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Towards a sustainable capacity expansion of the Danish biogas sector

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ABSTRACT

Promotion of bioenergy production is an important contemporary topic around the world. Vast amounts of research are allocated towards analysing and understanding bioenergy systems, which are by nature multi-faceted. Despite a focus on the deployment of multi-criteria decision-making (MCDM) methods for planning of bioenergy systems, only little research has addressed the location component of bioenergy facility planning. In this paper the authors develop a model for sustainable capacity expansion of the Danish biogas sector allowing for an identification and prioritization of suitable locations for biogas production. The model builds on a framework for spatial planning and decision making through the application of spatial multi-criteria evaluation (SMCE). The paper is structured around a case study including four Danish municipalities in order to demonstrate the power of the spatial multi-criteria evaluation model. The model allows a two level comparison of suitability, within municipalities as well as between municipalities. Criteria weights for generation of alternatives are obtained through an analytical hierarchy process (AHP) analysis, carried out among a group of Danish central governmental decision makers. We find that resource and production economic criteria are given highest priority followed by environmental and social criteria. In all four case study municipalities, the identified alternatives are compared through incorporating economic, environmental and social criteria. It is found that 4–6% of the municipal area is suitable for biogas facility location and among the best performing sustainable locations the potential of reducing overall production costs is 3% as compared with current biogas plants. The results of this paper can provide support to central governmental decision makers, regarding regional allocation of subsidies in the country. Likewise local decision makers can obtain important information for planning and decision support, allowing for a more inclusive and transparent planning procedure.

Introduction

Bioenergy production is gaining increasing awareness among researchers as well as authorities and industries around the globe. Biogas production is a technology that has gained much attention in many agri-intensive countries, e.g. Denmark and Germany, for both agri-environmental reasons as well as economic and social reasons. One of the important aspects of biogas production for the farmers is that the degasified husbandry slurry reduces the leaching of nutrients from agricultural lands and to the aquatic environment. This implies that a farmer engaging in biogas production has the potential to expand his husbandry production without increasing the emissions of nutrients. Whether or not permits for expansion will be granted when engaging in biogas production is a different matter. The present system in Denmark is a norm based system allowing for an individual assessment when carrying out an EIA (environmental impact assessment), which in turn will influence whether or not a permit will be granted. Suggestions have though set forth for changing this system into an emission based system (Miljøstyrelsen, 2014). Such a shift in regulation system would imply that the ecosystem services of biogas production would be appreciated in the agricultural legislation and by that create a direct incentive to engage in biogas production. Another aspect about biogas production is that it contributes to the production of renewable and sustainable energy and work as a flexible and predictable fuel in the Danish wind-based renewable energy system. Last but not least bioenergy production systems, in general, are also found to facilitate job creation (Lavrencec, 2010) and as biogas facilities normally are located in rural areas with fewer job opportunities, these jobs have a high social value (Al Saedi, 2008).

At the same time biogas production is concerned with a number of potential challenges, such as increased amounts of heavy transport, annoyances from high visibility of the plants in the agricultural landscape near local communities, where to access other biomasses

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than slurry, e.g. maize and potential environmental damages due to high concentration of nutrients from livestock manures.

As part of fulfilling its renewable energy obligations, Denmark has set a policy ambition to exploit 50% of all animal husbandry slurry by 2020, which in turn implies building approximately 20 new large centralized biogas plants (Bojesen et al., 2014). The location of these many new biogas facilities capture the dilemmas described above including economic, environmental and social factors and constraints resulting in a multi-criteria decision making problem, which needs to be resolved or tackled by authorities and other stakeholders. The trade-offs between the many concerns are experienced on a routine basis by planning officers at a local level when municipal plans are developed and project proposals evaluated; as well as at national level, when subsidies, in the form of project grants, are being distributed (Joensen and Mølgaard, 2010).

In this paper we develop a value-driven spatial multi-criteria evaluation (SMCE) model in order to identify and prioritize suitable locations for biogas production, balancing the multiple regards needed for sustainable capacity expansion of the Danish biogas sector.

The paper is structured around a case study including four Danish municipalities with significant biogas potential in order to demonstrate the power of the spatial multi-criteria evaluation model. We adapt an existing multi-attribute decision making modelling framework in order to allow for comparisons of alternatives within as well as between municipalities.

Challenges in biogas planning and decision making

As part the Danish planning system all municipal plans and local plans must be sent to public hearings (Retsinformation, 2013), as the ambition of the planning legislative framework is to include the general public as well as both private and public organizations and industries in the planning process. Establishment of biogas facilities is covered by this planning legislative framework and includes a requirement for environmental impact assessment (EIA) which underpins the need for public hearings. Further, public participation and local commitment or at least acceptance is seen as an important part of many biogas projects as this leads to a higher degree of social legitimacy (Daniels and Walker, 2001). The absence of local commitment can lead to among other things local resistance against projects, which in turn leads to high transaction costs.

