0.0040	0.0530	97.2420	1.7840	0.0570	0.4140
Measurement 3	0.0150	0.0030	0.0380	97.2450	1.7440	0.0570	0.4330
Average	0.0140	0.0033	0.0523	97.2253	1.7773	0.0583	0.4260
Deviations +	0.0010	0.0007	0.0137	0.0197	0.0267	0.0027	0.0070
Deviations -	0.0010	0.0003	0.0143	0.0363	0.0333	0.0013	0.0120

Table 9: *Deviations of measurements in the middle of the weld*

		Mo (%)	Nb (%)	Cu (%)	Fe (%)	Mn (%)	Cr (%)	Si (%)
With the panel	deviations +	0.0007	0.0007	0.0150	0.0480	0.0140	0.0003	0.0157
	deviations -	0.0013	0.0003	0.0090	0.0490	0.0130	0.0007	0.0103
Manually	deviations +	0.0010	0.0007	0.0137	0.0197	0.0267	0.0027	0.0070
	deviations -	0.0010	0.0003	0.0143	0.0363	0.0333	0.0013	0.0120

By using Formulas 1, 2, 3, and 4, we calculated (in percentages) how much more repeatable measurements made with the panel are. In Formula 1, we inserted the number of cases for which the manual measurements were more accurate, and we multiplied the result by 100. Next, we divided this result with the number of all manual measurements that were made. The result was subtracted from 100, and thus we obtained the result of how repeatable the measurements with the panel are (expressed in percentages).

$$Manual\ measurement = \frac{where\ manual\ measurements\ were\ more\ accurate * 100}{number\ of\ all\ manual\ deviations} \quad (3.1)$$

$$Manual\ measurement = \frac{21 * 100}{46} = 45{,}65\% \quad (3.2)$$

$$Measurement\ with\ the\ help\ of\ the\ panel = 100\% - manual\ measurement \quad (3.3)$$

$$Measurement\ with\ the\ help\ of\ the\ panel = 100\% - 45{,}65\% = 54{,}35\% \quad (3.4)$$

With the help of measurements that have been carried out manually and measurements with the aid of the panel, we find that successive measurements with the panel are 54.35% more repeatable. With this, we proved that manual measurement is also reliable, despite the fact that the hand is not still during measuring. However, a measurement made with the panel is better since the results can later be repeated or checked, by referring to coordinates of previous measurements.

Tables 10, 11, and 12 show the results obtained by means of X-ray analysis and spectral analysis. X-ray data analysis was done with the Niton Analyzer. We used the average of the three measurements on the same spot. Spectral data analyses were provided by the company Spectro Martini d.o.o. The analyses are also an average of three measurements on the same spot. With the help of these data, we calculated the difference or variation in each item. Measurements were carried out at three different places of the weld, as has already been mentioned in previous sections.

Table 10: X-ray and spectral analysis of the basic material

Basic material	Mo	Nb	Cu	Ni	Fe	Mn	Cr	Si
X-ray analysis	0.272	0.029	0.235	0.147	97.821	0.485	0.549	0.393
Spectral analysis	0.300	0.033	0.240	0.160	97.400	0.540	0.520	0.420
Difference	0.028	0.004	0.005	0.013	0.421	0.055	0.029	0.027

Table 11: *X-ray and spectral analysis on the edge of weld*

On the edge	Mo	Nb	Cu	Ni	Fe	Mn	Cr	Si
X-ray analysis	0.167	0.019	0.156	0.133	97.501	0.959	0.345	0.438
Spectral analysis	0.082	0.010	0.130	0.091	97.400	1.380	0.170	0.410
Difference	0.085	0.009	0.026	0.042	0.101	0.421	0.175	0.028

Table 12: *X-ray and spectral analysis in the middle of weld*

In the middle	Mo	Nb	Cu	Fe	Mn	Cr	Si
X-ray analysis	0.020	0.003	0.052	97.222	1.728	0.066	0.415
Spectral analysis	0.016	0.006	0.060	97.100	1.950	0.057	0.430
Difference	0.004	0.003	0.008	0.122	0.222	0.009	0.015

With the use of Formulas 5 and 6, we calculated an average deviation in elements when using two different measurement devices. In the formula above, we put the sum of all of the differences that we have specified in the above tables. The result was then divided by the number of differences. As a result, we obtain an average of differences.

$$Average\ of\ the\ differences = \frac{sum\ of\ the\ differences}{number\ of\ differences} \tag{3.5}$$

$$Average\ of\ the\ differences = \frac{1{,}851}{23} = 0{,}08\% \tag{3.6}$$

Using these measurements, we determined that the devices are comparable, as the average difference in elements was 0.08%. We also need to take into account that the spectral analysis measurement is made on the small spot, whereas x-ray analysis is measuring an area of 8 mm in diameter because of the larger lens. Nevertheless, the results are very similar. We must not forget that spectral analysis adds one percentage point of carbon, which is quite important to consider. In spite of the good qualities it has a downside: it is a breaking measurement method while the x-ray is a unbreaking method. Furthermore, the Niton device is more convenient for fieldwork, since it works on battery and does not need argon.

