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Use of Renewables in Rural Municipalities' Integrated Energy Systems

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The current contribution builds upon the locally-integrated energy sectors (LIES) concept. The LIES concept (Perry et al., 2008) extended the TS methodology (Dhole and Linnhoff, 1993) developed initially for industrial complexes mainly. LIES (Varbanov and Klemeš, 2011) offer a further extension of Total Site (TS) concept to accommodate collaboration between industry and local communities. This concept can be especially attractive for the municipalities abundant with natural resources. Recent research leads towards integration of energy users and energy producers over larger geographical area up to regional scale.
The design optimisation is investigated for local and regional energy supply at municipal and higher level to accelerate the use of renewable resources within rural municipalities. The demand levels and patterns of the involved energy user types are described, followed by the selection of promising renewable and fossil resources. The variability of renewables makes it necessary to accommodate varying availability by optimal demand side management, appropriate clustering of energy sources and sinks, as well as using energy storage.

1. Introduction

Achieving low carbon emissions is an important objective of policies in several countries, thus driving energy systems towards renewable and more sustainable ones. Rural municipalities have special features common to the rural landscape (Hoesen and Letendre, 2010). The organisation of energy systems and everyday activities are in general different from those in city areas. The differences include closer proximity to the natural resources and their relative abundance, as well as the environment is cleaner in rural areas as in cities. Therefore, the rural municipalities present suitable entities to transform them to the sustainability oriented communities (Duič et al., 2011). Due to abundance of natural resources and proximity of resources and consumers, the LIES concept (Perry et al., 2008) can be applied to rural communities to decrease imported, mainly fossil, energy consumption. LIES concept (Perry et al., 2008) includes also several energy user/generator types except industrial, such as residential, business, services, transportation and even agriculture. Since the introduction of the LIES concept, it has been applied only to city areas (Perry et al., 2008). However, the advantages offered by this concept could be spread also to rural areas. Decentralisation of energy systems could be encouraged in order to accelerate more reliable energy supply (Ramachandra, 2009).
Therefore LIES within rural municipalities could contribute to greater local self-sufficiency. In this case small rural local communities with local renewable resource abundance are especially appropriate for LIES integration (Varbanov and Klemeš, 2011). However, except the technical feasibility of the LIES, also its economic assessment should be performed. A crucial issue is the supply chain aspect which should consider biomass resource logistics (Lam et al., 2011) but also potentially downstream gas distribution

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(Manenti and Rovaglio, 2013). The structure of rural municipal energy system (MES) should be accounted for, such as integration of agriculture, tourism, households, industry and transport. In the following, specific features of each sector are addressed and their role in the rural LIES is defined, as well as possibilities for sectors integration are discussed due to specifics of rural energy systems.

2. Specifics of the Rural Municipalities

Rural municipalities are geographically situated outside main and sizable settlements. Table 1 presents different aspects of the rural municipalities.

Table 1: Features of rural municipalities

Demographic aspect (Niedomysl, 2007)	Energy aspect (Mondal et Al., 2010)
Low density of population	Greater decentralisation of energy supply Possible energy self-sufficiency of end-users
Migration to the city areas	Usually greater abundance of natural resources
Economic aspect (Hernik et al., 2013)	Environmental aspect (Pittman et al., 2011)
Mostly lower income of residents than average Lack of job opportunities	Better quality of the environment Lower emission level Different climate conditions and weather
Social aspect (Niedomysl, 2007)	
Migration of the residents to the cities Larger share of older population due to migration patterns	

Demographic aspects of rural municipalities show low density of population and migration to the city areas. There could be provided possibilities to attract those people to stay in the rural municipalities. The economic aspect in rural municipalities indicates lack of employment opportunities and mostly lower income in comparison to the city areas. Social aspect presents the migration patterns to the city and consequently the increased share of older population. With this pattern the development potential of rural areas is being decreased. The energy aspect shows the tendency of greater decentralisation and self-sufficient energy supply. There is mostly greater abundance of natural resources in rural municipalities; therefore the entirely renewable energy supply could present reality. The analysis of environmental aspect indicates the better quality of environment in comparison to the city areas and lower emission levels. Rural municipalities offer a variety of possibilities to increase development and economic potential. Repopulation of the country side could be accomplished by LIES implementation, while exploring better life conditions and healthy living style.