The need for local participation often leads to what Daniels and Walker (2001) term 'the fundamental paradox', which means that citizens and society as a whole demands technically sound decisions, but as situations become more complex fewer people have the technical background needed to either meaningfully contribute or critique the decisions. In effect planning processes easily get expert driven and public meetings and hearings concerning location of biogas facilities easily revolve around feelings such as the NIMBY (not-in-my-backyard) effect or specific interests instead of discussing how to balance the many tactical and strategic decision aspects and concerns. Ultimately such process characteristics may result in many undesired effects including increased transaction costs, prolonging project implementation, low levels of knowledge sharing between stakeholder groups and overall poorer decisions.

Appreciating the complex and multifaceted nature of biogas location planning, a participatory planning process may seem unrealistic and may not even lead to a better and more sustainable decision due to the high demands for technical understanding. Nevertheless the current planning situation calls for a planning process which can accommodate transparency and inclusion of multiple professional stakeholder viewpoints. Such a planning process is termed transactive planning (see e.g. Hudson, 1979). The SMCE framework, as applied in this paper, follows the same logic as synoptic/rational planning (see. e.g. Hudson, 1979), which includes goal-setting, identification of alternatives, evaluation of means against ends and implementation of decisions. On the other hand, the SMCE framework has the potential to function as a transactive planning approach due to the strong communicative qualities of GIS (see e.g. Batty, 2005), which in turn is also a core asset of the SMCE framework. Considering the need for definition and weighting of relevant criteria, SMCE models can also fulfil an important role as a platform for dialogue and mutual learning between professional stakeholders.

Literature review

There has been increasing awareness of the importance of location analysis throughout a number of industries including waste management, pulp and paper production as well as bioenergy production (Bojić et al., 2013; Braglia and Gabrielli, 2012; Sumathi et al., 2008; Möller and Nielsen, 2007). All these industries are highly concerned with minimizing production costs in general and transportation costs in particular as these, especially within bioenergy production systems are found to account for as much as 40% of the overall production costs (Jacobsen et al., 2013). Location analysis with regards to the production economic implications of different locations has proven to provide valuable decision support in a number of studies (e.g. Suárez-Vega et al., 2012; Clarke and Clarke, 2001; Birkin and Culf, 2001).

Bioenergy production systems include biomass production, conversion technology and energy distribution. These processes are embedded in multiple economic, environmental and social contexts. As a consequence these systems are highly complex and difficult to manage effectively, which in turn implies that location analysis within bioenergy production often focuses on only one or few components of the entire system. Relevant examples are provided by Höhn et al. (2014), Bojesen et al. (2014) and Panichelli and Gnansounou (2008) who use location-allocation models to determine the optimal location of bioenergy facilities minimizing transportation costs.

Romeo and Rehman (1989) argue that when decision problems are characterized by a single criterion they should be regarded as technological, whereas when multiple criteria need to be considered, problems of decision making become economic. This shift from technological to economic decision making is caused by the trade-off between multiple attributes, which in turn fulfils multiple objectives.

In contrast to the single- or dual criterion models developed within the location analysis context, a rich literature has been established within multi-criteria decision making (MCDM) and multi-criteria evaluation (MCE) concerning both location studies (e.g. Gorsevski et al., 2012; Farahani et al., 2010; Zucca et al., 2008; Sharifi and Retsios, 2003) and evaluation of bioenergy systems (e.g. Gebrezgabher et al., 2014; Theodorou et al., 2010; Karagiannidis and Perkoulidis, 2009; Buchholz et al., 2009; Beck et al., 2008; Rozakis et al., 2001). However, the combination of the two is a rarity despite the valuable examples provided by e.g. Perpiña et al. (2013) and Ma et al. (2005). In these examples the authors perform a suitability analysis concerning location of a biomass plant, but do not address the formation and prioritization of suitable location alternatives. Yet, as Sharifi et al. (2004a,b, 2006) and Zucca et al. (2008) have demonstrated how spatial multi-criteria evaluation can steer a value-driven design of sets of locations as well as choice between location sets within a range of different contexts. The before mentioned papers also demonstrate the value of applying spatial and a-spatial criteria simultaneously, since this allows for a simultaneous consideration of spatial dependency and independency in a decision making process.

In a literature review concerning more than 80 multi-criteria decision making studies within bioenergy systems. Scott et al.