Regional planning for renewable energy sources – new approach

Anna Oniszk-Popławska[1], Mariusz Matyka[2], Roman Buss[3]

[1] Institute for Renewable Energy Ltd., PhD student at the Faculty of Architecture TUW, aoniszk@ieo.pl,
[2] Institute of Soil Science and Plant Cultivation– State Research Institute in Puławy IUNG PIB,
[3] RENAC, Germany.

The energy market paradigm shift towards the so called "green revolution" assumes that in the next few decades dispersed energy sources will replace centralized generation systems. Despite growing energy related spatial conflicts, already accompanying the development of dispersed generation, it is not clear how to integrate new energy infrastructure into planning procedures. This article presents a new approach at the regional level, by unveiling the technology diffusion theory and its implications for the development planning of renewable energy sources (RES). It suggests how to integrate energy related issues into regional spatial policy, by presenting prospects for agricultural biogas plants (ABPs) in the Lubelskie region, Poland; dwelling on the experiences from a best practice region Lower Saxony, Germany.

Keywords and phrases: regional spatial and energy planning, regional policy, renewable energy, agricultural biogas.

Introduction

This article provides implications of the innovation diffusion theory for RES. The UN declared in 2012 that in 2050 RES should cover 77% of the world's energy demand. In 2007 the EU adopted the 3x20% package. Germany endorsed an ambitious plan to achieve 80% of electricity from RES as early as in 2050, with an increasing number of 100% RES communities and a total withdrawal of nuclear power to 2022. In the long term further RES development will require better planning in particular as regards *ex ante* implications for spatial, social and economic development [1]. In this article the emergence of a new approach to integration of spatial and energy planning for RES on a regional level, with two examples of mature and inception phase case study regions, is presented.

Spatial diffusion theories for innovative technologies

Technology diffusion theory (TD) was first defined in 1940's [2] as: the invention (doing something in a completely new way), innovation (modifying existing technologies to make the production of desirable goods and services more efficient), and diffusion (spreading the new and modified technologies throughout the economy). TD is a temporal and spatial phenomenon. The literature review showed that TD can be split into time phases, along an S-curve pattern [3], however, exact S-curve patterns have not been thoroughly analysed yet [4].

According to neo-classical economic theories TD is dependent solely on the financial incentives, other systemic approaches argue that RES should be supported by a combination of financial, technical, infrastructural and social policy-push measures. Whereas, the first one is supposed to be effective for centralised RES (such as large wind farms) the social aspects are an inevitable element of policy-push measures in the case of prosumer installations, which require radical changes [5].

The analysis of 14 case study regions under the EurObserv'ER [6,7], project enabled to identify phases of the technology diffusion S-curve (inception, demo-deployment, maturity and saturation), each characterised with a different set of policy-push measures (Fig. 1).

With time, regions become more mature in terms of RES development, at the beginning the development is slow, after a subsequent period of rapid growth the technology meets limits to its further development. As the EurObserv'ER case studies showed, once the upper point of the TD S-curve has been reached, the region will face limitations in the further

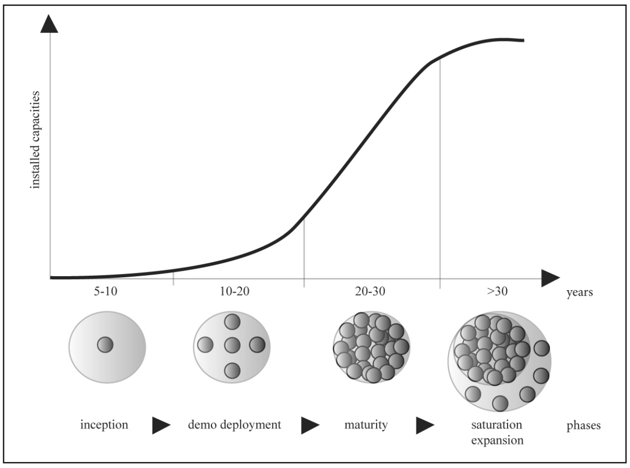


Fig. 1. Phases of the technology diffusion S-curve pattern

expansion of a given technology. Later policies tend to change either into restrictions on further development within the region, or to incentives to export the know-how outside, which was also confirmed by other regional case studies [8].

Policy push tools

The policy-push tools to support the diffusion of innovation and human capital are willingly applied by regions as the empirical experience shows that those regions, which do so become more prosperous than those that do not [9]. Spatial/temporal planning of TD involves wide spectrum of issues: on one hand governance, corporate organisation, policy integration, statutory/regulatory frameworks, technical analysis/design; on the other hand organisational/institutional capacity to realise assumed targets [10]. An approach change in policy making has been observed away from the so-far passive controlling of the land-use towards applying different stakeholder involving tools [11].

In policy making two kinds of "future" approaches can be applied: prospective or backcasting. The later envisions desirable future and in the next step elaborates temporal milestones how to achieve them; it answers rather the question of "what should" rather than "what would/could" happen and requires a more participatory approach of all interested stakeholders, often applied in a regional planning [12,13].

Regions willing to achieve a high penetration of RES can start planning their activities with setting the policy push targets. The regional policy push methodology was elaborated by the authors of this article under the EurObserv'ER project [6,7]. A crucial starting point is always the sufficient availability of the natural resources. Also the temporal aspect should be taken into consideration: with the passage of the time, regions become more mature in terms of RES development, each phase characterized with a different set of policy tools. Some policies will be more effective at the inception of the process, *e.g.* organisational measures, elaboration of policy documents or setting RES targets. Later on, demonstration investments (infrastructural base) and regional support instruments (financial support) tend to gain on importance. After 5-10 years, consequently implemented support actions start bringing fruits and lead to a dynamic increase of investments. In this maturity phase the consolidation of different actors and clustering of activities is gaining momentum (competitive intangibles). If the region decides to become a leading RES producer the infrastructural base and the presence of skilled workforce must be reinforced. The creation of public acceptance and involving citizens should be realised continuously at all stages. At the beginning, public acceptance is applied to attract citizens' attention and involve them in the policy formulation and decision making process to become energy prosumers, at the saturation phase actions tend to prevent public resistance in the face of high penetration of RES.

