

**BABEȘ-BOLYAI UNIVERSITY, CLUJ-NAPOCA FACULTY OF GEOGRAPHY
DOCTORAL SCHOOL OF GEOGRAPHY**

Summary

**Evaluation and Use of Renewable Energies in Central Development
Region of Romania**

PhD Adviser:

Acad. Prof. Dr. Benedek József

PhD Candidate:

Sebestyén Tihamér-Tibor

Cluj-Napoca

2020

Table of Contents

1. Statement of the Researched Topic	8
1.1. The theoretical framework of the present research	8
1.2. Impact areas of Renewable energy projects	10
1.3. Renewable Energy, from EU to the region	13
1.3.1. Renewable Energy Policy in EU	13
1.3.2. Renewable Energy Policy in Romania	16
1.3.3. The researched region	19
1.4. Objectives of the research	21
1.5. Structure of the thesis	22
1.6. Emphasis of the importance of the research	24
2. Assessment of Biomass Energy Potential in Centre Development Region of Romania	26
2.1. Data and methods	26
2.1.1. Quantitative data collection	28
2.1.3. Methodology for calculation of theoretical biomass potential	31
2.1.4. Technical Biomass Potential in Centre Development Region of Romania	37
2.2. Results of the Biomass Energy Potential Assessment	40
2.2.1. Theoretical Biomass Potential Assessment	40
2.2.1.1. Protected areas.....	41
2.2.1.2. Biomass potential from forest residues and wood waste	42
2.2.1.3. Vineyards and Orchards Pruning	45
2.2.1.4. Public area and landscape maintenance	47
2.2.1.5. Agricultural by-products	48
2.2.1.6. Sugar beet production and energy potential	52
2.2.1.7. Meadows and Pastures	53
2.2.1.8. Potential of energy crops production on abandoned, degraded and wetlands.....	54
2.2.1.9. Livestock manure for energy production	57
2.2.1.10. Municipal Waste for energy production.....	58
2.2.1.11. Energy production potential at Water Treatment Plants	60
2.2.1.12. Integrated Theoretic Energy Potential of Biomass Resources in CDR	61
2.2.2. Technical energy potential of biomass resources	66
2.2.2.1. Technical Energy Potential of Woody Biomass	66
2.2.2.2. Agricultural Residues and Municipal Waste	69
2.2.2.3. Technical energy potential of manure and sludge	72
2.2.2.3.1. Technical energy potential of cattle farms in the region	73
2.2.2.3.2. Technical energy potential from pig farms in the region	75
2.2.2.3.3. Technical energy potential of sheep farms in the region	76
2.2.2.3.4. Technical energy potential of poultry farms in the region	77
2.2.2.3.5. Technical energy potential of waste water sludge in the region	79
2.2.2.4. Integrated technical biomass energy potential assessment	81
3. Assessment Solar Energy Potential in Centre Development Region of Romania	84
3.1. Introduction in Solar Energy Potential Calculation	84
3.2. Data and Methodology	86
3.2.1. Mapping of the global solar radiation	86
3.3. Technical analysis of the PV power generation potential in CDR	88
3.3.1. On-Grid solar PV systems	89
3.3.2. Off-grid solar PV systems	91
3.4. Results of the Solar Energy Potential Assessment	92
3.4.1. Global solar radiation	92
3.4.2. Technical solar PV energy potential	94
3.4.2.1. Grid-Connected PV power generation	95
3.4.2.2. Off-grid PV power generation.....	98
3.4.3. Integration of energy outcomes of on-grid and off-grid PV system	99
3.4.4. Status of PV Electricity Generation in Region.....	102
4. Assessment of Wind Energy Potential in Centre Development Region of Romania.....	106
4.1. Wind energy in Romania	106
4.2. Methodology of annual wind energy production calculation by WindSim 9.0 simulator.....	107
4.2.1. Modeling of wind fields and annual energy productions by WindSim 9.0 software.....	107
4.2.1.1. Terrain	108
4.2.1.2. Wind Fields	109

4.2.1.3. Placing the objects	110
4.2.1.4. Exploring the wind database	111
4.2.1.5. Generation of wind resource maps	111
4.2.1.6. Annual energy production	112
4.2.1.7. Verifying the correctness of the modeling	115
4.2.2. Identification of optimal sites for wind turbines	116
4.3. Results of wind energy potential simulations	117
4.3.1. Wind energy potential in Alba County	118
4.3.2. Wind energy potential in Braşov County	124
4.3.3. Wind energy potential in Covasna County	130
4.3.4. Wind energy potential in Harghita County	136
4.3.5. Wind energy potential in Mureş County	142
4.3.6. Wind energy potential in Sibiu County	149
4.4. Evaluation of Wind Energy Potential	156
5. Integrated Renewable Energy Potential of Central Development Region of Romania	160
6. Social perceptions regarding to Renewable Energy Sources in Central Development Region of Romania	163
6.1. Social attitude survey regarding RES application	163
6.2. Methodology and data	166
6.3. Results of the questionnaire survey	171
6.3.1. Citizens energy usage patterns	172
6.3.2. Social awareness about renewable energy sources	183
6.3.3. Citizens expectations and visions about renewable energy management/citizens involvement	195
7. Conclusions	209
7.1. Results of the Evaluation of Renewable Energy Sources	209
7.2. Summary of the scientific results	212
7.3. Recommendations for implementation of renewable energy projects	214
7.4. Further scientific objectives	215
Bibliography	216

