Geo-Metrics and Geo-Politics:
Controversies in Estimating European Shale Gas Resources

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Original publication: Kama, K., & Kuchler, M. (2019) Geo-metrics and geo-politics: Controversies in estimating European shale gas resources. In: Bobbette, A., & Donovan, A. (Eds), *Political Geology*. Cambridge: Palgrave Macmillan, pp. 105–145. DOI: https://doi.org/10.1007/978-3-319-98189-5_4.

Chapter 4. Geo-Metrics and Geo-Politics: Controversies in Estimating European Shale Gas Resources[1]

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Abstract: This chapter explores the relationship between geoscientific knowledge production and geopolitical agencies in the making of new subsurface resources, specifically unconventional fossil fuels. Focusing on recent controversies surrounding the assessment of potential shale gas resources in Europe, we analyse the ways in which highly speculative and contested resource estimates have come to inform the geopolitical imagination of many EU states and, in turn, provided a new impetus for geoscientific inventories and exploration of shale formations. In the first part of the chapter, we engage with recent volumetric accounts in political geography and cognate disciplines to conceptualize these epistemic struggles of resource-making as a case of "subterranean geo-politics". The empirical analysis in the second part then traces the geo-politics of shale gas prospecting in Poland and the UK, describing how volumetric projections of resource abundance have become undermined by diverse materialities and socio-political constructions of the subsurface. This is evidenced by the difficulties of translating knowledge across geo-economically disparate sites of resource development, notably the failure to apply the US-based expertise to the European context. Finally, we document more recent efforts by the European Commission and other epistemic authorities to overcome the deficiency and incompatibility of local resource estimates by developing standard, EU-specific geo-metrics for shale energy assessment.

Introduction

Following the oil crises of the 1970s, many countries around the world have begun to explore opportunities for self-sufficient energy production by exploiting local geological formations which are rich in organic matter and thus a potential source of hydrocarbons. These diverse sedimentary deposits have been known for decades, but unlike conventional oil and natural gas resources, they have previously been considered either too difficult to access or sub-economic compared to hydrocarbon extraction, and consequently, only marginally studied by geologists. In light of growing concerns over declining hydrocarbon availability and energy security, however, the exploration of "unconventional" fossil fuels has rapidly intensified and already begun to transform both global energy economies and local livelihoods, especially concerning the exponential growth of shale gas, tight oil and bituminous sands production in Canada and the U.S. over the last two decades. At the same time, the emergence of unconventional hydrocarbon development has also generated unprecedented scientific controversy and public opposition to the industry, not least due to concerns over the radical uncertainties and latent hazards associated with the penetration of previously unexplored segments of the subsurface, the long-term economic feasibility of such boom-bust industries and, critically, their compatibility with international climate policy objectives (e.g. Neville et al. 2017; Mitchell, 2013; Willow and Wylie 2014). These controversies are compounded by recent efforts to replicate the "success" of the North American industry in other parts of the world, in substantially different geophysical and regulatory contexts (Neville et al. 2017; Stevens 2010).

[1] Kama K. and Kuchler M. (2019) Geo-Metrics and Geo-Politics: Controversies in Estimating European Shale Gas Resources. In: Bobbette A. and Donovan A. (Eds) *Political Geology*. Palgrave Macmillan, Cham, pp. 105-145.

The unprecedented rate at which the development of unconventional fossil fuels has taken off and become widely contested highlights a need to examine what makes little known geological occurrences to be deemed somehow worthy of exploitation and, indeed, how such heterogeneous organic-rich substances become reappraised and acted upon *as resources* in the first place. Like any resources, hydrocarbons are clearly not defined and given once and for all, but rather their essence and significance are continuously (re)made via competing scientific, political and economic interventions. By attending to the constitution of the subsurface as new sources of hydrocarbons, this chapter moves beyond popular accounts of the geopolitics of resources in political economy and international relations, which leaves the essence of resources themselves largely uninterrogated by regarding them as either a tacit background of inter-state competition over the access and control of material supplies, or as a key determinant of the political and economic performance of the producing countries. Departing from questions of "resource-claiming", our approach instead resonates with recent efforts in critical resource studies to conceptualize the collective practices of "resource-making" as distributed across multiple agencies, including the materialities of geological substances themselves (Ferry and Limbert 2008; see also Bridge 2011, Kama 2013; Kök-Kalaycı 2016; Li 2014; Weszkalnys and Richardson 2014). In this context, our aim is to develop an account of resource-making as a form of *politics of knowledge* over subterranean matters – and, further, to analyse how struggles around resource-making endeavours may reconfigure what we traditionally understand as geopolitical expertise and authority. Focussing on the assessment of unconventional fossil fuels in Europe, this analysis is specifically driven by a notable paradox: while there are currently no reliable estimates of shale gas and oil resources due to a substantial lack of both geological research and exploratory drilling, such estimates are nevertheless routinely produced and circulated by different epistemic authorities. As a result, these highly speculative projections of abundant hydrocarbon resources come to inform geopolitical visions of resource and energy security at both national and supranational levels, including the European Union (EU). In turn, however, these volumetric appraisals of resource abundance also provide a new impetus for geoscientific prospecting and inventories, which not just continue to constitute heterogeneous subsurface realities as potentially exploitable resources, but simultaneously also sustain the political hopes and aspirations concerned with security of hydrocarbon supplies and energy self-sufficiency.

The chapter therefore has two main objectives. In the first part of the chapter, we develop a conceptual framework for interrogating the relationship between geoscientific knowledge production and geopolitical agencies in the context of new extractive resources development. In the next section, we conceptualise the epistemic struggles of resource-making as a form of "*subterranean geo-politics"* (cf. Valdivia 2015; Barry and Gambino, forthcoming), with the aim to contribute to recent scholarly efforts to develop volumetric approaches to political geography and critical geopolitics. Moving beyond conventional accounts of the geopolitics of resources, the notion of "geo-politics" is used here to denote not just the significance of the subsurface to nation-building exercises (cf. Bridge 2014; Kuchler and Bridge 2018; Perreault and Valdivia 2010), but also a wider array of epistemic practices and political disputes that take issue with subsurface potentialities and indeterminacies. We argue that there is a need to complement emerging discussions around "political geology" with an analysis of the controversies arising from both scientific prospecting and politico-economic calculations of subsurface volumes, including how these codified practices open up new vectors of contestation and interrogation, beyond the domains of industry expertise and governmental politics. In this context, our analysis also shows how geoscientific inventories function as key performative devices which enable the collective exploration of “post-conventional energy futures” (Kuchler 2017) more generally in expert, political and public spheres.

Following from this analysis, the empirical discussion provided in the second part of the chapter documents the struggles of rendering diverse subsurface geologies into stocks of unconventional gas, and explores how these interventions become “translated” between geo-economically disparate locations of extraction and “metrological regimes” (Kama 2014; Kuchler 2017; Barry 2006; see also Latour 1987; Miller and Rose 2008). After providing an overview of the European context for shale energy development, we proceed with an in-depth analysis of the controversies surrounding recent projections of shale gas availability in Poland and the UK. Due to scant geological knowledge on European shale basins, initial estimates of potential resources were highly provisional and based largely on extrapolations of American shale play analogues. Yet, we observe that these estimates still had immediate geopolitical effects as they came to inform national energy security strategies and multiplied the number of exploration licences issued in several countries, while also raising significant public concerns and fuelling competing visions of possible energy futures in Europe. The next section further documents recent efforts to develop a more locally-specific knowledge base along with appropriate “geo-metrics” (Elden 2013) specifically for European shale basins, without relying too much on the American experience. Following the recent failure of commercial exploration in Poland and the proliferation of public discontent across the continent, there is now growing recognition that the EU needs to develop a uniform, “pan-European” approach to shale resources assessment and governance. However, while these efforts consolidate the vision for Europe’s common energy policy and resource governance, we observe that they likewise continue to be undermined by heterogeneous materialities of the subsurface and its divergent socio-political constructions.

