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Climate action, environment, resource
efficiency and raw materials

Deliverable 6.5

Quantitative Storytelling of shale gas extraction scenarios in the EU

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Abbreviations

BTU = British Thermal Units
EC = European Commission
EU = European Union
GHG = Greenhouse gas
IEA = International Energy Agency
MAGIC = Project Moving Towards Adaptive Governance in Complexity: Informing Nexus Security (H2020-water2b, GA 689669)
MuSIASEM = Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism
OPEC = Organization of the Petroleum Exporting Countries
USA = United States of America
WEF nexus = Water, food energy nexus
WFD = Water Framework Directive (2000/60/EC)

Summary for policy makers

The European 2030 Climate and Energy strategy marks the effort of the EU to implement the Paris Agreement commitments. To that end, most member states plan to increase the share of renewable energy and natural gas in the energy mix. However, the deterioration of the relations with Russia, the closure of the conventional gas field in Groningen, and the Brexit challenge natural gas supply within the EU. In this report we study the potential of a European shale gas sector as alternative to ensure natural gas supply.

The shale gas revolution that happened in the USA around the mid-2000s instigated a general wave of optimism about the potential of natural gas to become the main fuel for "clean" heating, power generation and transport. The premise that despite its environmental impacts and financial burden, shale gas extraction is a strategic national-security issue was maintained in the USA until gas prices sank in 2014. As of 2020 the first public voices demanding a ban can be heard in the US.

There is a vast literature that assess the impacts of shale gas development and hydraulic fracturing over the environment, the people and the local and national economies. However, their recommendations tend to be discordant. This type of assessments can greatly benefit from a transdisciplinary analysis. In this report, we use Quantitative Story-Telling (QST, see section Materials and Methods for further information about QST), an iterative technique that combines narrative analysis with multi-scale integrated assessment.

The narrative assessment considered the evolution of the informal narrative (for the general public) against the difference between gas extraction cost and market prices. The informal narrative greatly influences the formal narrative of the European Commission, which was assessed with an analysis of legal text and a round of interviews.

We assessed the socio-economic viability and the environmental feasibility to meet the EU natural gas demand in a situation of challenged supply by developing a shale gas sector in the EU. More concretely, we check whether an hypothetical shale gas sector could "*contribute almost half of the EU's total gas production and meet about around 10 % of the EU gas demand by 2035*" (COM2014/23 final page 4) while contributing to reduce GHG emissions and without contradicting the principles of the Water Framework Directive (2000/60/EC).

We concluded that:

- Shale gas net extraction (raw extraction minus energy use) would not be enough to meet EU needs.
- Some member states would be able to cover their needs with domestic extraction but current legislative framework give them freedom to sell their overflow out of Europe, thus not contributing to EU energy security.
- Due to the lowering of the gas prices, a fairly big high of wells will not cover their construction and maintenance economic expensive
- Methane emissions will be higher than for the extraction of conventional gas. Most of those emissions would come from wells that are not providing a surplus of energy.
- There are a few river basins that might not be able to meet the WFD commitments for the third review period. Most of the water use comes from the less productive or even unproductive wells.

Technical summary

The shale gas revolution that happened in the USA around the mid-2000s instigated a wave of optimism about the potential of natural gas to become the main fuel for “clean” heating, power generation and transport. Resulting from the current uneasy relations with main gas providers USA and Russia and the internal loss of other gas sources, EU Member States might start to reconsider their position on shale gas development. A potential development of shale gas in Europe is the object of this case study.

Despite the many research and political efforts done to navigate the uncertain pros and cons of shale gas development, the trade-offs present in the water-food-energy (WEF) nexus and the difficulties of assessing them have prevented a horizontal agreement about the suitability of this innovation in general. Different methods return contrasting conclusions but there is a general agreement that stakes at hand are high, risks not completely understood and the applicability of the works done, partial (Weber and Clavin, 2012). In that sense, a decision about developing a shale gas industry in Europe can greatly benefit from an integration of views that follows the premises of post normal science (Funtowicz and Ravetz, 1991), like the one developed in this case study of the MAGIC-Nexus project.

In Phase I we determine the narrative that would be used as testing case in the quantitative analysis. In the case of shale gas both informal and formal narratives were taken into consideration. We studied the evolution of the informal narrative with a temporally explicit media content analysis that included about 200 documents of two media with similar editorial lines: The New York Times (US) and The Guardian (UK). We assessed the predominance of positive or negative messages about shale gas against the difference between cost of extraction and selling price per cubic feet of gas produced. To explore the formal narratives, we assessed official EC shale gas related documents and then completed a round of five semi-structured interviews with key representatives of DG Environment and DG Energy, academia, the industry and NGOs. We identified two statements that served as the object for the study in phase 2:

- *Shale gas extraction in the EU can offset the closing of the Groningen fields and still cover 10% of the EU gas demand in 2035.*
- *The above production has the potential to reducing environmental impact in terms of CO_2 equivalent without producing a deterioration of status of the water bodies.*

In Phase II, we built a scenario in which all potential land was drilled with constant drilling rate within the period 2020-2030 and for wells no deeper than 4000 meters. We then studied their economic and energy breakeven points and environmental impacts in the period 2020-2035. The energy and economic breakeven points are analyzed in the viability domain and the methane and water use-offsetting capacity in the feasibility domain.

In subsequent sections, we report the process of engagement with stakeholders, who helped us frame the issue and the materials and methods for Phase I and II. Finally, we provide some reflections on the learning experience of applying QST to perform the quality check on shale gas as an innovation. We discuss the role of shale gas to offset losses of supply and natural gas demand growth in Europe. The shale gas sector designed here will only be able to contribute to energy security while the sector keeps drilling and the wells are young. However it would not contribute to decrease GHG emissions and most of the environmental impacts will come from wells with negative return on investment.

1 Introduction:

The transition to an economic system with lower greenhouse gas (GHG) emissions is key to reduce climate change and mitigate its effects. It has been argued that natural gas might be a good energy source for this transition when it comes to substitute other more polluting ones like coal (Burnham et al., 2012). Shale gas, one of the so-called "unconventional" source of natural gas that has only recently become economically viable to extract. The shale gas revolution that happened in the USA around the mid-2000s instigated a wave of optimism about the potential of natural gas to become the main fuel for "clean" heating, power generation and transport. The shale gas "factory" (Stephenson, 2015a) boomed in a short period of three years in areas where there was no previous experience of massive hydrocarbon development, know-how or proper regulatory frameworks like Pennsylvania. This boom has not only resulted in the substitution of other, more polluting fuels in American power stations; but has also internationally driven the design of gas-based technical innovations like gas-run transportation means, or gas celled batteries. The premise that despite its environmental impacts and financial burden, shale gas extraction is a strategic national-security issue was maintained in the USA until gas prices sank in 2014. As of 2019, some lobbies continue defending that claim, supported by a heavy federal subsidy program.

In Europe, lack of profit, political untimeliness and public opposition have challenged the global shale gas lobby up to 2019. However, the US shale gas industry has made its way through OPEP's oil and gas price-lowering maneuver (McFarlane and Minczeski, 2019). This is particularly true in countries like US and Canada or in China, a country said to have the highest shale gas reserves of the world. Resulting from the current uneasy relations with main gas providers USA and Russia and the internal loss of other gas sources, EU Member States might start to reconsider their position on shale gas development. A potential development of shale gas in Europe is the object of this case study.

Despite the many research and political efforts done to navigate the uncertain pros and cons of shale gas development, the trade-offs present in the water-food-energy (WEF) nexus and the difficulties of assessing them have prevented a horizontal agreement about the suitability of this innovation in general. Different methods return contrasting conclusions but there is a general agreement that stakes at hand are high, risks not completely understood and the applicability of the works done, partial (Weber and Clavin, 2012). In that sense, a decision about developing a shale gas industry in Europe can greatly benefit from an integration of views that follows the premises of post normal science (Funtowicz and Ravetz, 1991), like the one developed in the MAGIC project (Ripa and Giampietro, 2017).

Using MAGIC's approach to quantitative story telling (QST), we identified two statements intrinsic to the EU narrative on shale gas and then use a falsification process to check their robustness. In the overall architecture of MAGIC, this case has also provided ground for checking the implementation of and improving the QST method, an experiment for testing the NIS tool[1], and a database to propose visual dashboards of QST.

After this short introduction and a technical explanation of hydraulically fractured shale gas development, this report starts by providing an overview of the results for phase I and II. We then

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[1] One of the analytical tools created within the MAGIC project.

explain how we developed the engagement, our methods and then provide some reflections on the use of QST.

1.1 Hydraulically fractured shale gas extraction

Shale gas is considered an ‘unconventional’ resource because other techniques beyond drilling are required to facilitate gas extraction. The classification of a natural gas source as conventional or unconventional is more related to social than to geological attributes (Popescu and Anastasiu, 2016).

Figure 1. Structural and functional definition of resources (below) and representation of the shale gas factory (above, from Indiana.edu)

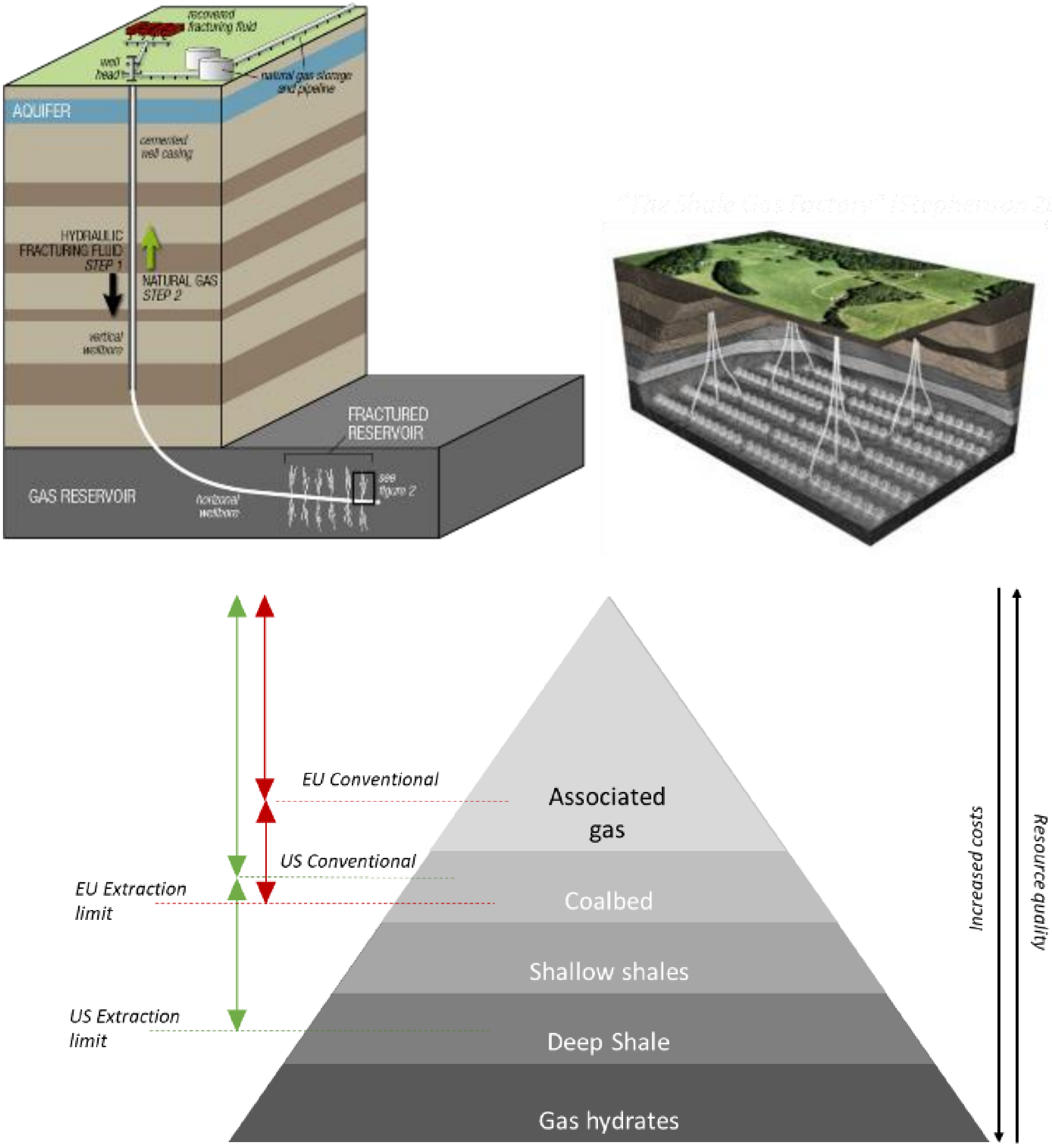
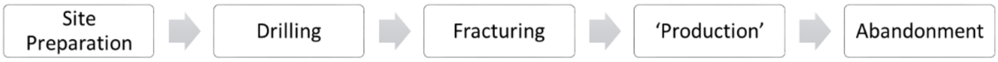


Figure 1 shows a structural classification of gas in the grey resource pyramid and the functional conventional/unconventional definition of extraction with limits in green (EU) and red (US). The lower positions in the pyramid indicate lower densities of gas within the stone. This gas is less rich in methane and has a lower return on investment in both economic and energy terms. The energy returns depend on the type of technology used whereas the economic return depends also on natural gas prices. Factors like the access to technical innovations and knowhow and natural gas prices play an important role in the definition of a resource as conventional or unconventional (Stephenson, 2015b).

The process of extraction of deep shale gas using horizontal drilling and hydraulic fracturing boomed in the US following a period of high natural gas prices in 2008. This drilling and stimulation technique reaches very deep shale layers, leaving an often hard to notice print in the surface but creating what Stephenson has name the shale gas factory (figure 1, above).

