Energy Policy 84 (2015) 80–95

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Scenarios for shale gas development and their related land use impacts in the Baltic Basin, Northern Poland

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HIGHLIGHTS

- A range of scenarios for shale gas development in Poland were modelled.
- The impact in terms of land take and competition for land was assessed.
- Of land used for industrial purposes, 7–12% was attributed to shale gas extraction.
- If unregulated, 24% of well pads were developed within protected areas.
- The legislative framework can have a major influence on overall environmental impact.

ARTICLE INFO

Article history:
Received 14 January 2015
Received in revised form
4 April 2015
Accepted 28 April 2015

Keywords:
Land use modelling
Shale gas
Environmental impact

ABSTRACT

Scenarios for potential shale gas development were modelled for the Baltic Basin in Northern Poland for the period 2015–2030 using the land allocation model EUCS100. The main aims were to assess the associated land use requirements, conflicts with existing land use, and the influence of legislation on the environmental impact. The factors involved in estimating the suitability for placement of shale gas well pads were analysed, as well as the potential land and water requirements to define 2 technology-based scenarios, representing the highest and lowest potential environmental impact. 2 different legislative frameworks (current and restrictive) were also assessed, to give 4 combined scenarios altogether. Land consumption and allocation patterns of well pads varied substantially according to the modelled scenario. Potential landscape fragmentation and conflicts with other land users depended mainly on development rate, well pad density, existing land-use patterns, and geology. Highly complex landscapes presented numerous barriers to drilling activities, restricting the potential development patterns. The land used for shale gas development could represent a significant percentage of overall land take within the shale play. The adoption of appropriate legislation, especially the protection of natural areas and water resources, is therefore essential to minimise the related environmental impact.

1. Introduction

OECD-Europe accounts for roughly 5% of global conventional natural gas reserves according to the latest outlook published by the International Energy Agency IEA (2014). The IEA also projects an annual average decline of 1% in the production of natural gas in Europe as a whole between 2012 and 2040, thus making it increasingly reliant on imported resources (IEA, 2014). This projected trend is supported by production statistics recently published by oil and gas companies (ENI, 2014; BP, 2014). In combination with increasing domestic energy consumption this has led to rising energy prices and security of supply concerns. There is therefore increasing interest in unconventional energy resources, amongst which shale gas has garnered particular attention over the last few years.

In the US, shale gas was first extracted by hydraulic fracturing in the mid-60's (Ray, 1976), and the industry has grown

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http://dx.doi.org/10.1016/j.enpol.2015.04.032
0301-4215/

significantly ever since. Shale gas accounts for some 30% of the nation's natural gas reserves (USDE, 2011), and has become vital to the security of domestic energy supply. Even though there are no European countries among the 10 with the highest technically recoverable shale gas resources in the world (Melikoglu, 2014), resources in Europe may also play an important role in fulfilling the gas demand, and are currently being explored in several countries (Pearson et al., 2012).

Even though there is a push to try and replicate some of the economic successes of the US, the situation in Europe on the topic remains volatile. At this point in time hydraulic fracturing is banned in France, the Netherlands, and Luxembourg due to concerns on the environmental impacts involved. Higher population densities, a more challenging geological situation (shales generally lie deeper), and a more regulated market, together with the availability of technology infrastructure, also suggest that the development of shale gas as a resource in Europe may not progress so smoothly (see, as examples, Asche et al., 2012 and Selley, 2012, in Sovacool, 2014). For most European countries there is also as yet no specific legislation, and the regulations in place for conventional gas are assumed.

At the time of writing there was still no unified EU policy on the utilisation of shale gas resources (Melikoglu, 2014), even though both general and specific parts of European environmental legislation apply. In order to counteract an increasingly diversified operating framework among different Member States, the European Commission is developing a basic level of regulation for all EU countries. After two resolutions were adopted by the European Parliament in November 2012 (EP, 2012a,b), the need for a coherent framework at European level led to the adoption in 2014 of a Recommendation on"minimum principles for the exploration and production of hydrocarbons (such as shale gas) using high volume hydraulic fracturing in the EU" (EC, 2014a). This Recommendation was accompanied by a Communication outlining the potential opportunities and challenges stemming from shale gas extraction in Europe, as well as an Impact Assessment focused on the socio-economic and environmental impacts of various policy options (EC, 2014b,c).

