Reassembling Energy Policy: Models, Forecasts, and Policy Change in Germany and France[1]

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Abstract

Forecasts and scenarios calculated by energy system models are ubiquitous in energy debates. They are used by a wide range of public and private actors to make investment decisions, identify problems, and support or criticise specific forms of political intervention. The article presents an analytical framework for studying such entanglements between predictive practices and policy-making. Drawing on work in STS and the anthropology of politics, energy policy is conceptualised as a field of contention, populated by competing *predictive policy assemblages*. This concept is applied to a historical study on German and French energy policy-making, focusing on two periods. In the post-WWII decades, energy forecasts contributed to the structuring of 'energy policy' as an autonomous policy domain concerned with choosing between different energy *supply* options. This dominant paradigm was challenged in the 1970s and 1980s, when new modelling techniques forged by civil society groups brought energy demand and renewable energies to the fore politically and helped structure new political alliances. The article concludes by arguing that new ways of 'assembling' energy systems in models and forecasts can contribute to policy change, if they successfully 'perform' energy policy along three dimensions: by instituting alternative future-visions; by enabling new forms of political intervention; and by contributing to the formation of new 'predictive policy assemblages'.

Keywords: modelling, foreknowledge, policy change, performativity, policy assemblage.

Introduction

In a section entitled "The War of the Models" in *Adults in the Room*, a book on his time in office as the Greek finance minister during the European debt crisis, Yanis Varoufakis (2017: 603) recalls the following situation:

> … whenever I argued that in a struggling economy marred by poverty and tax evasion the best way to increase the state's revenues from VAT or from corporate tax was to *reduce* VAT and corporate tax rates, the troika would retort that their models showed the opposite: only by *increasing* the rate of VAT and corporate tax would tax revenue rise. And my country's Council of Economic Advisers, under Georg Chouliarakis, was using the same models to produce the same argument in favour of austerity. One day, incensed and incredulous, I asked to be allowed a glimpse inside the models. I was told that such models were complex, the implication being I would not understand, but I insisted: in a previous life I had been an econometrician, I replied.

This is a telling tale of the role of economic models in public policy. In a context requiring decisions about complex economic phenomena, such models provide political actors with a tool to evaluate possible directions of economic change, weigh the effects of alternative policy options, and legitimise potentially controversial decisions. The authority of such models stems from the professional prestige of economists and their seemingly objective quantifications, but also from their opacity to non-experts, which protects the underlying assumptions and worldviews from critique.

Like econometric models in economic policy, models and their outputs – forecasts, simulations or scenarios – play an increasingly important role in a wide range of policy fields (Nelson et al., 2008; Guston, 2014). This applies particularly to energy policy, where models have been used since the post-WW II decades to inform governments, energy utilities and the public about future trends in energy demand and supply, identify potentially problematic evolutions, and choose between different policy options (Baumgartner and Midttun, 1987). And yet, claims to objectivity in foreknowledge are circumscribed by the complexity of social processes and a range of 'if-then' assumptions that characterise the model-world. Consequently, scholarly debates soon questioned the 'knowability' of the future (Polak, 1973) and focused instead on the 'construction' of futures and the wider social and cultural settings in which these are embedded (e.g. Andersson and Rindzevičiūtė, 2015).

Some of the more productive current lines of research in this direction currently cluster around what could be called the 'performativity paradigm' in economic sociology (Callon, 2007; MacKenzie et al., 2007), which holds that the discipline of economics, rather than simply *describing* or *representing* economic activity, actively contributes to *shaping* it. This argument echoes longstanding sociological debates, on the constitutive nature of speech acts (Austin, 1962), the ways in which actors' definitions of a situation alter these very situations (Merton, 1948), and the self-validating and self-referential nature of social institutions (Barnes, 1983).

The paper attempts to widen the analytical scope of the "performativity idiom" (Pickering, 1995: 5) by connecting it to recent work in political anthropology on 'policy assemblages' (McCann and Ward, 2012). It envisions energy policy-making as a field populated by different *predictive policy assemblages*. This new concept points to material-semiotic constellations of actors, practices, discourses and material artefacts, which *compete* in the enactment of different energy futures. Such a perspective 're-embeds' models and forecasting practices in their socio-political environment, so as to better capture their circulation across social spaces and their involvement in administrative practice and policy debates. It also displaces the common focus in the performativity literature on dominant models and theories, to take into account alternative approaches. The concept hence allows obtaining a more fine-grained understanding of the conditions under which predictive practices indeed 'perform' successfully.

The first section of the paper develops this conceptual framework against the backdrop of the existing literature. The second and third sections apply the framework on a historical comparative study on the role of models and predictive practices in German and French energy policy. The study covers the period from the post-WWII decades to the late 1980s, and draws on an extensive document review, archival research, and 30 semi-structured interviews with energy modellers as well as public and private end-users of modelling results.[2] The article closes with general reflections on the role of predictive practices in energy policy-making, and on the interplay between evolutions in such practices and broader dynamics of policy change.

Performing in a contested environment: predictive policy assemblages

How does a focus on *predictive policy assemblages* change established ways of studying the role of predictive practices in energy policy-making? In what follows, I first review the existing literature to examine how different authors understand and operationalise performativity. I then introduce the notion of 'predictive policy assemblages' against the backdrop of recent critiques of the performativity paradigm. Lastly, I distinguish different com-

ponents of predictive practices in the energy field and assess their role in policy-making.

Unpacking performativity: discourses, practices and social organisation

As to the question of how exactly predictive practices affect or 'perform' social reality, (at least) three broad approaches can be distinguished in the literature.

A first line of reasoning points to the ways in which foreknowledge influences the beliefs and expectations of political and economic actors (Beckert, 2013). Such a view informed one of the earliest social science analyses on energy modelling, which examined the making of the first global energy forecast in the late 1970s (Wynne, 1984; Thompson, 1984). The authors contend that normative assumptions built into model-design deeply biased the forecast, which in turn underpinned a policy paradigm centred exclusively on large-scale energy supply technologies. The argument here is that *model outputs* (forecasts and scenarios) influence the *discursive context* of policy-making by reducing the undetermined, 'open' future into an actionable set of 'plausible' development trajectories.

A second approach foregrounds that the production of forecasts and scenarios unfolds within organisational networks of state administrations, energy experts, firms and activists. In an early comparative study on energy forecasting in different Western countries, Baumgartner and Midttun (1987) show that ministerial forecasting committees, scenario-building exercises and participatory foresight groups constitute specific ways of assembling energy policy worlds and may either stabilise or, to the contrary, unsettle and recompose these networks. Such "social performativity" (Schubert, 2015) points not to discourses and beliefs, but to the ways in which *anticipatory exercises* affect *social organisation*.

A third school of thought – often labelled the 'new economic sociology' – has shifted the analytical focus from discourses, expectations and social organisation, to 'sociotechnical arrangements' and the use of material devices in economic practice. MacKenzie (2008) for instance shows how the Black-Scholes model of option pricing altered the functioning of stock markets, as traders equipped with such models tend to act very differently than 'naked' agents. The circulation of such models in turn draws the contours of peculiar social spaces, in which agents are linked not by shared causal beliefs (although this may be the case), but by the common use of a material-semiotic artefact, the numerical model. Here, it is claimed that *models themselves* shape social reality because they form part of *shared practices* of prediction and planning.