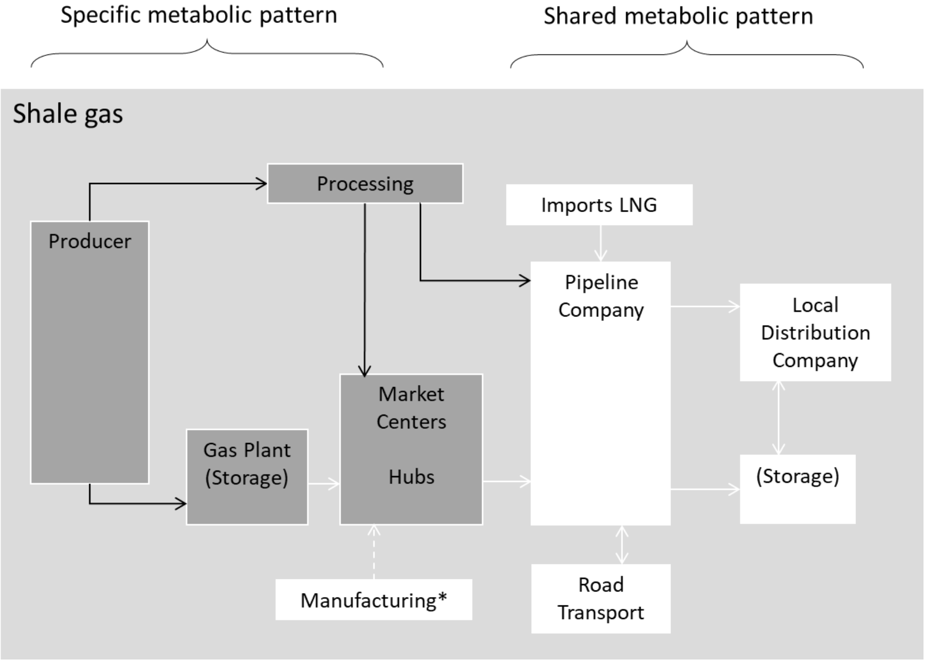
The public debate about the impacts of shale gas development has turned into a global phenomenon that nicknamed the activity ‘fracking’ (Evensen et al. 2014). Fracking refers to the extraction, processing and use of shale gas and their related environmental and socio-economic impacts. However hydraulic fracturing is just one of the processes involved in the life cycle of a well, as shown in figure 2.

Figure 2. Sequential pathway in the life of a well



Indeed, shale gas and conventional natural gas share a big portion of the delivery chain and have only differences in the extraction process and the processing stages, due to the different compositions of the gas. These differences translate in a differentiation between specific and shared metabolic patterns (or flow/fund composition) as shown in figure 3.

Figure 3. Scheme of the specific and general metabolic patterns for shale gas supply



In this study we assess the specific part of the metabolic pattern, which only includes extraction and processing of shale gas. The reader will note that consequently, the methane emissions and the water and energy demands will be partial, and that the total for the entire sector will be higher than the ones showed here.

2 Phase 1: Shale gas narratives

Following the adapted QST cycle, the objective of phase one is to determine the narrative that would be used as testing case in the quantitative analysis. In the case of shale gas both informal and formal narratives were taken into consideration. We studied the evolution of the informal narrative with a temporally explicit media content analysis that included about 200 documents of two media with similar editorial lines: The New York Times (US) and The Guardian (UK). We assessed the predominance of positive or negative messages about shale gas against the difference between cost of extraction and selling price per cubic feet of gas produced. To explore the formal narratives, we assessed official EC shale gas related documents (see Annex I) and then completed a round of five semi-structured interviews with key representatives of DG Environment and DG Energy, academia, the industry and NGOs. We identified two statements common to the formal and informal narrative that served as the object for the study of the robustness of the narratives in phase 2. Complementary information about legal texts, interviews and media analysis is covered in Madrid-Lopez (Forthcoming).

A number of parameters might influence perceptions and the formation of a narrative about shale gas (Evensen et al., 2017; Lis and Brändle, 2017; Sangaramoorthy et al., 2016). However, in general lines four main narratives can be identified combining a positive and negative position about its contribution to energy security and environmental impacts. Table 1 shows the four options found in the analysis performed in phase I and highlights the one chosen in this study, which we found to the closer in the EU, as found in phase 1 of the analysis.

Table 1. Narrative descriptions at the pole energy security/environmental impact

Security/Environment	**Positive**	**Negative**
Positive	Shale gas can provide energy security and its impacts can be controlled/are not critical	Shale gas can provide energy security but its impacts cannot be controlled/are critical
Negative	Shale gas cannot provide energy security but its impacts can be controlled/are not critical	Shale gas cannot provide energy security and its impacts cannot be controlled/are critical

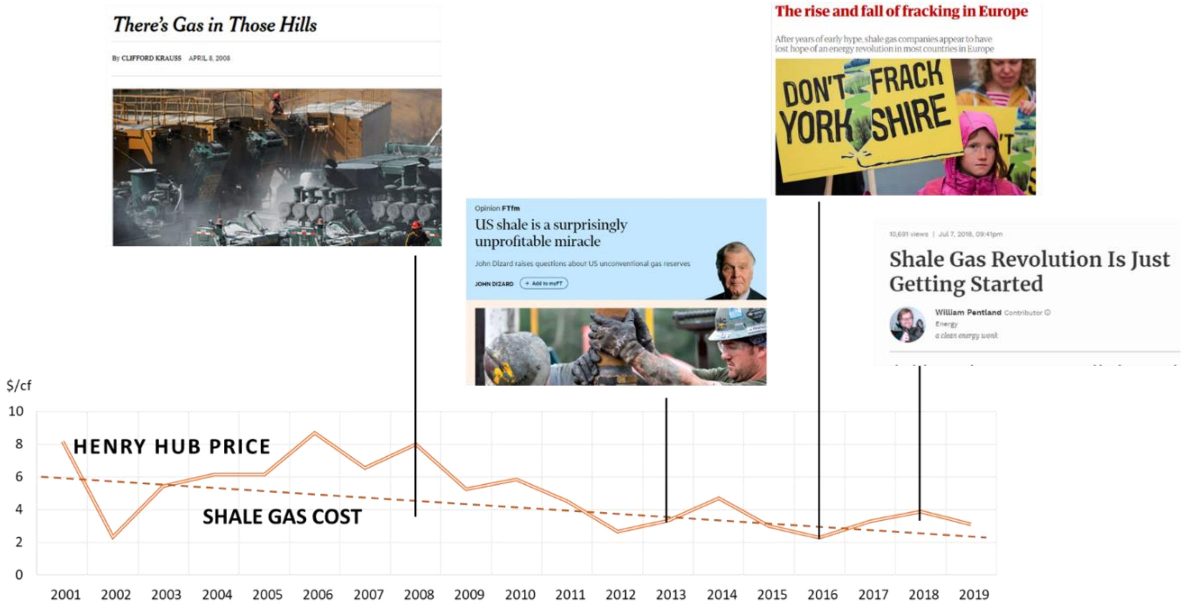
2.1 Informal narrative: 10 years of written media about shale gas

The link between the formal and the informal narratives is strong in the case of shale gas. Public opposition to shale gas is one of the main challenges to shale gas development in the US (Boudet et al., 2014; Evensen et al., 2017) and the EU [interview NGO]. With the purpose of understanding how the informal narrative about shale gas has formed in the US and how it translated to the EU we analyzed 200 documents written in two media with similar editorial lines: The New York Times (US) and The Guardian (UK).

In the US, the shale gas activity started in 2007-2008 in Pennsylvania, as a result of a process of natural gas price increase that followed the deep decrease of 2002. The state had relatively short capacity and experience in industrial fossil fuel extraction and policy makers faced a number of uninformed decisions and lacked the policy instruments to control the activity. The media covering that period in the US is mostly positive and optimistic about the innovation. The New York Times' Krauss (2008) reports that "if all goes well, the Marcellus could help moderate the steep climb in natural gas prices and reduce possible future dependence on natural gas from the Middle East[…]". Indeed, shale gas production in the US has propitiated a shift on the energy geopolitics of the country from a largely importing country to an exporter in 2019.

We contrasted the changes in the main currents of the public narrative with the differences between natural gas prices and the cost of extracting a cubic feet of shale gas. As figure 4 shows, media articles tend to be kinder with shale gas when the difference between gas prices and shale gas cost is positive. Also, the term "shale gas" is more frequently used with positive connotation and "fracking" with negative connotation (Stoutenborough et al., 2016).

Figure 4. Evolution of difference between shale gas extraction cost and natural gas price and dominant



There's Gas in Those Hills

By CLIFFORD KRAUSS APRIL 8, 2008

Opinion FTfm

US shale is a surprisingly unprofitable miracle

John Dizard raises questions about US unconventional gas reserves

JOHN DIZARD + Add to myFT

The rise and fall of fracking in Europe

After years of early hype, shale gas companies appear to have lost hope of an energy revolution in most countries in Europe

10,691 views | Jul 7, 2018, 09:41pm

Shale Gas Revolution Is Just Getting Started

William Pentland Contributor

Energy

a clean energy wonk

This dynamic was inherited by European media. European press was more inclined to talk about the benefits of shale gas, the relevance of the Polish reserves or the exploitation plan in the UK when the prices were higher than the average costs, and vice versa. However, the environmental impacts were better known in Europe when the first explorations started, so the positive discourse tend to be more moderate and the narrative in general more cautious. The formal narrative of the European Commission has been formed under this more cautious climate.

2.2 The short history of shale gas in the EU

We reviewed and analyzed relevant EU legal documents dealing with shale gas, including the impact assessment performed by the European Commission (COM2014/23 final and SDW2014/22 final), its recommendations on minimum principles (2014/70/EU) and its report on the effectiveness of those minimum principles (COM2016/0794 final).

The impact assessment report was commissioned by DG ENV and came to inform the *Commission Recommendation of 22 January 2014 on minimum principles for the exploration and production of hydrocarbons (such as shale gas) using high-volume hydraulic fracturing* (2014/70/EU). In this communication, the EC description of shale gas as a potential factor for energy security was clearly stated (page 4):

> *"While the EU will not become self-sufficient in natural gas, natural gas production from shale formations could, at least partially, compensate the decline in the EU's conventional gas production and avoid an increase in the EU's reliance on gas imports. Indeed it would be, in a best case scenario,* ***able to contribute almost half of the EU's total gas production and meet about around 10 % of the EU gas demand by 2035****".*

At the same time the shale gas discussion happened in the EU, (2013-2014) the US gas market saturated, US shale gas market became damaged by OPEC's campaign to sink shale oil (McFarlane and Minczeski, 2019) and prices began to fall, bringing a number of issues to many American gas SMEs. However, these issues were public and known in the EU only by 2016-2017 [interview DG Environment]. The incipient shale gas industry in the UK and Poland, which started back in 2011, began to understand the financial risks of shale gas development. However they took two different paths. Whereas the Polish industry desisted in 2017 (Bault, 2018), the industry in the UK continued with explorations and with an exploitation plan. By the end of 2019 the UK is in the process of making stronger environmental regulations that in practice will partially ban the activity (Ambrose, 2019; Harrabin, 2019).

Despite fruitless technical efforts in shale gas development, the Krimea crisis in 2014 and the deterioration of the relations with the EU's main external gas provider, Russia, present the EU with a difficult situation regarding natural gas supply [interview DG Energy]. This situation is worsened by the closure of the conventional gas field in Groningen, The Netherlands, and the Brexit. The Dutch government plans to stop natural gas production were first announced in 2018 for 2030 (Sterling, 2018), then a year later moved to eight years earlier. Unless otherwise established **the EU will face Groningen's yearly reduction of 22 billion cubic meters of natural gas supply by 2023 and an uncertain gas supply from the United Kingdom**, which, as of February 2020, is still negotiating gas trade conditions with the EU[2].

EC expectation on shale gas were high and so was the need to reduce the uncertainty associated with its impacts. In 2014, in the first work program of the Horizon 2020 research framework, the European Commission opened a call for a specific topic on '*Understanding, preventing and mitigating the potential environmental impacts and risks of shale gas exploration and exploitation*' **under the call on**

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[2] The Reader can check the updated situation in https://www.gov.uk/government/publications/trading-gas-with-the-eu-if-theres-no-brexit-deal/trading-gas-with-the-eu-if-theres-no-brexit-deal

Low Carbon Economy LCE-16-2014[3]. This call shows the concern of the EC about understanding impacts, with especial attention to emissions, water use and pollution, and earthquake generation.

Besides a number of issues related to earthquakes, the Dutch plan to lock out from natural gas by 2022 responds also to the demands of the European 2030 Climate and Energy strategy [interview Academia]. This strategy is part of the effort of the EU to implement the commitments acquired at the signature of the Paris Agreement in 2016. For most of the rest of the member states, however, the reduction commitment is to be achieved with an increase of renewable energy and natural gas in the energy mix. **This natural gas increase is expected to lower the GHG emissions and global warming potential of the energy system** [interview, DG ENERGY, industry] as it comes as a result of the decrease of more polluting fossil fuels like coal.

Water use and pollution is a bigger concern for Academia, NGOs and DG Environment [all interviews] as the third evaluation period of the Water Framework Directive (WFD) becomes close. Fracking-driven water issues are presented as a constraint for industrial shale gas development as they might **create tension between energy and water security guiding policies** [interview, DG environment].

2.3 The shale gas statements

Using the highlights of the interviews, we extracted the two statements checked in phase 2:

- ***Shale gas extraction in the EU can offset the closing of the Groningen fields and still cover 10% of the EU gas demand in 2035.***
- ***The above production has the potential to reducing environmental impact in terms of CO_2 equivalent without producing a deterioration of status of the water bodies.***

3 Phase 2: A hypothetical shale gas sector in the EU

In Europe, shale gas seems to “not to be out of the table” because of difficult internal and external political situations [interview DG energy]. Externally, we refer to the complicated diplomatic relations with main external gas providers Russia and the US. Internally, we mean the decrease in supply due to the closing of the Groningen fields and the Brexit. Even though the initial plan was to focus on a few relevant countries in the EU, after the narrative analysis was completed, an analysis at the EU level seemed more relevant for the robustness check.