Shale gas is exploited by (1) horizontal drilling of Shale beds to increase borehole contact with the shale and (2) high-volume hydraulic fracturing (fracking) of the shale surrounding boreholes to enable migration of the gas through the shale (King, 2012). Fracking involves high pressure pumping of fluid into the formation, in order to produce hydrofractures which propagate through the surrounding shale.

There are several environmental concerns involved with this extraction procedure, including impacts on water and air quality, noise and visual pollution, potential impacts on biodiversity and nature conservation objectives, and even seismic triggering (NYSDEC, 2011; Rutqvist et al., 2013; Gény, 2010). Since the development of shale gas resources requires extensive drilling across large areas, competition with existing/alternative land uses is also of concern (Racicot et al., 2014). Besides causing visual pollution, the actual take of land for shale gas exploitation may have serious and lasting impacts on the landscape, especially in densely populated areas (Wood et al., 2011). The composition of the fracking fluid used is not often publicised, but predominately consists of fresh water combined with sand and a variety of chemical additives, some of which may be toxic (Centner, 2013).

In this paper we focus on developing a methodology to simulate the extraction of shale gas by hydraulic fracturing over time, in order to analyse the possible impacts it may have on the landscape and understand the influence of legislative restrictions. Specifically, we aim at answering the following questions for our study site in Northern Poland:

- *What are the aggregate land-use requirements associated with shale gas development?*
- *What are the associated land-use conflicts, including competition with alternative land uses?*
- *What impact could legislative constraints have on the land take for shale gas development?*

We reviewed the current available literature in order to identify the variables that most influence the land requirements associated with shale gas development. We also looked into the current legislation in place on shale gas both in Poland and the US. We then derived a range of representative values spanning worst- and best-case scenarios (in terms of environmental impact) for each variable. On this basis, we defined 2 specific technology scenarios and 2 legislative scenarios for shale gas development in Northern Poland for the period 2015–2030.

These scenarios were run using the land-use model EUCS100 (Lavalle et al., 2011a) to assess the quantity of land necessary for shale gas extraction and the spatial distribution thereof. Shale gas extraction sites (well pads) were modelled as a separate land-use class, with its own specific requirements and allocation rules. This paper follows on a literature review (Kavalov and Pelletier, 2012), and previous modelling exercise (Lavalle et al., 2013). The impacts on water resources for the scenarios developed here are further discussed in Vandecasteele et al. (in press).

1.1. Study area

The study area covers 11,313 km^2 within the Baltic Basin in Northern Poland. Poland is currently one of the most active EU member states in exploring its shale gas resources, with estimates ranging from 23 to 1549 Bcm (PGI, 2012; EIA/ARI, 2013). To date some 40 exploratory wells have been drilled (Uliasz-Misiak et al., 2014). Fig. 1 shows the location of our study area, as well as the current shale gas concessions and exploration wells throughout Poland.

The study area was defined based on data availability and the thickness, depth and thermal maturity of the shale deposit (Fig. 2, derived from PGI, 2012). This site was already identified as particularly suitable for development in Lavalle et al. (2013).

As detailed in Table 1, the predominant land uses within the shale play area are arable land and forest, which occupy respectively some 56% and 28% of the total shale play area. Other uses, such as permanent crops, pasture land, and semi-natural vegetation are scarcely represented. The area is predominantly rural, even though there are larger urban areas, such as the city of Gdansk. There are also several areas protected under European and National schemes within the study site, namely Natura 2000 sites and Nationally Designated Areas. Together these account for 22% of the shale play area.

1.2. Data availability

Although the issue of potential shale gas development in the EU is receiving considerable attention, to date only a relatively small number of exploratory drilling activities have been undertaken. There is hence little available information at present on which to base EU-specific technology scenarios. Consequently, we based our scenarios on the best data available from the literature, using in as far as possible Polish data. Where sufficient information was not available we assumed data derived from the longer-running US shale plays (e.g. Marcellus and Barnett plays) to give a reasonable estimate, especially in the case of factors affecting the well placement and development rate.