Explaining biomass niche readiness through network analysis: the Lithuanian case

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Abstract

In recent years biomass production for energy purposes has gathered increasing attention as a feasible alternative to traditional energy sources. Biomass represents the biggest renewable energy source in the EU and is expected to contribute significantly to achieving the 20% EU renewable energy target by 2020 by reducing the dependence on fuel from non-member countries, emissions from greenhouse gases, and energy costs from oil prices. However, the transition towards a biomass-based economy can occur only when the biomass niche has reached a sufficient degree of maturity in terms of (i) network formation among niche actors, (ii) expectations about the future development of the niche, and (iii) learning processes at multiple dimensions (technical, cultural, infrastructural, societal and environmental). Using the social network analysis, the present paper aims to investigate the level of readiness achieved by the Lithuanian niche of biomass producers. Results suggest that, although such producers have increased their extent of knowledge exchange, their expectations about the future development of the niche are still too weak. However, institutions might play a crucial role in raising the level of expectations and knowledge of biomass producers given their central position in the investigated network.
Keywords: biomass, niche readiness, social networks analysis, Lithuania.

1 Introduction

In the last years, EU countries have been called to increase their use of renewable energy sources (RES) to meet the requirements established by the

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Renewable Energy Directive no. 2009/28/EC [1]. The Directive requires the EU to fulfil at least 20% of its total energy needs with RES by 2020 and specifies national renewable energy targets for each country, taking into account its starting point and overall potential for renewables. In order to meet these targets EU members must organise the general course of their renewable energy policy in national renewable energy action plans. To achieve this goal, all types of RES must be used, including biomass-based energy sources, such as solid biomass, biogas, and biofuels for transport. Biomass represents the biggest RES in the EU and is expected to contribute significantly to improve the energy supply available to EU countries by reducing the dependence on fuel from non-member countries, emissions from greenhouse gases, and energy costs from oil prices [2, 3]. Moreover, biomass use for energy purposes is expected to further increase in the medium term, in the context of the EU's effort to move to a low-carbon economy by the middle of the century [4]. However, to replace the current (unsustainable) fossil-based regime, the biomass niche must be 'ready' [5]. Following the sociotechnical transition perspective [6, 7], the readiness of the biomass niche should be assessed mainly in terms of (i) network formation among niche actors, (ii) expectations about the future development of the niche, and (iii) the learning processes at multiple dimensions (technical, cultural, infrastructural, societal and environmental) [8–11]. In other words, the transition towards a biomass-based economy can only occur when the three aforementioned key mechanisms at niche level have reached a sufficient degree of maturity [12]. In this framework, the present paper aims to investigate the readiness achieved by the Lithuanian biomass niche using social network analysis. Lithuania represents an interesting case-study, since the country possesses an amount of biomass-related energy sources that are not only sufficient for fulfilling the requirements provided for in the aforementioned EU directive, but also substantially surpassing them. The paper is organised as follows. Section 2 deals with the theoretical framework. Section 3 reports the case study background and the methodology employed to carry out the empirical investigation. Section 4 describes the results achieved. Finally section 5 ends with some concluding remarks.

2 Theoretical framework

In order to assess the potential of the Lithuanian biomass niche to replace the existing fossil-based regime, we employ a multilevel perspective approach (MLP), first introduced by Kemp and Rip [13] and then refined by Geels [14]. MLP is an approach dealing with, *inter alia*, the complex issue of sustainable development. It is a mix between evolutionary theory approaches and patterns of long-term changes. Particularly, it seeks to explain sociotechnical transitions through the interaction of dynamics at three different levels: macro, meso and micro level, respectively landscape factors, regimes and niches [13, 14]. More specifically, the approach nests upon a theoretical model that consists of three main components: (i) sociotechnical regime, (ii) sociotechnical landscape, and (iii) niche innovations [15]. The sociotechnical regime represents the meso-level of the model and includes the whole institution, techniques, rules, practices, etc., that determine the normal development and use of technologies [7]. The sociotechnical landscape is the macro-level of the model and consists of a set of variables (such as material infrastructures, political culture, social values, paradigms, etc.) that affect activities carried out by the socio-technical regime [16]. Finally, the niche innovations denote the micro-level of the model and can be viewed as 'incubation rooms' where rising technologies are protected against too strict selection and are provided with space to grow and mature through gradual experimentation and learning processes performed by producers, researchers, users, as well as governmental and other organizations [7]. Along with such characteristics, niches also provide the social space to build various networks that might support innovations (e.g. supply chains, user-producer relationships, etc.) [12]. Through processes of social learning within multiple experiments, articulating promising expectations and heterogeneous networking, niche innovations can become mature and eventually compete with established technologies [17]. In accordance with the MLP, transitions arise as a consequence of dynamics at the different levels. Landscape factors could put pressure on current regimes and open windows of opportunities for "mature" niches to break through and contribute to important changes, or shifts, in socio-technical regimes, figure 1.