To assess the productivity and the impacts of a potential sector, we built a scenario in which all potential land was drilled with constant drilling rate within the period 2020-2030 and for wells no deeper than 4000 meters. We then studied their economic and energy breakeven points and environmental impacts in the period 2020-2035. The energy and economic breakeven points are analyzed in the viability domain and the methane and water use-offsetting capacity in the feasibility domain. Figure 17 summarizes the steps taken in the quantitative analysis in phase 2.

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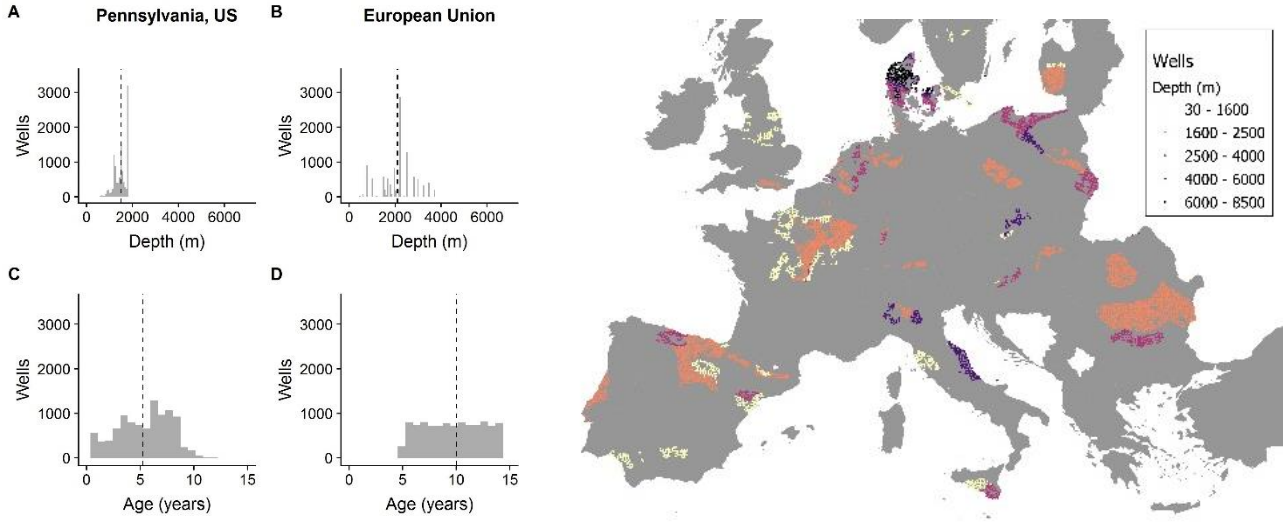
[3] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/lce-16-2014

Figure 5. Distribution of wells (right) and structural (A,B) and functional (C,D) differences between the PA, US, and the EU well population (left). Dotted lines show averages.



3.1 Structural composition

Once the restricted areas were clipped from the area surfacing shale layers, and with a distance of 10 km between pads, the EU land could hold about 12 10^3 wells in 4.5 10^6 Km^2 of pads. This is 1.5 times more than the 2017 well population of Pennsylvania, US, which, in turn has a pad area of 12 10^3 Km^2.

After a 15 year development period, the EU average age of the wells is twice the age in the US due to land saturation that prevents the opening of new wells. Real wells in Pennsylvania rarely reach beyond 10 years of active life whereas in our EU scenario wells remain active for a longer period. In geological terms, European wells are about 1000 meters deeper in average. Figure 5 shows the location of the wells by depth and the main differences in depth and age of the EU and Pennsylvania well populations.

3.2 Viability domain: The energy security statement

Shale gas extraction in the EU can offset the closing of the Groningen fields and still cover 10% of the EU gas demand in 2035.

The International Energy Agency reported that the EU would be able to meet 10% of the natural gas demands with shale gas by 2035 (Pearson et al., 2012). Following data of Eurostat on natural gas consumption (nrg_cb_gas) this translated in the shale gas industry having to provide at least 50 billion cubic meters of ready-to-use natural gas. Added to the 20 bcm that the Groningen fields will stop producing, they sump up to a gap of about 70 bcm that the shale gas industry should offset.

The viability of the security statement was not only assessed in extensive terms, but taking into account structural and functional typologies of the well population. We summarized the analysis in productive and unproductive wells. Despite previous studies have shown that shale gas has a positive energy return on investment (Aucott and Melillo, 2013), these refer to the single wells only and compare well energy inputs and outputs. We took into consideration the requirements of the whole system, including the energy hypercycle (Giampietro et al., 2012; Sorman et al., 2009).

Figure 6. Structural processor of shale gas well and its relation with the functional hierarchy (left) and processor mixes from a functional perspective (right)

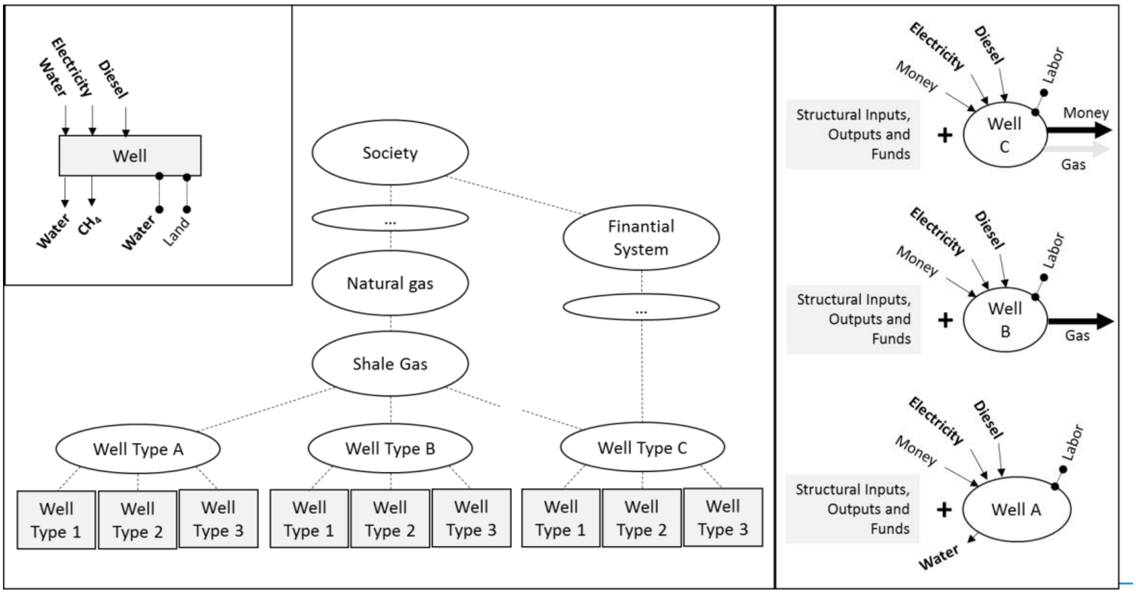
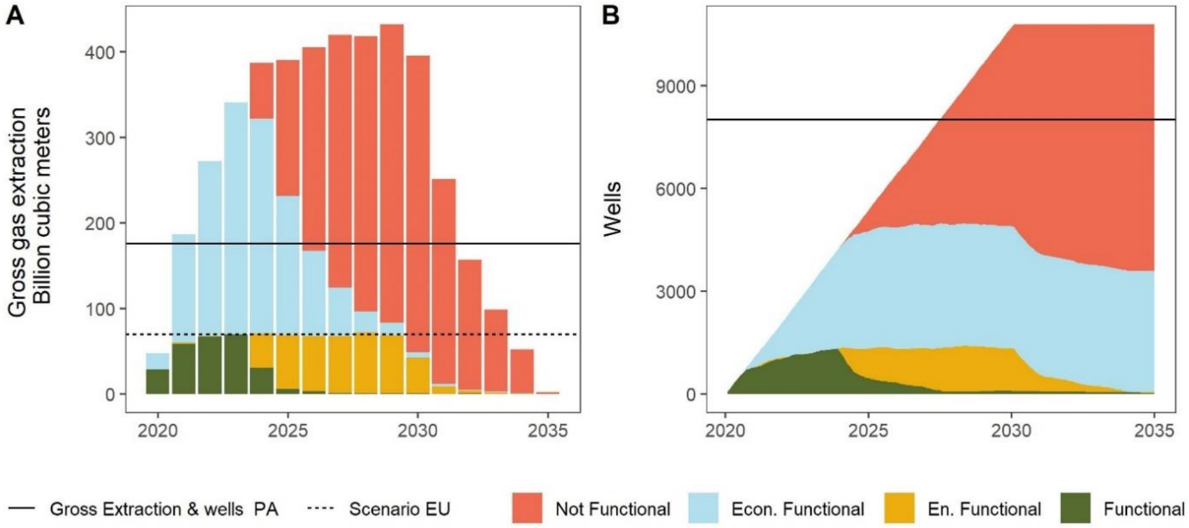


Figure 6 shows the main differences between productive and unproductive wells. Note how there are two ways of representing a well. As a structure the well remain the same, whereas the function it provides to society might change. Type A wells are fully productive in energy terms for the society and in economic terms for the company that manages them. After some time, wells are no longer energetically productive but they are economically productive and become part of group B. When wells are fully nonfunctional they become type C, are sold by their companies as assets. Type C wells are no longer filling a function of the energy system, but rather contribute to the financial activity of the society.

Figure 7. Evolution of number of wells per functional type (B) and of shale gas production (A) in the EU against the offsetting scenario and the production in Pennsylvania (PA)



We found four types of wells according to the function they can provide to the society. Fully functional wells (green) are meeting both expected *final causes* (Allen and Giampietro, 2006): a surplus of energy for the society in the form of gas and a surplus of money for the industry. Wells that are only energetically functional (yellow) are able to provide a surplus of energy for the society, but at the cost of economic losses for the company. They both can be considered "productive" wells in energetic terms and are associated to the younger stages of wells. We found that these types of wells would be rare in the EU as the drilling activity stops and wells age.

The other two types of wells, not functional (red) or only economically functional (blue), can be considered "unproductive" in energy terms. Deeper and older wells belong to these types. They represent almost 100% of wells by the end of the period.

Functional and only energetically functional wells are productive in energy terms and represent two thirds of the wells by the end of the period. They are the reason why a monetary inflow is necessary in the form of subsidies to maintain the shale gas industry (Cooper et al., 2018; Kinnaman, 2011). When this extra economic inflow is not enough, shale gas companies must find other ways of making wells economically productive. One strategy leads companies to go public and sell their shares with a questionable "clean" or "green" label (Harvey, 2011), which would likely be the future of a European shale gas industry as well.

Productive wells have a positive balance of metabolic rates in GJ/h. The metabolic rate measures the energy used and produce per hour of well activity. Figure 8 shows the evolution of the metabolic rates for both end use and production of energy carriers during the life of wells. Whereas it clearly shows that positive balance for the case of productive wells, it also shows that the difference is relatively small. Consequently, the productivity of shale gas wells can be considered low and the productivity of the sector dependent on the average age of its well population.

Figure 8. Evolution of the metabolic rates of energy use and production in the life of a well, full (A) and border detail (B)

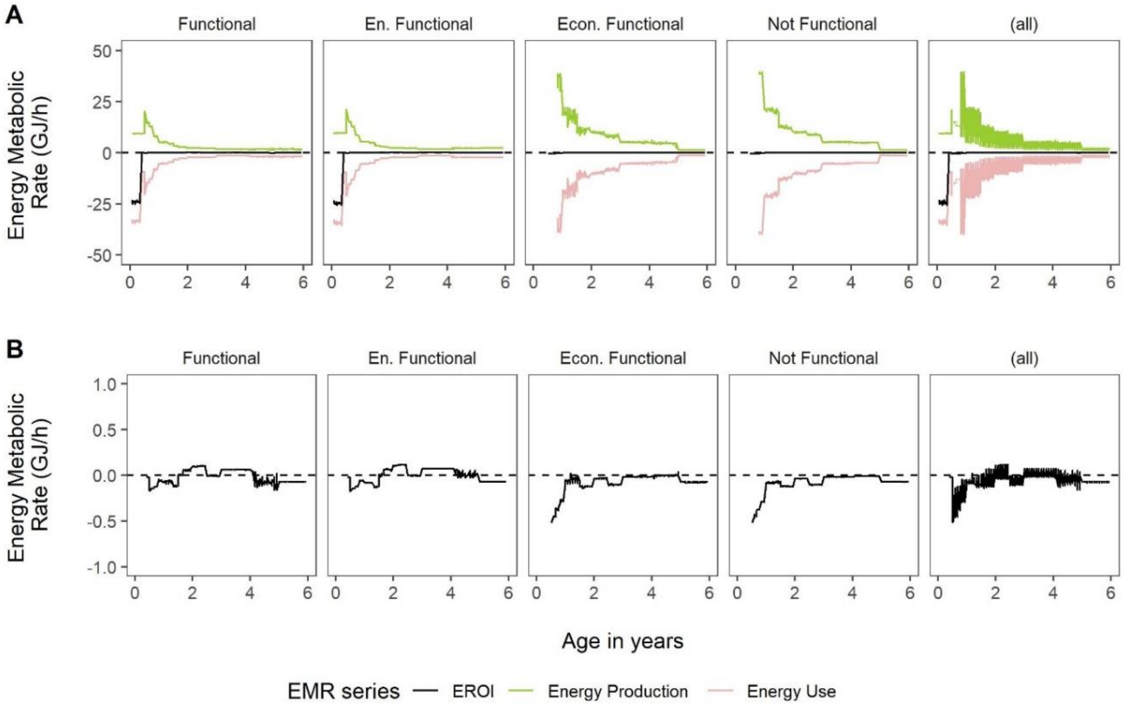
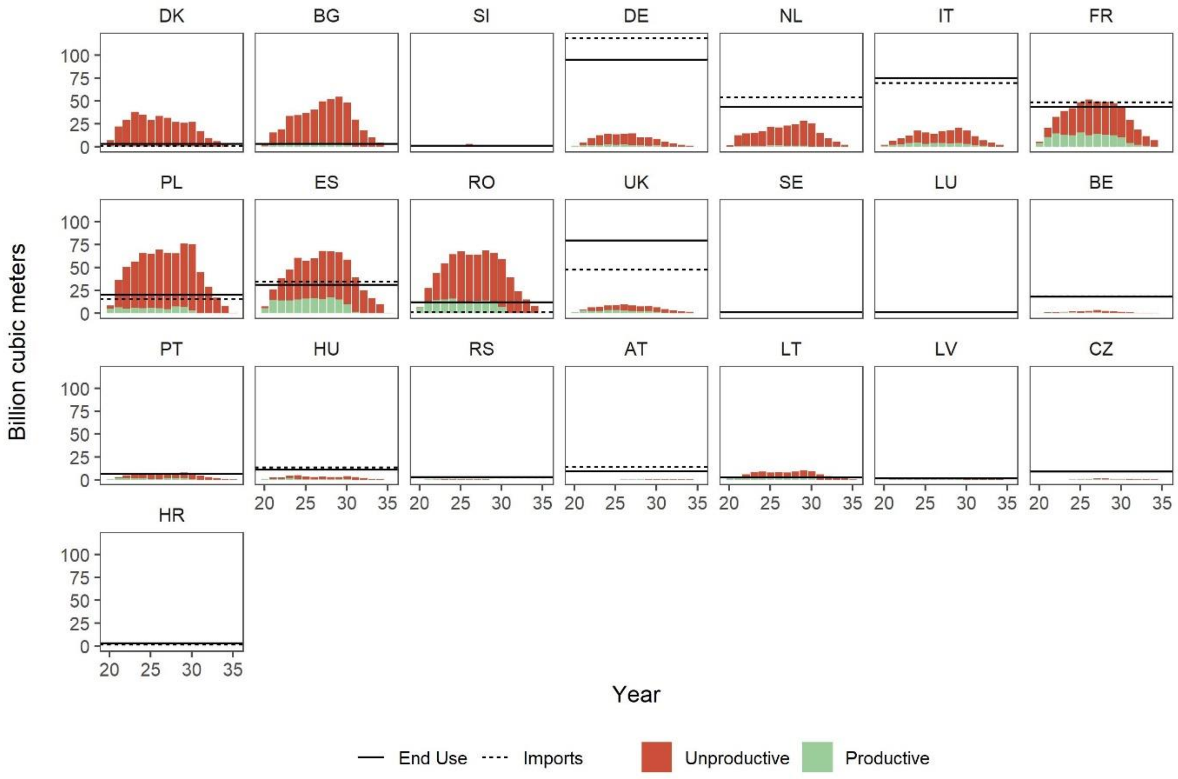