3. Locally Integrated Energy Sectors (LIES) within Rural Municipality

Beneficial values for rural LIES in comparison with integration of LIES in cities are abundance with natural renewable resources and stronger connection to the agriculture sector as the supplier of the power generated from renewable resources. In the process of the LIES integration within rural municipalities, there arises major problem such as long distance among potential end-users, which creates economical problems, losses in the energy transport and increased footprints for the networking. In the planning process of the potential LIES this has to be respected in order to overcome stated disadvantages. Connection among sectors is beneficial, while it recognises sources and sinks within municipal energy system and with further sectors integration yields overall synergy effect. Sectors such as industry, household, service, transport, agriculture and public sector should be specifically analysed to trigger the synergy potential of the community and propose technical possibilities for the integration of RES. Figure 1, represents connections among different sectors within the LIES.

Sectors, identified as the end-users, in the rural municipalities have some specific featers are as follows:
(i) Households: The building stock in the rural households is consisted out of more individual houses than blocks. The individual heating and electricity needs could be covered by various technologies using renewable energy resources e.g. heat pumps, solar photovoltaics, solar thermal, micro wind turbines, biomass boilers. On the other hand the energy requirements could be covered in joint installations such as district heating systems and district heating and cooling systems. The district heating systems on local biomass in order to harness renewable energy resources could be acknowledged as an attractive possibility from the technology and economic view point.

(ii) Industry: Industry sector is not so present like in cities e.g. industrial cones. Nevertheless, in some areas, some special factories are located, who offer a variety of possibilities for energy integration with other sectors. The waste heat could be used in connection to the households, whereas agriculture sector could provide resources as supply for generation of green energy in the industry sector.

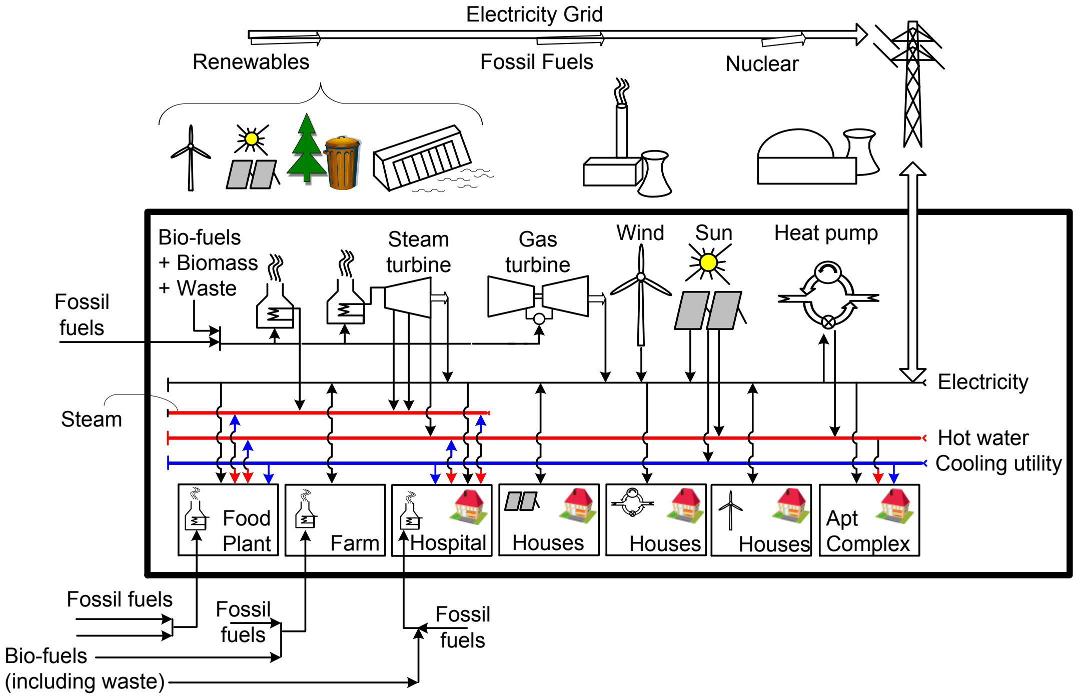

Figure 1: Representation of the Locally Integrated Energy Sector (after Perry et al., 2008)