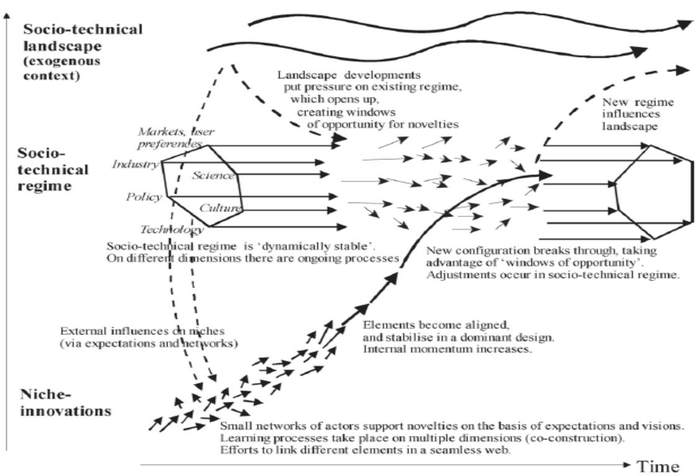


Figure 1: Multi-level perspective on transitions [14].

Within this extensive framework we especially focus on the niche development process, since we believe this is a key aspect through which policy makers could potentially intervene to locally address future technological innovations. The Strategic Niche Management (SNM) is a recently developed analytical approach that is proposed expressly to enable the introduction and diffusion of very new sustainable innovations through the study of successes and failures of societal experiments in which the various stakeholders are encouraged to collaborate and exchange information, knowledge and experience. In this way, *they embark on an interactive learning process that is expected to facilitate the incubation of the new technology* [18, p. 619]. Grounded on a series of considerations from innovation studies [8, 9], three internal mechanisms have been singled out for a technological niche to succeed: (i) *expectations* which are considered crucial for niche development because they provide guidance towards learning processes, (ii) *learning processes* at multiple dimensions (technical, cultural, infrastructural, societal and environmental) and (iii) *network formation* which creates a constituency behind the new technology. The three mechanisms described above are the pre-conditions that need to coexist for allowing the breakthrough of an innovation niche [19].

3 Case-study and methodology

3.1 The Lithuanian biomass niche

Like many EU countries, Lithuania is facing challenges in the energy sector mainly in terms of energy independence, competitiveness, and environmental and economic sustainability [20]. Before 2010, Lithuania's primary energy resources comprised mainly of imported fossil fuel and nuclear energy. However, the dismantlement of the *Ignalina nuclear power plant* at the end of 2009, along with the limited possibilities of a wider use of local fossil resources (oil, peat), has driven the country to move increasingly towards the use of RES [21]. According to the European Commission, the energy obtained from Lithuanian RES amounts approximately to 15% of the country's final gross energy consumption and should increase to at least 23% by 2020 according to the Renewable Energy Directive no. 2009/28/EC [1]. In this framework, the National Strategy for the Development of RES approved by Resolution No. 789 of the Government of the Republic of Lithuania on 21 June 2010 has indicated the RES development as one of the most important priorities of the National Energy Policy. With specific regard to biomass for energy purposes, Lithuania possesses an enormous amount of biomass resources that substantially surpass the target mentioned in the aforementioned EU directive. According to the Lithuanian Biomass Energy Association (Litbioma) [22], the potential amount of biomass production for energy purposes in the country comes mainly from wood cutting and forest cleaning residues, followed by straw, energetic willow, and municipal waste (table 1).

Table 1: Potential amount of biomass and energy production per year.

Source	**Potential amount**	**Potential energy production**
Wood	1 million m^3	2,152 GWh
Straw	0.5 million tons	1,500 GWh
Energetic Willow	11,500 plantations	500 GWh
Municipal Waste	1.3 million tons	30% of supplied thermal energy

The above figures suggest that Lithuania has a large capacity for bioresources, which could significantly help the country to fight its environmental challenges. Moreover, Lithuania provides many biomass equipment producers and national scientists in the field of bioenergy research with a potential for knowledge development and diffusion [23].