Organisational measures include actions such as the formulation of policy documents, setting ambitious but realistic targets as well as the simplification of administrative procedures. Ambitious targets were the starting point to develop RES must be outlined. Competitive intangibles refer to measures aiming to support research, development and innovations but also organisation of regional discussions and clustering activities. Support for innovation and research as well as a positive atmosphere for cooperation is crucial for investors. Clustering activities include cooperation between science, education and industry; also active involvement in professional regional associations. Human capital, under this category, is understood as building up professional know-how or business skills *e.g.* to develop a strong manufacturing base. Financial support provides incentives for investors, including innovative instruments such as start-up capital or private-public partnership. A sufficient level of financial and legal support on the national level is a starting point for any development of RES, however regional support schemes tend to give an additional stimuli. Infrastructural base means any physical investments or infrastructure supporting development of RES, such as a well-developed transportation logistics, brownfield sites, remains of the heavy industry, which can be transformed into special economic zones to attract new investments. Additionally the location within an international transportation hub facilitates the export of the RES artefact abroad. Social acceptance creation involves citizens and the general public to facilitate a dynamic development of RES by organisation of public debates, information campaigns and measures to increase public acceptance. The creation of social acceptance and active involvement of citizens, educating them even to become future energy prosumers is becoming increasingly important, especially for biogas investors (such investments seem to face strong opposition) [7].

Maturity phase case study region

The development of agricultural biogas plants (ABPs) in Nidersachsen *i.e.* Lower Saxony (LS), Germany was chosen to exemplify a successful mature region. Its 30 years experience of implementing policy-push tools can be transferred to regions, which are at the beginning of the pathway. Germany's ABPs market is the largest in Europe, whereas, LS boasts 27% of the domestic production. The region's economy is driven by agriculture, industry and science. The local farmers as well as endorsed policy push actions stimulated a dynamic growth of the ABPs sector (in 2012: 1,480 ABPs with total 783 MW_{el}, additionally 21 biomethane installations feeding gas to the natural gas grid were installed). The biogas support scheme led to engagement of 3,000 farmers, 2.5 billion EUR investments in rural areas since 2002 and 1,500 direct (and 5,000 additional indirect) work places. Also the use of biogas as transport fuels has started to take shape at two biogas petrol stations. Until 2020 the biogas capacity is projected by to grow to 900 MW_{el} [6,14].

Under the EurObserv'ER [6] project LS was described in detail as the best practice region to examplify the policy push tools for ABPs. LS has defined energy as major strategic sector of the economy and started to position itself and emphasize its crucial role as an "energy state" over recent years (heading the German league in terms of overall installed RES capacity). It is hardly surprising as Bavaria and LS are the largest states in terms of size and characterized by vast agricultural lands, alongside with many animal breeding farms. But the success of the massive biogas expansion can also be explained by other factors. An advanced biogas training programme for farmers gave the region a head start compared to other agriculture dominated regions. Also the proximity of R&D clusters to the agricultural land were fostering the biogas boom over the past decade. The growing market also proved to be fertile ground for local ABPs and equipment manufacturers that co-evolved in LS turning into a leading European biogas industry player. Below the policy push- measures applied in LS over the last 30 years are described.

Financial support. As in other RES sectors, the nationally guaranteed feed-in tariff for RES electricity (EEG) was the major driver for investments and the biogas boom. However, additional regional investment subsidies were present till 2003, but then withdrawn as the region entered a maturity phase.

Municipal initiatives. There is already a significant accumulation of local initiatives and promotional networks of biomass power such as the Bioenergie Region Weserbergland and Göttingerland, or Germany's first 100% RES powered villages of Jühnde and and Beuchte. The ultimate ambition of the net-

Table 1. Characteristic of the maturity region Lower Saxony, [6]

General information	
Name of the region	Lower Saxony (Niedersachsen).
Territorial Unit	NUTS I.
Number of inhabitants	7,9 million, 75% in rural areas.
Area km^2	47,624.
Topography	Vast agricultural areas and forests, with urban clusters of Hannover, Göttingen, Braunschweig, and Wolfsburg.
Economy	Agricultural sector, automotive industry and suppliers, Hannover Fair, tourism, academia and universities as main economic sectors
RES technology developing dynamically in the region	Mature: biogas, all other RES (PV, wind, biomass, hydro); 31% of renewable electricity in entire Lower Saxony as compared to 17% on national average.
Installed and planned capacities in the region compared with the national development	Single districts clearly above national average in RES electricity; first energy autonomous municipalities (Jühnde) have switched to 100% RES supply; 1,480 ABPs in operational and 21 biomethane installations (gas fed to the natural gas grid) by end of 2012, biogas provides 9% of electricity supply.
RES technology potential in the region	Projection of 6.4 TWh of biogas electricity by 2020. Potentially, biogas could supply 19.5 TWh of primary energy an 900 MW_{el}.
RES technology development in the region starting date	2000's (but the first experimental biogas plant already in 1948).
Investment dynamics	Estimated € 2.5 billion in biogas since 2002; the annual turnover of € 1.2 million in biogas sector.
Employment	1,500 direct (mainly farms/agriculture) and 5,000 indirect jobs (plant manufacturing and component supply, logistics, R&D planning and consulting).
Main reasons to support	Additional income generation for rural population and enterprises; shift to 100% renewable energy supply, regional energy independence
Actions taken	Establishment of energy and renewable research clusters; announcement and declaration of 48 municipalities to become the first energy autonomous energy region in Germany, and to achieve a 100% renewable energy supply by 2050.
Regional support policies	
Regional financial incentives	No longer subsidized but were at the inception phase by AFP: Agricultural investment support programme, KfW loans.
Authorities active in supporting RES	3N competence centre for sustainable resources; Ministry of Agriculture Lower Saxony, State Chancellery; various local energy and climate protection agencies.
Regional educational programs	Dedicated biogas education programme (10 years: 3,000 farmers trained); Energy Research Centre Lower Saxony (EFZN), Leibniz University, Research Network Bioenergy, Solar Energy Research Centre, Research Network Geothermal Energy.
Benefits for the region	Regional added value and turnover generation by production of equipment, job creation, energy independence, avoided fossil fuel imports.
Regional investment environment	
Number of companies active in the region	Major bioenergy / biogas plant manufacturers and component suppliers are firmly based in the region such as MT-Energie, Bioconstruct, Biogas Weser-Ems, EnviTec Biogas AG , AgroEnergien, BKN biostrom AG.
Origin of developers/investors	Mostly regional and domestic individual farmers joining cooperatives.
Reasons for choosing of the region by the investors	Land and substrate availability; diversification and new sources of income for farmers (independence from fluctuating resource prices), local energy demand.

work of 49 municipalities of the Metropolregion of LS and districts launched in 2009 is to cover 100% of energy demand for power, heat and mobility with RES by 2050. The region is the first of its kind to formulate such ambitious objective, also in terms of CO_2 emission reduction.