Political geology: measuring and governing subterranean volumes

By examining the politics of geoscientific knowledge production concerned with anticipating, prospecting and appraising the availability of new subsurface resources, our chapter engages with growing scholarly efforts to move beyond the conventional definition of geopolitics as power struggles over given geographical territories endowed with limited resources. In addition to the common notion of the “geos” as a *geographical* extension, terrain or territory (see Elden 2010), there is now a resurgence of academic interest in the politics of the *geological*, concerning how diverse political and epistemic communities make sense of and interact with earthly materials and forces which far exceed human control, yet at the same time continue to be inextricably entangled with the “geo-body” of nation state sovereignty. A broad question that guides our interest is therefore “how should the geopolitical take account of the geophysical?” (Elden 2014, 2017). On the one hand, we ask how the underground is rendered intelligible and governable as a strategic energy resource when its actual qualities and latent potentialities are not directly visible to human gaze and, worse still, unfold over geological timescales that transcend our limited histories of extractive capitalism? On the other hand, however, we also explore how these practices of envisioning the “known unknowns” of the subsurface (Kuchler 2017) implant powerful geopolitical imaginaries that create a possibility for new forms of political strategy, action and contestation (Bridge 2013; Barry and Gambino, forthcoming). In this regard, our analysis concurs with recent calls to account for the sociopolitical constitution of the geos in relation to the indeterminate, yet differential capacities of subsurface materials themselves, or what been interchangeably labelled as “geologic politics” or “political geology” (e.g. Barry 2016; Bobbette and Donovan, this volume; Clark 2013; Yusoff 2013). But it does so by drawing upon recent scholarly literature which employs the governmentality lens to critically explore how the (sub)terrain is rendered an economically calculable and politically governable domain by virtue of different techniques and practices of geo-expertise (Agrawal 2005; Braun 2000; Elden 2007; Kuchler 2017; Ó Tuathail 1996; Rose-Redwood 2006).

As a first step towards augmenting the notion of geo-politics, our study therefore calls for closer analysis of the ways in which geopolitical performances of hydrocarbon security (cf. Bridge 2015) come to be infused with provisional, often highly speculative scientific claims on heterogeneous subsoil structures and materialities which do not easily allow for classification and measurement. This is particularly the case in unconventional fossil fuels development, as these resources have until recently deemed either inaccessible or sub-economic for extraction, and hence been only scantly covered by geological surveys and exploratory drilling. Yet, it is important to note that the existence and sheer size of such geological deposits has for a long time captivated the geopolitical imaginations of energy sovereignty and resource-based economic modernization amongst many resource-holding countries that lack access to conventional hydrocarbons, especially when such aspirations converge on the life-long efforts of geoscientists and technology developers to utilize new geological substances as resources (Kama, forthcoming). In the resurgence of interests in such “indigenous” geo-energy resources, political aspirations can thus open up both investments in scientific research programmes and companies’ access to concessionary rights. At the same time, however, geoscientific abstractions of the subsurface may themselves become “a terrain of geopolitical uncertainty”, as noted by Valdivia (2015: 1427). Indeed, such projections of “geological potential” can easily fail to materialize, for example, when drilling holes reveal no significant findings and exploration projects become suspended or indefinitely delayed (Weszkalnys 2015). Yet, similarly to recent observations of other nascent extractive economies, our analysis shows that speculations around geological prospectivity create a significant “economy of expectations” (Weszkalnys 2011) which enables government funding and investment capital to flow into the sector even *in the absence* of reliable data, not to mention evidence of actual production (see also Kama 2013; Kuchler 2017; Weszkalnys 2015). Meanwhile, continued support for geoscientific research on unconventionals can easily raise concerns that the government has already opted for particular modes of energy production and, in this way, come to serve as new vectors of contestation and public discontent with the industry. As a result, geoscientific knowledge controversies problematize existing affairs and open the design of “post-conventional energy futures” up to wider public interrogation (Kuchler 2017; Kama, forthcoming). This has important democratic implications insofar as such controversies lead to the formation of novel political engagements and collective identities around the subsurface. More conceptually, this also begs the question of what difference the “geos” itself, in its various socio-material manifestations, makes to the conduct of extractive politics.

By exploring the interaction of geosciences and geopolitics in the making of subsurface resources, our analysis therefore resonates with a growing interest in “vertical territories” (Braun 2000, Elden 2013) and “volumetric” approaches to political geography and critical geopolitics (e.g. Adey 2015; Barry and Gambino, forthcoming; Bruun 2018; Clark 2013; Dalby 2013; Huber and McCarthy 2017; Squire 2015; Steinberg and Peters 2015; Melo Zurita et al. 2017). In particular, we follow Elden’s (2013) call to critically examine the political technologies of “securing the volume” in respect of subsurface (and aerial) formations and infrastructures, which importantly extends the question of territorial control beyond the two-dimensional perspective of bounded areas of state jurisdiction. Developing Elden's argument further for critical resource geographies, Bridge (2013) affirms that we need to move beyond a simple "3-D" perspective and specifically account for the practices through which the subterranean realm becomes imagined and reappraised as stocks of resources that are deemed essential for future exploitation and consumption. As Bridge argues, "volume is a primary metric of anticipation and potential: calculations of what space contains (cubic meters of gas, ounces of gold), and what contained materials mean that space could become, are essential to the performance of resource landscapes" (Bridge 2013: 56). Indeed, it is the question of the *future prospectivity* of subsurface materials which is central to any efforts to render geological strata into new kinds of resources, not just a matter of accurate representation of what is hidden deep beneath the country's territory, beyond already-known accumulations.

A key issue to vertical geopolitics is that the bowels of the earth are not directly accessible to the human eye and hence "cannot be measured directly" (Mitchell 2013: 244). To be governed, any geological formation needs to be first rendered intelligible and calculable via a range of abstractive and cartographic practices (i.e. surveying, mapping, prospecting, assaying, seismic imaging, 3D modelling etc.) (Braun 2000; Kuchler 2017). The invention of such calculative practices, or "geo-metrics" (Elden 2013; Dalby 2013), is thus central to the political rationalities of government in rendering subterranean volumes into a space of national scientific enquiry, identity and security – indeed, part of the "geo-body" of the nation. At the same time, the performance of such geo-metrics of resource assessment is plagued by radical uncertainties, arising from both the uneven dynamics of subsurface stratigraphies and the limits of technological intervention in accessing these stratigraphies. As such, the extent to which state-building exercises and their relationship with global capital come to rely on particular geo-metrics is inevitably prone to scientific controversy, corporate speculation and political contestation (Bridge 2013; Valdivia 2015).

Further, any calculation of subsoil volumes not just needs to account for invisible, geophysically and geochemically variegated sedimentary layers, but simultaneously provide estimates of their future production. On the one hand, the process of abstracting, classifying and measuring the messy subsoil world is anything but straightforward. As Bowker suggests in his historical analysis of the early days of oil exploration, it takes a lot of time and work to define a unit of measurement for resource assessment and simultaneously *maintain* this unit with the help of a set of technical, managerial and social techniques. This "infrastructural work" eventually comes to define how the invisible world of the underground is pictured in the scientific discourse, which inevitably gives some experts a vantage over other possible ways of constituting the subsoil as a resource (Bowker 1994). Developing the perspective of Science and Technology Studies, resource estimates should not be understood as representing physical objects, but rather as social constructs which are necessarily *performative*, insofar as such projections themselves begin to "create new objects and realities" for resource and energy governance (cf. Barry and Slater 2005: 11).