3.2 Data

Overall, the network is composed of 54 actors operating in the Lithuanian biomass niche (i.e. 19 producers, 12 suppliers, 9 distributors, and 14 institutions such as national authorities, universities, NGOs, etc.). Data were collected by means of an *ad hoc* designed questionnaire, administrated by using both a CATI (Computer Assisted Telephone Interviewing) and a CAWI (Computer Assisted Web Interviewing) technique, as requested by each respondent. The questionnaire can be virtually split in two parts. The first part collected information on (i) the current level of actors' expectations on the future niche development, the current level of knowledge (learning process) about biomass-related energy sources, and (iii) the policy capability of institutions. The second section gathered information about networking activities among actors by defining two different network types, i.e. the 'information' network and the 'knowledge exchange' network. The first describes the generic knowledge among actors (i.e. who knows who), while the second is more relevant for assessing the impact of the network architecture in boosting expectation convergence and learning processes, which are necessary for the biomass niche to succeed (see Sica and Falcone [5]). More specifically, respondents were asked to specify how their informational and knowledge exchange relations with other niche actors have changed in the last 8 years (i.e. in 2007 and 2015).

3.3 SNA

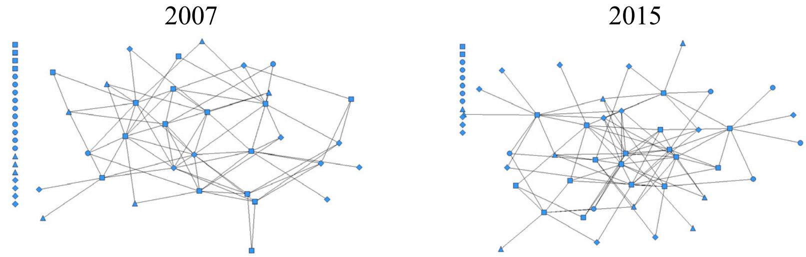
In order to investigate the degree of maturity of the Lithuanian biomass niche and its evolution over time, we employ the social network theory, which consists of a *"finite set or sets of actors and the relation or relations defined on them"* [24, p. 20]. In particular, the Social Network Analysis (SNA) method provides an explicit formal way of measuring social structural properties by modelling the relationships among a set of actors to explain relevant network features [25]. For a better understanding, as already emphasized by Morone *et al.* [26] it is worth mentioning some significant basic concepts of network theory: (i) actors and their actions are viewed as interdependent rather than independent units; (ii) relational ties between actors are channels for transfer or flow of resources (expectations and knowledge, in our case); (iii) network models focus on individuals' views on the network structural environment as a source of opportunities or constraints on individual actions; (iv) network models conceptualise structure as lasting patterns of relations among actors [14]. As discussed in the theoretical framework, we carried out our analysis looking at three key niche mechanisms: (1) expectations, (2) learning processes and (3) network formation (see Kemp *et al.* [10]). All of these mechanisms fully reflect the presence of a significant social component; the first mechanism concerns an upward convergence of expectations (several actors share a positive idea about the niche innovation), the second mechanism, identified as learning processes, implies that firms and other stakeholders involved in the niche network will share knowledge, finally, the third mechanism regards the building of an effective social network in terms of a variety of actors (e.g. firms, users, policy makers, scientists, and other relevant actors) and regular interactions among them. Therefore, SNA is a valuable tool to tackle the above mentioned research question since it allows: (i) clearly defining the key actors forming the Lithuanian biomass network, (ii) examining the evolution of the network architecture's properties during the last 8 years, and (iii) understanding the role of the different actors involved in the convergence of expectations and learning processes.

4 Results achieved

Data collected were arranged through symmetric network adjacency matrices and then elaborated by means of the UCINET 6.5 software. The results presented hereafter will be mostly based on the visual inspection of networks by differentiating them according to the type of interactions between 'information' and 'knowledge exchange' networks. Additionally, networks will be enriched by single or multiple attributes linked to biomass producers (i.e. the level of expectations and of knowledge) and then institutions (i.e. policy capability).

4.1 General findings

We started by analysing the 'knowledge exchange' network and looking at its evolution over time (i.e. in 2007 and 2015) (figure 2).



Legend: Circles = Distributors; Diamonds = Institutions; Up triangles = Providers; Squares = Producers.

Figure 2: The evolution of the 'knowledge exchange' network.