Support for R&D. On an institutional level numerous universities and other R&D institutions were set up. In 2007 the Regional Energy Research Centre; and in 2009 a Research Network Bioenergy were founded. Investors see a positive role in those institutions, mainly in that they provide information and a well-trained staff. One of the world's largest industrial Fairs – the Hannover Messe – is also a vital showcase for the biogas industry.

Other support measures. The successful expansion is also based on the combination of other factors such as individual attitudes of local investors, the institutional setup of regional imitative and bundling of competences, and a R&D infrastructure that have been built up over the last years. Above all, a dedicated education programme trained more than 3,000 farmers and provided them with hands on experiences on plant construction and operation. An informal success factor is also the characteristic of the investors. Farmers working on lower quality soil needed to find innovative ways and take more risks to secure and diversify their incomes: local farmers displayed an entrepreneurial and innovative spirit. In effect, ABPs are largely built by farmers or local cooperatives that joined forces with utilities. Although there are limits to further biogas expansion (competing land uses between food and energy crops, unintended but highly visible side effect of creating monocultures, public scepticism), ABPs still have a future (but with limits) in LS. The combination of urban and rural areas with their specific advantages of density of research institutions and industrial support and land availability can be vital elements in the challenge of a shift to 100% RES.

Some elements of the regional policies are replicable elsewhere. Setting of clear targets (and limits), promotional R&D institutions that provide a trained technical staff, a transparent dialogue with stakeholders, information campaigns, together with coordinated regional activities and networks may also pave the way and stimulate the emergence of a regionally based SME biogas industry elsewhere.

Certainly some of the policy-push measures applied in LS will be specific only to this particular region. However, as other EurObserv'ER case studies showed most of the replicability factors can be used to formulate regional policies elsewhere also due to country to country spill over effects [15].

Inception phase case study region

The agricultural character of the Lubelskie region (eastern part of Poland) makes it a natural arena for the development of ABPs, which is hopped to accelerate restructuring of its agriculture. The regional authorities chose ABPs as one of the regional development priorities; further steps require translation of political will into strategic planning and horizontal policies. The following step by step approach for programming spatial and temporal diffusion of ABPs is suggested [16]:

- Identification of boundaries,
- Formulation of scenarios,
- Suggestions for policy actions.

Identification of boundaries

Feedstock for biogas production

Theoretically the Lubelskie province has favourable conditions for the production of organic material (animal manure, agro-food industry waste and energy crops) for ABPs. Unfortunately, the organizational structure of agriculture greatly reduces the possibility of the development of ABPs. It was estimated than there are only *c*. 340 holdings where the agricultural area exceeds 100 ha; *c.*1,200 for 50-100 ha and *c*. 9,400 for 20-50 ha [17]. There is a tendency for consolidation of land and increasing farms' sizes, however, it is still not enough to make larger ABPs economically viable [16].

Another stream of organic substrates is the agro-food sector. In the region following industries were the most promising market players: sugar, alcohol, dairy, meat processing, as well as fruit and vegetable industries. Entities producing over 1,000 ton of waste per year (18% of all manufacturers) deliver 94% of the total volume of waste. Unfortunately, when calculated to biogas energy potentials agro-food waste streams will have only a local impact, the total biogas energy volumes are not significant [16].

Compared to the EU-27, the degree of concentration of land and livestock production in Poland is lower, on top of this the Lubelskie province has the most fragmented farming structure. As a result, the development of large and medium ABPs can be problematic. Smaller farms are a prerequisite for the dynamic development of ABPs but it will be possible only if the horizontal consolidation of producer groups is encouraged. Increasing the momentum of the system will depend on the measures to promote the development of energy crops as feedstock for biogas production and organizational measures in order to include smaller farms in its production. If such actions are undertaken even a few hundred MW_{el} of ABPs installed capacities are realistic in the Lubelskie province over the next 20 years [16].

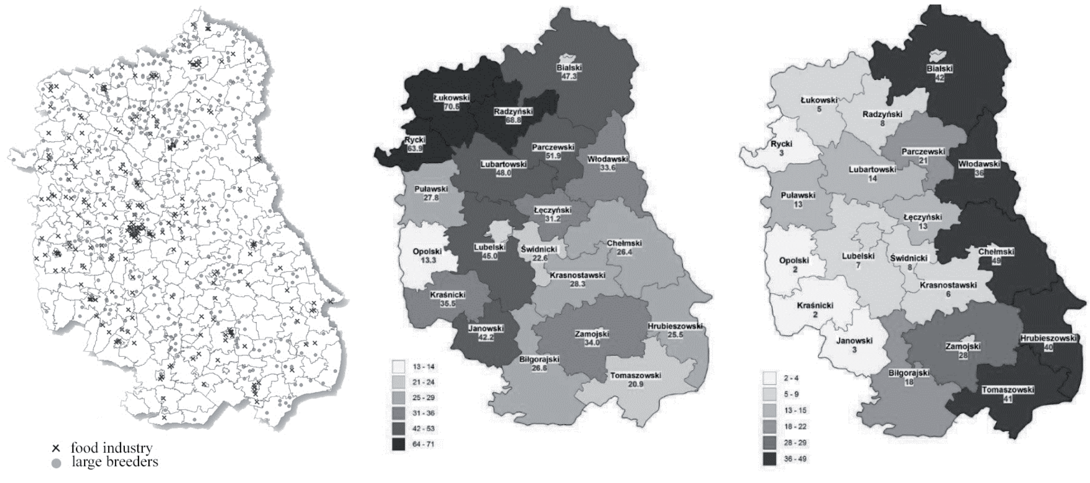
Table 2. An average size of farms as per the acreage, [17]

Average farm size			Year
20-50 ha	50-100 ha	>100 ha	
27.5	64.8	212.2	**2002**
30.1	67.0	257.0	**2010**
32.8	69.0	311.0	**2020***

*Simulation for the year 2020 are extrapolated from 2002-2010 trend lines.