On the other hand, the problem of calculation involves also the paradox that resource inventories are "far from stable objects" but expected to have a cumulative effect in time (Bridge 2010: 527). For crude oil and natural gas assessment, the quantity of resources suitable for recovery and production is not assumed to be given once and for all, but only estimated within a certain timeline or "forecast span", and therefore expected to increase when technology improves or fears of scarcity bring previously non-economic sources to the market. For unconventional hydrocarbons, the technological dimension – vis-à-vis geological characteristics of the subterranean strata – is of particular importance in estimating the recoverability factor. Unlike conventional methane which is held in naturally occurring geological reservoirs, the unconventional gas "reservoir" must be *created* or made permeable by hydraulically fracturing the shale rocks (Kuchler 2017: 37). Accounting for possible technological (and economic) developments is thus key to the reappraisal of heterogeneous subsoil formations as hydrocarbon resources which are expected to become exploitable in not so distant future. Broadly speaking then, the geo-metrics of resource assessment do not just provide volumetric representations of below-ground realities, but also operate as *projective devices* which guide future flows of production and, in this way, enable prospective extractive economies to be anticipated and become politically operational in the present (Barry 2008; see also Weszkalnys 2015; Wood 2016).

The appraisal of shale gas resources in Europe, like any fossil fuels assessments, is thus underpinned by the crucial distinction between resources and reserves, specifically between total gas resources estimated to be geologically available or *original gas "in place"* (OGIP) and *technically recoverable resources* (TRR), which are only a fraction of the total geological resources (see Kuchler 2017; McGlade 2012; McGlade et al 2013). Importantly, as McGlade et al. (2013) explain, TRR includes not just known deposits which are assumed to be feasible to exploit with currently available technologies, but it also may or may not contain projections of unknown formations that are yet to be discovered. Unlike American shale gas resources which are already exploited at a commercial scale, the discoveries in Europe are not yet calculated as *economically recoverable resources* (ERR), because this would require longer term evidence of production flows. Curiously, however, they are occasionally still expressed as "reserves" with decreasing degrees of probability – respectably, proven (P90), probable (P50), and possible (P10) reserves. In practice, there is widespread confusion in applying this overall framework (see e.g., Bradshaw et al. 2015), because the ways in which such categorizations are established depend on the specific geophysical properties of the basin as well as the presence of particular technological solutions (and politico-economic conditions) which inevitably change over time. For geologists, it is thus common sense that any appraisals of subsurface resources are always "estimates, not measurements" (Klett 2004: 595). In consequence, the geo-metrics of resource appraisal tend to vary across different types of hydrocarbons, as well as between the practices of national geological surveys and other institutions of resource-holding countries. Furthermore, in situations where geological data is obsolete, deficient or patchy, as in the case of European shale formations, estimates of resource recoverability (or more specifically, TRR) must be routinely conducted by analogy to other basins which are better explored or already in production, such as shale plays in the USA. This is based on the idea that the subsurface is *continuous* across the earth's crust and hence possible to reveal through standardised methods and devices (Kuchler 2017, cf. Foucault 2002).

A related question is thus how such geo-metrics of resource assessment are translated across different institutional standards associated with specific geo-economic settings, or what Barry (2006) terms "metrological regimes". Although the overall framework for fossil fuel resources assessment has become more standardized over time, national geological surveys and their counterparts have typically developed their methods in close association with the material properties of local deposits and the technologies developed for their exploitation. Moreover, these methods reflect historically embedded meanings and definitions of resources or "resource ontologies", which are specific to these localities (Kama 2013, 2016; Richardson and Weszkalnys 2014). This is particularly the case for organic-rich shale formations, the production of which has until this date remained geographically limited to a few larger prospective basins. As a result, estimates of unconventional resources – and recoverable resources, in particular – are not always commensurable across different countries; especially when it comes to less-explored geological occurrences that are not yet subject to commercial exploration. So, the key question is which "centres of calculation" (Latour 1999) will get the upper hand in defining the terms and methods of assessment for new subsurface resources. While particular geological surveys and industry actors can be expected to dominate the field and set the standard for others, their "infrastructural work" (Bowker 1994) may also become challenged or disputed, not least due to the vast heterogeneity of world deposits. Yet, it can be difficult to dispense with such volumetric imaginaries of a singular, global resources base, because these estimates are central to capital accumulation and speculation, especially in the context of increasing financialization of extractive industries (Kama, forthcoming). Resource inventories therefore always operate as "gestures" towards future prosperity and profit for industry and resource-holding governments alike and therefore continuously add to the making of resources as *economic assets*, not just as representations of geological realities (Weszkalnys 2015; cf. Tsing 2005).

Making shale a resource for Europe

Following the "revolution" in U.S. shale gas development over the past two decades, significant attempts have been made to replicate the industry in other parts of the world, notably in Europe, but also in Argentina, Australia, China and Russia (Neville et al. 2017). In the popular geopolitical literature, the European continent is typically described as the arena of intense and controversial power struggles over securing its natural gas supplies along the transnational assemblage of pipelines and political relations that mediate energy flows especially between the East and West (Bouzarovski and Konieczny 2011; Bouzarovski et al. 2015; Hiteva and Maltby 2014). Following this perspective, one of the obvious reasons for the growing enthusiasm to develop domestic shale resources amongst some EU member states and energy companies is the concern with increasing dependence on and disruptions of gas imports from Russia (Kuhn and Umbach 2011; Medlock et al 2011; Sakmar 2011). Triggered particularly by the Russia-Ukraine gas conflict in 2009, these concerns of supply security were further ascertained by intense energy diplomacy, such as establishment of the U.S.-EU Energy Council in November 2009 and the promotional tour of the former U.S. Secretary of State Hillary Clinton around European countries in 2012. These diplomatic exchanges led to attempts to experiment with implementing the U.S.-based technological expertise in Europe, or what has also been called a "shale gas laboratory" (Blake 2014; EC 2009: 10).

At the same time, the development new fossil fuel resources is seemingly at odds with the efforts of the EU to assume global leadership in climate policy by significantly curbing its greenhouse gas emissions. Indeed, many actors in Europe would argue that continued reliance on fossil fuels contradicts the transition to a lower-carbon energy system. By contrast, some member states and industry experts have promoted domestic shale energy production as the key option to facilitate supply diversification and to help reduce dependence on external providers, notably Russia (e.g. Gený 2010; Kuhn and Umbach 2011) – instituted with the approval of the EU Energy Security Strategy in 2014 and the increasing "securitization" of energy as a trans-European policy issue under the Energy Union agenda (Kama 2016; Judge and Maltby 2017). Deploying the rhetoric of shale gas proponents in other parts of the world (see Neville et al. 2017), some policy institutions and experts have thereby from early on framed shale gas as "bridge fuel" which alongside conventional natural gas is claimed to be compatible with the de-carbonization agenda and suited to facilitate EU climate policy objectives (IEA 2011, 2012). Other political and scientific authorities in Europe, however, have been much more cautious due to deficient understanding of both potential gas resources and their technical recoverability, not to mention growing public discontent with prospective exploration projects (e.g. European Parliament, 2014; McGlade et al. 2016). Consequently, the debates over whether the industry is technologically and economically feasible or even socio-politically desirable have become quickly polarized between and within EU member states; culminating with temporal moratoriums or outright bans on fracking enforced in Bulgaria, France, Germany, Ireland, Netherlands, and also parts of the UK (Wales, Scotland). Moreover, for the EU authorities in Brussels, any considerations of shale gas and oil as an energy policy option have arguably become much more complicated after the Paris Agreement.

What is omitted from this account of the political controversies surrounding shale energy development, however, is that the scientific knowledge base for assessing the potential resource remains highly uncertain and unequally covered across the European continent, especially with regard to those resources that can be recovered with currently available technologies. Until this date, very few exploratory drilling wells have actually been completed (e.g. maximum 72 in Poland), so there is simply not enough bottom-up data to more accurately evaluate either the technical recoverability of the shale gas and oil found in specific European basins, or the technological and environmental risks associated with the characteristics of local geological formations. Yet, as we proceed to discuss below, with the "known unknowns" of shale prospecting (Kuchler 2017) on the table, geoscientific institutions across Europe are still keen to seek and accept funding for geological surveys and research, and hence also more likely to support the industry's applications for commercial exploration. While more exploratory drilling certainly improves existing knowledge of geological formations, it is also feared to encourage political support for the industry and consequently drives public opposition, as the proliferation of "anti-fracking" protests around drilling sites across Europe makes acutely clear (e.g. Bradshaw and Waite 2017; Lis and Stankiewicz 2016; Short and Szolucha 2017; Vesalon and Creţan 2015). Indeed, we observe that the production of geoscientific knowledge *overall* has become subject to controversy, because it appears to solidify the position of shale energy as a legitimate policy option, rather than enabling better deliberation of possible energy futures for Europe (see also Lis et al., forthcoming).