4 CONCLUSIONS

In the research, we were focused primarily on the study of welds using the Niton Analyzer Gold+ device. For this device, we made a support panel, so we were able to compare the measured data obtained by hand and with the help of the support panel. We assumed that the results obtained with the use of the panel would be more accurate, but also we found that the data obtained manually to be accurate, and there are no major discrepancies. We also have a comparison of spectral and X-ray analyses, and we found that both devices produce highly similar results.

With the panel, we have achieved more accurate and reproducible measurements. With it, we are also able to repeat the measurement the next time on the same spot via the coordinates. The panel also enables us to control the measurement device via PC, and we do not have to hold it in our hands. In the meantime, we can do something else: for example, preparing a report for the previous measurements.

We cannot influence the development of the device, as this is a matter of the company that manufactures it. Furthermore, the device is very advanced, because the company is constantly upgrading its features. Regarding further development, they could develop a new support panel, which could be managed with the help of a computer and appropriate software. Thus, we could enter coordinates, and the support panel would automatically place the device on designated spot. To protect against possible damage, the device would have a contact switch, so the panel would stop immediately if the device touched the measured object. Such a panel would ensure greater accuracy, ease of use, and safety of the device.

References

[1] Arhiv, [online]. Available: http://www2.sts.si/arhiv/tehno/varjenje/var13.htm (10.1.2016)

[2] **D. Beg**: *Projektiranje jeklenih konstrukcij po evropskem standardu ENV 1993-1-1*. Fakulteta za gradbeništvo in geodezijo, Ljubljana 1997

[3] **B. Čretnik**: *Tehnologija spajanja in preoblikovanja: učbenik za predmet Tehnologija v 4. letniku programa Strojni tehnik in 2. letniku programa Strojni tehnik*. Ljubljana, 2008

[4] E gradivo, [online]. Available: http://egradivo.ecnm.si/SIV/tig_varjenje.html (20.1.2016)

[5] Feritscope, [online]. Available: http://www.masterflex.com/assets/Manual_pdfs/54100-15%20feritscope_manual.pdf (6.1.2016)

[6] Gradim, [online]. Available: http://www.gradim.si/naredi-sam/varjenje-mig-mag-tig-postopek.html (15. 1. 2016)

[7] **F. Kržič**: *Jeklene konstrukcije I*. Fakulteta za gradbeništvo in geodezijo, Ljubljana, 1994

[8] MIG varjenje, [online]. Available: https://www.google.si/search?tbm=isch&q=mig+-varjenje&imgrc=sT90T9NNXENLfM%3A (20.5.2016)

[9] MAG varjenje, [online]. Available: https://www.google.si/search?tbm=isch&q=-mig+mag+varjenje&imgrc=RGBvxhc5ySr0tM%3A (20.5.2016)

[10] Messer, [online]. Available: http://www.messer.si/aplikativne_resitve/varjenje_in_r-ezanje/zgodovina_v_svetu/index.html (15.12.2015)

[11] **Z. Praunsesis**: *Vpliv znižane trdnosti na lomne lastnosti zvarnih spojev*, Doktorska disertacija. Univerza Maribor, Fakulteta za strojništvo, 1998

[12] **Z. Praunsesis**: *Gradniki v energetiki, univerzitetni učbenik*. Krško: Fakulteta za energetiko, 2012

[12] Spectro, [online]. Available: www.spectro.com (25.12.2015)

[13] Thermo Fisher Scientific, Navodila za uporabo, 2011

[14] Zvarni spoj, [online]. Available: lab.fs.uni-lj.si/lavek/index.php/.../33-predavanja-zvarni-spoji-predloga (10.2.2016)

[15] Zvar. [online], Available: https://www.google.si/search?q=oblike+zvarov&client=firefox-b-ab&source=lnms&tbm=isch&sa=X&ved=0ahUKEwip3r397vrNAhVDfhoKHW5GA-kUQ_AUICCgB&biw=1280&bih=913#imgrc=28Mtu_irpI6rXM%3A (10.2.2016)

[16] **I. Vogrin**: *Določitev mehanskih lastnosti heterogenih zvarnih spojev*: diplomsko delo, Krško: Fakulteta za energetiko, 2013

MAIN TITLE OF THE PAPER SLOVENIAN TITLE

Author[1], Author [2], Corresponding author[ℜ]

Keywords: (Up to 10 keywords)

Abstract

Abstract should be up to 500 words long, with no pictures, photos, equations, tables, only text.