Table 3. Input data for the evaluation of the feedstock potential for large ABPs [16]

Industrial organic waste producers	Animal waste (slurry, manure)	Energy crops



Amount of agro-food waste	Livestock unit per 100 ha for farms >100 ha	Number of farms with acreage for farms >100 ha

Infrastructure

In 2010, the total power generation units of electricity in the region was 442 MW_{el} (1.2% of domestic). However, electricity consumption amounted to 5.934 GWh, which means that 68% of electricity demand was delivered from outside the region. Historically, the dependence on external supplies of electricity has increased in the region [18]. The increasing demand for energy, in the absence of new generation sources creates a negative trend affecting the decrease in security of energy supplies. This trend can be reversed by new generation capacities, in particular RES (including ABPs). It is expected that the potential for large investments will be met in the immediate vicinity of medium and high voltage infrastructure. In the longer term, grid connection problems may emerge along with a rapid expansion of other RES, such as wind.

From the point of view of the possibility of using ABPs to produce biomethane fed to a gas infrastructure, the most important is to assess the natural gas distribution networks. Out of 41 cities in the Lubelskie province only 6 cities are not covered with natural gas supplies. In rural areas, access to the natural gas is limited, only 9.6% of households (national average 17.6% in rural areas). There are sufficient transmission reserves in the regional gas grids, however, taking into account the fact that biomethane projects are usually big and capital intensive, the substrate base for such projects in the region is rather limited; only a few biomethane projects can emerge [16].

Formulation of scenario narratives

The regional market potential of ABPs includes both the spatial (sub-regional breakdown) and temporal dimensions (short/medium and long-term), in which potentials are coupled with profitability indicators, political support policies and infrastructural conditions. The future market can be envisioned by the formulation of narratives (scenarios). It is proposed to determine technology development by the identification of the following scenario parametric groups [19]:

- External factors: economic (*e.g.* national support mechanisms and competition with other sources), national policies (*e.g.* environmental, agricultural),
- Endogenous factors: regional policies, infrastructural conditions,
- Targets and boundaries for future developments: elaboration of action plans and policy milestones.

The economic or implementation potential is usually expressed as demand-driven assessments [20], to reflect the penetration of biomass resources on a competitive market. Integrated assessment models are designed to assess policy questions (such as population and income growth, as well as technological developments and policy incentives). Scenario multi-dimensional storylines can be built to reflect assumptions about future development trends: socio-economic, technological and environmental developments [21,22].

A scenario is not a forecast of the future, it reflect an internally consistent story about the path from the present to the future. A collection of the scenarios can be called a futures map, they should be characterised with plausibility and internal consistency the emergence of the future should be based on the past and the present situation. They can be described as comprehensive ideas against which the plans and strategies can be elaborated [22].

For the Lubelskie province a scenario storyline was formulated, emerging from the basic policy question: "will the domestic RES policy give sufficient incentive for ABPs development on a national level" (<u>a primary driving force</u>), a negative answer leads to a negative future, the SCENARIO S0, and to the discontinuation of regional activities. A positive answer to this question leads to another question: "will the additional regional support be provided" (<u>a driving force 1</u>), a negative answer to this question leads to the SCENARIO 1, EASY FEEDSTOCK; a negative answer leads to the next question