This last approach has proved particularly fertile in scholarship on the construction of markets, including energy markets (Silvast, 2017). However, a series of recent papers has taken a more critical stance towards the new paradigm, pointing to conceptual flaws (Mäki, 2013), theoretical shortcuts (Miller, 2002) and empirical problems (Brisset, 2016). While some of the critiques arguably only address a "stripped-down version" of the performativity thesis, which holds that markets would materialize more or less directly from economic theory (Silvast, 2017), others point to more substantial deficiencies. Hence, markets are also shaped by wider social institutions and political struggles (Cochoy et al., 2010), which may drive market design in quite different directions than economic theories. Furthermore, by (rightly) stressing the constitutive role of economics, the 'new economic sociology' may at times have underestimated the internal diversity of economic theory, which offers not a single reality to be enacted, but many (Henriksen, 2013). The question of which theory or model finally prevails and 'performs' reality hence constitutes a research puzzle in its own right.

Predictive policy assemblages

In other words, the performativity paradigm appears ill-equipped to properly account for the interplay between predictive practices and wider social and political dynamics, such as, for instance, the contentious *politics* of policy-making in a field like energy policy. Indeed, the bulk of social science research on foreknowledge has been dedicated to showing how dominant models and predictive practices reproduce dominant worldviews and stabilise social order (e.g. Callon, 1998; Mackenzie, 2006), while non-hegemonic models and practices have received far less attention. Conversely however, historical accounts of major

shifts in energy policy mostly focus on political struggles between powerful actor coalitions (e.g. Unruh, 2000; Meadowcroft, 2009) and tend to overlook that actors involved in policy-making have to justify their decisions and policy preferences in the light of appropriate foreknowledge. Building capacities to produce foreknowledge therefore constitutes an important strategy that actors employ to advance their respective agendas (Chateauraynaud, 2013), and established practices of energy forecasting have historically been challenged by civil society groups, leading to a diversification of modelling sites and techniques (Aykut, 2015).

This is precisely where a perspective in terms of *predictive policy assemblages* complements existing approaches. "Policy assemblages" designate constellations of discourses, human bodies, social practices and material artefacts, in which specific forms of governing are "enacted" (McCann and Ward, 2012). This allows models and their material supports (computers, programs, databases), as well as resources and energy technologies, to be considered as central parts of wider political formations. Additionally, the assemblage metaphor draws attention not only to stable and formalised 'coalitions', but also to more loosely coupled ensembles. Their constitution, evolution and disappearance can be retraced by looking at processes of "translation" (production of equivalence, comparison, representation) and "linking" (associations, networks, compositions) between heterogeneous elements (DeLanda, 2006).

Placing predictive policy assemblages at the centre of the study of energy policy-making hence allows capturing both the central role and 'performative' effects of predictive practices, and the ways in which different actor-coalitions use models and forecasts in their quest for public attention and political influence. Instead of focussing on 'naked' actors and discourses, or on dominant models and their performative effects, it foregrounds the emergence and expansion of different actor-coalitions 'equipped' with their respective models and forecasts. By focusing on the *competition* of such assemblages for the enactment of distinct energy futures, such a view also opens up new perspectives on policy change. It allows an examination of the role of predictive practices in the formation, stabilisation, and transformation of dominant policy networks and paradigms, while also shedding light on the ways in which the emergence of new actor coalitions and problem framings may trigger innovations in model-design. Such innovations can in turn enable new forms of political intervention.

Predictive practices in the energy field

To understand how predictive practices intervene in the formation and competition of different predictive policy assemblages, we must further distinguish between the different components of such practices: energy models, databases, scenarios, and anticipatory exercises.

Energy (system) models emerged in the 1950s in the industrialised world, as the need for heavy investments in energy infrastructure drove the development of new planning and forecasting techniques. Part of a wider trend toward quantification and scientisation in public policy (Porter, 1995), such models isolate and 'represent' specific features of energy systems in stylised fashion, thereby constructing a 'mini-world' populated by a set of 'components' which are either endogenous (calculated by the model) or exogenous (external inputs), and which are related to each other in specific ways (e.g., linear or other forms of coupling). Since the 1970s, model development draws on methods from a wide array of disciplines, "including engineering, economics, operations research and management science" and uses different techniques, such as "mathematical programming (especially linear programming), econometrics and related methods of statistical analysis and network analysis" (Hoffman and Wood, 1976: 423). Despite this diversity, energy models broadly fall into two categories: top-down or economic models take an aggregate view and highlight the role of prices and markets in driving energy demand and supply. Bottom-up, process or engineering models stress the specificities of energy technologies and the technical determinants of energy demand. Such differences in model design have important political implications, as different model types tend to foreground different processes, and enable particular forms of political intervention.

Databases aggregate statistical time-series of real-world evolutions of key variables that drive energy demand and supply. They serve to establish basic relationships between different model components – usually a specific coefficient or 'elasticity' – and to 'calibrate' the model-world on observations (Edwards, 2010). Data production is a highly time-consuming process of assembling (sometimes purchasing), homogenising, and standardising heterogeneous information from different public and private sources. Databases thus form the backbone of energy models, which in turn inherit the value-laden categorical definitions of each of the initial datasets (Bowker, 2000).

Scenarios consist in coherent narratives about possible evolutions of the world that are used to simulate specific developments. Operationalised as quantified hypotheses for the evolution of key variables (e.g. GDP or population growth), such narratives are applied to the modelled mini-world. Scenarios broadly fall into three categories: *forecasts* extrapolate the most likely developments from existing trends; *exploratory scenarios* simulate specific changes or policy interventions; and *normative scenarios* aim to attain a specific policy objective. The term is ambiguous, as it also applies to the output of such model-simulations. In both cases, scenarios play a crucial role in mediating between models and their users. They make the abstract formalisations and quantifications of models intelligible, and also contribute to model-development, as a new scenario may demand the representation of new model components.

Lastly, *anticipatory exercises* designate a series of techniques through which scenarios are built and forecasts produced (Baumgartner and Midttun, 1987). As such exercises oftentimes associates major political, industrial, and civil society actors, they also contribute to the circulation and public uptake of forecasts. Conversely, discussion in such contexts may in turn stimulate new research and even alter model design (Angeletti, 2011). Practices of foreknowledge production thus involve not only *epistemic* representation (reconstructing energy systems in models), but also forms of *political* representation (reconstructing policy communities in forecasting committees).

To sum up, predictive practices influence energy policy-making in several distinct ways: scenarios and forecasts shape actors' expectations and provide them with 'actionable' future visions; energy models circulate in public and private planning practices and enable specific forms of political intervention; and anticipatory exercises assemble stakeholders in ways that may strengthen, sideline or rearrange existing policy communities. As I will show in the following sections, competing predictive policy assemblages can usefully be differentiated along one or several of these dimensions, as they often rely on different future-visions, use different types of models, and engage in distinct types of anticipatory exercises.

Making national energy (supply) policies (1950-1975)

In most Western countries, energy policy was characterized until the 1970s by the "energy syndrome" described by Leon N. Lindberg (1977), that is, increasing energy demand combined with weak national energy policies and the dominant role of energy utilities. This particularly applies to Germany, where the evolution of the energy sector was largely driven by industrial actors until the federal State claimed a more central role in the wake of the 1973 oil price shock. Such claims were underpinned by energy demand forecasts warning of a looming "energy gap" if no action was taken (e.g. Bundestag, 1979: 14809-14814). New modelling techniques also represented the national economy in greater detail, and examined processes of substitution between different energy carriers, especially domestic coal and imported oil. The result of these discussions was a progressive redefinition of the respective roles of the state and the market in energy policy. The French case is singularised by the existence, well before the 1970s, of nationalised energy companies and an institutionalised practice of forecasting and planning carried out by the French planning bureau (the *Commissariat général au Plan*, hereafter: CGP), which associated major stakeholders and administrations. Here too, energy demand forecasts played an important role in stabilising a new policy assemblage: pro-

duced by the monopoly of Electricité de France (EDF), they contributed to aligning political and economic actors on an acceleration of the nuclear program.