Keywords: evaluation of renewable energy potentials: solar, wind and biomass, social perceptions regarding to renewable energy sources

Summary:

Evaluation and Use of Renewable Energies in Central Development Region of Romania

The theoretical background – discussed in first chapter - of the researched topic is based on the newest regional development approaches, namely the utilization of renewable energy sources has unique role in the sustainable development of the regions. In the literature, there is discussed the contribution of renewables to regional sustainability, highlighting the social, economic and environmental advantages and benefits.

According to the system theory, the renewable energy related policy is positioned under the long-term national development policies but also has relevance in regional development strategies. The incorporation of renewable energy projects into strategic action plans on regional level could act as constructive and additional subsector, while diversification of economy is also worth to be mentioned. Moreover, by implementation of renewable energy based projects the mitigation of carbon emission and secured energy supply contributes to the competitiveness of region, due to increasing the rate of employment in new economic sectors and mitigate the negative impact of economic activities on local environment. Taking into account the above-mentioned aspects the implementation of renewable energy projects has significant and positive influence on regional development towards sustainability.

In the following three chapters the present research contains regional analysis on estimation of three main renewable energy sources, namely on biomass, solar, wind energy. Based on energy outputs, a large number of thematic maps have been elaborated by ArcGIS 10.1 and WindSim 9.0 softwares. The energy output maps are including all 413 local administrative units from the analyzed Central Development Region.

Regarding to methodology and data used in the present research, the biomass energy potential is based on local statistic database (agricultural, forestry, livestock, waste management, etc.). The solar energy potential was analyzed by ArcGIS 10.1 software Solar Irradiation Module, while the availability of areas for PV solar parks and roof-tops was assessed using scientific estimation based

on available literature and gained experiences. In case of wind energy potential, there are 23 meteorological stations in the researched region, the input meteorological data was collected from these stations from 10 up to 30 years timeframe. For wind energy potential simulation a special wind park simulator software, the WindSim 9.0 was applied. Since the used copy of the software is a trial version the resolution of simulated area was limited, therefore each county was analyzed separately. In the end of wind energy simulations an integrated wind energy potential map for the whole region was elaborated.

In each case the theoretical and technical energy potentials were estimated, taking into account the latest available renewable technology solutions and energy conversion ratios. In addition, final integrated map of potential energy outputs from the different sources was elaborated for each local administrative unit in the researched region.

Above and beyond the investment costs of renewable energy projects, it cannot be neglected the social acceptance, because it can be a catalysator of the investments or a difficult obstacle in front of implementation. In this perspective, socio-economic circumstances of households, energy usage pathways as well as the participation and possible involvement of different stakeholder groups, group of interests and citizens were analyzed.

Considering all above-mentioned factors, after the detailed evaluation of renewable energy potentials, in the second part of the research the perception of citizens has been also evaluated using a representatative questionnaire survey and several interviews were also done. The main goal was to collect a large amount of information from region's inhabitants about their knowledge related to renewable energies, about their energy consumption behavior, and about their attitude to RES applications. The survey was carried out by the author of present research and after the filling the questionnaire some interviews with focus groups including local entrepreneurs, mayors, local decision makers, etc. were organized in different towns in the region. The assessment of the survey was carried out using the SPSS program, which is capable of handling large amounts of data and can perform all analyses.

In the conclusions there are summerized the scientific results of the research, recommendations for implementation of renewable energy projects and further scientific research objectives. In the PhD research, as a summary of the achieved objectives, the followings can be mentioned:

- Elaboration of self-developed methodology for integrated energy potential estimations

- Implementation of the methodology for evaluation of renewable energy sources in a chosen region
- Estimation of theoretical and technical renewable energy potentials on local level from the following sources: biomass, wind and solar
- Identification of the location where significant biomass energy sources, suitable fields are available for solar PV plant or wind turbine installations, including energy output simulations
- Analysis of geographical, meteorological parameters for evaluation of renewable energy sources,
- Mapping of potential energy outputs by GIS-supported and wind farms simulator software
- Based on a representative questionnaire survey, evaluation of social perception to renewable energy source, energy usage patterns, knowledge, openness and willingness in participation for implementation of renewable energy projects on local level
- Conclusion on the role of local inhabitants in the implementation of different renewable energy projects in the researched region.