The architectural structure of the network seems to change over time. Compared to 2007, in 2015 the overall network appears to be more connected and clustered with some actors – initially disconnected – entering the network and sharing biomass related knowledge with other peers. Moreover, a number of firms (mainly producers) gain a central role in the network by increasing their neighbourhood relations. Although niche evolution leads producers to cluster and share more knowledge, this is not true for institutions that still remain marginal in the network. Since the graphic display may appear poor with an increasing number of actors and related associates, we turned to the investigation of some network indexes in order to achieve more detailed information and, thus, strengthen our findings. Table 2 therefore reports density, number of ties, average degree, and clustering coefficient of the network to provide further evidence about the niche's evolution.

Table 2: Networking indexes: 'Knowledge Exchange' network.

	2007	**2015**
Density	0.05	0.06
Number of ties	142	188
Average degree	2.63	3.48
Clustering Coefficient	0.18	0.12

Networking indexes from table 2 seem to confirm the results achieved from the visual inspection. Between 2007–2015 the number of ties increased from 142 to 188. Similarly, the network density has slightly grown from 0.05 to 0.06, suggesting that a larger portion of all possible connections is actually used to exchange knowledge directly related to biomass based energy sources. Despite this, the low index values indicate the potential for a larger number of knowledge sharing interactions, which is currently unexploited. A similar trend is also observable for the average degree, which has increased from 2.63 to 3.48. In contrast, the clustering coefficient has declined over time moving from 0.18 to 0.12, suggesting a decrease in the average of the densities of the neighbourhoods of all the actors in the niche. In other words, actors also seem to exchange an increasing amount of knowledge with peers located far away from them.

As argued earlier, in conjunction with networking, niche readiness should also be assessed in terms of current expectations and knowledge level. To this end, we look at the 'knowledge exchange' network of biomass producers with attributes in 2015. For the sake of clarity we report in table 3 a summary of the distribution of producers' attributes.

Table 3: The Lithuanian biomass production network in 2015: attributes distribution (% values).

	Expectations	Knowledge
Very low	31.58	47.37
Low	21.05	15.79
Medium	42.11	15.79
High	5.26	21.05
Very high	0.00	0.00

It can be easily observed that, in general, both expectations and knowledge are overall low. The percentage of biomass producers exhibiting low and very low expectations about the possibility of completely replacing the current unsustainable regime is equal to 52.63%. At the same time, no biomass producer declared being highly optimistic about the future biomass niche development. As for knowledge, we can notice that almost 65% of producers have low and very low levels of knowledge exchange concerning the biomass production processes in terms of existing technologies, regulations, public policies, etc. In figure 3 we report the attributes of the 'knowledge exchange' network related to both expectations and knowledge in 2015.

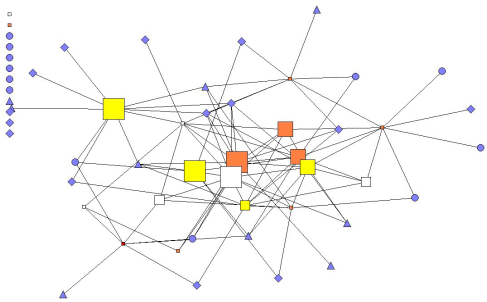


Figure 3: 'Knowledge Exchange' network with knowledge and expectation attributes: year 2015. Shape represents actors (Circles = Distributors; Diamonds = Institutions; Up triangles = Providers; Squares = Producers). Colour represents expectations (Black = Very high; Red = High; Orange = Medium; Yellow = Low; White = Very low). Size represents knowledge (the greater the size, the more knowledge).

At a first glance, looking at the expectation attribute we can observe the presence of a group of producers occupying a central position in the network but with a low-medium level of expectation. This could represent a possible obstacle to future niche development with respect to the convergence of expectations mechanism, as argued in section 2. Furthermore, these central actors possess a high level of knowledge, thus making the scenario more problematic. This is due to the existence of a central group of knowledgeable actors, highly connected with the remaining part of the network, which exhibit a low-medium level of expectation concerning future niche breakthroughs. Moreover, it is worth noting that the existence of two producers outside the network is not a critical issue, since both of them exhibit a low level of knowledge.

4.2 Institutions and niche readiness

Starting from the analysis carried out in the previous section, it seems that the niche is not ready for a breakthrough. Indeed, despite the fact that networking capabilities of biomass producers have improved the sharing of knowledge over time, the other two mechanisms necessary for niche readiness (i.e. expectations and knowledge) are still too weak. In general terms, determinants of technological change are not only to be found in individual firms, but also in institutional structures and related policy actions [27]. Institutions can significantly contribute to triggering convergence of expectations and raising the level of knowledge among actors. In order to understand the potential contribution that institutions could provide to the Lithuanian biomass niche development, we carried out a further investigation based on the analysis of their policy capability within the biomass producers' network. To this end, we derived the general relation network (i.e. the 'information' network) focusing mainly on the flow of information between institutions within the biomass niche. The network was enriched with the policy capability attribute, as reported in table 4.