Povzetek

(Abstract in Slovenian language)

Submission of Manuscripts: All manuscripts must be submitted in English by e-mail to the editorial office at jet@um.si to ensure fast processing. Instructions for authors are also available online at http://www.fe.um.si/en/jet/author-instructions.html.

Preparation of manuscripts: Manuscripts must be typed in English in prescribed journal form (MS Word editor). A MS Word template is available at the Journal Home page.

A title page consists of the main title in the English and Slovenian language; the author(s) name(s) as well as the address, affiliation, E-mail address, telephone and fax numbers of author(s). Corresponding author must be indicated.

Main title: should be centred and written with capital letters (ARIAL bold 18 pt), in first paragraph in English language, in second paragraph in Slovenian language.

Key words: A list of 3 up to 6 key words is essential for indexing purposes. (CALIBRI 10pt)

Abstract: Abstract should be up to 500 words long, with no pictures, photos, equations, tables, - text only.

Povzetek: - Abstract in Slovenian language.

Main text should be structured logically in chapters, sections and sub-sections. Type of letters is Calibri, 10pt, full justified.

ℜ Corresponding author: Title, Name and Surname, Organisation, Department, Address, Tel.: +XXX x xxx xxx, E-mail address: x.x@xxx.xx

[1] Organisation, Department, Address

[2] Organisation, Department, Address

Units and abbreviations: Required are SI units. Abbreviations must be given in text when first mentioned.

Proofreading: The proof will be send by e-mail to the corresponding author in MS Word's Track changes function. Corresponding author is required to make their proof corrections with accepting or rejecting the tracked changes in document and answer all open comments of proof reader. The corresponding author is responsible to introduce corrections of data in the paper. The Editors are not responsible for damage or loss of submitted text. Contributors are advised to keep copies of their texts, illustrations and all other materials.

The statements, opinions and data contained in this publication are solely those of the individual authors and not of the publisher and the Editors. Neither the publisher nor the Editors can accept any legal responsibility for errors that could appear during the process.

Copyright: Submissions of a publication article implies transfer of the copyright from the author(s) to the publisher upon acceptance of the paper. Accepted papers become the permanent property of "Journal of Energy Technology". All articles published in this journal are protected by copyright, which covers the exclusive rights to reproduce and distribute the article as well as all translation rights. No material can be published without written permission of the publisher.

Chapter examples:

1 MAIN CHAPTER

(Arial bold, 12pt, after paragraph 6pt space)

1.1 Section

(Arial bold, 11pt, after paragraph 6pt space)

1.1.1 Sub-section

(Arial bold, 10pt, after paragraph 6pt space)

Example of Equation (lined 2 cm from left margin, equation number in normal brackets (section. equation number), lined right margin, paragraph space 6pt before in after line):

Equation (1.1)

Tables should have a legend that includes the title of the table at the top of the table. Each table should be cited in the text.

Table legend example:

Table 1: *Name of the table (centred, on top of the table)*

Figures and images should be labelled sequentially numbered (Arabic numbers) and cited in the text – Fig.1 or Figure 1. The legend should be below the image, picture, photo or drawing.

Figure legend example:

Figure 1: *Name of the figure (centred, on bottom of figure, photo, or drawing)*

References

[1] **N. Surname:** *Title,* Journal Title, Vol., Iss., p.p., Year of Publication

[2] **N. Surname:** *Title,* Publisher, Year of Publication

[3] **N. Surname:** *Title* [online], Publisher or Journal Title, Vol., Iss., p.p., Year of Publication. Available: website (date accessed)

Examples:

[1] **J. Usenik**: *Mathematical model of the power supply system control*, Journal of Energy Technology, Vol. 2, Iss. 3, p.p. 29 – 46, 2009

[2] **J. J. DiStefano, A.R. Stubberud, I. J. Williams**: *Theory and Problems of Feedback and Control Systems*, McGraw-Hill Book Company, 1987

[3] **T. Žagar, L. Kegel**: *Preparation of National programme for SF and RW management taking into account the possible future evolution of ERDO* [online], Journal of Energy Technology, Vol. 9, Iss. 1, p.p. 39 – 50, 2016. Available: http://www.fe.um.si/images/jet /Volume 9_Issue1/03-JET_marec_2016-PREPARATION_OF_NATIONAL.pdf (7. 10. 2016)

Example of reference-1 citation: In text *[1],* text continue.

Nomenclature

(Symbols)	(Symbol meaning)
t	time

JET

JET I Journal of Energy Technology I Vol. 9, Issue 3, October 2016 I University of Maribor, Faculty of Energy Technology

ISSN 1855-5748

9 771855 574008