Epistemic struggles in resource assessment: Poland and the UK

Poland

The existence of organic-rich shale deposits beneath Poland's territory became better known when a series of deep boreholes were performed between the 1950s and 1960s in the Lower Palaeozoic formations (i.e. Upper Ordovician and Silurian) as part of the national geological survey (Sokołowski et al. 1970). Yet, back then the natural gas potential of the documented organic content was either ignored or omitted due to lack of know-how and technology to access such substrata at that time. It was only since around 2006, following the "fracking" boom in the U.S. and with a working technology supposedly in place, that Polish geologists have again hypothesized on the possibility of utilizing the organic-rich formations for domestic shale gas exploration, although this time from Upper Ordovician–Silurian shale formations in the Baltic-Lublin-Podlasie basins located in north-east

Poland (Kiełt 2010; Poprawa 2010; Poprawa and Kiersnowski 2008) (see Table 4.1). While this presupposition of abundant gas resources initially concerned a relatively large area, it was based on skimpy and historical data rather than on a robust number of up-to-date test drillings. Hence, since 2007, Poland's Deputy Minister of Environment and Chief National Geologist at that time, Professor Mariusz Orion Jędrysek, started granting concessions for prospecting and exploration to both national and foreign companies, with most operations concentrated in the Baltic and Podlasie basins (MOŚ 2016). At that point, licencing was deemed necessary to give an incentive to the industry that could perform bottom-up well tests and thus be in a better position compared to the state geological survey to estimate the production capacity of shale gas in designated areas. Over the next seven years, however, the majority of exploration drilling results turned back inconclusive. All major international energy corporations – Chevron, CoconoPhillips, Exxon Mobil, Shell – pulled out of the country after drilling a total of 72 test wells, claiming that there were no substantial amounts of economically recoverable gas to be found – but somewhat more ambiguously also hinting at disagreements with the government over regulations and revenue distribution (Anderson 2014). By 2017, most companies had stopped or suspended exploration, including Polish energy companies.

This relatively short-lived boom of interest in the Polish shale gas potential has commonly been associated with the state's struggles to maintain its natural gas supplies in the context of frequent disruptions to gas deliveries from Russia to Europe. Indeed, we contend that whilst the organic rich content in shale formations had fascinated local geologists for a longer time, it was eventually brought into existence *as a shale gas resource* in direct response to calculations of geopolitical risks associated with Russian supplies and the growing efforts to replicate the U.S. experience of fracking to other countries (cf. Kama 2016). Although natural gas continues to play a marginal role in Poland's coal-dominated energy mix (Kuchler and Bridge 2018), particularly in electricity production, since the 1990s subsequent governments have struggled to diversify imports – which cover around 70% of consumption – and reduce both infrastructural and supply dependence from Russia. Notably, in response to the gas disputes between Russia and Ukraine in 2006 as well as between Russia and Belarus in 2007 (and the launch of Nord Stream pipeline that bypasses central-eastern European countries), the Polish authorities were frantically looking for means to increase national energy security through diversification of gas supplies, which amongst other plans included a terminal for liquidified natural gas (LNG), a proposal for the Baltic Pipeline and other infrastructural investments. Following the second Russia-Ukraine gas crisis in 2009, the geopolitical significance of the shale gas promise was further spurred by Poland's struggles to re-ratify the long-term gas deal with Gazprom. Intensely negotiated in 2010, the contract with Gazprom was highly criticized by the wide spectrum of the national political arena, energy experts and media outlets. The European Commission had to intervene in the negotiation process because the proposed agreement did not comply with the rules of the EU Gas Directive adopted in 2009 as part of the EU energy market legislation aka The Third Energy Package. Hence, the prospect of producing indigenous unconventional gas was, perhaps unsurprisingly, quickly appropriated by Polish politicians and industry experts as an ideal way to fix the country's supply problems and to move towards national energy sovereignty. Moreover, this view was keenly supported by the U.S. government, who also lamented the Russian (Gazprom's) actions as a threat to European countries' independence. This led to intense diplomatic efforts to facilitate cooperation with the American shale gas industry, which took place between 2009 and 2011, amongst others with former Secretary of State Hillary Clinton visiting Warsaw in 2010 and discussing the industry's prospects with Poland's former Ministry of Foreign Affairs Radosław

Sikorski. During the meeting between Clinton and Sikorski it was announced that Poland would join the US in the Global Shale Gas Initiative (GSGI), through which both countries would expand their "cooperation to promote environmentally-sound shale gas development in the context of a global forum of selected countries worldwide" (U.S. Department of State, 2010). Furthermore, the Polish government also strongly promoted fracking developments on the EU arena, for example, by using its EU presidency in 2011 for forwarding shale gas as a geopolitical "game changer". Later, in cooperation with other East European member states, the government also successfully lobbied for "sustainable production" of indigenous fossil fuels to be prioritized in the first EU Energy Security Strategy which was adopted in 2014.

Table 4.1. Estimates of (risked) technically recoverable resources (TRR) of shale gas in Poland

Sources	**Tcm**[a]
Wood Mackenzie (2009; see PGI 2012)	1.36
ARI (2009)	2.83
Rystad (2010; see PGI 2012)	1
Kuhn and Umbach (2011)	1.86
EIA/ARI (2011)	5.29
USGS (2012)	0.11[b]
PGI (2012)	1.92[b]
EIA/ARI (2013)	4.19
EIA/ARI (2015)	4.13

[a] Trillion cubic meters
[b] Maximum estimated value

In line with these diplomatic efforts, a number of persuasive, albeit highly uncertain volumetric imaginaries of shale gas estimates for Europe started to surface at private industry conferences and expert meetings (e.g. Wood Mackenzie 2009) (Table 4.1). One of the first publicly available reports indicating that the territory of Poland could be conceivably rich in unconventional gas came from a US-based private consulting and research company called Advanced Resources International (ARI). Published in 2009, the report pointed to three geological regions in Europe that might have productive deposits: the Silurian Shales in Poland, as well as Alum Shale in Sweden and Mikulov Shale in Austria. For the Polish shales, ARI (2009: 14) preliminarily estimated "the unrisked resource endowment" to be almost 20 Tcm with "a risked recoverable resource" (TRR) of up to 3 Tcm. Although ARI's estimates were based on the scanty historical research on geological formations in Western and Eastern Europe, they indicated that shale gas potential was twice as large for the region than assumed by Rogner's top-down speculations on unconventional resources (Rogner 1997).

Two years later, the U.S. Energy Information Administration (EIA) delegated ARI to perform a more comprehensive assessment of unconventional gas availability worldwide. Published in 2011, the EIA/ARI report now projected that the volumetric territory of Poland could contain up to 5.3 Tcm of technically recoverable shale gas resources (EIA/ARI 2011) – the highest estimate of all so far and, perhaps unsurprisingly, also the figure most often referred to by Polish policy and industry actors. However, similarly to the ARI report from 2009, this projection was also based on local historical well log data on Silurian shales in Poland – the same knowledge that had already been used by Polish geologists to generate volumetric imaginaries of resource abundance since 2006. In other words, no new test wells were performed to provide data for this appraisal and the number was speculated purely on the basis of previous assumptions regarding the geological structures identified as Lower Palaeozoic. Contrary to the previous ARI (2009) report that discussed Polish Silurian shales as a single geological layer, however, the 2011 assessment distinguished between three basins in which Lower Silurian-Ordovician shales were deposited: the Baltic basin, the Lublin basin, and the Podlasie basin. According to the report, “the organically rich shales in these three basins appear to have favorable characteristics for shale gas exploration” (EIA/ARI 2011: 135). With this assertion, the promise of organic content was brought into existence as a definite shale gas resource and thus established the possibility of its recoverability. The list of favourable characteristics, however, was limited to only four parameters: reservoir pressure, average TOC (total organic carbon), thermal maturity, and clay content – an insufficient amount of data that yields highly speculative assumptions. Most of gas potential was allocated for the Baltic basin, with amount of 3.6 Tcm TRR.