'Elasticity': calibrating France on a nuclear future

The structure of the French energy sector is the result of a historical process that led to the progressive institutionalisation, after World War Two, of a productivist, centralized energy policy paradigm (Lucas, 1985). This placed the state and a small number of nationalised energy utilities – especially the electricity monopolist EDF – at the centre of policy formulation and implementation. The nationalisation endowed these companies with a public function, and convinced their directors that the optimum for all and for their company were one and the same (Wieviorka and Trinh, 1991: 40). The intellectual coherence of this configuration of actors was ensured by the omnipresence of state engineers from the prestigious *Corps des Mines* in key positions in public companies and ministries, such as the all-mighty *Direction générale de l'énergie et des matières premières* (DGEMP). This cemented a relatively closed network that monopolized the decision-making process on energy and ensured coherence of discourse and values, centred on notions of technological *grandeur* and national independence (Hecht, 1998).

This institutional and intellectual context was paramount to the constitution of a French energy mix that is particularly atypical in its heavy reliance on nuclear energy. The foundations of this policy were laid in 1974, when the conservative government of Pierre Messmer (1972-1974) decided to accelerate the deployment of nuclear energy projects in the aftermath of the first oil price shock (Radanne, 2006). While it is generally argued that this new orientation resulted from considerations of energy dependence (Puiseux, 1982) this explanation overlooks an essential factor that made the energy dependence argument plausible in the first place: the discursive and political construction of future electricity demand.

The locus of French 'future-making' – in the double sense of knowledge production and political intervention – and the centre of a near-hegemonic 'predictive policy assemblage' at that time was the French planning bureau. Created in 1946, the CGP was unique among Western countries in associating major stakeholders – ministerial bureaucrats, industry representatives, and union leaders – and experts in a given policy domain to prepare five-year plans that should, in de Gaulle's words, serve as "orientation" not "coercion" for policy and investment decisions (Massé, 1965). Although the mobilisation of foreknowledge – from quantified forecasts to qualitative assessments – was commonplace in the CGP's various commissions, in-house models were exceptional until the 1980s (Angeletti, 2011). The practice of future-making institutionalised by CGP is described by Puiseux (1987), former head of the forecasting division of EDF and member of the CGP energy commission, as "technocratic elitism", in that it resembled more a cordial and expert-led "gentlemen's discussion" between high-ranking officials than a rigorous science-based assessment. In other words, the aim was not to 'discover' the most plausible future, but to collectively 'construct' a future that would at the same time prove reasonably plausible and acceptable enough to all that it could then be implemented collectively (Desrosières, 1999).

In line with political action horizons, the CGP produced 5-10 year energy demand forecasts, on which the state was to base its investment decisions (Château, 1985: 2). Estimates of future electricity demand were quite naturally provided by EDF, the only actor with the technical expertise, data, and modelling tools required for this task. With its status as a state-owned company, it could also claim to produce objective, non-biased results. The reluctance of the energy commission and relevant public administrations (especially DGEMP) to produce their own energy models or rely on independent expertise hence institutionalised an asymmetry in the production of authoritative knowledge claims about energy futures, which limited the discursive space of the deliberations. Bernard Laponche[3], a nuclear physicist working for the leading public nuclear research facility CEA, and who participated in the commission as a representative of the trade union CDFT, recalls:

> It was EDF who showed up saying "All right, I've made my forecasts, we need a trillion kilowatt hours in the year 2000", oh really. So Syrota[4] says "but we can find some savings," etc. […] and the Chairman says "come on, maybe you can at least explain this to us," and Boiteux says "well Mr. President sir, if you would like to look at the code I can have it delivered by truck"… (Interview 9).

As in other countries, the modelling techniques used by EDF at that time consisted mainly in more or less sophisticated extrapolations from the past, and reproduced the prevalent dogma in expert circles of a doubling of energy consumption every 10 years.[5] However, there also was a specific 'French touch' to EDF's estimates, which resulted from the ambiguous institutional status of the company. Marcel Boiteux, who directed EDF from 1967 to 1987 and was its first CEO without an engineering background,[6] had gradually modernized the company and provided it with a commercial and industrial strategy. Formerly director of the company's Department of General Economic Studies, he had championed a new approach to the calculation of electricity tariffs, which aimed to 'optimise' pricing and investment decisions by linking the investment-reimbursement cycle of plant construction to the evolution of electricity demand and the load profiles[7] of power plants (Romeiro, 1994: 27). The approach stressed the importance, from an industrialist's point of view, of the foreseeability of future electricity demand. This in turn transformed the nature of EDF's projections, as described vividly by Puiseux (1987: 190):

> On that day the chairman of the Energy Commission of the Planning Bureau suggested privately to me that if only EDF would decide to engage in somewhat more vigorous commercial activities, it would be possible substantially to increase the value of the GNP elasticity of electricity consumption. In this way the numbers which resulted from my regression calculations stopped being natural constants and became instead political action variables. This was quite a shattering discovery for a naïve soul.

To understand the distress of EDF's chief forecasting expert, recall that by the mid-1970s, a controversy opposed the electricity monopoly, which favoured an acceleration of the French nuclear program, and the Ministry of Finance, which was concerned about the associated investment risks. EDF backed its arguments with demand forecasts using consistently overestimated values for the 'elasticity' of electricity demand, i.e., the relationship between GNP growth and growth in electricity consumption (Château, 1985). The discrepancy between the modelled and observed relationship between these two variables became plainly visible in the 1970s, when electricity demand grew less than expected, and even stagnated briefly in 1974/1975. While this resulted partly from the oil price shocks and ensuing economic downturn, it also reflected a long-term evolution: economic growth in the after-war period, on which the models were calibrated, had been particularly electricity-intensive because of the imperatives of reconstruction, industrial development, and rural electrification. In the 1970s France entered a new era, in which the basic relationships between key variables changed.

The company did not respond to this discrepancy by adjusting its models to observed changes. Instead, a public campaign for household electrification, summed up by Boiteux's famous slogan *tout* électrique*, tout nucléaire* – "all electric, all nuclear" – was designed to ensure that the electricity intensity of economic development would be in phase with EDF's industrial strategy (Romeiro, 1994). Backed by the state, its implementation temporarily restored the relationship between electricity demand and economic growth observed in the 1960s (Puiseux, 1987: 193). In other words, the French economy had successfully been 'calibrated'[8] by the dominant predictive policy assemblage to fit EDF's models and official forecasts based on the company's calculations.

'Substitution': the making of German energy policy

The German energy sector has historically been structured around private or semi-public energy utilities with regional monopolies. This mode of organisation was codified in 1935, in an energy bill (*Gesetz zur Förderung der Energiewirtschaft*, EnWG) that excluded economic competition and aimed instead to ensure a stable energy supply and the construction of power grids in a context of ongo-

ing war preparations. As the regulation of the sector was in the hands of the federated *Länder*, Germany did not have a genuine federal energy policy before the 1970s (Stier, 1999). The limited role of the federal level did not mean, however, that the state was not engaged in multiple ways in energy governance – through subsidies and funding for energy-related research; legislative or administrative rule-making affecting the building of transmission lines, power plants, and resource-extraction; and even as a market actor, through utilities that were partly or wholly owned by municipalities or *Länder*. This entanglement of regulated energy companies and the state administrations that regulated them was a characteristic feature of German corporatism (Beyer, 2002). It created a complex terrain for energy policy, whose main actors were the federal state, the *Länder*, municipalities, energy utilities, and large industrial consumers (Kleinwächter, 2007).