Table 4: The Lithuanian biomass network in 2015: institutions' policy capabilities.

Policy Capability Level	Number of Institutions (%)
Very low	42.86
Low	7.14
Medium	28.57
High	7.14
Very high	14.29

From table 4, the percentage of institutions exhibiting high and very high levels of policy capability is quite limited (only 21%), while institutions with low and very low levels amount to 50%. The 'information network' built upon the above attribute distribution is reported in figure 4.

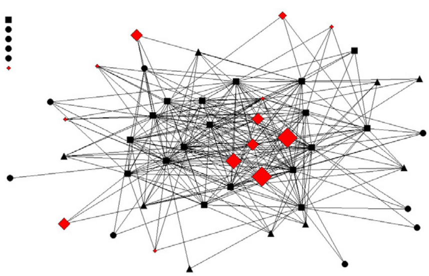


Figure 4: 'Information' network with institutions' policy capability: year 2015. Shape and colours represent actors (Circles = Distributors; Diamonds = Institutions; Up triangles = Providers; Squares = Producers – Red = Institutions; Black = all other actors. Size represents policy capability (the greater the size, the more capability).

The fact that the network density increases significantly as we move from the 'knowledge exchange' network (figure 3) to the 'information' network (figure 4) is immediately noted. In particular only 6 actors out of 54 are now disconnected from the network, of which only 1 is an institution. This finding provides evidence that only a small portion of all potential connections is actually used to exchange knowledge directly related to biomass production, suggesting that there is potential for a larger number of interactions, which is currently unexploited. This is confirmed by the analysis of networking indexes reported in table 5.

Table 5: Networking indexes: 'Information' network – year 2015.

Density	0.17
Number of ties	500
Average degree	9.26
Clustering Coefficient	0.39

From table 5 it can be observed that the number of ties in the information network drastically increases compared to the 'knowledge exchange' network in 2015. The same increasing trend is also observable for density, average degree, and clustering coefficient. Moreover, compared to the 'knowledge exchange' network, at least five institutions gain a central role in the biomass niche. This suggests that, along with a core group of producers, other actors (not directly involved in the production process) play a key role in the 'information' network, which has yet to be exploited for channelling knowledge. Furthermore, the central actors are now institutions with higher policy capability. Accordingly, if their central role was preserved, even in the exchange of knowledge, they could significantly contribute to the biomass niche readiness. At the same time, their central position could help to raise actors' expectations through active policy interventions (e.g. tax relief, actors' involvement in dedicated meetings and *fora*, etc.).

5 Conclusions

The present article investigates the degree of maturity of the Lithuanian biomass niche in replacing the current fossil based regime. By means of the SNA, we analysed the niche's readiness on the basis of three interlinked key mechanisms: (i) networking, (ii) expectations, and (iii) learning. With this insight, the SNA carried out provides us with the following findings:

1. The network of the Lithuanian biomass niche appears to be more connected and clustered now than it was eight years ago, with some actors – initially disconnected – entering the network and sharing biomass related knowledge with other peers.
2. A number of sceptical and knowledgeable actors (mostly producers, characterised by a low-medium level of expectation about the future development of the niche) have a central position in the network.
3. Along with a core group of producers, other actors (not directly involved in the production process) play a key role in the information network that is currently yet to be exploited for channelling knowledge.

These findings would suggest that the architectural structure of the network offers great opportunities for further technological niche development, some of which are not yet fully exploited. Actors are generally knowledgeable and can contribute to the learning mechanism indicated by the increased level of clustering during the last eight years. The weakest feature of the system is the low-medium level of expectation, which could potentially hinder the niche's development process. However, looking at the general relations (information network), the institutions with higher policy capability gain a central role. Therefore, if their role in the exchange of knowledge is also strengthened, they could significantly contribute to the biomass niche's readiness by raising actors' expectations through active policy interventions.

References

[1] Directive 2009/28/EC on the Promotion of the use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC, 2009.

[2] Adams, M., Ford, W., Schuler, T. & Thomas-Van Gundy, M., Effects of Natural Gas Development on Forest Ecosystems, *Proceedings of the 17th Central Hardwood Forest Conference*, pp. 219-226, 2011.