Figure 9. National security: Shale gas production against natural gas imports and end use by well productivity.



The above mentioned estimation of the potential production of shale gas (Pearson et al., 2012) referred to gross extraction without taking into account how functional would that gas be. In the EU, member states retain the right to manage their energy security independently and regulate their internal energy market. Figure 9 compares gross energy extraction (red) and the functional part of it (green) with the country's natural gas end use and imports. The functional part of the production is the actual surplus of energy provided by the sector and potentially the natural gas available for end users. Consequently, it is against the functional gas production that the robustness check of the scenario is performed, and not the gross extraction.

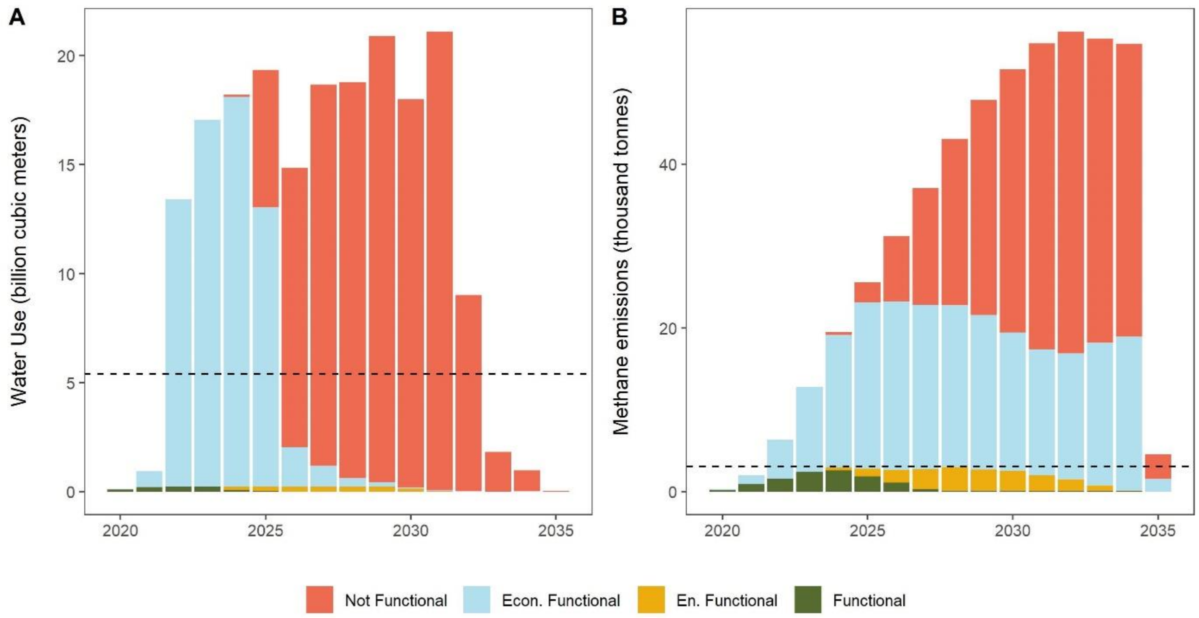
In this scenario, only Romania, Bulgaria and Lithuania would become self-sufficient in natural gas and only for a couple of years. Indeed, with a functional perspective, the whole EU shale gas industry show in figure 7 would barely meet the 70bcm mark a few years, and only 2023 would the sector provide that gas with fully functional wells that will also provide economic benefit.

3.3 The clean energy statement

The above production has the potential to reducing environmental impact in terms of CO2 equivalent without producing a deterioration of status of the water bodies.

Whereas a comparative study between shale gas and other fossil fuels is out of scope here, we checked the contribution of the modelled shale gas sector to methane emissions and water use. Figure 10 shows the contribution to those environmental pressures by well functionality against a reference. In both cases most of the pressures do not have a justification in terms of social energy production (green and yellow). At the beginning of the period for water use and about a third of the methane emissions at the end of the period, environmental pressure comes in exchange for economic benefit for the industry only.

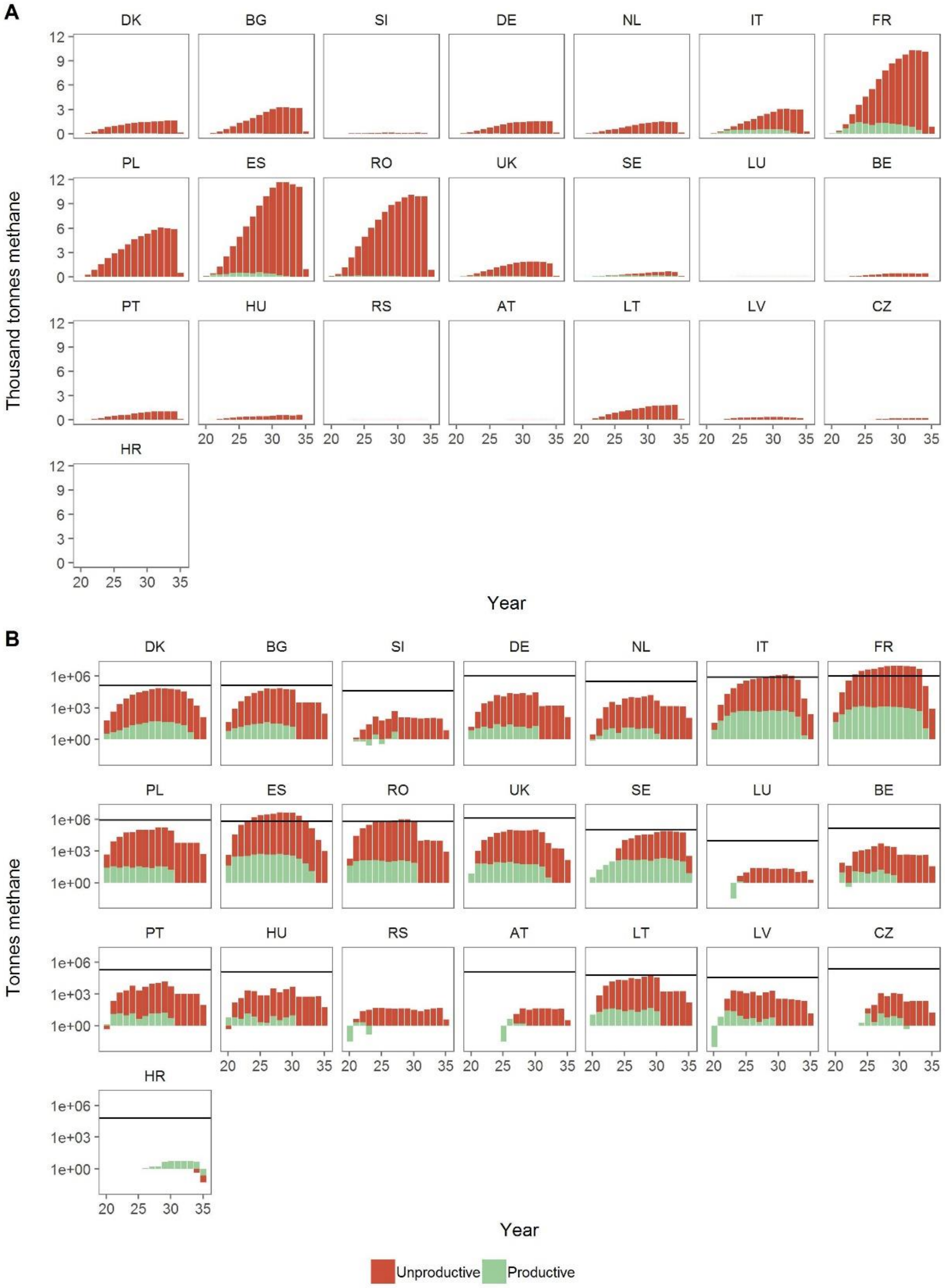
Figure 10. Water use (A) and methane emissions (B) per functional type. Reference lines show average total water extraction in Germany (A) and industrial methane emissions in UK in 2017 (Eurostat)



The Climate Strategy 2030 lines out strategies to reach the commitments of the Paris Agreement in the EU. Those commitments are acquired by each country independently. Figure 11 shows methane emissions coming from each producing country in the EU. Because of the number and/or the depth of the wells, Spain, Romania and France would be the countries with the highest level of emissions. However, the general line is that most of the emissions come from wells that are unproductive in energy terms.

Some countries emissions like France or Spain would be higher than the national GHG reduction objectives in methane equivalents, and mostly from unproductive wells. With these results, shale gas does not seem a good innovation to reduce GHG emissions, as the use of other energy sources would already have to offset these emissions.

Figure 11. Scenario Methane emissions (A) against the reduction proposed in the EU 2030 climate and energy strategy (B)



The environmental impacts of shale gas extraction are well documented in extensive terms or by unit of energy produced (Costa et al., 2017; Loh and Loh, 2016). As argued previously (Madrid-López and Giampietro, 2015) intensive indicators of water metabolism provide better information for policy making about the drivers behind water flows. Figure 12 shows how the water metabolic rate changes with the energy metabolic rate per hours of well activity. The value range is similar for productive and unproductive wells. However, unproductive wells seem to have a higher water metabolic rate at high energy metabolic rates.