The dominant fuel during the reconstruction period was coal, which provided over 90% of primary energy in 1950. However, in accordance with Germany's post-war ideology of market liberalism, market forces were to drive the choice of energy fuels and the construction of new power plants. Forecasts and the first energy system models emerged in this context as planning tools for energy companies that had to make decisions about how to meet steeply rising energy demand, and convince public and private investors to fund the construction of ever-larger coal, gas, and later nuclear power plants (Kraus, 1988; Herbst et al., 2012: 112).

Rather loosely structured and lacking a central anchoring point like the CGP in France, this dominant 'predictive policy assemblage' was challenged in the 1950s and 60s by quickly rising consumption of imported oil and gas, and the opening of the German market to imported coal in 1956. These developments heavily impacted the domestic coal industry, which entered a phase of decline, and provoked a rise in energy dependence from 8% in 1960 to 60% in 1977 (Meyer-Abich and Dickler, 1982). The crisis in the coal industry spurred heated debate within government: while social conservatives led by Chancellor Adenauer defended government support for the mining industry, market liberalists around the Minister of the Economy Ludwig Erhard refused government intervention.

In this context, Adenauer encouraged the creation of a parliamentary commission on energy policy (*Energie-Enquete*) in 1959. The commission was to evaluate the future prospects of German coal against the backdrop of the evolution of global energy markets and domestic energy demand. Its final report presented an analysis based on a 10-year forecast established by a consortium of major German economic institutes.[9] The study championed a new modelling methodology that was considered highly innovative at the time (Wessels, 1962): while earlier energy demand forecasts had represented the national economy as an aggregate whole, the new technique disaggregated the economy into three major sectors – industry, transportation, and households – and went into further detail in the industry and transportation sectors (three subsectors each). Designed to provide finer-grained descriptions of substitution processes between different energy technologies and sources, the method was thought to allow for more robust estimations of the future energy mix and its implications for the coal sector. The report also initiated an extensive data collection program supported by the federal government and major energy utilities, which made it possible to represent the German economy in unprecedented detail. Finally, it included a discussion of plausible alternative evolutions to the main, 'business-as-usual' forecast. While the sectorial approach highlighted ongoing substitution processes between German coal and imported fuels, the discussion of alternative evolutions gave these substitution processes a political dimension: instead of 'natural' evolutions in a market-driven economy, they now appeared as the result of a voluntary choice between political intervention and non-action.

In other words, through its method and the way it presented its results, the report backed calls for a genuine federal energy policy. On the basis of its conclusions, successive federal governments forged a "coal-priority-policy" (*Kohlevorrangpolitik*), an unprecedented and massive infringement of the dominant free-market ideology (Krisp, 2007: 26, 27). However, the report's impact was not merely due to its methodological sophis-

tication or empirical detail. The workings of the *Energie-Enquete* also contributed to further structuring and stabilising the dominant predictive policy assemblage, which in turn ensured the reception and uptake of the report by relevant actors: in the preceding years, economic institutes with close ties to industry and government[10] had begun to establish energy forecasts based on econometric models that became increasingly complex over time, and could therefore only be understood and challenged by a handful of actors (Seefried, 2010a). Designed with help and crucial input from main actors in the energy establishment, including energy producers, large industrial consumers and state bureacracies, they tended to reproduce the views of these actors (Kraus, 1988: 25). As in France, a characteristic feature of such models was their tight linear coupling of economic growth and growth in energy demand. Combined with the post-war ideology of economic development as a foundation of the West German social contract, this left no room for demand-oriented interventions in the energy system. However, following the methodology introduced by the *Energie-Enquete*, models progressively went from assembling the economy in a highly aggregated fashion to more detailed representation of some sectors that were subject to 'structural changes', and were therefore of particular political and economic interest (like the coal and steel industries). In line with the framing provided by energy models, energy policy hence emerged as 'energy supply policy': demand was considered outside the realm of politics, and policy-making limited to a choice between different fuel and technology options.

Accordingly, the first federal energy programme, launched on 3 October 1973, complemented the coal-priority-policy with a series of measures designed to kick-start an ambitious German nuclear program. Once again, this was justified on the basis of modelling results, which suggested that the macroeconomic costs of coal subsidies could be counterbalanced by the development of an alternative, supposedly cheap energy source (Bundestag, 1979: 14812). Rising oil prices at the end of 1973 accelerated the move from fragmented measures to a coherent and encompassing federal energy policy. Resumed by the formula "CoCoNuke" – for the triptych of conservation, coal and nuclear – the emerging paradigm for the first time included a focus on energy demand reduction, so as to diminish energy dependency (Düngen, 1993). Lacking significant political support, demand reduction measures were, however, not forcefully implemented at the time. This contrasted with the other two objectives: the proportion of primary energy consumption supplied by coal was stabilised at around 30% in the 1970s, and atomic energy's contribution to electricity production rose from 3.7% in 1970 to 40% in 1985 (Herzig, 1992: 153). The capital-intensity of the nuclear programme also accelerated concentration tendencies in the energy sector, where, already in 1974, two companies alone (RWE and Veba AG) controlled over 50% of the market (Nelkin and Pollak, 1981: 18).

Nonetheless, German energy policy did not form a monolithic whole. Beneath the dominant focus on energy supply, two policy assemblages struggled over the definition of energy policy. The first assemblage included abundant black and brown coal reserves in the Ruhr basin of North-Rhine-Westphalia, the Social Democratic Party that ruled the most populated federated State continuously from 1966 to 2005, the trade unions and the largest coal producer RWE. Together they enacted a policy that articulated social concerns for coal workers with a strategic focus on energy independence, understood as the capacity to fuel economic development using domestic resources. The second assemblage brought together the less densely populated areas in both northern and southern Germany whose rural geography allowed for the construction of atomic power plants far from urban centres, as well as banks and industrial conglomerates in southern economic centres and the two Christian democratic parties that governed Bavaria (CSU, since 1953) and Baden-Württemberg (CDU, 1957). This assemblage enacted an energy policy framed as industrial policy, and aimed at ensuring economic competitiveness through low energy prices. Energy independence was defined not in resource terms, but in technological terms, as the need to acquire nuclear know-how, so as to stay competitive in a globalised economy.

The general orientation of German energy policy in the 1970s and 80s thus involved a fragile compromise. Institutionalised in the "coal round tables" (*Kohlerunden*)[11] and the "atomic forum" (*Atomforum*),[12] the bipartition of energy policy-making hindered the emergence of a unified pro-nuclear front and favoured the emergence, in the 1980s, of a new political constellation.

Toward Change? The politicisation of Energy Futures (1975-1990)

Towards the end of the 1970s, the energy discourse changed yet again. The failure of dominant econometric models based on linear coupling of economic growth and energy demand to explain the impact of the oil-price shocks had cast macroeconomic forecasts into doubt and triggered the development of new modelling techniques (Château, 1985; Seefried, 2010b). Bottom-up (or engineering) models improved the representation of energy efficiency and alternative energy production techniques such as distributed renewables. These modelling approaches, which emerged first in the US (e.g. Ford Foundation, 1974) and France, and only some years later in Germany, suggested possible ways to decouple growth from energy demand through efficient resource-use. In the context of growing opposition to atomic energy, forecasts also became politically contested, and a multiplicity of contrasting energy futures came to populate public debate. Forecasts would no longer be created only by State administrations, research institutes, and energy companies, but also by experts close to the anti-nuclear movement (Kraus, 1988: 18). This also changed their status: from a public policy instrument, forecasts evolved into a weapon in energy controversies, used by civil society groups to repoliticise energy futures. In other words, the landscape of energy modelling and anticipatory exercises diversified, resulting in the emergence of competing 'predictive policy assemblages'.