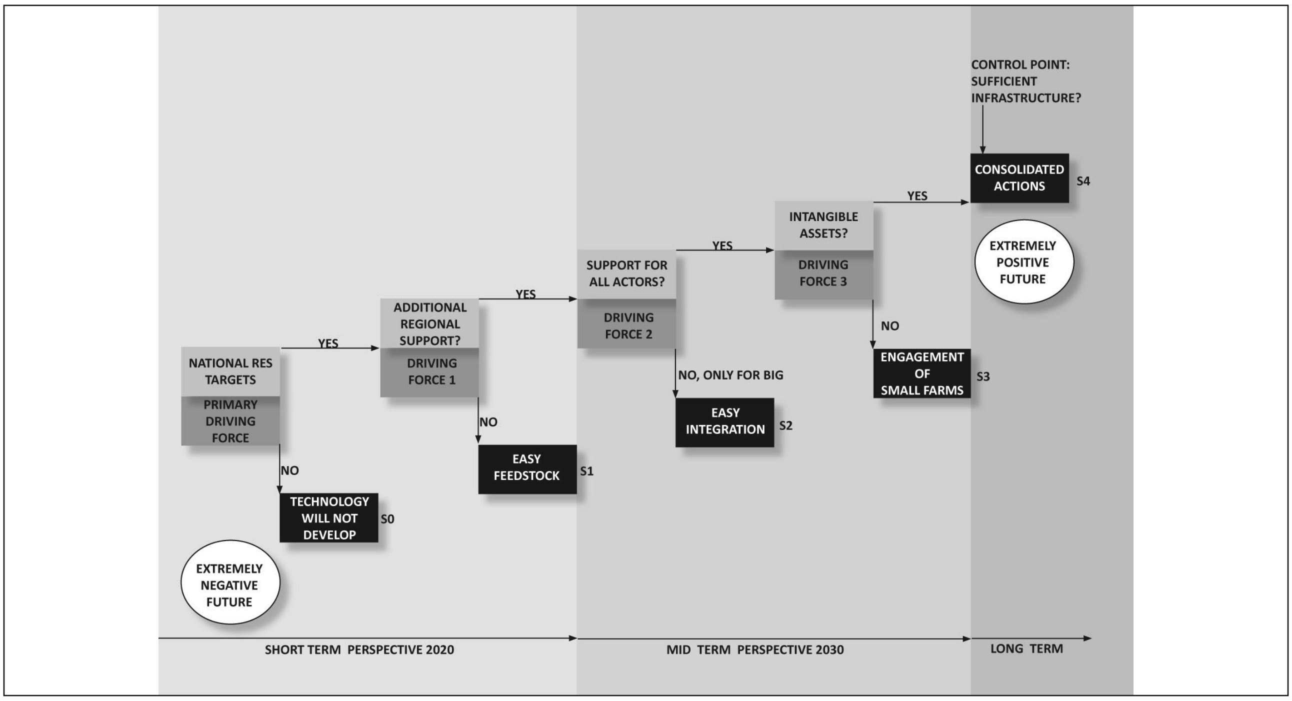


Fig. 2. Economic potential scenarios' storyline

Table 4 Scenarios' assumptions

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Scenario name	EASY FEEDSTOCK	EASY INTEGRATION	ENGAGING SMALL FARMS	CONSOLIDATED ACTIONS
Farm's entry acreage	100 ha	50 ha	20 ha	20 ha
Interests in energy crop production farms				
20-50 ha	0	0	5%	10%
50-100 ha	0	10%	15%	20%
>100 ha	10%	15%	20%	25%
Fraction of disposable animal excrements	30%	40%	50%	60%
Fraction of disposable agro-food industry waste	50%	60%	60%	60%

"will the support be provided to all actors" (a driving force 2). The answer: "the support will be provided only to big players" leads to the SCENARIO 2: EASY INTEGRATION. A positive answer leads to a more detailed question "will intangible assets such as clustering activities, education for farmers and consultation points be provided" (a driving force 3), a negative answer to this question leads to the SCENARIO 3: ENGAGEMENT OF SMALL FARMS. A positive answer leads to the extremely positive future SCENARIO 4: CONSOLIDATED ACTIONS. The scenario story line is presented in Fig. 2 below.

Parameters of each scenario assumptions are entered to a dedicated Excel sheet stimulation tool and characterised by a set of scenario variables (Table 4). The results of the calculations, together with a narrative for each of the 4 scenarios is presented below.

In each of the scenarios energy crops play a crucial role as a substrate base for biogas to energy production. However, for sustainability reasons 2 criteria are always kept: energy crops do not take more than 10% of the arable land, the mass input to ABPs does not exceed 60% (90% in energy terms).

EASY FEEDSTOCK scenario (S1) assumes that the current level of support (on the national level) for agricultural biogas will continue but no regional effort will be made to further support the development of this technology. The substrate market potential for installed power capacities amounts to 24 MW_{el} and is easily reached by 2020 (4% share in final electricity consumption). The number of plants will raise to *c.* 15 large plants (waste potential from industry will be used up), and *c.* 25 medium sized. Small biogas plants will not develop under this scenario due to insufficient support. Additional part-time employment for *c.* 370 people in harvesting energy crops for 2 months/a and *c.* 100 jobs for O&M are ex-

Table 5. Summary of the scenarios' outcomes

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Scenario name	EASY FEEDSTOCK	EASY INTEGRATION	ENGAGING SMALL FARMS	CONSOLIDATED ACTIONS
Primary energy contained in biogas	*c.* 2 PJ	*c.* 4 PJ	*c.* 8 PJ	*c.* 12 PJ
Installed capacities	*c.* 25 MW_{el}	*c.* 50 MW_{el}	*c.* 100 MW_{el}	*c.* 150 MW_{el}
Number of biogas plants, with capacity share	*c.* 40	*c.* 75	*c.* 200	*c.* 450
large>1 MW_{el}	50%	50%	30%	30%
medium 500- 1,000 kW_{el}	50%	50%	40%	40%
small 150-500 kW_{el}	0	0	30%	30%
Share of in final electricity consumption	4%	7%	11%	15%
Required area for energy crops, ha	*c.* 10,000	*c.* 20,000	*c.* 40,000	*c.* 60,000
% of arable land area in good practice	<1%	1,5%	3%	5%
Farmers involved				
20-50 ha	0	0	*c.* 350	*c.* 700
50-100 ha	0	*c.* 100	*c.* 150	*c.* 200
>100 ha	*c.* 30	*c.* 50	*c.* 50	*c.* 100
Employment (FTE)				
seasonal employment (energy crops)	*c.* 370	*c.* 800	*c.* 1,500	*c.* 2,300
O&M	*c.* 100	*c.* 200	*c.* 900	*c.* 1,300
Regional turnover (MEUR)				
new investments	*c.* 120	*c.* 250	*c.* 500	*c.* 700
electricity fees stay in the region	*c.* 15	*c.* 30	*c.* 40	*c.* 50
Emission reduction				
electricity generation $MtCO_{2eq}$	0.2	0.3	0.5	0.6

pected (a few hours/d per each plant). The required area of energy crops is about 10,000 ha, which makes less than 1% of the share in arable land and requires involvement of *c.* 30 farms above 100 ha acreage. Biogas plants installed are likely to be based on a market sound technology (CHP).

EASY INTEGRATION scenario (S2) assumes the intensification of energy crops production (such as maize) as input material but only among bigger players (farms above 50 ha). The condition for achieving *c.* 50 MW_{el} of installed capacities (7% share in final electricity consumption) is to involve 10-20% farms in the production of dedicated energy crops (in total about 150 farms). Expected number of ABPs amount to *c.* 25 large plants >1 MW_{el}, 50 medium sized plants 150-500 kW_{el}, no small installations are expected. Additional part-time employment for *c.* 800 people in harvesting energy crops for 2 months/a and *c.* 200 jobs for O&M are expected (a few hours/d per each plant). The required area of energy crops is about 22,000 ha, which makes more than 1.5 % of the share in arable land.