(iii) Service sector: There are usually not so many services represented in the rural municipalities in comparison to the city areas. However, tourism is highly represented and the services connected to this branch. Eco-tourism is gaining significance; therefore the energy for touristic settlements should be generated out of renewable energy resources. The possibilities are similar to those listed under the household sector.
(iv) Transport sector: Transport sector does not present such a strong concern as in the cities. However, the production of bio-fuels in the farms could supply large share of transport sector within rural municipality.
(v) Agriculture sector: Agriculture sector may play a focal point in the LIES implementation in more agriculture oriented rural municipalities. It could represent a supplier of the renewable energy sources such as manure, waste crop, grass for biogas installations and different types of biomass for biomass boiler installations. In the more agriculture oriented rural municipalities there could be performed joint projects for community beneficial projects as the biogas plants for entire municipality.
In accordance to the sectors representation, the LIES concept has many pro-bono values for rural municipalities, revealing completely different open loops than those in cities. Moreover, also other local activities in the rural municipalities in connection to the energy sector have to be properly addressed. For example, forestry needs to be organized in the optimal way and supply chains for example the wooden biomass should be formed (Klemeš et al., 2010).

4. General Workflow of LIES within Rural Municipalities

The general workflow for the LIES integration within rural municipalities consists out of four sequential steps. Step one requires analysis of the present situation (expanded energy audit) and identification of regional and local specifics of the rural community. The second step identifies the core activities of the agriculture sector, while agriculture sector has the central role in the more agriculture oriented rural communities. Only after both of the before mentioned steps, the third step plans the integration of sectors within the municipality and provides feasibility studies and other possibilities for deployment of RES within the rural municipality (Klemeš and Varbanov, 2012). The integration of intermittent RES would require implementation of certain techniques for their development (Nemet et al., 2011). In the final step the evaluation of LIES integration within rural municipalities is conducted. In future research work also other aspects e.g. economic, social, environmental, beside technical one would be analysed. In Figure 3 is represented the general workflow of the LIES integration within rural municipality.

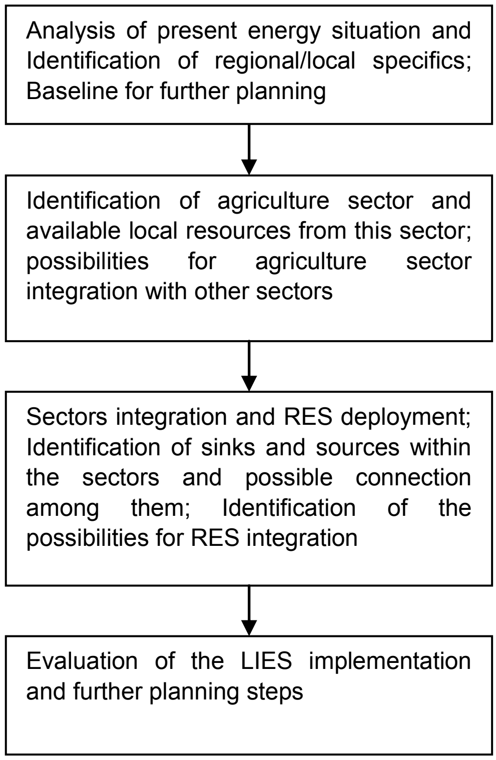

Figure 2: General workflow of LIES integration within rural municipality

Special stress is given to the local natural resources integration in accordance to the rural nature. In this direction, the connection with the supply chains of different RES has to be provided (Lam et al., 2011). Initially, before establishing strategies for RES integration, the feasibility studies for special renewable resources have to be conducted.

5. Case study – possibility of LIES within Podlehnik rural municipality

The Podlehnik municipality in Slovenia is rural oriented and has prospective with the high share of RES in present energy balance, to become entirely renewable community and energy independent in the future. Therefore, the possibilities for LIES within Podlehnik municipality could be acknowledged. At first the energy consumption has to be identified with performing the energy audit. The profiles of each sector has to be independently evaluated and offering the possibilities for further integration. In the Table 2, the data for the electricity and heat consumption are presented for the Podlehnik municipality in general.