Figure 12. Metabolic rates nexus trade-offs

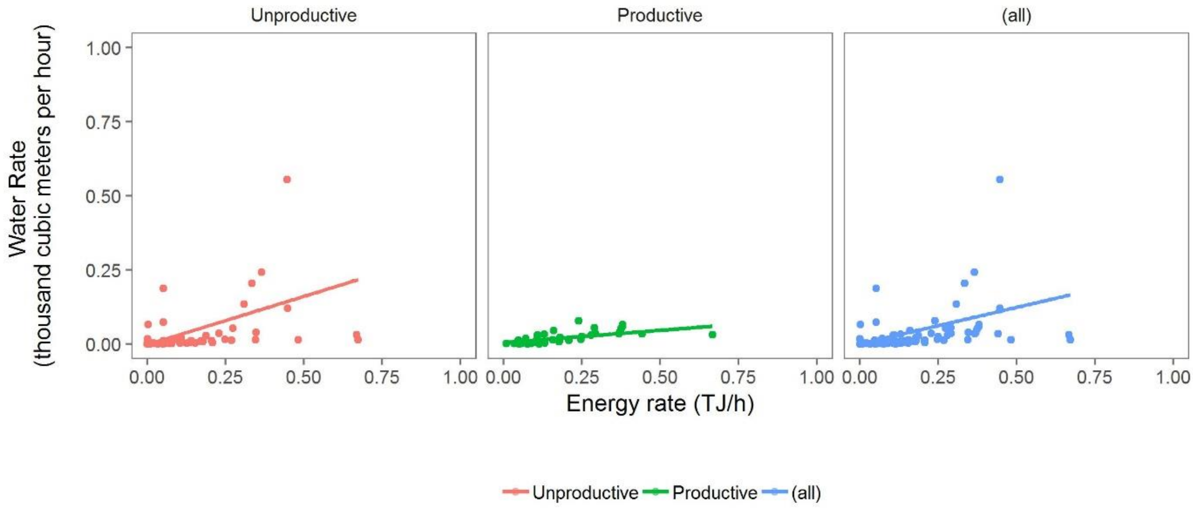
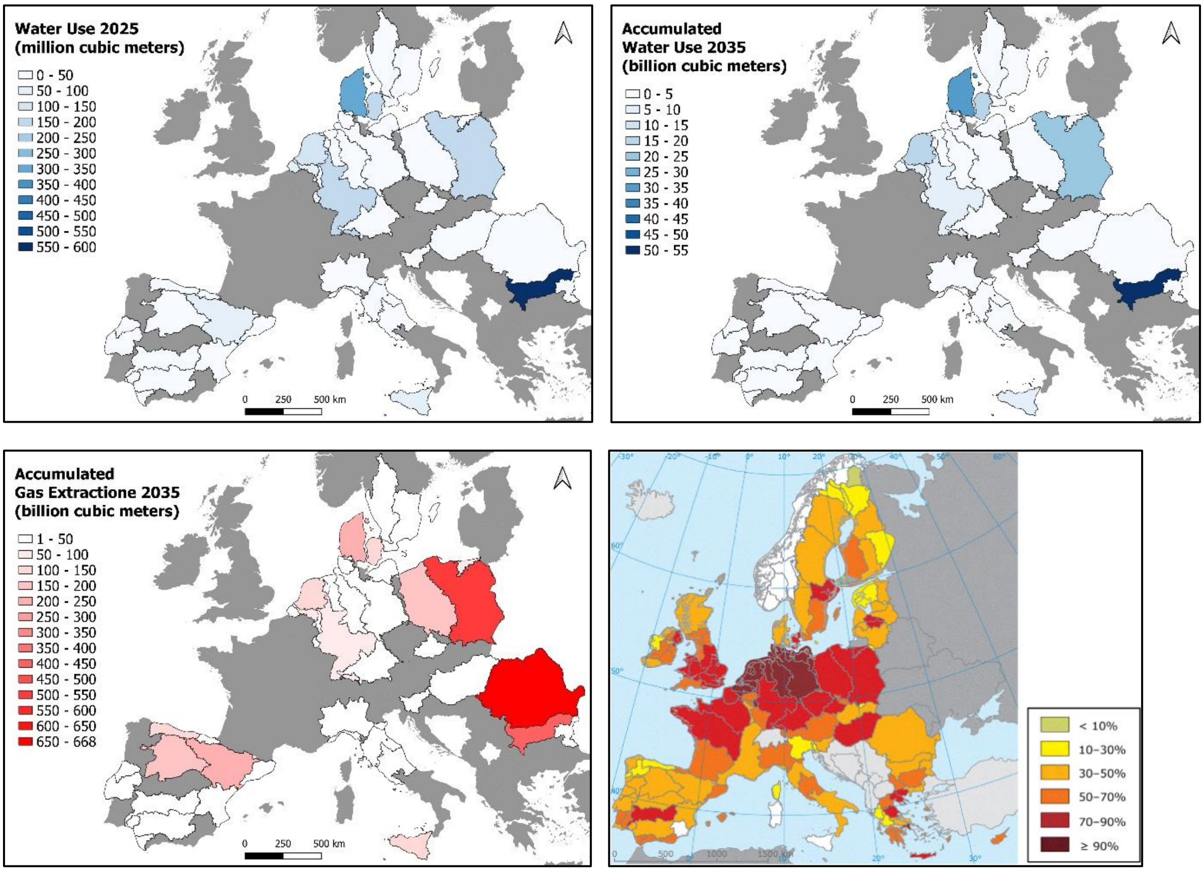
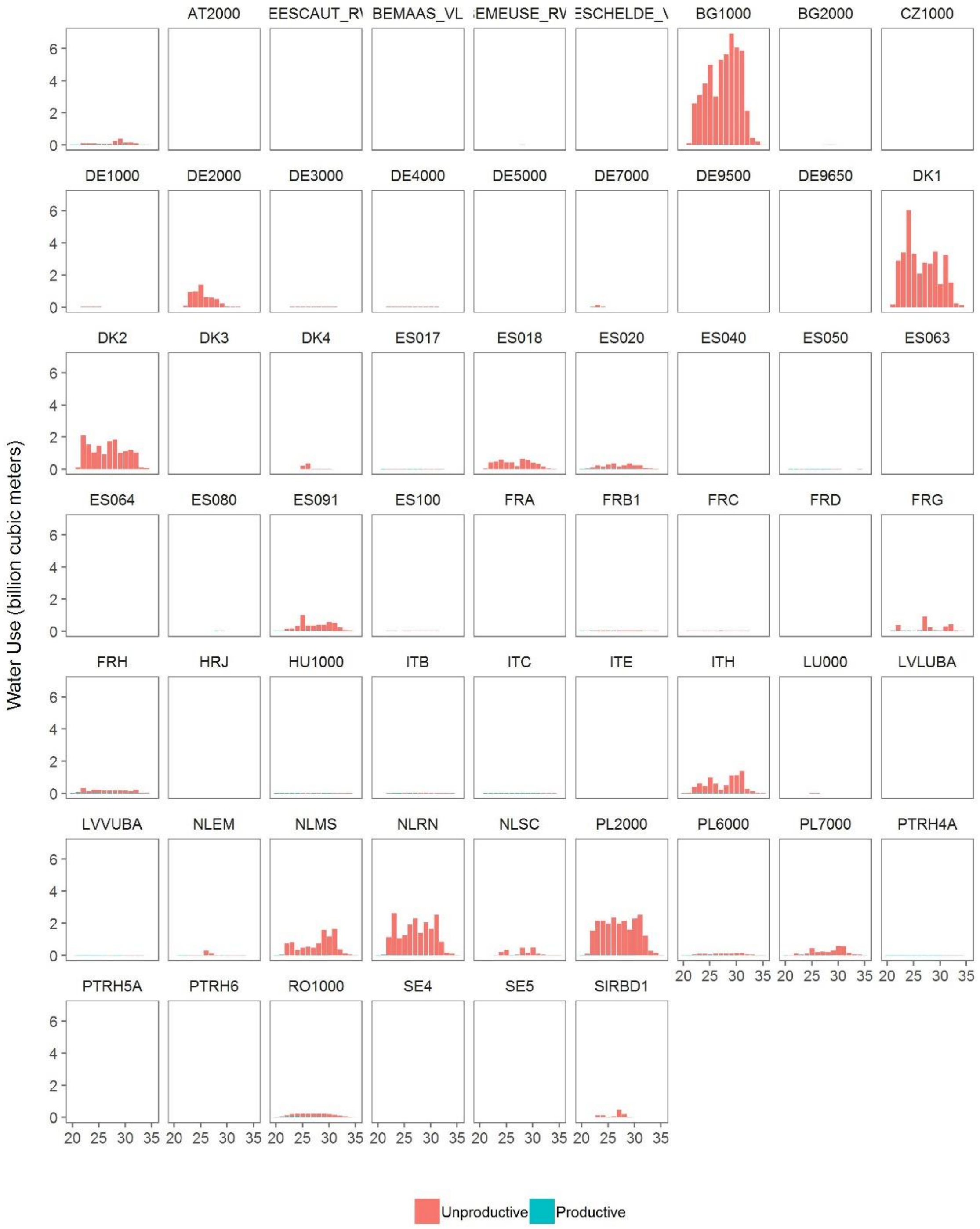


Figure 13. Water use and functionality. Baseline water use and accumulated by end of period (upper, left, right), total accumulated gas extraction (lower left) and percentage of water bodies not in good ecological status or potential to be (lower right) (Giakoumis and Voulvoulis, 2018).



The feasibility of water use is checked against water availability in river basins. Figure 13 shows water use (accumulated and per year) against volume of gas extracted and river basin status as defined by the Water Framework Directive. In it, there is hardly any river basin in which water has been used by productive wells. The River basins with highest level of gas extractions are not those with higher water use, nor hold the highest percentage of endangered water bodies. However, there is shale gas activity that takes place in river basins with a high percentage of endangered water bodies.

Figure 14. Distribution of water use by river basin and functionality



In summary, shale gas seems to not to be a good innovation in environmental terms. A comparative analysis would only give an idea of the difference in performance of different innovations. Here we have done an extensive analysis of environmental pressure, which provides a better idea of the dimension of the pressure in a scenario of application. Environmental pressures not only depends on the intensive performance of the inputs and outputs but also in the size of their flows.

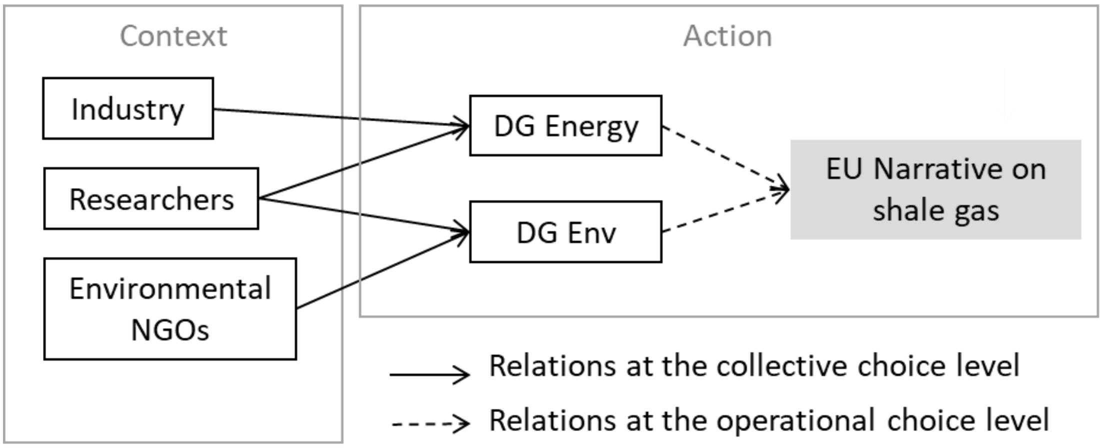
4 Stakeholder Engagement

The stakeholder engagement for shale gas had the aim to gather insights for the identification of the relevant narrative and associated statements. We used a round of semi/structured interviews. An ethics protocol with the engagement plan was reviewed by UAB's Ethics Council Board.

4.1.1 Identification of relevant engagement actors

The objective on phase one was to identify relevant narratives about shale gas within the European Commission. To that end, we identified typologies of actors involved in the process of formation of that narrative using Ostrom's distinction between collective and operational choices (1990). Specific actors for the interviews were identified by reading EU legal texts and media articles. Figure 15 shows the type of actors included in the engagement and how they relate at the collective and operational choice levels.

Figure 15. Typologies of actors and how they relate to the formation of the narrative in the EU



4.1.2 Interviews

This first round of engagement was done to identify the relevant narratives with semi structured interviews. Selected interviewees were chosen after the review of EU legal and policy documents. We interviewed two high rank representatives of DG Energy and DG Environment, a member of the natural gas industry lobby, the coordinator for shale gas of an environmental NGO in the EU and the coordinator of a H2020 funded project assessing potential shale gas risks in the EU.

The round took place during spring 2018 and spring 2019. Interviews were confidential, conducted in person and had a duration of about 45 minutes. Transcripts were codified and the file relating names and codes saved separately.

After a first block of general topics we prepared a second block of discussion topics that were specific for each of the profiles. The topics were chosen taking into account the materials gathered in the interviews done in the US for the project IANEX and the results of the project M4shale gas (Brunsting et al., 2017; Thomas and Pidgeon, 2017). Table 2 summarizes the topics defined for each of the profiles.

Table 2. Interview topics

Block	Topics
Common	• Relation with Shale gas development in EU • How did the debate start in the EU • How did it change • What will happen in the next 10 years
DG Energy	• Likeliness of shale gas development in the EU • The role of shale gas in EU energy security • Low carbon economy transition • Coordination with other DGs
DG environment	• Challenges in risk control and impact mitigation • Low carbon economy transition • Coordination with other DGs
Industry	• Fitting of shale gas within natural gas industry • Ability of the industry to develop a shale gas sector in the EU • Main problems encountered
Env. NGO	• Issues with scientific studies • Main reasons for opposition
Academia	• Role of science in shale gas risk assessment • Challenges found

4.1.2.1 *Interview Outcomes*

Given the heated public debate around shale gas, a certain diversity of opinions was expected. However, we found that among the people interviewed there was a generalized idea that a wave for shale gas development has passed. Some of the people could see future opportunities in case of price rise, environmental requirement relaxation or cost-lowering technological development and confirmed that shale gas development is still an option for the European Commission. In contrast, some other people thought that shale gas is no longer a realistic political option and that a new niche for shale gas development, in case, would come when renewables are too developed for an investment in shale gas to be worth.

Shale gas was perceived as a worthy energy and economy activity by energy-related interviewees, whereas more environmentally sided considered the issues of return on investment. At the time of the interviews, the economic issues with the major US shale gas extraction companies (Meyer and Raninson, 2019) had not been publicly acknowledged.

In terms of the perception of the validity and the usefulness of shale gas related scientific studies, policy makers and academics were more optimistic than the industry and NGO representatives. This is one of the few views shared by these last two groups.