ENGAGING SMALL FARMS scenario (S3) assumes the intensification of energy crops production (such as maize) as input material for ABPs among farms above 20 ha. The condition for achieving *c.* 100 MW_{el} of installed capacities (11% share in final electricity consumption) is to additionally involve 5% of smaller farms in the production of dedicated energy crops (in total about 580 farms and 40,000 ha). Expected are *c.* 30 large plants >1 MW_{el}, 80 medium sized plants 500-1,000 kW_{el} and 200 smaller plants 150-500 kW_{el}. Additional part-time employment for *c.* 1,500 people in harvesting energy crops for 2 months/a and *c.* 900 jobs for O&M (a few hours/a per each plant) are expected. The required area of energy crops is about 42,000 ha, which makes more than 3% of the share in arable land.

CONSOLIDATED ACTIONS assumes that the uninterrupted integrated RES regional policy will bring its fruits. A dynamic development of RES will be facilitated by the necessary organizational and technical infrastructure. The total installed capacities will reach 150 MW_{el}, the required acreage of energy crops will be 62,000 ha, and the involvement of some 1,000 (70%) of 20-50 ha farms in the production of dedicated energy crops will be required, almost 5% of arable land. It will be a logistic and organizational challenge and will require activities in consolidation, education and training of farmers. The scenario dwells on the strengthening of the social network. The most important task will be to facilitate the horizontal consolidation of farms for the joint production of biogas and energy crops. Expected are *c.* 40 large plants >1 MW_{el}, 100 medium sized plants 500-1,000 kW_{el} and 300 smaller plants 150-500 kW_{el}. Additional part-time employment for *c.* 2,300 people in harvesting energy crops for 2 months/a and *c.* 1,300 jobs for O&M are expected (a few hours/d per each plant). In this scenario ABPs, with the possibility to store energy, start to play a balancing role in the regional power system (to even up the production of energy from other intermittent RES such as wind). In this scenario technologies other than cogeneration of heat and power start to gain momentum (biomethane for grids and for transportation).

The sensitivity analyses were performed for the crucial scenario parameters, listed in the Table 4. The most important parameter is willingness to engage in energy crops production. Other decisive parameters are fractions of animal and agro-food waste, which can be obtained as input material to ABPs. The analyses have shown that the interest indicators in two groups of farm sizes 20-50 ha and above 100 ha are the most sensitive parameters. In S4 increasing the interest of farms in the production of dedicated energy crops in smaller farms from 10% to 20% can lead to almost 180 MW_{el} of the total regional installed capacities. The sensitivity analysis also showed a very limited impact of the agro-food industry waste as input material having impact on the overall installed capacities in the region (Fig.3).

Integration of scenario outcomes into regional policies

The so-far common approach to RES planning was to calculate technical potentials and evaluate the biomass feedstock for ABPs, without much consideration of other assets important for policy formulation. However, the integration of not only resource potential but also other assets are considered to be pillars of the future RES diffusion in a region [24]. The scenarios' story line and assumed targets led to formulation of policy implications, which are summarised below.

The below recommendations are suggested to be integrated into official policy documents, which should include