'Useful Energy': establishing demand-side policies in France

In France as in other Western democracies, nuclear energy provoked widespread opposition. In contrast to other countries, however, the anti-nuclear movement struggled to institutionalise into a lasting political force (Nelkin and Pollak, 1981; Szarka, 2002). Two main explanatory factors are invoked to explain this specific French trajectory: a particularly powerful policy community around nuclear energy (Simmonot, 1978; Kitschelt, 1986), and the fragility of counter-expertise in a country where state engineers in ministries, the public research body CEA, and EDF enjoyed a near-monopoly in energy expertise (Restier-Melleray, 1990; Topçu, 2013). But the applicability of the second, at least, appears less straightforward than is frequently assumed. France has been at the forefront of the development of sophisticated modelling tools for energy demand, and the elaboration of alternative energy futures. Accordingly, what has to be explained is less the lack of alternative expertise than its failure to 'perform', i.e., by federating a new policy assemblage that would enact an alternative vision of the French energy future.

Throughout the 1970s, the anti-nuclear movement was supported by scientists engaged in fundamental research outside the nuclear establishment, as well as unionists from EDF and CEA (Topçu, 2006: 253). Discursively, it could draw on alternative forecasts produced by a new type of models, in which France soon became a front-runner. The most prominent example is the MEDEE model family developed at the *Institut Economique et Juridique de l'Energie* in Grenoble. First set out in a doctoral thesis co-authored by two engineers, Bertrand Château and Bruno Lapillonne, MEDEE pioneered a bottom-up approach to energy demand. The basic structure of the model (figure 1) couples a macroeconomic module with sectoral modules (households, industry, transportation, etc.) to determine "useful energy demand", which is distinguished from "final energy", i.e., the energy delivered to end-users in the form of electricity, natural gas or fuel. In replacing aggregate demand with a focus on the satisfaction of particular social needs like transportation, heating and production, MEDEE departed radically from existing approaches and helped establish demand as a politically influenceable variable (Interview 5).

Throughout the 1970s, MEDEE gradually evolved from a set of equations into a numerical model (Interview 12). This heavy "investment in form" (Thévenot, 1984) proved to be a crucial

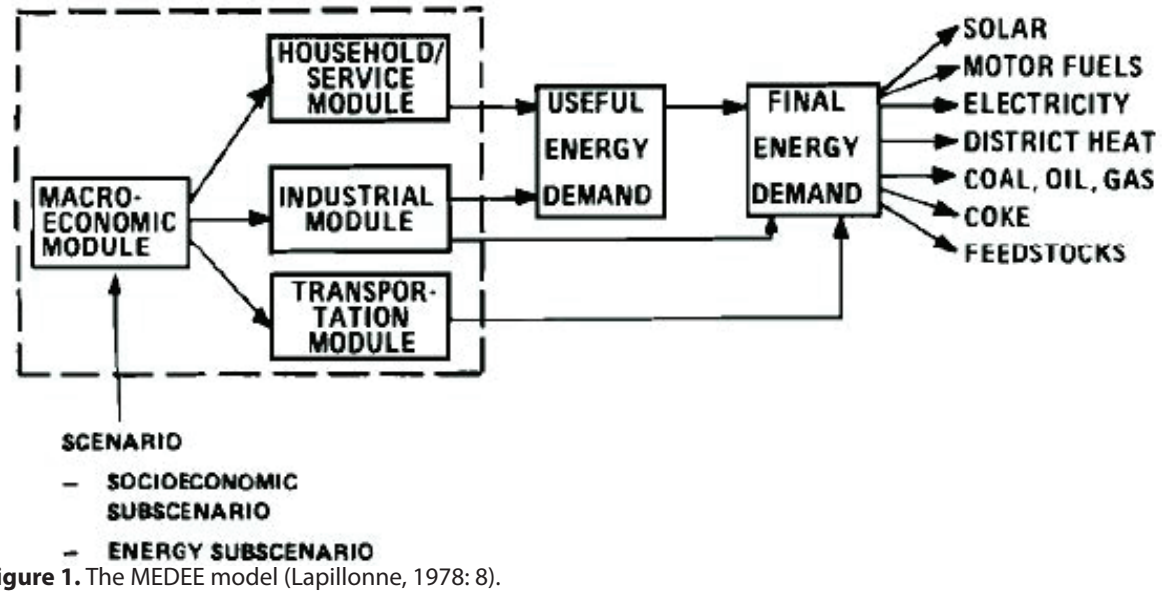

Figure 1. The MEDEE model (Lapillonne, 1978: 8).

and lasting asset: the model could now be adapted and used indifferently by a wide array of end-users, and its formalisation increased its legitimacy in public discourse. Although its bottom-up approach at first aroused resistance, both empirical observations and international evolutions in energy modelling soon seemed to validate its basic hypotheses. Both model-development and the extensive data collection programme it necessitated were supported by French and European research funding, and major industrial actors in the energy field contributed by providing data. MEDEE's role in the energy debate gradually evolved as a result: first used to provide alternative forecasts to official estimates, it progressively came to be included in official forecasts in the 1980s.

A second alternative approach, the ALTER project, emerged when a small group of researchers close to anti-nuclear circles – mathematician Philippe Courrège, agronomist Philippe Chartier, and economist and engineer Benjamin Dessus – carried out a normative scenario-building exercise to demonstrate that France could in principle satisfy all its energy needs from renewable sources (Collectif de Bellevue, 1976). The heart of the project consisted in a modelling effort that reassembled the French economy through its basic energy flows and provided a static physical representation[13] of a future energy system in which industrial and social activities were fuelled exclusively by solar energy and biomass. As recalled by Benjamin Dessus, this made it possible to reconceive the relationship between demand- and supply-side policies:

> So I was like a lot of people: do we do solar, wind turbines, or nuclear? But that wasn't enough of a response at all. This exercise taught us an idea, that you have to bring the whole system into play, on energy demand as well as supply, which was not at all… in the culture we came from. Engineers are used to making things. (Interview 1)

While the insistence on small production units and demand reduction measures facilitated the uptake of the scenario in local ALTER plans elaborated by civil society groups, its disruptive vision of the future encountered strong resistance in national policy circles. An especially controversial point was that the authors had based their estimations on precise calculations of future 'energy needs', defining the average size of apartments, heating temperature, electrical equipment, transportation kilometres, and so on. Many policy-makers considered precise determination of such variables to be beyond the state's mandate (Interview 1). Moreover, the absence of market mechanisms in the model that formed the basis of ALTER seemed to suggest an all-encompassing planning approach to energy policy. In retrospect, Philippe

Courrège argues that this exposed the scenario to critiques of its underlying political philosophy, as opponents conjured the Orwellian vision of a centralised, almighty State controlling the national economy and intruding even into the personal life of its citizens (Interview 3).