4.1.3 Challenges

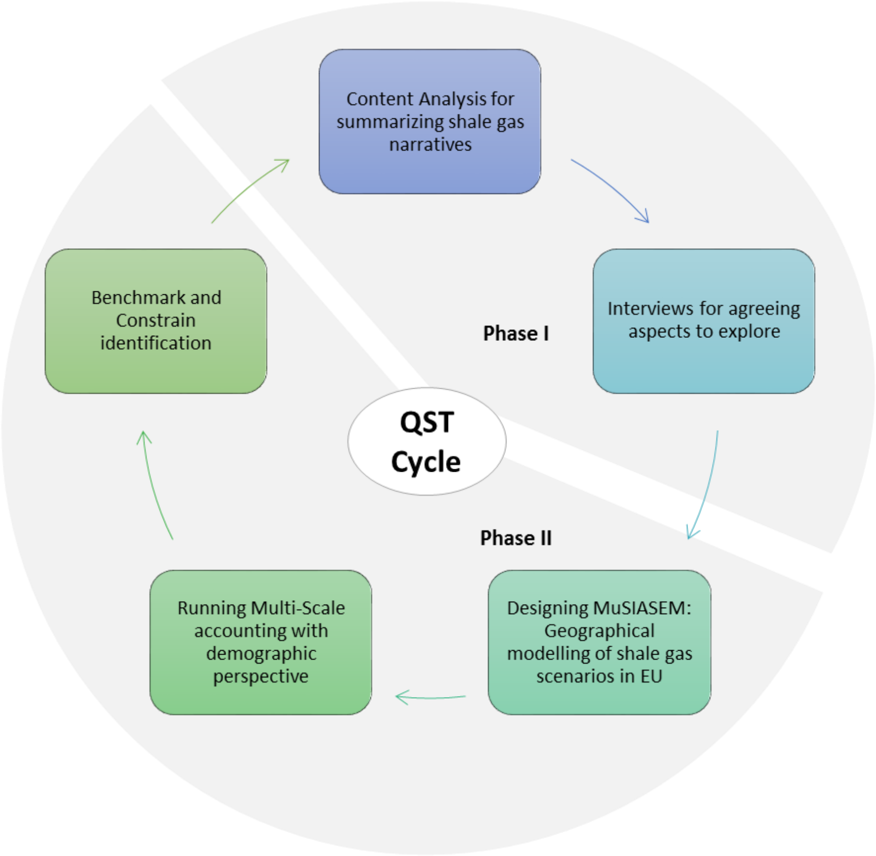
There were two challenges worth mentioning in this engagement. First, the fact that reaching the European Commission was difficult, particularly at the technical levels. Negative answers were justified by lack of time of the technicians or by impossibility of answering due to political positions about shale gas.

The second and most important challenge was the lack of interest of some agents on shale gas. Whereas at some DGs in the European Commission shale gas is still not completely dismissed as energy source, at the national and regional levels were shale gas is banned or under moratoria we found more difficulties to complete an engagement process. Indeed, our original plan of doing a workshop series could not be completed for this same reason.

5 Materials and methods

Following the quantitative story telling cycle explained in MAGIC deliverable 4.1 (Ripa and Giampietro, 2017) and later developed by Matthews et al. (2017), the analysis of innovation shale gas is divided in two phases, summarized in Figure 16. In phase I, a narrative related to shale gas was delimited, from which we later on identified the research statements presented above.

Figure 16. Implementation of the quantitative story telling cycle for innovation shale gas



In phase II we checked the robustness of the narrative by checking to what point these two beliefs were possible. The quantitative assessment required the construction of a scenario of wells drilled in Europe that would allow us to test their functional viability and their socio-environmental feasibility. We used an approach that studied the contribution of a mix of structural wells to the function of the shale gas sector taking into account the age of the wells (demographic metabolism).

This scheme is a bit different from the one used in the rest of the innovations (Matthews et al., 2017) in two ways. First, it not only identifies the main innovation related narrative, but this is also decomposed into two statements. This follows the logic that it is impossible to falsify a narrative, described as a set of believes, which are by definition, real to the subject defining them (Bruner, 1991). What can be falsified, however, is the set of statements that form the narrative as a representation of the reality. We believe that this approach is more respectful with different points of view and more critical, as it treats all narratives as equally valid, though some of them might be based on false statements.

Second, this QST cycle does not has as aim the definition of benchmarks per se. Rather, we have used them to create an option space for shale gas development, see for exampleFigure 7. Evolution of number of wells per functional type (B) and of shale gas production (A) in the EU against the offsetting scenario and the production in Pennsylvania (PA) Figure 7. This is the only case study that had no current baseline situation in the EU, as most of the shale gas development in Europe has been low-scale and cannot be classified as industrial. Consequently we did not have a proper ground for the development of benchmarks that could be use as reference in further studies.

5.1 Phase I

5.1.1 Formal narratives

The EU has closely followed the outcomes of the American shale gas development. Despite the high expectations the US activity generated, the EU has not been able –or willing- to develop a shale gas industry. We analyzed the reports generated during the discussions about shale gas impacts that took place at the European Parliament during 2013 [COM(2014) 23 final plus annexes and corrections]. Since there were no further legislative documents after 2013, we completed a round of anonymous semi-structured interviews. We interviewed two high ranking representatives of DG Energy and DG Environment, a member of the natural gas industry lobby, the shale gas coordinator of an NGO and the coordinator of a H2020 funded project assessing potential shale gas risks in the EU, as explained in the previous section.

5.1.2 Informal narratives

Media has been described as both an expression of narratives and as a key factor in their formation (Fulton, 2006), especially regarding the issue of manufactured risks (Beck, 1992), which deeply relate to the formation of narratives in shale gas. In this study, the description of shale gas activities in media is used as a proxy to understand the development of the related narratives.

We used a corpus-based media content analysis (Kutter and Kantner, 2012). The study considers about 200 written articles about shale gas in the EU and the US. We gathered all articles published by two media of similar editorial lines, US's *The New York Times* and EU's *The Guardian,* from January 2007 to September 2019. These were content-analyzed against a corpus of relations describing positive or negative description of shale gas as described in Madrid-Lopez (Forthcoming). Due to time limitations, the corpus was not defined in a participatory way, but we used the outputs of the IANEX[4] project round of interviews in the US to design it. We checked for % of positive messages about shale gas in different time periods.

Given that shale gas developed in the US as a result of natural gas price increase (Stephenson, 2015a), our time-explicit media analysis was compared to the evolution of the difference between average cost of producing a cubic feet of natural gas and gas prices at the US' Henry Hub. Henry Hub prices are extensively used as indicator of variation for global natural gas process. We focused on the periods of either cost-reducing technological change or price falls, which defined pyramids or inverted pyramids in the price/cost evolution and assessed what was the main dominant discourse in the analyzed media. In periods of pyramid (prices higher than costs), we expect to find a tendency towards positive messages in the media. During inverted pyramid periods (costs higher than prices), the expected tendency is to have a majority of negative messages. This analysis complemented the formal analysis in the definition of the narrative.

5.2 Phase II

The robustness analysis departed from the statements identified in phase I:

- ***Shale gas extraction in the EU can offset the closing of the Groningen fields and still cover 10% of the EU gas demand in 2035.***
- ***The above production has the potential to reducing environmental impact in terms of CO_2 equivalent without producing a deterioration of status of the water bodies.***

Following QST as described in MAGIC deliverables (Ripa and Giampietro, 2017) and previous work in MuSIASEM (see, for example, Madrid-López and Giampietro, 2015) we used a viability and a feasibility assessment respectively to check the robustness of these statements. The energy security statement, is related to the viability descriptive domain in MuSIASEM and was studied using a social scale in the determination of the system boundaries. The clean energy statement is related to the feasibility descriptive domain and studied using a geological (natural) delimitation of the system.

To test these statements, we built a scenario in which all potential land was drilled with constant drilling rate within the period 2020-2025 and for wells no deeper than 4000 meters. We then studied their economic and energy breakeven points and environmental impacts in the period 2020-2035. The energy and economic breakeven points are analyzed in the viability domain and the methane and water use-offsetting capacity in the feasibility domain. Figure 17 summarizes the steps taken in the quantitative analysis in phase 2.

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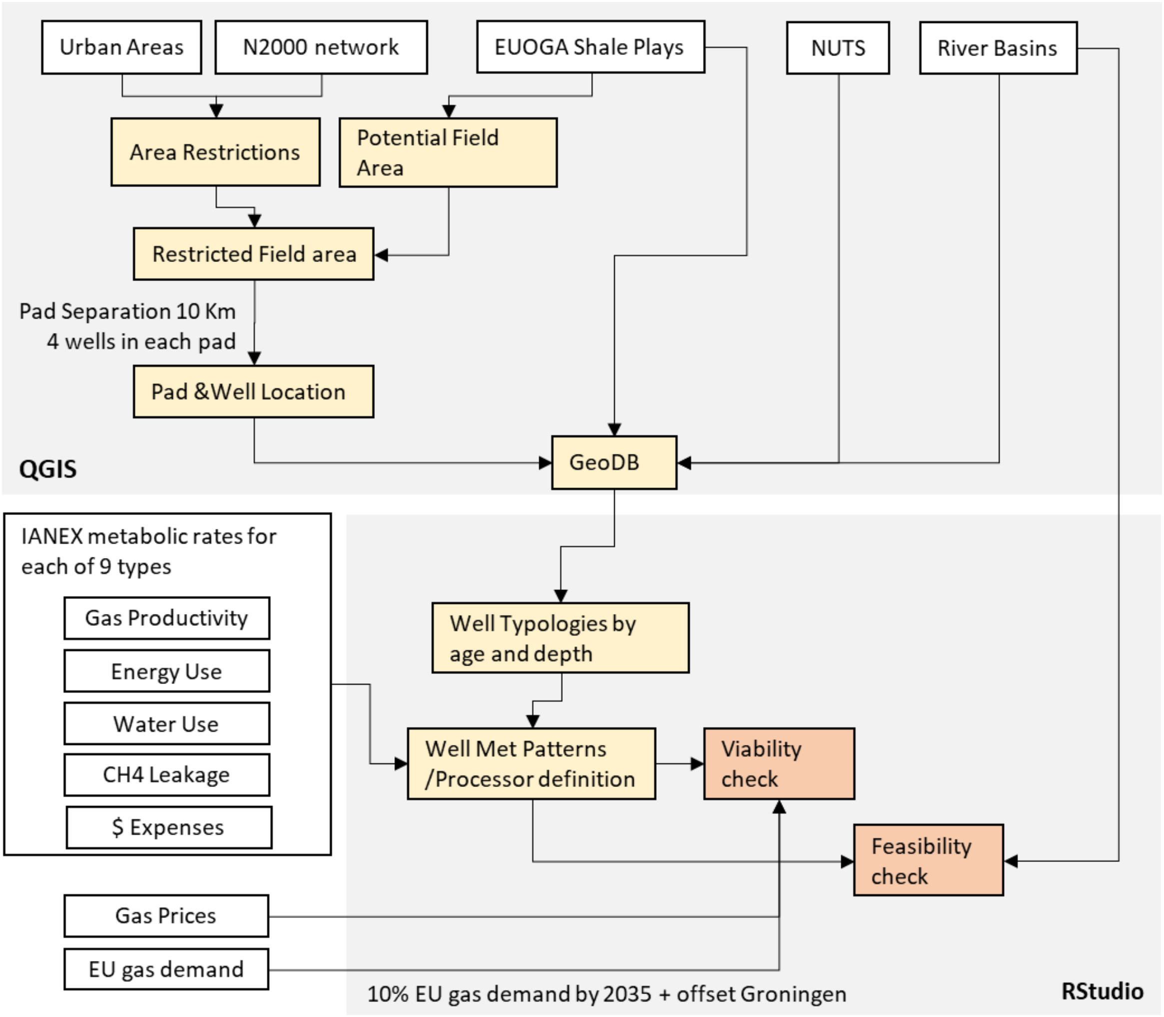
[4] Integrated Assessment of the Nexus: The case of hydraulic fracturing. 7th Fp marie Curie Action GA 623593

Figure 17.Overview of the steps followed in the quantitative assessment, data (blank filling) and tools (shaded areas)



5.2.1 Construction of the well and pad geographical database.

Due to the lack of industrial development of shale gas, the potential pad and well locations were modelled within restricted boundaries of areas for extraction. The restricted areas for extraction resulted from clipping out areas where shale gas extraction may not occur (urban communities, protected natural areas and water bodies and a buffer of 100 meters) from the area surfacing the location of the shale layers.

Figure 6 shows the location of the basin surfaces by depth of the shale layer and the restricted areas. We modelled well pads in QGIS[5] with a random point sampling within restricted areas with a separation of 10Km and four wells in each of them. Urban area information was extracted from the Corinne Land Cover Dataset, Water bodies and information on the Natura 2000 network is developed by the European Environmental Agency. Information on shale gas plays was gathered from the EUOGA project[6].

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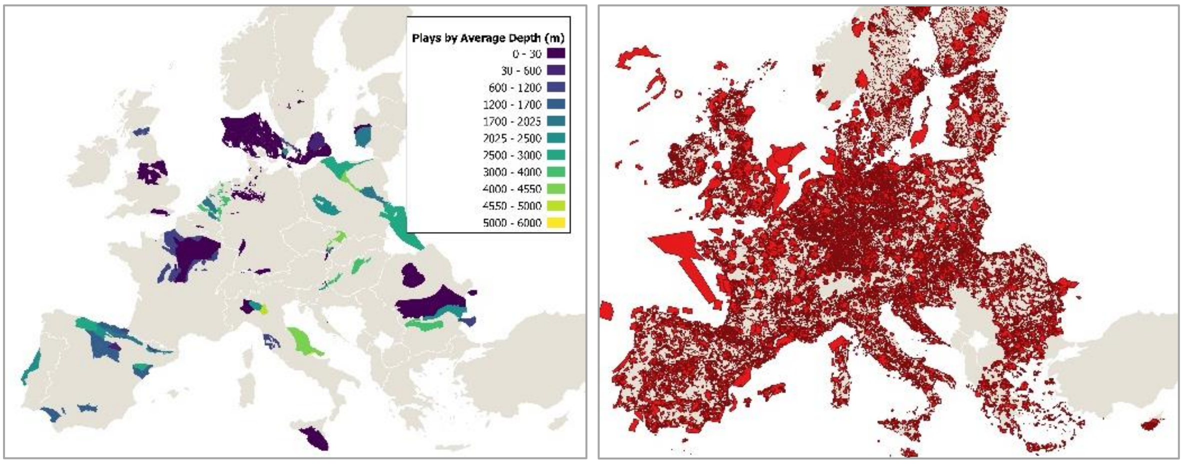
[5] https://qgis.org/ca/site/

[6] https://ec.europa.eu/jrc/sites/jrcsh/files/pl1-britze.pdf

Figure 18. Shale plays surfaces included in the analysis by depth (m) (left) and restricted areas (right)