In 2012, the Polish Geological Institute (PGI) published eagerly awaited estimates for shale gas recoverable resources in the onshore and offshore Baltic-Podlasie-Lublin basin (PGI 2012). It is important to note that this inventory was prepared primarily by the Polish geologists in cooperation with the U.S. Geological Survey (USGS). According to the PGI’s report, the maximum potential of Poland’s shale deposits was now downgraded to be only 1.9 Tcm. Worse still, the “probability range of *recoverable* shale gas resources” was projected to be only between 0.34 and 0.76 Tcm (PGI 2012: 5). As these estimates were significantly lower compared to previous projections by the U.S. epistemic authorities (2011, 2013), the PGI’s results were perceived as deeply disappointing by Polish policy-makers, energy experts and industry representatives (for analyses of the political debate, see also Godzimirski 2016; Lis and Stankiewicz 2016). Due to a continuous lack of sufficient data from up-to-date test wells – including data on “porosity and permeability of shale reservoir, gas composition, reservoir pressure or initial production” – the PGI’s assessment was made by applying “average Estimated Ultimate Recovery (EUR) from each individual well, and average well drainage acreage” adopted from the analogues of North American shale basins (PGI 2012: 4). Three alternative scenarios were adopted based on different productivity levels of the U.S. analogues: poorly performing shales for the minimum, lower range producing cluster of shales for the optimal, and some of the best performing shales for the maximum (PGI 2012: 18). Being unable to come up with one definite volumetric appraisal for the Polish resource potential, PGI thus provided a wide array of values ranging from 37.9 bcm to 1919.7 bcm (19.2 Tcm) for both onshore and offshore basin areas (PGI 2012: 25). Since such extreme values have very little certainty, PGI then concluded that the most optimum numbers would be somewhere in the range of 346.1 to 767.9 bcm.

Despite being highly appealing to the Polish government, the largely speculative nature of these volumetric imaginaries have not gone uncontested. For example, the concerted efforts of the Polish government and geological survey to assess and prospect domestic gas resources were heavily criticized by Poland’s Supreme Audit Office (NIK 2013; 2017). In its latest report from 2017, the audit office concluded that the activities undertaken to appraise the resource potential had so far been insufficient, which meant that the estimates provided by PGI cannot be considered credible and conclusive. The critical issue was an insufficient amount of test wells performed and, consequently, lack of findings that would allow for allocation and credible estimation of the volumetric potential of recoverable deposits. According to the audit report, for any estimates to be reliable there should be least 200 test wells drilled, but at the current rate of prospecting it would take at least 12 years to achieve this number (NIK 2017).

United Kingdom

Like the Polish shales, the British subterranean strata with organic-rich content have been known to local geologists since the end of the nineteenth century, but they were disregarded or overlooked by the energy industry until the mid-1980s (Royal Society 2012). According to the British Geological Survey (DECC/BGS 2010: 1), "shale has not previously been considered a hydrocarbon reservoir rock in the UK, but instead its organic-rich shales have been studied as world-class source rocks in which oil and gas matured before migrating into conventional fields." Following the shale gas boom in North America, however, there has been a rapid growth of interest in performing more thorough geoscientific appraisals that would lead to estimating the UK's shale gas endowment. Somewhat similarly to the Polish context of resource-making, the government's interest has been supported by concerns about dwindling natural gas supplies. In this case, however, the government has been worried about the depletion of conventional gas reservoirs located in the North Sea and its consequent dependency on global gas markets and prices, spurred by a growing demand for gas which resulted from the policy to divest from coal as the key source of power generation until recently (Bradshaw et al. 2014; McGlade et al. 2016). According to a detailed analysis of Kök-Kalaycı (2016), the issue of UK gas security has thus played a distinctive geopolitical factor in making shale gas a resource for the nation and building enthusiasm for commercial exploration, articulated as the possibility of harvesting "home-grown" energy resources and going "all out for shale", which has been the political rhetoric since David Cameron's government came to power in 2010.[2] Yet, as in Poland, recent volumetric speculations as to whether the organic-rich shale formations, located hundreds of metres beneath the country's surface, might actually have the potential to produce unconventional gas through fracking have so far been based on historical and scanty geological data, with remarkably little drilling conducted exclusively for shale gas exploration – indeed, only 4 wells to date.

Contrary to Poland, where natural gas continues to be a marginal source in the national energy mix and particularly in coal-dominated electricity production, the UK's gas consumption has played a significant role in the recent decline of coal. In 2016, almost 45% of electricity output and 85% of heating in the UK was generated by gas (Carbon Brief 2017). The British use of gas accounted to almost 80 bcm in 2016, of which 34 bcm came from imports via pipelines from Norway and the Netherlands, noting a 22% rise compared to 2015 (BEIS 2017; BP 2016). As a result, the UK policy-makers and the energy industry have been navigating between two strategic lenses with natural gas in focus: one related to the securitization of supplies and the other concerned with decarbonisation of the energy system. Gas, including shale gas, has thus become appraised by some government officials and experts as a key "bridge fuel" that could facilitate the country's efforts to achieve a low-carbon energy economy by 2050 and meet international climate policy commitments (e.g DECC/DCLG 2015; Task Force 2015). Yet, this framing has also been fiercely challenged by other leading energy experts (Bradshaw et al. 2014; Broderick et al. 2011; McGlade et al. 2016). Besides the "bridge fuel" narrative, policy-makers have also embraced the British shale gas potential to ensure future supply security, as the country faces decline of domestic conventional gas production

[2] UK government's shale gas policy is available: https://www.gov.uk/government/publications/about-shale-gas-and-hydraulic-fracturing-fracking/developing-shale-oil-and-gas-in-the-uk. See also the speech of Andrea Leadsom, former Minister of DECC, at the Shale World UK 2016 conference, https://www.gov.uk/government/speeches/governments-vision-for-shale-gas-in-securing-home-grown-energy-supplies-for-the-uk

and increase of imports, with DECC projections suggesting that net imports could reach up to 73% by 2030. Hence, in their statement on UK shale gas policy in 2015, DECC and DCLG concluded that "…developing home-grown shale resources could reduce our (and wider European) dependency on imports and improve our energy resilience" (DECC/DCLG 2015). Hence, the (re)discovery of potential shale gas beneath the UK onshore territory and its volumetric representations, albeit highly uncertain, have opened up a possibility to redefine energy geopolitics in the UK context, and in Europe more broadly, as it conveys the promise of recovering from the rising instability of both physical supplies and gas prices.