The trajectories of the two projects converged in the early 1980s, as actors from both ALTER and MEDEE came to occupy influential positions in the newly founded Agency for the reduction of energy demand (AFME).[14] Its creation was a sign of growing political interest in energy efficiency, fuelled by rising energy prices, increasing overcapacity in electricity production (Puiseux, 1987: 185), and the brief political opening created by the arrival into power of Mitterrand's socialists. The agency, which was soon at the centre of a major political battle over energy demand, became the home of critical researcher-activists: Bernard Laponche was appointed director general, while Dessus became director of technical services, Chartier scientific director and Château director of economic studies. Château brought with him the MEDEE model, which enabled the agency to challenge official forecasts not only from a normative perspective, but also on technical, quantified grounds. As a consequence, the MEDEE model became the agency's official modelling tool and contributed to its international strategy,[15] while the agency gradually came to constitute the central node of an emerging, alternative 'predictive policy assemblage'.

The model informed the French planning bureau's first long-term energy forecast in 1983, carried out in preparation of the Ninth Plan. Designed to test the viability of the nuclear program, the exercise was the first official forecast to project decreasing energy demand as a result of the economic crisis and changing policy orientations. The final report estimated that the number of planned reactors in 1990 was too high by 25 to 30%, and suggested that no new reactors would be needed before the end of the decade (CGP, 1983: 21, 51-55). These conclusions were a shock to the nuclear establishment and spurred heated debate. Yet, once again, considerations of industrial policy prevailed.

EDF reacted to the problem of overcapacity – which now took the form of an impending industrial catastrophe rather than a distant and abstract economic risk – with a twofold strategy: an ambitious program to provide electricity to neighbouring countries (especially Switzerland), and an intensification of household electrification. This was fundamentally at odds with a reorientation of energy policy towards demand reduction. The electricity monopoly's position was strengthened in the mid-1980s, when falling oil prices not only decreased political interest in energy efficiency, but also seemed to contradict the gloomy predictions of peak oil and rising energy costs that had come to populate public debate in the 1980s. In 1986, the election of a conservative government put an end to the controversy: the budget of the agency was cut by almost 80% and its personnel diminished by one third (Evrard, 2013). EDF was allowed free reign to define French energy policy. Alongside this gradual disengagement of the state, the central locus of future-making, CGP, progressively lost its importance in the 1980s. Until well into the 2000s, no other institution emerged which could perform somewhat authoritative collective forecasting or scenario-building exercises.[16]

'Energiewende': reassembling German energy policy

In Germany as well, alternative models and scenarios emerged in a context of growing anti-nuclear protest, which reached a peak at the end of the 1970s with massive demonstrations against a fast-breeder reactor under construction in Kalkar (North Rhine-Westphalia) and a planned atomic waste storage facility in Gorleben (Lower Saxony). Contrary to France, different safety standards in the different *Länder* facilitated legal challenges, and courts progressively evolved into a public forum for anti-nuclear experts and a range of grassroots, popular education, or research institutions like *VHS Wyhler Wald* (created in 1975) and the Öko-Institut[17] (1977), which provided expertise on nuclear risks and informed about alternative, renewable energy sources.

Öko-Institut proved to be particularly influential. The 1980 "energy turnaround" report (Krause et al., 1980) by three of its experts – Florentin Krause, a chemist, Hartmut Bossel, an engineer and philosopher, and Karl-Friedrich Müller-Reissmann,

a theologian and computer scientist – outlined a far-reaching transformation pathway that durably influenced the German energy debate. As in the French case, it rested on a bottom-up approach with detailed representation of potential energy savings and possible contributions of decentralized renewables. The subtitle of the study, "growth and prosperity without oil and uranium", indicated that the proposed energy transition would neither entail material sacrifices nor imply a departure from Germany's post-war ideology combining market liberalism and a social contract based on economic growth.

Alongside this concession to the dominant discourse, the authors operated a series of *strategic displacements* in the report, by redefining basic notions and concepts from mainstream forecasts. In line with recent modelling trends in other countries, they proposed to disaggregate energy demand in 'energy services' – heat, light, kinetic force, transportation kilometres – and criticised the domination of energy debates by neoclassical economic theory. The study then concentrated its attacks on three elements of mainstream forecasts: the tight coupling between economic growth and energy demand; the concentration of energy policy on the production side; and the reliance on oil and nuclear as basic pillars of the energy system.

The scenario-technique played a central role in establishing these arguments. Unlike the ALTER project, the report was based on a pragmatic and dynamic (as opposed to static) approach that used official economic forecasts and excluded deep changes in the economy (like a departure from industrialism) or energy consumption patterns (such as lifestyle changes). Accordingly, the authors qualified their method as a "technical fix" approach, aimed at satisfying projected energy needs even of "overtly growth-euphoric forecasts" (Krause et al., 1980: 10). On the basis of a detailed analysis of the evolution of energy needs and services, the report proposed three scenarios: a "business-as-usual" pathway, assuming unchanged production and consumption patterns, which the authors labelled the "suicide scenario" and dismissed as "unrealistic"; a "coal and gas" scenario that attempted to convince moderate critics of atomic energy that it was possible to phase out nuclear energy by implementing ambitious policies to favour energy efficiency, coal and gas; and a "sun and coal" or *Energiewende* ('energy turnaround') scenario, which the authors clearly preferred, and which presented the advantage of relying exclusively on domestic resources. This, they contended, would not only minimize risks, but also make the German economy virtually self-sufficient in terms of energy supply.

Most importantly, the latter scenario was carefully designed to construct alliances with major actors in West German energy politics. Not only did the 'coupling' of coal and renewables contribute to building bridges between the ecological movement, the trade unions, and parts of the coal industry; its technology-oriented bottom-up approach also provided a discursive underpinning for advocates of an "ecological modernization" of the German economy (Mol and Jänicke, 2009). The calculations laid out in the report were thus in line with a larger reconceptualization of environmental policies as *industrial* policies. Its pragmatic outline hence proved instrumental in ensuring the report would find an audience well beyond environmental activist circles.

The long-term performative effects of the *Energiewende* report, however, cannot be understood by analysing its content alone. Equally important are concomitant political changes, through which parliamentary Enquete Commissions gradually emerged as a central forum for official forecasting practices, especially in the energy field. Such commissions had been institutionalised and endowed with considerable autonomy and resources after a parliamentary reform in 1969, aimed at strengthening parliament's independence from ministerial expertise (Knelangen, 2000). In line with this objective, these commissions are composed of equal numbers of parliamentarians and experts. A corollary of this practice is that experts, who are full, voting members of the commission, are chosen not only to provide specialist knowledge, but also to represent a particular social force or political position. This way of organising the production of policy-relevant knowledge through a dialogic process that associates relevant viewpoints has been described as

a specifically German "civic epistemology" which holds the potential (but not the guarantee) of opening such processes up for contesting voices (Jasanoff, 2005; Beck, 2004).

In line with these developments, the wider uptake of both Öko-Institut's future vision and its modelling approach are intimately linked to the workings of a parliamentary Enquete Commission established in 1979 on "future nuclear energy policy" (Altenburg, 2010; Aykut, 2015). The political context was explosive. Public opposition to atomic energy, and in particular to the fast-breeder in Kalkar, had been growing, fuelled by external events like the nuclear accident in Harrisburg (USA) in 1979, and events in neighbouring Austria, where atomic energy had just been rejected in a national referendum. As a consequence, all parties, but especially the Social Democrats, had to cope with internal division over the nuclear issue. Accordingly, key criteria for the selection of experts in the Enquete Commission were their ties either to atomic research or the environmental movement, and more generally their stance towards nuclear energy. "The commission was composed politically", as Klaus-Michael Meyer-Abich, a 'natural philosopher' and moderate critic of atomic energy who participated in the commission, recalls (Interview 14); its members further included Günter Altner, one of the founders of Öko-Institut, but also Wolf Häfele, the former head of fast-breeder development at the nuclear research centre KfK and one of Germany's most vocal nuclear advocates, and Klaus Knizia, CEO of VEW, a local electricity producer with interests in both coal and nuclear.