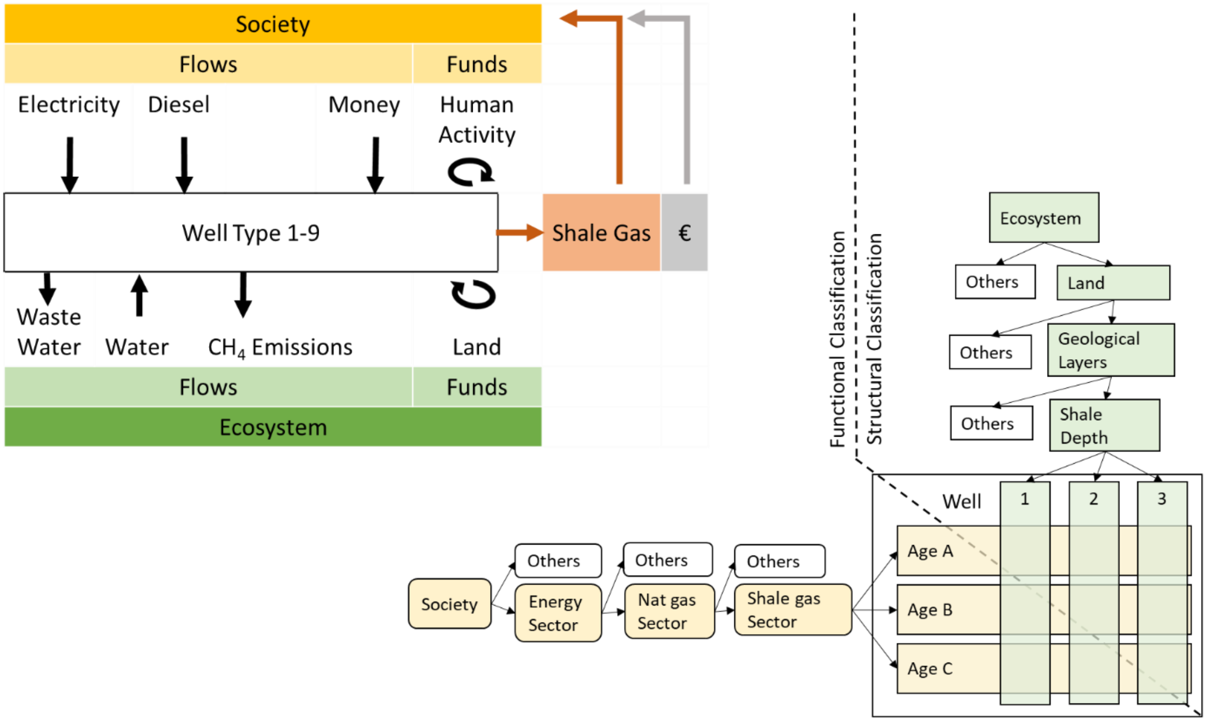


5.2.2 Demographic metabolic patterns

Once located, wells were defined as processors (González-López and Giampietro, 2017) from two different perspectives - the functional and the structural (Di Felice et al., 2019)- as shown in Figure 19.

From the **structural** point of view, wells are a set of georeferenced infrastructure. As such, they have the ability of *extracting* gas from shale while producing an impact over their near environment. The structural view is here assessed within the feasibility domain and we distinguish three types of structural wells (1 to 3) according to their depth [0-1000, 1000-2000 and +2000 meters].

Figure 19. Analytical definition of the shale gas well as a processor (above) and as a system component (below)



From the **functional** point of view, wells are expected to have two *final causes*: i) *producing* natural gas in the form needed by the society and ii) making a gas derived economic benefit. As social functions, well maintenance requires a certain social investment in terms of energy and money flows. The functional view is here assessed within the viability domain and we used the IANEX project[7] definition of shale gas well life stages [Drilling, Production and Decay] to define three functional typologies of wells (A to C). For each of the 9 typologies, technical coefficients coming from the IANEX database were used to estimate extensive flow and fund coefficients.

The EU population of wells was studied in the interval from January 1st 2020 to January 1st 2035, simulating monthly reporting periods. At each period, each member state is assigned a number of wells in drilling stage that are later on summed to the pool of previously drilled wells. The result is a pool of wells formed by different well types. For each well type, the input and output metabolic rates were defined by hour of well activity, defining this way wells as fund components themselves and shifting the n level of the assessment to the well population. The functionality of the EU well population was later examined.

This way of defining an energy 'producing' structure is different to the one used in recent MuSIASEM studies of energy metabolism (Di Felice et al., 2019; Fierro et al., 2019; Velasco-Fernández et al., 2018) as it takes into account the ageing of the structure and the age profile of the typology mix. We could call this a ***demographic perspective*** in the definition of the metabolism of the functional units that evaluate the above-mentioned rates per hour of well activity. This functional approach associated with the "demographic" characteristics of wells is also very different from other studies on shale gas, which typically describe the well as a structure (Burnham et al., 2012; Raj et al., 2016). As mentioned below, that approach has issues with robustness in the development of indicators. See for example how water use is accounted for by BTU in most of the analyses (Weber and Clavin, 2012).

Table 3 shows the steps taken for the quantitative assessment of the demographic metabolism for the EU scenarios proposed. The mathematical development is covered in Madrid-Lopez (Forthcoming).

Table 3. Steps of the quantitative assessment

#	**Step**
1	Identification of relevant e,s typologies from the IANEX DB
2	Grouping DB by (e,s) pairs
3	Summing extensive variables
4	Calculating metabolic rates per typology
5	Merging typology data with European scenario well typologies (e,s)
6	Adapting IANEX metabolic rates as using them as technical coefficients to calculate extensive indicators for the EU
7	Calculating accumulated intensive variables: gas production, economic costs, income, energy use, water use, waste generation and methane emissions
8	Assessing functionality of wells and checking robustness of energy security statement
9	Assessing potential systemic impacts and checking the robustness of the clean energy statement

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[7] https://cordis.europa.eu/article/id/300717-a-decision-support-system-for-shale-gas-extraction-plans

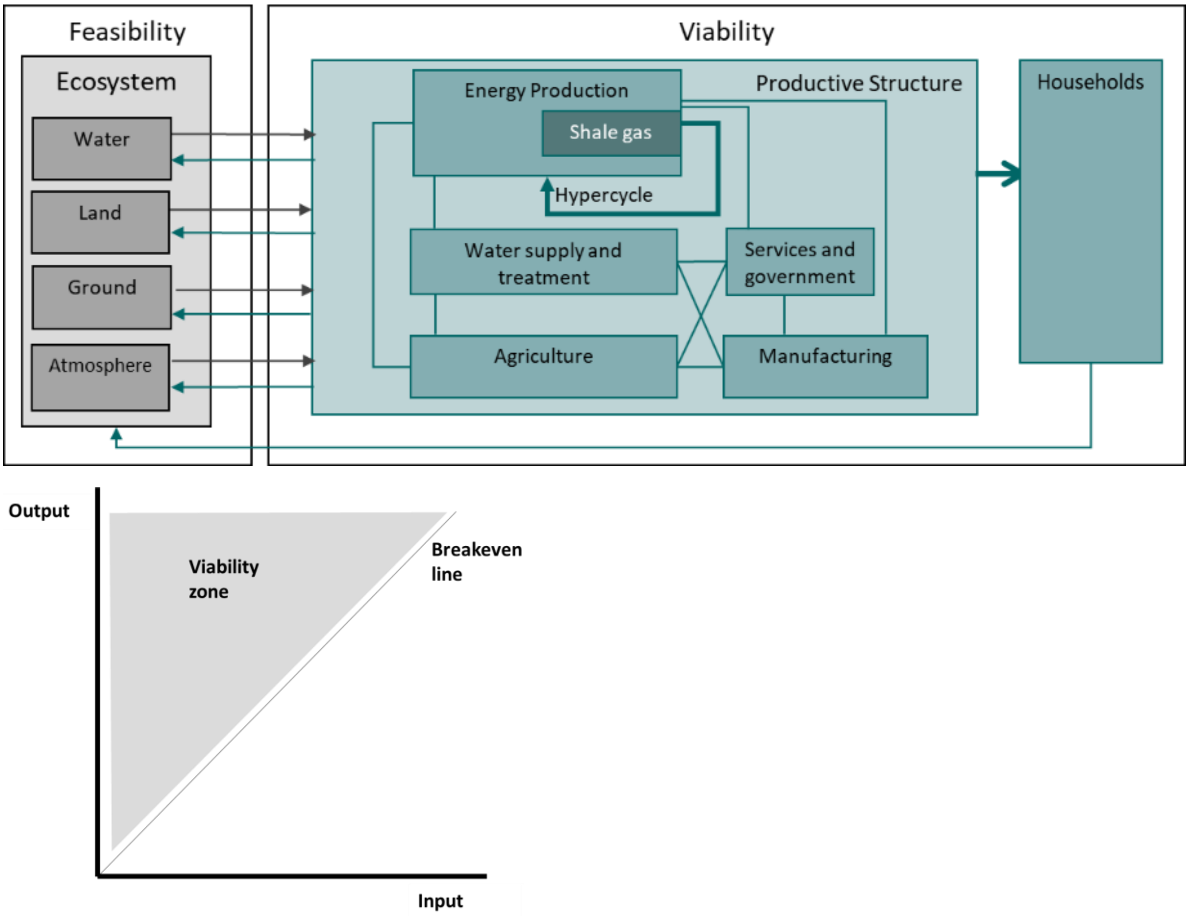
5.2.2.1 *Checking the energy security statement*

Shale gas extraction in the EU can offset the closing of the Groningen fields and still cover 10% of the EU gas demand in 2035.

If shale gas is to contribute to the energy security of the EU in the way the European Commission foresees, the activity would have to not only produce enough gas to decrease external dependency by 10% but also offset the closing of the Groningen fields in The Netherlands. The closing of the Groningen fields will decrease domestic natural gas supply in the EU for about 22 billion m^3 (Sterling, 2018) whereas the natural gas inland consumption in 2017 as calculated by Eurostat was about 490 billion m^3. With a very conservative estimation in which natural gas demands will not increase in the next 15 years, this means that shale gas would have to reach a production of at least 70 billlion m^3 (22 billion to offset Groningen closure plus 49 billion to reduce external dependency).

Following the functional logic of MuSIASEM associated with the energy hypercycle of the energy sector (Giampietro et al., 2012; Polimeni et al., 2008), extraction is but one of the parameters to consider in the analysis. If shale gas production must provide the function of energy supply to the society, this return on investment must be positive. In other words, wells extracting shale gas have to reach and pass their energy and economic breakeven points for the activity to be viable. In Figure 20 right showing the broad input/output option space for a processor, the viability zone is above the breakeven line.

Figure 20. Functional location of the shale gas sector (above) and scheme of the viability zone (below)



Wells that are over the economic and energy breakeven lines can be considered productive in functional terms, as they are actually producing a surplus of energy and associated monetary flows. Wells that are only viable in economic or energy terms can only meet one of the two functions. Wells that are not viable in any term are not able to meet the function they are meant to provide, even if they do contribute to the overall gas production of Europe (with an overall negative balance of in relation to energy use and supply).

5.2.2.2 Checking the clean energy statement

The above production has the potential to reducing environmental impact in terms of CO2 equivalent without producing a deterioration of status of the water bodies.

The clean energy statement describes shale gas as an energy source that has less environmental impact than other fossil sources. Such comparison has been done using a life cycle assessment (LCA) approach and reports a significant reduction of life cycle GHG emissions when shale gas substitutes other fossil fuels in power stations or for transport end use although uncertain benefits as substitute of conventional gas (Burnham et al., 2012). However, LCA results like these, have been criticized for lacking a reference and potentially being misleading in decision making (Bjørn et al., 2016; Bjørn and Hauschild, 2013).

In the search of more relevant results, we provide this reference in two ways. First, taking into account the “demographic” consequences on the metabolism of wells as explained above (internal reference). Second, considering how that demographic metabolism’s GHG emissions and water use impact the environment (external reference) and challenge the objective of other EU and member state policies, in line with other work on innovation assessment in MAGIC –see for example Ripoll Bosch et al (2017).

Internal Reference. An important factor in the development of shale gas in the US is the perception that the energy security or economic benefits justify its impacts (Cruz et al., 2014). However, those supposed benefits are assessed without taking into account the functionality of the wells. We assess the GHG emissions and the water use by well functional typology. Our aim is not to find a justification for environmental damage, but to find what percentage of those pressures belong to fully functional wells.

External reference. For the feasibility check, MuSIASEM differentiates between environmental pressure and impact. In here, we define environmental impacts as changes in the hydrosphere and the atmosphere brought by GHG emissions and water use, which are, in contrast pressures. Pressures in water use and methane emissions are assessed in metabolic rates against fully functional energy production, reflecting the trade-offs between nexus elements. The impact to the hydrosphere was assessed by comparing water extraction against the ecological status of the water bodies as reported in the second Water Management Plan cycles covered in the WFD. In the case of the atmospheric impacts, we calculated methane emissions associated with shale gas production in Europe and compared them against the Paris reduction objectives for each member state covered in the 2030 Climate and energy strategy[8]

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[8] https://ec.europa.eu/clima/policies/strategies_en

6 Reflections on learning experience

6.1 Discussion of main findings

While the total extraction of natural gas has often been used as indicator of the potential contribution of shale gas to energy security (IEA, 2019), only “productive” wells provide the society with an energy surplus. Following this logic for the assessment of environmental pressures allows the identification of the share of environmental impacts created by functional and not functional wells.

6.1.1 Is it worth it to have shale gas in Europe?

A shale gas industry in Europe that develops with similar parameters than the ones proposed here is not worth it. Neither the gas productivity nor the environmental impacts are justified by the function provided to the society, a claim that has been frequently made by the industry in the US (Rahm and Riha, 2012).

After drilling activity stops in 2030 the amount of productive wells and the extraction itself will decrease abruptly. Europe would have very few fully functional wells and consequently the shale gas extraction will consume more energy than it would provide. Besides, that production would be concentrated in few member states that might decide to export it to non EU countries. Contribution to European gas supply is therefore not ensured.

In order for Europe to maintain a shale gas industry, new wells would have to be drilled every year at a faster rate. The US shale gas sector is arriving at the point where wells can neither fulfill a function as gas producers nor as financial assets. Haynesboone reports that 32 oil and gas drillers have filed for bankruptcy in 2019 and giants of the shale industry like Chesapeake Energy are approaching an unsustainable financial situation, with a debt that sums up about 10$ billion (Richter, 2019).