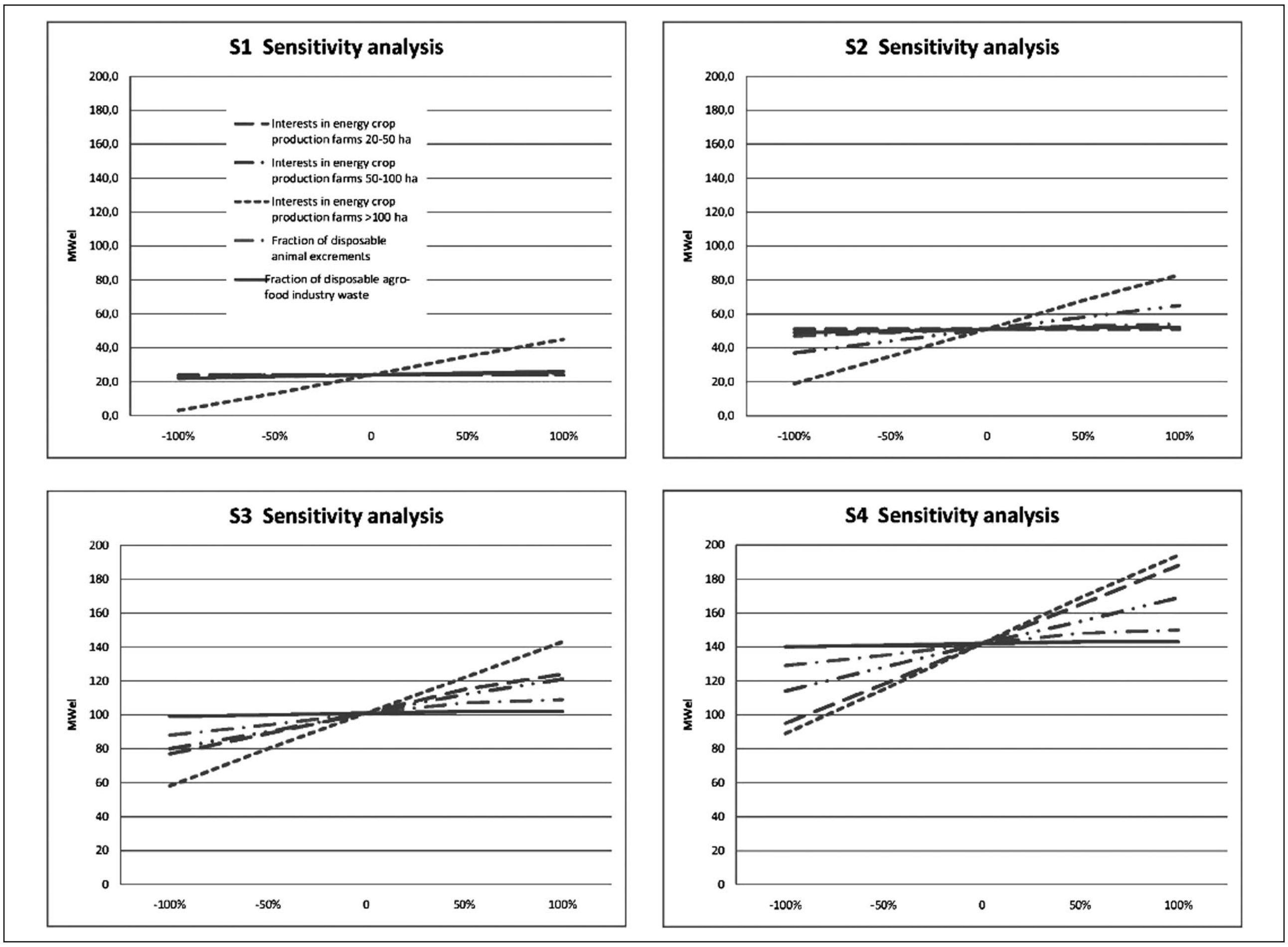


Fig. 3. Scenarios' sensitivity analyses

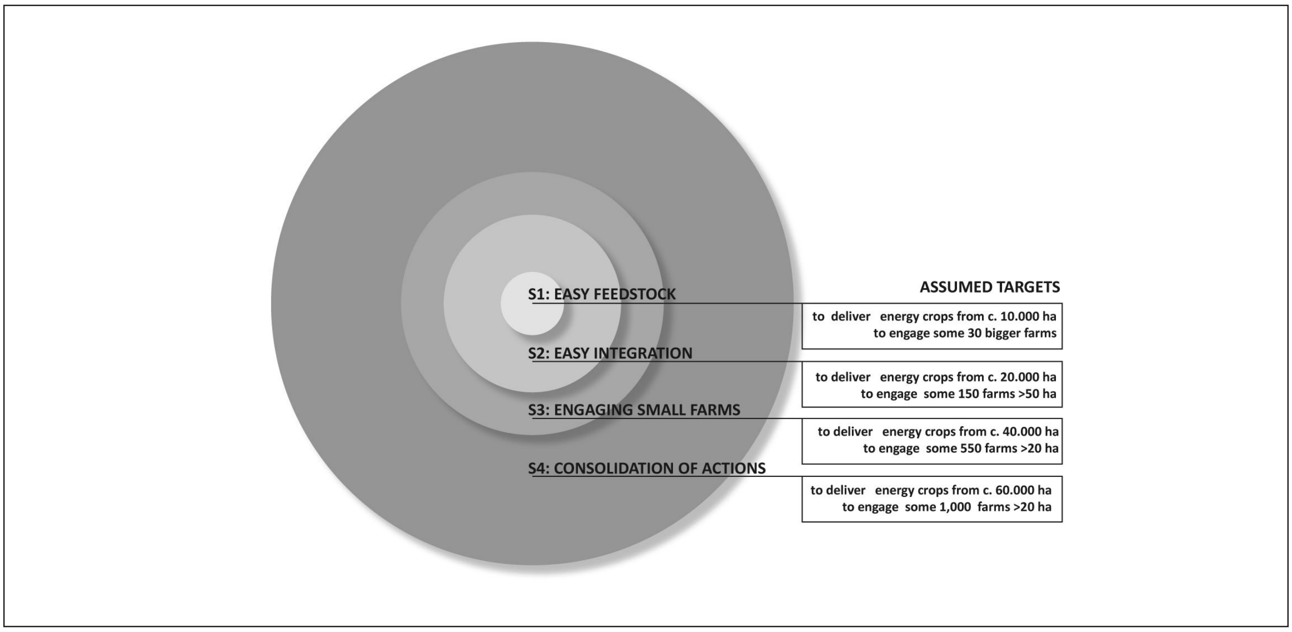


Fig. 4. Targets assumed for the scenarios

clear targets within chosen time horizons; designate authorities responsible for their implementation, monitoring and update. The below list of assumptions for policy implementation is not complete, but indicates the most important ones.

Policy implementation. Assumed policy targets should be concrete in numbers (not vague and general), have a clear time horizon; be accompanied with a set of policy-push measures, additionally there should be a political declaration for their endorsement by the regional authorities. Regional policies such as energy, agricultural, social should be integrated horizontally for example *via* spatial planning policies.

Technical assistance for municipalities. Municipalities are not likely to make an effort to integrate different RES policies due to costs, time, lack of data and expertise. Therefore, they should be advised on how to integrate plans for extension of new, planned energy infrastructures into local policy documents (spatial and energy master plans), as well as into the investment process (issue of licenses, agreements, public consultation *etc*.). Technical assistance should be provided by the regional authorities.

Information and education. Public regional authorities should continually initiate and support local expertise, thematic publications, training, workshops, increase public acceptance for ABPs. Both population, municipal authorities and investors/developers should be approached to learn how to co-operate and peacefully resolve conflicting situations. The construction of a ABPs should be perceived positively by the authorities and local population in order to create acceptance and avoid escalating of protests against investments of infrastructural origin.

Investment support. Regional RES investment support should have clear targets and budgets. The purpose of planning is that the financial support is targeted at investments with the greatest economic potential. The development strategy of dispersed generation (incl. biogas) should actively involve local authorities. The first biogas installations erected with the public support should be converted into open-access vocational training, and educational units.

Consolidation of actors. Due to economic reasons it is recommended that farmers work together in order to jointly produce feedstock and energy. Horizontal consolidation and co-operation of farmers will not happen without external organisational support, thus, the regional authorities should facilitate planning, organisation and financing of the first dedicated co-operatives in rural areas. The process of horizontal consolidation of smaller farms should be aimed at co-operatives of biogas and energy crops producers. The region should take advantage of the existing local organizational infrastructure such as regional agricultural advisory centres. Another direction could be to strengthen the creation and activity of a thematic cluster consisting of suppliers, competitors, customers and associated enterprises of industry, but also added value-chain actors such as universities, research institutions, local governments, industry associations, financial institutions and intermediary organizations of science and technology.

Summary

This article presented policy-push measures characteristic to the diffusion S-curve of any RES projects. A success story of a region with 30 years experience in supporting agricultural biogas was described (Lower Saxony, Germany), in order to transfer its experiences to an inception phase region (Lubelskie province, Poland), whose authorities want to plan a reasonable but dynamic development of this technology. A storyline scenario building procedure was presented in order to stipulate the market potential for the development of ABPs in the region. The results can be used as an input for formulation of regional policies; of which spatial policy seems to be the most important having an integrating role for other policies: environmental, energy, agricultural *etc*.