In this heated atmosphere, the stated aim of the commission was to channel open confrontation into a "rational" debate (PEK, 1980: 2). Interestingly, its members believed that such a debate could be furthered through a systematic clarification of different future visions. Based on a comprehensive research programme that included major German energy research institutes and a long series of hearings with energy experts, they elaborated four scenarios, two with and two without nuclear energy, and set out to analyse their implications in political, social and economic terms:

> To further mutual understanding, the commission has attempted to make the visions of the energy future that result from different convictions amenable to reasoned discussion. It therefore agreed to represent these in four internally coherent energy policy paths. This required the willingness of all to outline the limitations and consequences of the respective energy paths. The commission thereby sought to create the conditions to sound out the prospects for a broad consensus on energy policy in a manageable time frame. (PEK, 1980: 23)

The four energy paths were designed to represent important standpoints in the German energy debate. The first reflected the vision of the nuclear industry and mainstream energy economists. It projected a doubling of energy demand by 2030, almost all of which was to be satisfied through atomic energy. The second path expressed a view shared by industrialists and parts of the governing coalition, and combined moderate demand reduction with diversification of (conventional) energy technologies. It projected 50% demand growth, to be met by increasing nuclear and coal. In the third path, demand was stabilized and nuclear energy progressively phased out. This roughly corresponded to the position of nuclear critics within the political establishment. Finally, the fourth path involved a rapid nuclear phase-out, associated to heavy energy savings and deployment of renewables. This adapted version of the *Energiewende* scenario mirrored the views of anti-nuclear activists.

The fifteen commission members also established four common criteria – "economic viability", "international compatibility", "environmental compatibility", and "social compatibility" – to evaluate the scenarios and create common ground for policy recommendations. Although a consensual assessment proved difficult (Interview 14), the commission succeeded in forging a common position on measures for the medium term. Based on Lovins' (1976) famous distinction, it advocated a temporary "parallel approach" aimed at giving both the "hard path" (combining fossil and fissile technologies) and the "soft path" (efficiency and renewables) an equal chance. This was justified on the grounds that the evolution of key variables, such as structural changes in the economy, public

acceptance of nuclear energy, effects of energy-saving policies and the feasibility of fast-breeder technology, was too uncertain to be forecasted properly. The commission therefore suggested pursuing both the construction of the fast-breeder *and* stringent energy savings until the end of the decade. By postponing the choice between the two paths, it delegated the final decision on the energy future to the political system. For anti-nuclear activists, an important result was that the commission considered a nuclear phase-out to be a viable option at all:

> The whole thing was decided unanimously. And at the beginning, people always said: it's not possible without […] This commission was the first one where everyone decided collectively: yeah, it's possible without. It's possible with, but it's also possible without. Politically, this was already quite a success at that time (Interview 14).

The commission participated in a redefinition of the front lines in the energy controversy. Widely discussed and publicised, the four energy paths made it clear that an energy transition was not only in the interest of radical ecologists, but could benefit wider parts of the industrial and political establishment (Interviews 14, 28). Not only did the struggling coal industry, trade unions, and their social democratic allies find – at least temporarily – that they had common strategic interests with anti-nuclear activists; other industrial branches and the emerging 'green sector', as well as local actors and municipalities[18] progressively discovered that they might well profit from an alternative path that, by not relying on capital-intensive energy supply technologies, could allow them to develop and commercialize energy saving and efficiency technologies (Weidner and Mez, 2008). This was backed by environmental economists who began to collect evidence that such a transformation could be accomplished within a reformed social market economy (Binswanger et al., 1981). The resulting redefinition of roles and interests contributed to structuring and consolidating an alternative 'predictive policy assemblage', which was equiped with its own modelling tools and a future vision that broadly corresponded to the *Energiewende* scenario. Parts of this vision were enacted almost 20 years later by a coalition government of Social Democrats and Greens (1998-2005).

Conclusion

Models and forecasts occupy a central position in energy debates. They propose the future-visions that populate public discourse, provide market actors and policy-makers with ontologies to understand energy systems, and shape wider policy networks in scenario-building exercises and through the circulation of models across social spaces. In doing so, they can stabilise dominant framings, practices, and policy assemblages, or rearrange and reorder policy worlds, thereby contributing to the formation of new assemblages that enact alternative conceptions of energy policy. Energy controversies therefore unfold not only as political or ideological struggles about the problems of energy production and suitable ways of dealing with such problems; I have argued here that they can be understood as struggles between competing 'predictive policy assemblages', in which new actors, their problem-framings and predictive practices challenge both how established models compose energy systems and how major anticipatory exercises include relevant actors in the production of energy futures.

Unsurprisingly, then, there were close parallels between model-development and evolutions in policy-making in Germany and France. Social and political events in different periods triggered innovations in modelling, which required the production of new data. This in in turn contributed to transforming problem definitions, induced or accompanied changes in energy policy, and helped to sustain novel institutions and organisations. The way energy forecasts relate to energy policy, however, has differed in the two countries, and this relationship has changed over time.

Anticipatory exercises in France were traditionally carried out by the national planning bureau CGP, and their status was not only epistemic, but also explicitly political. Although CGP associated major actors in the energy field, it was characterised by an inherent asymmetry: estimations of electricity demand were almost exclusively calculated by EDF's models, and matched the company's industrial strategy. When model predictions and real-world developments diverged in

the 1970s, the dominant 'predictive policy assemblage' enacted a policy of household electrification that re-calibrated the electricity-intensity of economic development to a level compatible with the country's ambitious nuclear program.

In Germany, national energy forecasts emerged in a context of crisis in the coal sector, which challenged the role of the federal state in energy policy. The 1959 *Energie-Enquete* commission was created in response. It introduced innovations in modelling techniques that made visible substitution processes in economic sectors, and called for government to take a more proactive role. Progressively institutionalised in the preparation and evaluation of federal policies, the modelling approach envisioned energy policy as a choice between different energy carriers, and furthered the emergence of new dominant framings such as the 'coal priority' and 'CoCoNuke' policies.

In both countries, established predictive practices and dominant policy paradigms were challenged by new actors and modelling techniques in the 1970s. A situation where forecasts were more or less directly embedded in policy-making and models established by experts close to the energy policy establishment gave way to a new configuration, characterised by a multiplication of model-types and a politicisation of forecasts, which were produced and taken up by a wide range of actors in an increasingly controversial debate. But while alternative scenarios succeeded in reassembling German energy policy along lines that proved to be conductive to policy change, this did not occur in France, where demand-side modelling was institutionalised in the energy savings agency *Ademe*, but failed to enrol potential agents of a new political constellation.

Common attempts to explain this rigidity of French energy policy point to the homogeneity of the dominant actor-coalition and the heavy investments made by EDF (e.g. Puiseux, 1987: 195). A focus on predictive practices adds two important elements to the puzzle: first, while bottom-up models did provide a powerful tool to counter dominant discourse, and formed the quantitative backbone for demand-reduction policies in public discourse and inter-ministerial negotiations, they did not deliver a coherent future vision in which major actors of French energy and industrial policy could recognize or project themselves. As for the ALTER scenario, which could have provided such a vision, its architecture was too uncompromising to offer such actors – progressive industrialists, entrepreneurs or municipalities – a plausible and desirable future in which their expertise and activities would be valued.