Table 2: Data for energy consumption for the rural municipality of Podlehnik in Spodnje Podravje region

Heat (MWh)		Electricity (MWh)		Energy consumption (MWh)	
Conventional energy sources	RES	Conventional energy sources	RES	Total	RES share (%)
4,145	5,378	3,224	1,746	14,493	49.15

For each sector the energy consumption data have to be evaluated. In the Table 3, the data for the heating consumption for the households, industry and public sector are presented.

The industry sector is underdeveloped in the municipality Podlehnik, while it is the rural oriented municipality. The high share of the wood and wood residues in the energy consumption is acknowledged. With this, the agriculture sector covering the forestry branch is already recognised as the valuable supplier of the resources for the energy generation. In the future plans based on the evaluated potentials the agriculture sector would be included in the energy supply in greater extend. After the analysis, the demand requirements by sectors are defined, which is required for future planning of the replacement of conventional resources with the renewable ones. For different end-user types different renewable resources are more suitable assessing the technology, environmental and economic aspects. On behalf of this, the optimal mixture of the renewable resources would be selected. While in the paper is the focus on increasing the use of the renewable resources on local level, the potentials for future integration have to be defined.

Table 3: Presented data for energy consumption by sectors in the rural municipality Podlehnik

Types of resources	Households (MWh)	Industry (MWh)	Public sector (MWh)	Total (MWh)
Heating oil	2,538	555	293	3,386
Liquefied petroleum gas	-	48	508	556
Wood and wood residues	5,341	38	-	5,379
Coal	120	-	-	120
Other resources	82	-	-	82
Total heat consumption	8,081	641	801	9,523

In the Table 4, is presented technical assessment of the renewable energy resources potentials for future power generation within municipality Podlehnik.

Table 4: The identified technical potential for the RES integration within Podlehnik rural municipality

Types of RES	Potential for future RES integration
Biomass	18,230 MWh/y
Biogas from crops	7,737 MWh/y
Biogas from manure	2,378 MWh/y
Solar photovoltaics	38,850 MWh/y
Geothermal	5,392 MWh/y
Total potential	72,587 MWh/y

The whole evaluated potential for the future power generation from RES could entirely replace the usage of the conventional fuel resources, while the potential exceeds the present energy consumption of the entire municipality around five times. Based on these findings the strategies for sectors integration and projects for renewable integration could be depict to ensure the sustainable development of the municipality.

6. Discussion

Several environmental burdens caused by the conventional fuels usage for power generation within present energy systems is recognised as a problem. Various methods and concepts are available to solve this issue and support the decarbonisation of present energy systems. The LIES concept, proposed from other authors (Perry et. al, 2008) could be considered as one of the solutions. However, the LIES integration within the rural municipality differs from those in the city ones. Posing the agriculture sector as the main energy supplier of the energy produced from renewable energy sources in the rural municipalities is the main difference in comparison to the city ones. The general workflow for the LIES integration within rural municipalities is proposed in the presented paper. The initial attempt for the implementation of the general workflow of LIES integration is presented in the case of the Podlehnik municipal energy system. In the following work problems occur by integrating the renewable energy sources within the rural municipalities. The variations of RES supply, heat storage technological problems, economical problems and others are recognised within the integration process. In the following work, the procedure for the renewable energy resources integration within LIES in rural municipalities would be developed. Firstly, the present energy consumption by sectors should be assessed. The energy model for the municipal energy system should be established. After the analysis of present energy consumption and the evaluated possibilities for Heat Integration, the calculation of Total Site Profiles and Total Site Composite Curves would be performed. The following step requires the assessment of the supply and demand for the power generated from renewable energy sources and potential for their usage. The Time slice methodology would be integrated, providing the integration of the supply variability from renewable energy sources. The objective is to connect the end users that require the power generated from renewable energy sources with the related suppliers of “green” energy.

7. Conclusions

The paper proposes the general workflow for the LIES integration within rural municipalities. The special focus is on the agriculture sector, supply chains and especially natural renewable resources. Therefore, the possibilities to form energy self-sufficient sustainable community especially lies on the rural municipalities. This kind of municipalities could present the initial attempt to establish entirely renewable energy systems.

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