[3] European Commission, State of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU. Commission Staff Working Document, Brussels, 2014.

[4] European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A policy framework for climate and energy in the period from 2020 up to 2030. Commission Staff Working Document- Impact Assessment, Brussels, 2014.

[5] Sica E. & Falcone, P.M., The Economic Crisis and Sociotechnical Transitions: The Case of the Italian Biofuel Industry'. *Proceedings of 3rd European Business Research Conference*, 2014.

[6] Geels, F.W., Technological transitions as evolutionary reconfiguration processes: multi-level perspective and a case study. *Research Policy* **(31)**, pp. 1257-1274, 2002.

[7] Geels, F.W. & Schot, J., Typology of transition pathways. *Research Policy* **36**, pp. 399-417, 2007.

[8] Genus, A. & Coles, A.M., Rethinking the multi-level perspective of technological. *Research Policy* **37**, pp. 1436-1445, 2008.

[9] Kern, F., Using the multi-level perspective on socio-technical transitions to assess innovation policy. *Technological Forecasting and Social Change* **79(2)**, pp. 298-310, 2012.

[10] Kemp, R., Schot, J.W., & Hoogma, R., (1998), Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management, *Technology Analysis and Strategic Management* 10, pp. 175-196.

[11] Hoogma, R., R. Kemp, J. Schot, & Truffer, B., *Experimenting for sustainable transport: the approach of strategic niche management*. London: Spon Press, 2002.

[12] Lopolito, A., Morone, P., & Sisto, R., Innovation niches and socio-technical transition: A case study of bio-refinery production. *Futures* **43(1)**, pp. 24-38, 2011.

[13] Kemp, R. & Rip, A., Technological change. In: Rayner, S. & Malone, E.L. (Eds.) *Human Choice and Climate Change*, vol. 2. Battelle Press, Columbus, pp. 327-399, 1998.

[14] Geels, F.W., Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy* **31**, pp. 1257-1274, 2002.

[15] Berkhout, F., A. Smith, & Stirling, A., Socio-technological regimes and transition contexts. In Elzen, B. Geels, F.W., & Green, K. (eds.) *System innovation and the transition to sustainability: theory, evidence and policy*, pp. 48-75. Cheltenham: Edward Elgar, 2004.

[16] Rotmans, J., Kemp, R., & van Asselt, M., More evolution than revolution: transition management in public policy. *Foresight* **3**, pp. 15-31, 2001.

[17] Geels, F.W., & Raven, R.P.J.M., Non-linearity and expectations in niche-development trajectories: ups and downs in Dutch biogas development (1973–2003). *Technology Analysis & Strategic Management* **18**, pp. 375-392, 2006.

[18] Caniels, M.C.J. & Romijn, H.A., Actor networks in strategic niche Management: insights from social network theory. *Futures* **40(7)**, pp. 613-629, 2008.

[19] Geels, F.W., A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies. *Journal of Transport Geography* **24**, pp. 471-482, 2012.

[20] Raslavičius, L., Narbutas, L. Šlančiauskas, A., Džiugys, A., & Bazaras, Z., The districts of Lithuania with low heat demand density: A chance for the integration of straw biomass. *Renewable and Sustainable Energy Reviews* **16**, pp. 3259-3269, 2012.

[21] Katinas V, Markevicius, A., Perednis, E., & Savickas, J., Sustainable energy development – Lithuania's way to energy supply security and energetics independence' *Renewable and Sustainable Energy Reviews* **30**, pp. 420-428, 2014.

[22] Litbioma, http://www.biokuras.lt/en/about-us.html

[23] Raslavičius, L., Kučinskas, V., & Jasinskas, A., The prospects of energy forestry and agro-residues in the Lithuania's domestic energy supply'. *Renewable and Sustainable Energy Reviews* **22**, pp. 419-431, 2013.

[24] Wasserman S. & Faust K., *Social Network Analysis. Methods and Applications*, Cambridge University Press, 1994.

[25] Mitchell, J.C., *Social network in urban studies*. Manchester: Manchester University Press, 1969.

[26] Morone, P., Tartiu V.E., & Falcone, P.M., Assessing the potential of biowaste for bioplastics production through Social Network Analysis. *Journal of Cleaner Production* **90**, pp. 43-54, 2015.

[27] Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlman, S., & Smits, R.E.H.M, Functions of innovation systems: a new approach for analysing technological change. *Technological Forecasting & Social Change* **74**, pp. 413-432, 2007.