In Germany, by contrast, the *Energiewende* scenario not only 'equipped' the ecological movement with new arguments in its battle for a non-nuclear future; it also 'reassembled' energy policy in a way that opened up energy debates. Öko-Institut's vision functioned as a "prospective structure to be filled in by agency" (Van Lente and Rip, 1998), proposing both a new narrative and a new arrangement of energy policy that could subsequently be enacted. This was accompanied by a formalisation of bottom-up models at Öko-Institut and other modelling centres. Increasingly used in policy-making and administrative practice, these models contributed to durably anchoring efficiency and renewables policies in policy circles (Interviews 15, 22).

Finally, a symmetrical, yet opposite evolution in the 1980s increased the discrepancies between the energy trajectories of the two countries. The established French locus of future-making, the CGP, progressively lost its central position, making it more difficult for alternative modelling approaches and future-visions to enter policy circles and gain public acceptance. In Germany, in contrast, the parliamentary Enquete Commissions, which provided a forum for contesting actors and alternative futures, became a central node in energy debates in the following decade. The scenario technique introduced by the 1979 commission also durably changed official anticipatory exercises: used in subsequent commissions and committees on climate and energy policy, it was instrumental in organising energy discourse around a set of distinct, mutually exclusive future-visions, which not only reflected divergent policy preferences, but also corresponded to different ways of 'assembling' energy system and envisioning political interventions in such systems (Interviews 27, 28).

The long-term 'success' of the *Energiewende* report can therefore only be fully appreciated by jointly analysing how it 'performed' along three dimensions, through: an alternative future-vision that contributed to re-structuring German energy debates; a bottom-up modelling approach that circulated in administrative and civil society practice and enabled new forms of political intervention; and the formation of a new 'predictive policy assemblage' capable of enacting an alternative energy future.

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Notes

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2 Interviews were conducted between 2010 and 2017. Documents were collected from parliamentarian, ministerial and personal archives. All quotes have been translated to English by the author.

3 Laponche, who had critically examined energy forecasting techniques in his PhD thesis, later became a leading figure among anti-nuclear activists.

4 A senior civil servant and industrialist, Jean Syrota directed Cogema (later Areva) (1988-1999) and chaired the *Corps des Mines* (1993-1997). He distinguished himself by opposing EDF's strategy, advocating for energy savings policies instead.

5 Modelling techniques used at that time all entailed the implicit assumption of a stable relationship between energy demand and economic growth (Puiseux, 1987: 188,189).

6 Marcel Boiteux is a mathematician and graduate of the elite institutions *Ecole Normale Supérieure* and *Institut d'études politiques de Paris* (Sciences Po).

7 In electrical engineering, load profiles are graphs that represent variation in electrical load over time.

8 Yon (2014) shows how French state engineers invented the marginal cost curve to "calibrate France".

9 The consortium was led by the University of Cologne's *Energiewirtschaftliche Institut* (founded in 1943).

10 EWI is financed by a consortium including the energy utility RWE and the federated State of North-Rhine Westphalia. Two other economic institutes with important energy divisions, Ifo (Munich, 1949) and RWI (Essen, 1943), have close ties to industry. Other actors in the field included the State-financed DIW (Berlin, 1925), *Prognos AG*, a Suisse institute (1959), as well as technical universities and atomic research institutes (e.g., *TU Karlsruhe*, *Kernforschungszentrum Jülich*).

11 Initiated in 1983, these negotiation cycles associate firms, trade unions, the *Länder*, and the federal State.

12 Founded in 1959, the lobbying association is composed of major industrial actors and research institutes.

13 Such 'physical economics' were opposed by the authors to the dominant econometric models (Interview 3).

14 The *Agence française pour la maîtrise de l'énergie* (transformed to Ademe in 1991) resulted from the merger of two pre-existing public bodies in 1982.

15 To encourage energy demand policies in the global South, the model – together with its architect Château – were 'exported' to developing countries (Interviews 5, 12, 9).

16 While CGP continued to produce energy forecasts until the late 1990s, its last five-year plan was adopted in 1989. The institution was abolished in 2006.

17 Founded by activists in Wyhl (*Baden-Württemberg*), the institute is financed by a philanthropic association.

18 Local *Energiewende* committees took up the transition scenario and used it for community level activism, thereby giving it a wider audience.

Appendix 1. List of Interviews

French energy experts and modellers (interviews 1-13)

Benjamin Dessus (energy expert and activist, formerly director of research at Ademe; *interview conducted on* 1.6.2011), Pierre Radanne (energy expert, formerly president of Ademe; 7.12.2008), Philippe Courrège (energy modeller and activist; 6.5.2011), Pierre Matarasso (energy expert and activist; 6.5.2011), Patrick Criqui (energy modeller, EDDEN; *first interview*: 18.03.2015), Patrick Criqui (*second interview*, *conducted with Alain Nadaï*, 25.1.2017), Kimon Keramidas (energy modeller, JRC of the EU; 28.5.2015), Silvain Cail (energy modeller, head of global forecasting at Enerdata; 29.05.2015), Nadia Maïzi (energy modeller, CMA; 21.1.2016), Bernard Laponche (energy expert and activist, formerly CEA and director of Ademe; *conducted with Alain Nadaï,* 19.01.2017), Jean-Charles Hourcade (energy modeller, Cired; *conducted with Alain Nadaï* 19.4.2017), Michel Colombier (energy expert, Iddri; *conducted with Alain Nadaï* 15.3.2017), Bertrand Château (energy modeller, Enerdata, formerly IEPE and Ademe; 31.5.2017), Bruno Lapillonne (energy modeller, Enerdata, formerly IEPE, IIASA and Ademe; 15.6.2017)

German energy experts and modellers (interviews 14-22)

Klaus Michael Meyer-Abich (philosopher, energy expert and member of PEK atomic energy; 20.4.2010), Wolf-Peter Schill (energy modeller, DIW; 15.7.2016), Nico Bauer (energy modeller, PIK; 22.1.2015), Alexander Popp (energy modeller, PIK; 25.9.2015), Elmar Kriegler (energy modeller at PIK; 25.9.2015), Jan C. Minx (energy & environmental policy expert, Mercator Institute, formerly IPCC; 25.9.2015), Julia Repenning and Ralph O. Harthan (energy modellers, Öko-Institut; 31.10.2016), Sabine Gores (energy modeller, Öko-Institut; 26.10.2016), Felix Matthes (energy modeller, head of Öko-Institut; 31.1.2016)

French civil servants and politicians (interviews 23-26)

Dominique Chauvin (head of sustainability at Total, member of several public energy forecasting exercises; 16.7.2016), anonymous interviewee (civil servant, ministry of economy, formerly ministry of ecology; *interview by Alain Nadaï*, 24.11.2016), anonymous interviewee (energy modeller, Ademe; 2.2.2017), anonymous interviewee (civil servant at ministry of economy, formerly ministry of ecology; *conducted with Alain Nadaï*, 26.4.2017)

German civil servants and politicians (interviews 27-30)

Klaus Töpfer (former minister of environment; 29.4.2010), Reinhard Loske (former member of parliament, member of PEK climate; 27.4.2010), Martin Weiss (civil servant and energy expert, ministry of environment; 18.7.2016), Kai Kuhnenn (energy expert, formerly at UBA; 15.7.2016)