In this context, as Kök-Kalaycı argues, "disputes about the *geological reality* of the shale gas resource base proved critical for the UK's political aspirations to achieve domestic energy security" (2016: 117, emphasis added). Intriguingly, the UK was initially overlooked in earliest assessments of unconventional gas potential in Europe by U.S. private consulting and research companies, including in the reports by ARI and Wood Mackenzie from 2009. This initial lack of interest might be because the U.S. energy diplomacy efforts were focussed on continental Europe, which is largely dependent on Russian gas and gas infrastructure. Instead, following the takeover of the UK government by the Conservatives and their "all out for shale" policy, in 2010, the former Department of Energy & Climate Change (DECC) commissioned the British Geological Survey (BGS) to outline the prospects of utilizing the hitherto little studied shale formations. The BGS geologists took a somewhat more cautious stance compared to their European and American colleagues. Published by DECC in 2012, the BGS summary notes that "while the onshore UK basins have had over 2000 conventional wells (…), drilling was not targeted at shale reservoirs" (DECC/BGS 2012: 4). Moreover, the report acknowledges that "the UK shale gas industry is in its infancy, and ahead of more drilling, fracture stimulation and testing there are no reliable indicators of potential productivity" (DECC/BGS 2012: 1). Nevertheless, for the onshore territory, BGS identifies three basins with the best shale gas potential: the Upper Bowland Shale of the Pennine Basin, the Kimmeridge Clay of the Weald Basin, and the Lias of the Weald Basin (DECC/BGS 2012: 4). More strikingly, despite the lack of proper geological data and with no production in place, the BGS still speculates that "by analogy with similar producing shale gas plays in America, the UK shale gas *reserve* potential could be as large as 150 bcm (5.3 TCF)" (DECC/BGS 2012: 1, emphasis added). While the BGS projected a relatively low shale potential – which would effectively substitute for no more than 5 years of British gas imports – it is striking that their report provides a highly uncertain and unsubstantiated appraisal of "reserves" instead of a more generic estimation of total in-place or technically recoverable resources which do not require the establishment of gas production flows.

Parallel to these efforts of the British Geological Survey, ARI also included the UK shales in its 2011 assessment of 14 regions outside North America, commissioned by U.S. Energy Information Administration (EIA/ARI 2011). According to ARI, the UK's shale gas potential – identified in both Upper Bowland Shale in the North and Liassic Shales in the South – accounted to 2.74 Tcm (97 TCF) of gas-in-place (OGIP), of which only 566 bcm (20 TCF) was counted to be recoverable. These estimates were likewise highly speculative, as they were based on no other information than the historical and scanty data obtained from the BGS. The next ARI report from 2013 increased the gas-in-place estimates for both shale basins in the UK. For the Bowland Shale prospecting area alone, almost 3.55 Tcm (125.6 TCF) was allocated for gas-in-place. However, the recoverability volume was reduced to 226 bcm (8 TFC) only. As these reports effectively run only new probabilistic calculations on existing data, they added to the confusion and uncertainty as to how much shale gas might be available in the UK. Nevertheless, all such estimates were quickly popularized in various policy documents and media reports on the industry (Table 4.2)

Table 4.2. Estimates of shale gas potential in the UK (note different categories)

Sources	**Tcm**[a]
DECC/BGS (2012), "reserves"	0.15
EIA/ARI (2011), "TRR"	0.566
Andrews (2013), "OGIP" (optimal)	37.6
EIA/ARI (2013), “TRR”	0.226

[a] Trillion cubic meters

Following the preliminary overview of geological information in 2010, DECC then commissioned the BGS to prepare a set of more thorough studies. The first paper, published in 2013, assesses Carboniferous Bowland–Hodder shales stretching through central Britain (Andrews 2013). Two other studies, issued in 2014, focus on the Jurassic shale of the Weald Basin in southern England and on Carboniferous shales in the Midland Valley of Scotland (Andrews 2014; Monaghan 2014). These basins have been associated with production of conventional gas and oil. Contrary to the previous BGS’ assertion of the potential “reserves” amounting to 150 bcm, the three volumetric appraisals now focus exclusively on total gas-in-place – i.e. the most uncertain category that does not account for technical or economic recoverability of the potential resource. The Bowland-Hodder shales are pronounced as the most promising of the three studied areas, with impressive gas-in-place estimates ranging from 23.3 (90% probability) to 64.6 Tcm (10% probability), and an optimal estimate of 37.6 Tcm (50% probability). Since the lower unit of the Bowland Shale was out of reach for both well and seismic 3D tests due to its much deeper placement in the substrata, estimating the gas potential for it was essentially a highly probabilistic exercise (BGS 2013). As Andrews (2013: 11) explains, “although several thousand wells and boreholes have been drilled within the assessment area, only 64 of these reached sufficient depths to record more than 50 ft (15 m) of net shale in the Early Carboniferous section (…) Very few wells have drilled more than 1000 feet (300 m) of the section of interest.” Moreover, the “vintage” seismic data from the UK Onshore Geophysical Library was “of variable quality” (Andrews 2013: 12). Similarly to the projections in Poland, the BGS thus had to use on the analogue of the American shale plays in order to estimate the gas potential in Bowland-Hodder shale formations.

Until this date, the UK shale gas industry has remained in a molecular and highly controversial state, without any commercial production in place and all exploration projects but one[3] being currently suspended or delayed. At the same time, these highly speculative geoscientific assessments of subsurface potentialities continue to be widely circulated and contested, and have thus importantly reshaped the politics around the “geos”. While the national government continues to rely on optimistic volumetric projections of resource abundance, the reliability and indeed relevance of these estimates continue to be contested amongst a variety of epistemic communities. At the same time, the “all out for shale” frenzy has simultaneously triggered concerns amongst various experts, local governments and affected communities, who begin to question the radical uncertainties and latent hazards arising from the penetration of the deepest substrata, including earth tremors,

[3] Cuadrilla completed the UK’s horizontal well for shale gas exploration on New Preston Road in Lancashire in April 2018.

methane leakage and water pollution (for in-depth analysis, see Kök-Kalaycı 2016). The very first shale gas exploration well, Preese-Hall-1, drilled by Cuadrilla near Blackpool in August 2010, caused seismic events, which despite being rather low magnitude received a lot of publicity and led the government to place a temporary 18-months moratorium on fracking (which later informed permanent fracking bans in Scotland and Wales). Since then the new licences issued for commercial exploration have been met with fierce civil resistance around drilling sites, particularly in Lancashire (Bradshaw and Waite 2017; Short and Szolucha 2017). This wider "geo-politics" of the UK has thus made a significant departure from the government's initial volumetric imaginaries of abundance and instead become distributed across various other political movements, both established and totally novel ones, who take issue with the subsurface and add their own knowledge and value claims to the dispute.

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What the cases of Poland and the UK also evidence is that in a situation where local geoscientific institutions were unable to provide reliable evidence for decision-making, the geo-political imaginaries of resource abundance borrowed from more distant knowledges of the "geos", based on the analogy of the North American shale plays already in production. While it is common for geoscientific calculations to assume a degree of similarity between distant resource basins, based on the supposed continuance of the subsurface (Bowker 1994; Kuchler 2017), our analysis shows that this analogy eventually proved impossible to sustain, as it became increasingly clear that the European substrata are substantially different from the American shale plays (see also McGlade et al 2013). Moreover, these struggles also made visible the problem that European shales have been studied to a very different degree and through different methods across countries (and by both state and private actors), with the result that existing geoscientific inventories are largely incompatible even if they apply to the same geological basin (see also Kama 2013; Kuchler 2017). As we proceed to document in the next section, this has led to ongoing efforts on behalf of the European Commission and other authorities to overcome discrepancies in the methods of resource classification and to develop more uniform "geo-metrics" for shale energy development.