When the population of wells ages, structural representation of wells does not change, but the functions they provide to the society do. As previously shown, the older the wells are, the less able they are to meet the energy provision function. The highest the share of older wells in the population, the less able the population is of providing the function expected (Figure 21).

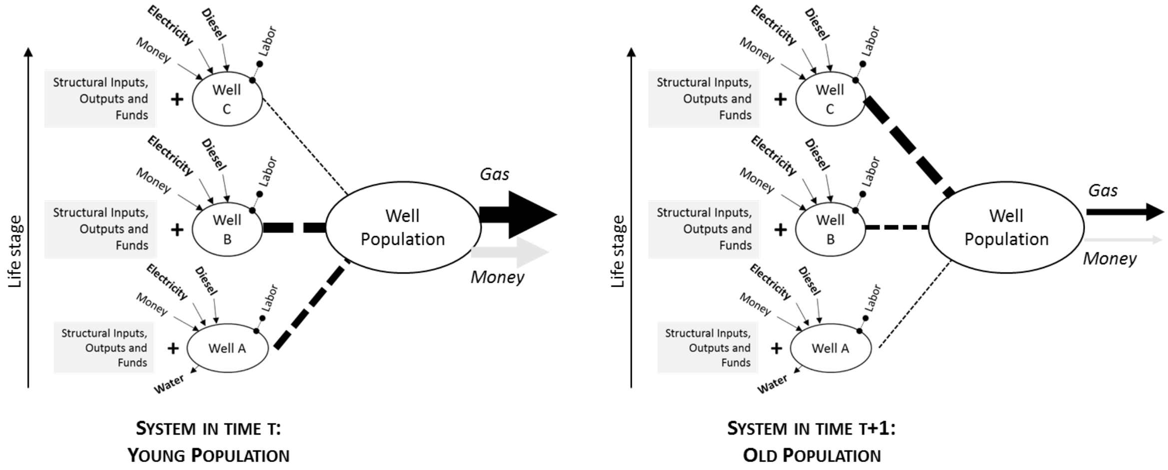
6.1.2 A functional analysis of demographic metabolism

The functional analysis of the demographic metabolism is not only valid for the assessment of shale gas. Any social function that extract resources from a stock can be assessed using this approach. The difference between a functionally young and a functionally old well (time t and t+1 in Figure 21) is short (about two years) and variable. In Pennsylvania this difference is a bit longer than in Europe, around ten years vs 15. Besides, the European industry of shale gas would have saturated the land by 2030 and the population might become too old to be productive in only five years.

A *functionality window* that indicates the time between functional stages of a well –or the difference between time t and time t+1– is a better indicator of its useful life than productivity per hour. In the case of shale gas this is closer to 2 years whereas in conventional gas ranges around 30 years as reported by Clark et al (2011).

This functionality window is much bigger in resources that come from funds (renewables). In this case the ageing of the structure will equally happen but it may maintain its functionality if the extraction rate respects the recovery rate of the resource exploited. The short functionality window of shale gas wells does not result from the ageing of their structures but from the depletion of the shale layers.

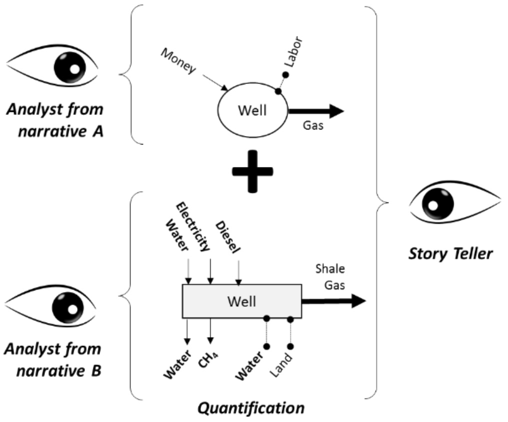
Figure 21. Ageing of the shale gas well population as changes in the mix of different well functional types from time t to t+1



6.2 A reflection on methods

In MuSIASEM, innovations are described as processors that depend on the rate of its input and output flows to maintain its function. The impact over the environment does not only depend on those input and output rates, but also on the size of the processor, which is given by the level of diffusion of a technology. Political narratives and policies form boundary conditions that influence the level of diffusion of a technology. However this parameter cannot be assessed within MuSIASEM and other frameworks for the assessment of socio-technological transitions like Geels' (2011) multi-level perspective are needed.

Figure 22. Differences between narrative-guided analyst and story teller in shale gas



MuSIASEM is not a quantitative method for the assessment of narratives. Rather, it provides an ontology to check the environmental limitations of a political strategy or an innovation implementation. However in order to complete properly a QST cycle other quantitative methods with different ontologies like life cycle inventory or GIS are needed.

The structure/function connection provided by relational analysis lays the ground for true transdisciplinary sustainability evaluations. Quantitative story telling can only use its maximum analytical potential when analysts are able to detach from their own narrative and become meta-observers (Figure 22) aware of how the choosing of the narrative influences the methods and the results of the analysis.

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Annex I. Legal Documents

Date Document	Document type	Title	Code	Link
2/1/2018	EU Lex - Study	Energy and the MFF	IPOL_STU(2018)614223_EN	http://www.europarl.europa.eu/RegData/etudes/STUD/2018/614223/IPOL_STU(2018)614223_EN.pdf
22/1/2014	EU Lex - Study	COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT on the exploration and production of hydrocarbons (such as shale gas) using high volume hydraulic fracturing in the EU	COM(2014) 23 final	https://eur-lex.europa.eu/legal-content/GA/TXT/?uri=CELEX:52014DC0023R(01)
22/1/2014	EU Lex - Study	COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT Accompanying the document COM(2014) 23 final	SWD(2014) 21 final	https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A52014SC0015
25/11/2014	EU Lex	European Parliament resolution on Towards a new Energy Strategy for Europe 2011-2020 (2010/2108(INI))	P7_TA(2010)0441	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52010IP0441
14/4/2016	EC	Towards a new Energy Strategy for Europe 2011-2020	2010/2108(INI)	https://ec.europa.eu/energy/en/consultations/towards-new-energy-strategy-europe-2011-%E2%80%93-2020
11/10/2010	EU Lex	Energy 2020, a strategy for competitive, sustainable and secure energy	SEC(2010) 1346	https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52010DC0639&from=EN

H2020 MAGIC PROJECT POLICY BRIEF / FEBRUARY 2020

Ensuring natural gas supply in the low carbon era
The potential of shale gas

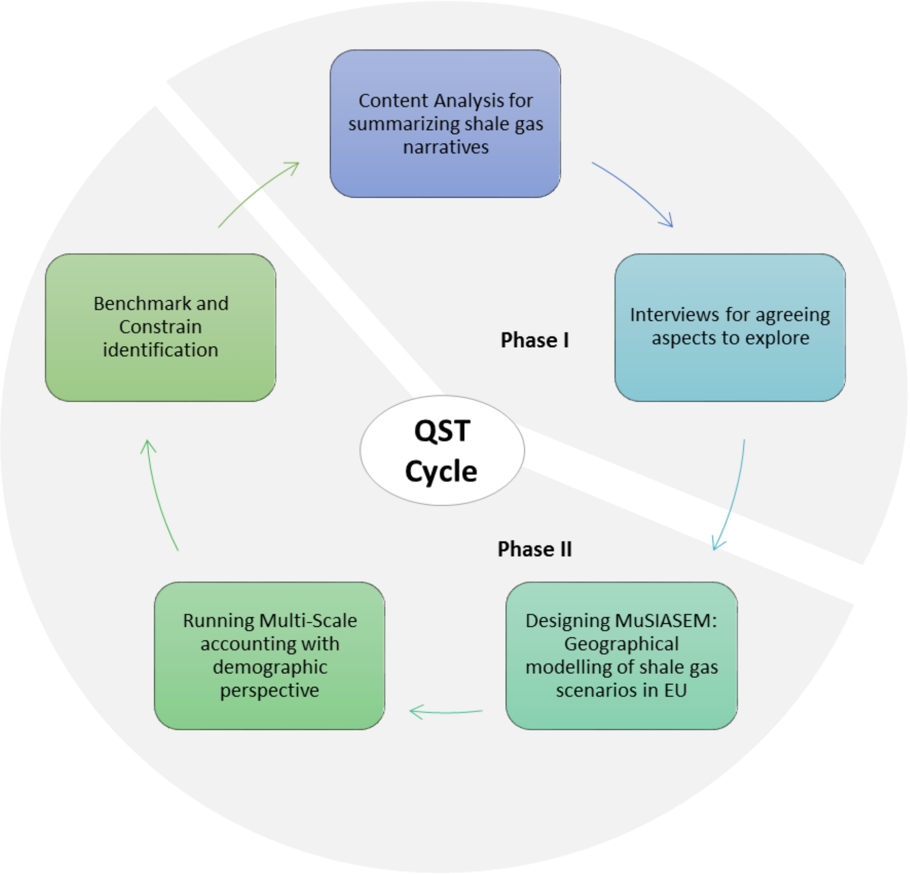
Overview

The European 2030 Climate and Energy strategy marks the effort of the EU to implement the Paris Agreement commitments. To that end, most member states plan to increase the share of renewable energy and natural gas in the energy mix. However, deterioration of the relations with Russia, the closure of the conventional gas field in Groningen, and the Brexit challenge natural gas supply within the EU.

Despite the many research and political efforts done to navigate the uncertain pros and cons of shale gas development, the trade-offs present in the water-food-energy (WEF) nexus and the difficulties of assessing them have prevented a horizontal agreement about the suitability of this innovation in general. Different methods return contrasting conclusions but there is a general agreement that stakes

Method

Fig 1. Implementation of the quantitative story telling cycle for innovation shale gas [1]



We identified two statements for the study in phase II:

- *Shale gas extraction in the EU can offset the closing of the Groningen fields and still cover 10% of the EU gas demand in 2035.*
- *The above production has the potential to reducing environmental impact in terms of CO_2 equivalent without producing a deterioration of status of the water bodies.*

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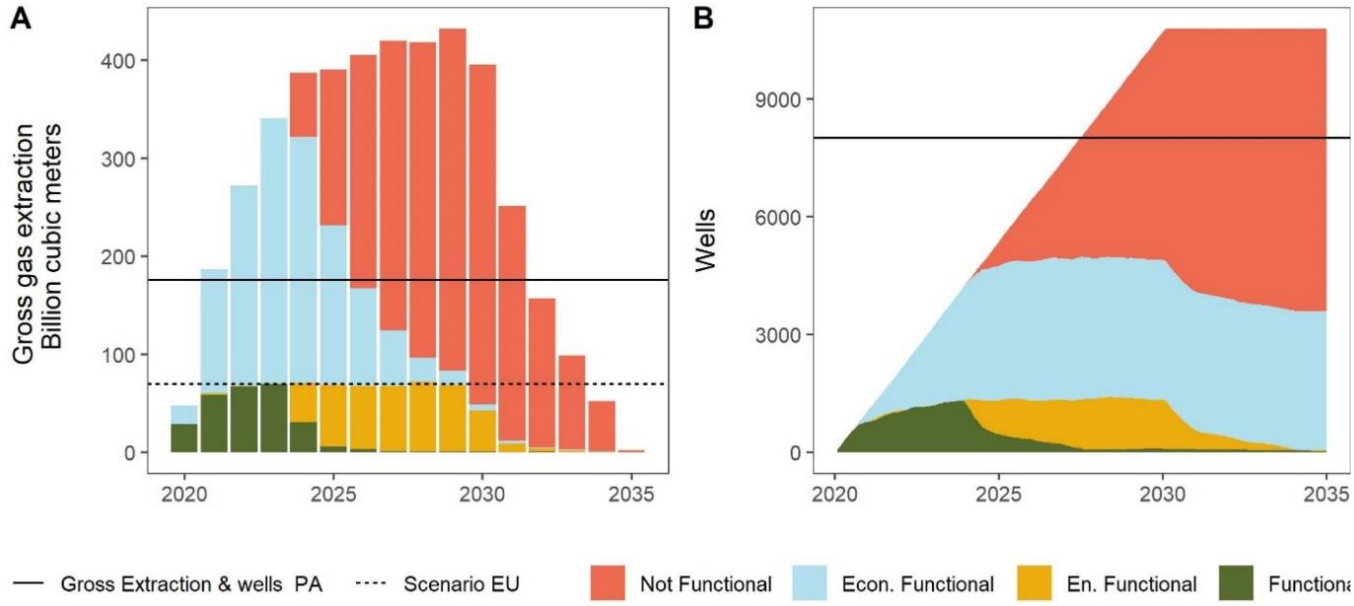
Fig 2. Evolution of number of wells per functional type (B) and of shale gas production (A) in the EU against the offsetting scenario and the production in Pennsylvania (PA) [2]



Recommendations:

- Shale gas net extraction (raw extraction minus energy use) would not be enough to meet EU needs.
- Some member states would be able to cover their needs with domestic extraction but current legislative framework give them freedom to sell their overflow out of Europe, thus not contributing to EU energy security.
- Due to the lowering of the gas prices, a fairly big high of wells will not cover their construction and maintenance economic expensive
- Methane emissions will be higher than for the extraction of conventional gas. Most of those emissions would come from wells that are not providing a surplus of energy.
- There are a few river basins that might not be able to meet the WFD commitments for the third review period. Most of the water use comes from the less productive or even unproductive wells.

CONCLUSION: The shale gas sector designed here will only be able to contribute to energy security while the sector keeps drilling and the wells are young. However it would not contribute to decrease GHG emissions and most of the environmental impacts will come from wells with negative return on investment.

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[1] Madrid Lopez, C. Forthcoming. Evolution of narratives about shale gas in the EU.

[2] Madrid Lopez, C. Forthcoming. Why we should not have shale gas in Europe? An evaluation of the demographic metabolism of shale gas development.

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