For replication measures, one needs to consider the medium and long term characteristic of RES deployment: the dynamic development occurs with some time lapse (5-10 years), it is preceded by planning, controversial debates, stakeholder involvement and demonstration projects, and needs political involvement that extends beyond the short-term political election period.

Acknowledgements

This work has been supported by the European Union in the framework of European Social Fund through the Warsaw University of Technology Development Programme, realized by Centre for Advanced Studies.

References

[1] Cowell R. *Wind power, landscape and strategic, spatial planning—The construction of 'acceptable locations' in Wale*, in: Land Use Policy, Vol. 27, Issue 2, April 2010, pp. 222-232. Elsevier.

[2] Weyant. J.P. *Accelerating the development and diffusion of new energy technologies: Beyond the "valley of death"*, in: Energy Economics, Vol. 33, Issue 4, 2011, pp. 674-682. Elsevier.

[3] Wonglimpiyarat J. T*echnological change of the energy innovation system: From oil-based to bio-based energy* , in: Applied Energy, Vol. 87, Issue 3, 2010, pp. 749-755. Elsevier.

[4] Barreto L., Kemp R. *Inclusion of technology diffusion in energy-systems models: some gaps and needs*, in: Journal of Cleaner Production, Vol.16, Issue 1, Supplement 1, 2008, pp. S95-S101. Elsevier.

[5] Negro S.O., Alkemade F., Hekkert M.P. *Why does renewable energy diffuse so slowly? A review of innovation system problems*, in: Renewable and Sustainable Energy Reviews, Vol. 16, Issue 6, 2012, pp. 3836-3846. Elsevier.

[6] EurObserv'ER. *The state of renewable energies in Europe in 2010*. Paris: Observ'ER, 2011. ISSN 2101-9622.

[7] EurObserv'ER. *The state of renewable energies in Europe in 2011*. Paris: Observ'ER, 2012. ISSN 2101-9622.

[8] Bruns E., Ohlhorst D., Wenzel B., Köppel J. Innovation Framework for Generating Biogas and Electricity from Biogas, chapter in: *Renewable Energies in Germany's Electricity Market*, Pages 89-159.

[9] Domański, R. *Spatial management, theory*. Warsaw, 2006: PWN SA.

[10] Crawford J., French W. *A low-carbon future: Spatial planning's role in enhancing technological innovation in the built environment,* in: Energy Policy, Vol. 36, Issue 12, 2008, pp. 4575-4579.

[11] Quitzau M-B., Hoffmann B., Elle M. *Local niche planning and its strategic implications for implementation of energy-efficient technology,* in: Technological Forecasting and Social Change, Vol. 79, Issue 6, 2012, pp. 1049-1058. Elsevier.

[12] Mander S.L., Bows A., Anderson K. L., Shackley S., Agnolucci P., Ekins P. *The Tyndall decarbonisation scenarios—Part I: Development of a backcasting methodology with stakeholder participation,* in: Energy Policy, Vol. 36, Issue 10, 2008, pp. 3754-3763. Elsevier.

[13] Vergragt P.J., Quist J. *Backcasting for sustainability: Introduction to the special issue,* in: Technological Forecasting and Social Change, Vol. 78, Issue 5, 2011, pp. 747-755. Elsevier.

[14] Höher C. G. *Biogas in Niedersachsen 2012*. 2012. Conference materials: EuroTier 2012. URL: http://www.3-n.info/pdf_files/Vortraege/121115_1_hoeher.pdf.

[15] Verdolini E. Galeotti M. *At home and abroad: An empirical analysis of innovation and diffusion in energy technologies,* in: Journal of Environmental Economics and Management 61 (2011) pp.119–134. Elsevier.

[16] Oniszk Popławska A., Matyka M. *Kompleksowa ocena uwarunkowań w zakresie produkcji biogazu w województwie lubelskim,* in Polish *(Analysis of the conditions for agricultural biogas development in the Lubelskie region). Final report.* Lublin Marhall's Office, 2012, pp. 80.

[17] Central Statistical Office (GUS). 2012. C*haracteristics of farms in Lubelskie province. National Agricultural Census 2010*.

[18] Agencja Rynku Energii S.A. Statystyka *elektroenergetyki polskiej*. Warszawa: ARE, 2011.

[19] Starick A., Klöckner K., Möller I., Gaasch N., Müller. *Entscheidungs hilfen für eine nachhaltigeräumliche Entwicklung der Bioenergiebereitstellung – Methoden und ihre instrumentelle Anwendung (Decision aids for sustainable development of bioenergy supply - instrumental methods and their application)*, in German, in: Raumforsch Raumordnung (2011) 69: pp. 367–382. Springer-Verlag.

[20] Vis M., Dees M. 2011. *Harmonisation of Biomass Resource Assessments, Best Practices and Methods Handbook Building and environmental technology*. VDM Verlag Dr. Müller. ISBN-13: 978-3-639-29018-9.

[21] Batidzirai B., Smeets E.M.W., Faaij A.P.C. *Harmonising bioenergy resource potentials—Methodological lessons from review of state of the art bioenergy potential assessments*, in: Renewable and Sustainable Energy Reviews, Volume 16, Issue 9, December 2012, pp. 6598-6630. Elsevier.

[22] Goodwin P., Wright G. 2010. *Decision Analysis for Management Judgment*, 4th Edition . ISBN 978-0-470-71439-3. John Wiley &Sons Ltd.

[23] Rikkonen P., Tapio P. *Future prospects of alternative agro-based bioenergy use in Finland—Constructing scenarios with quantitative and qualitative Delphi data,* in: Technological Forecasting and Social Change, Volume 76, Issue 7, September 2009, pp. 978-990. Elsevier.

[24] Doloreux D., Parto S. *Regional innovation systems: Current discourse and unresolved issues,* in: Technology in Society, Vol. 27, Issue 2, 2005, pp.133-153. Elsevier.