The development of Pan-European geo-metrics

In the situation described above, there is now growing recognition at the level of both EU and national authorities that Europe cannot simply copy the U.S. experience by first launching the industry and then regulating it "lawsuit by lawsuit". While the potential abundance of the deep underground continues to be highly appealing for the geopolitical strategies of many EU member states, governments have taken radically different approaches by either fully embracing shale energy development, like the UK and Poland, or by imposing various restrictions and moratoriums on fracking. Meanwhile, institutions of the Union as a whole have so far declined to outright reject the industry despite mounting public pressure to do so, but equally remained ambiguous and conflicted about its longer-term prospects. Instead of simply replicating the American "revolution", the authorities in Brussels have more recently begun to call for a cautious "evolution" in developing locally-based expertise on the subject, both in terms of evaluating the potential resource base and inventing less environmentally-destructive technologies for extraction (e.g. European Parliament 2014). Yet, it has proven immensely difficult to ensure good deliberation of the industry due to mounting uncertainties and public discontent, which is exacerbated by the fact that the EU lacks a mandate to directly regulate and monitor unconventional fossil fuels as a distinct policy issue; especially following the Lisbon Treaty which affirmed the sovereignty of member states in deciding over the allocation of supply sources in the national energy mix (Reins 2014). As the EU authorities are able to make only non-binding policy recommendations on fracking, the European Commission has chosen to maintain its authority through the accumulation of most up-to-date knowledge in the field. Following the publication of its first policy recommendations in January 2014,[4] the Commission has thus made a concerted effort to consolidate the existing knowledge base on the exploitability of domestic "geo-energy resources" across Europe. This is in line with broader policy objectives of resource and energy security, especially since the approval of its Energy Security Strategy in 2014 and other developments around energy market integration and the Energy Union programme.

The key authority tasked to develop EU energy expertise, including on shale resources, is the Commission's own in-house scientific institution, the Joint Research Centre (JRC) – specifically the JRC Institute for Energy and Transport (JRC-IET). One of the first steps of the JRC towards developing "epistemic authority" in the field was to establish an independent platform for expert advice, called poignantly the *European Science and Technology Network on Unconventional Hydrocarbon Extraction* (UH-Network). Launched in early 2015,[5] the intended purpose of the UH-Network was to analyse the prospectivity of exploratory drilling results, but also to evaluate the safest technologies available for fracking. The majority of this data was hoped to be gained from the energy companies who already had experience with a number of fracked wells in Europe, but in pursuit of balanced dialogue the JRC also opened participation for state authorities, non-governmental organisations and independent academics. However, as Lis et al. (forthcoming) observe in their detailed ethnographic account of the network, the epistemic experiment quickly failed due to the inability of participating experts and the network's chairs to reach an agreement even on the basic terms of the debate and the issues at stake. Whilst industry representatives were not forthcoming about access to confidential data, NGO participants accused the Commission of pro-industry bias and called for the network to be "scrapped" immediately, arguing that the EU should explicitly ban fracking, not to spend any effort in generating knowledge on how best to implement it (FoEE and CEO 2015). In response, the Commission curtailed the network's mandate as limited only to the collation of existing technical data, without being authorized to give any policy advice. In this way, as Lis et al. argue, the Commission desperately tried to "unframe" shale energy as a legitimate policy option for Europe, especially since the industry had become even more contentious following the Paris Agreement. The proliferation of controversy around the UH-Network eventually made the Commission to disband the network altogether, after only one year of activity, without having led to better deliberation of the industry or even gaining much new knowledge in the field.

From the beginning, however, one of JRC's key aims was to collate knowledge also on the potential resource base and to come up with a *uniform* resource assessment methodology for the entire continent. They had realized that the data of state geological surveys were deficient and largely incompatible (and in many cases publicly inaccessible), so there was effectively no reliable estimate of total shale resources for the EU as a whole. As a leading JRC official confided during one of the

[4] Commission Recommendation 2014/70/EU on minimum principles for the exploration and production of hydrocarbons (such as shale gas) using high-volume hydraulic fracturing, *Official Journal* L 39, 8.2.2014, 72-78.
[5] The idea for establishing this network was initially put forth by the European Parliament in 2012 and later confirmed in the Commission's 2014 policy recommendations, but it took until February 2015 for the network to convene for the first time (for detailed overview, see Lis et al. forthcoming).

UH-Network's meetings: "I don't care which method we choose, as long as we have *one* method" (KK field notes, 24 February 2015). The JRC was thus keen to institute a coherent "basin-by-basin" approach which would cut across national territorial borders and country-specific metrological regimes, with the results being later made available to European publics in an interactive GIS system (Nelskamp et al. 2017). After funds were secured from the Horizon2020 scheme, the assessment was tendered to GEUS (Geological Survey of Denmark and Greenland) in cooperation with TNO (Netherlands Organisation for Applied Scientific Research), who further subcontracted 19 other national geological surveys via the EuroGeoSurveys network. Named the *European Unconventional Oil and Gas Assessment* (EUOGA), this exercise therefore came to rely primarily on the expertise of national geological surveys, but unlike earlier studies it was now conducted under close guidance of the European Commission (specifically the JRC-IET and DG Research and Innovation). The project was subsequently carried out over a period of 1.5 years, between September 2015 and March 2017; separately from the work of the UH-Network, although its initial results were shared at the network's meetings.

Unlike the estimates of the Polish and UK epistemic authorities discussed above, the EUOGA project had no ambition to assess technically recoverable resources (TRR), given the fundamental lack of geological data. Since it now prioritized EU-specific knowledge and the majority of member states had no experience with actual production (and in the majority of cases not even sufficient levels of exploration), the exercise was limited to total geologically available or "in place" shale gas and oil resources (OGIP/OOIP), with no estimates of potential recoverability in terms of technology. In a similar manner to the BGS estimates discussed above, these were expressed with different degrees of probability, with the possibility to be later converted into TRR estimates. Critically, the project's findings were based entirely on analysis of existing data, and even this was scaled down to "the most interesting shale formations per country/basin with enough data available for a full assessment" and excluded offshore formations (Nelskamp et al. 2017). No new exploratory drillings were undertaken. Data were eventually gathered from the majority of EU member states and some neighbouring countries, with the exception of Cyprus, Greece, Ireland, Luxembourg, Slovakia and Switzerland who decided not to participate, whereas for Germany the assessment was for some reason conducted independently from the Federal Institute for Geosciences and Natural Resources (BGR– one of the key authorities in world's fossil fuels assessment), though it incorporated public reports available on their website. However, out of the 26 participating countries only 21 had any shale occurrences, sharing between themselves a total of 82 shale formations identified across 38 larger sedimentary basins on the European continent. Out of these formations, a "stochastic volumetric assessment" was further conducted only for 49 more promising shale plays.[6]

Despite being aimed at developing Europe-specific geo-metrics, the EUOGA project could eventually also not dispense with the analogy of American shale formations. Notably, the guidelines and templates for national geological surveys were prepared by drawing primarily on the U.S. experience. Moreover, in order to rank different basins according to their prospectivity, the assessed geological units were assigned classes of "chance of success" in direct comparison with shale plays already in production in North America, with only Class 1 sedimentary layers being potentially worthy of production as having parameters similar to the Barnett Shale (thickness more than 20 m; TOC content over 2%, depth less than 7 km). The other units (Class 2) were considered too distinct

[6] Out of which 15 turned out to hold both shale gas and oil, 26 only shale gas and 8 only shale oil.

from American shales and hence less promising, while Class 3 units lacked the information to draw any conclusions.

Following this assessment, the final report of the EUOGA project claims that there is a total of 89.23 Tcm in-place shale gas resources in Europe, along with 31.4 bbl of shale oil resources, if estimated with P50 probability (Schovsbo et al. 2017).[7] The UK and Poland were noted to have the largest share of gas-in-place, respectably 35.432 Tcm and 13.243 Tcm (in addition to 4.16 and 6.64 bbl of shale oil). It is striking that the authors decided to come up with such *a definite, singular number* of total resource potential, despite admitting that their estimates still remain subject to significant uncertainties and knowledge gaps. Most crucially, they conceded that many European formations are not sufficiently covered by either seismic survey data or well data to be included in the ranking of formations – or sometimes, such data is known to exist, but is either withheld by industry or rendered confidential by the state government. Moreover, the difficulties of creating a uniform "metrological regime" for Europe were compounded by the problem that both the geophysical properties of the subsurface *and* the level of geoscientific knowledge and stratigraphic definitions varied significantly across state borders, even if they applied to the same shale formation. In brief, it was clear that there is "no such thing as 'a typical European gas shale or oil shale'", but each formation has a unique geological history, stratigraphy and properties. Worse still, these conditions were noted to vary significantly even within the same deposit (with gas saturation and porosity being the most variable and uncertain parameters) and they were accounted for in disparate and uneven ways. Only the Lower Palaeozoic shales in Poland and the Alum Shales in Sweden and Denmark were considered to have sufficient prospecting data to draw any conclusions; in addition to some Mesozoic shales in the UK, Netherlands, France and Germany which had been studied due to the presence of conventional hydrocarbon wells. Yet, the authors admit that even for Poland, which holds the largest number of drill holes to date, only the "(supra)regional context" of prospectivity could be estimated, with hundreds if not thousands of more drillholes required to estimate the prospectivity of concrete deposits. Moreover, due to the material and spatial heterogeneity of the subsurface, it would not matter if these deposits in Poland or elsewhere may be eventually considered a technical recoverable resource (TRR), because this will admittedly "have very little (if any) impact on the prospectivity of other formations" (Schovsbo et al. 2017: 19).

These attempts to constitute heterogeneous subsoil realities as a uniform resource basin to be utilized for European resource and energy sovereignty should also be understood against the wider backdrop of the EU political project, which has been centred on raw materials supply since the very beginning of the Coal and Steel Community. In a way, knowledge of the deepest subsurface strata can be considered intrinsic to the building of the Union's "geo-body" as both containing and exceeding the volumetric territories of its member states. Perhaps unsurprisingly then, the final report of the EUOGA project calls for more exploratory drilling by both industry and governments as a matter of urgency. In essence, the authors recognize the need for a more bottom-up approach based on local experience, contra to the JRC's initial ambitions to generate a top-down methodology for the entire continent. At the same time, however, by providing a singular, definitive figure of resource potential they also continue to extend this idea of "pan-European" geo-metrics, which can be expected to invoke further geopolitical imaginaries. The further implications of this project

[7] There is some inconsistency in the final report: elsewhere in the text, the authors also provide slightly smaller numbers – 86.5 tcm shale gas and 30.2 bbl shale oil.

remain to be seen, but in June 2017 the JRC made the project's results publicly available via a joint "Pan-European" database for geo-energy resources, called the European Unconventional Hydrocarbons Portal (*Open-ECHO*, https://openecho.jrc.ec.europa.eu/). The long-term ambition of the JRC is to open this platform for the use of not just industry experts but also interested citizen scientists who can submit their data on a well-to-well basis. The Commission's approach bears striking similarities to the WellWatch research experiment documented by Wylie and Albright (2014), which a "searchable open layers map" where "users could add stories, notes and complaints about particular facilities", which generated data on a million wells across the U.S. If such experiments take hold on either side of the Atlantic, then this may generate a unique set of alternative geoscientific data, along with a new range of actors who become empowered and authorized to produce knowledge on the subsoil, thereby opening up interesting opportunities for more "collective geo-politics" (Conway 2016).

Conclusions

As the difficulties with shale gas development in Europe make acutely clear, the constitution of previously unstudied organic-rich rock formations as new extractive resources is far from a straightforward exercise which can be carried out in the same manner across otherwise disparate geological conditions, regulatory regimes and politico-economic contexts. In line with recent scholarly analyses of "resource-making" practices, our chapter has specifically documented the epistemic struggles through which heterogeneous subsurface realities become rendered intelligible, measurable and governable as a strategic "indigenous" or "home-grown" energy resource awaiting exploitation. Although efforts to know the vertical territory have been central to any exercise of nation-building over the last two centuries (Braun 2000, Elden 2013), in Europe, shale gas has recently become constituted as a resource primarily – although by no means exclusively – in response to specific considerations of energy security and self-sufficiency; such as the risks associated with Russian supply disruptions in Poland or the anticipated vulnerability to global gas market fluctuations in the UK. Yet, these geopolitical concerns are simultaneously "geo-political" insofar as they become infused with contentious developments in the geological sciences in depicting and measuring the subterranean realm. The above analysis thus started by noting a particular paradox in the European case of resource-making: while any assessments of available shale gas resources remain highly uncertain and speculative due to a substantial lack of geoscientific research, such estimates are nevertheless routinely produced and reproduced by various epistemic authorities, both public and private. Subsequently, these speculative appraisals have become central to the geopolitical imagination of energy sovereignty for several European governments, at the same time as they are fiercely disputed by other political and epistemic authorities.

As the European shale gas controversies specifically evidence, central to resource-making endeavours are volumetric projections of geological prospectivity, which not just strive to provide more accurate representations of the vertical territory, but critically operate as "gestures" at future economic prosperity and energy sovereignty (Barry 2008; Weszkalnys 2015). As we documented, the performance of such gestures and associated "geo-metrics" of resource assessment have until this date relied largely on the analogy of U.S. shale formations and industry experience, although there is now growing recognition that European geological surveys need to develop a locally-specific knowledge base on the deepest layers of the vertical territory – the properties of which are not just substantially distinct from the American shales but also vary largely across different shale formations and even across the same basin. Indeed, the initial entrance of shale gas into Europe's geopolitical imagination was chiefly driven by U.S.-based epistemic authorities and diplomatic exchanges, which effectively created what has been called the "shale gas laboratory" across Europe by escalating both geoscientific research programmes and commercial exploration licences in the hope of replicating the American "success" story. However, since the highly speculative character of these initial estimates became more visible and contested, the task of estimating the potential resource base has been overtaken by European geological surveys who are now working to generate more reliable estimates in order to uphold the interests of both governments and energy companies, often in the face of growing public discontent and widespread protests at drilling sites. More recently, national geological surveys have also come to cooperate under the guidance of the European Commission in a collective effort to invent "pan-European" geo-metrics for shale resources, which are hoped to eventually overcome the problem of incompatible resource definitions and measurements across national territorial borders and metrological regimes.

More broadly speaking then, our analysis concurs with recent scholarly efforts to move towards a more distributed account of "geo-politics" as *politics of the geos*. At first sight, the rapid rise of interest in domestic shale gas production could easily be explained in terms of the conventional geopolitics of resources as an inter-state space of competition over limited supplies – in this case natural gas supplies. However, we contend that this popular explanation is far too limited to account for the complex and ambiguous role of the geosciences in informing national politics, and even more so to explain the emergence of other epistemic communities, political agencies and collective identities as a result of such resource-making controversies (see also Bridge 2013; Le Billon 2013). On the one hand, as we have explained, what are conventionally understood as the geopolitical strategies of nation-states require *and* enable heterogeneous subsurface formations to be reconstituted as a uniform, singular resource – or more specifically as "recoverable reserves" – which in turn has important performative effects by augmenting both geological research and commercial exploration programmes. On the other hand, the resulting speculative volumetric projections may themselves become "a terrain of geopolitical uncertainty" and may easily fail to materialize, at least within the short timeframe assumed by the lead times of investments projects and governments' election cycles (Valdivia 2015: 1427).

In this respect, the generation of geoscientific knowledge per se becomes a geopolitical act for many actors in Europe, as it seems to legitimize particular resource ontologies and energy futures, whilst silencing other ways of conceiving the subsurface. As performative devices, geoscientific inventories thus clearly do not have the expected "anti-political" effects in providing a reliable knowledge base for decision-making (Barry 2006), but may well open up new vectors of contestation beyond traditional spaces of resource governance and geopolitics. What we consider "subterranean geo-politics" thus enables a collective exploration of low-carbon transitions and "post-conventional energy futures" more generally in expert, political and public spheres. In summary, we therefore argue that there is a need to expand the emerging scholarly debate around "political geology" with a discussion of the controversies arising from scientific prospecting of subsurface volumes and the invention of competing "geo-metrics", especially concerning how these volumetric projections come to interact with more distributed forms of expertise and "geo-political" engagements with the subsurface.

Acknowledgments

This research is funded by the UK Economic and Social Research Council (grant number: ES/N016351/1) and the Swedish Research Council Formas (grant number: 2015-455).

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