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Celestial bodies and satellites – Energy issues, models, and imaginaries in Denmark since 1973

Emil Urhammer *

Department of Development and Planning, Aalborg University Copenhagen, Denmark

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ABSTRACT

This article uses the history of macroeconomic energy modelling in Denmark as a case for presenting a theoretical framework which describes *issues*, *publics* and *imaginaries* as an important nexus for energy policy. The story evolves around the actions, tensions, and entanglement of two publics – the traditionalist and the environmentalist – and presents macroeconomic modelling as an instrument for *issue articulation* and the construction of *energy policy imaginaries*. The article concludes that macroeconomic modelling is an effective instrument for articulating the economic realities of energy policy, and that economic growth plays a key role in these articulations by determining the basic preconditions for collective imaginaries of energy system futures.

1. Introduction

The world is on the verge of climate disaster. Human-induced temperature increase is threatening societies across the planet, and global energy system transformations are urgently needed[1] (IPCC, 2014). At the same time, governments all over the world are staring fixedly at the economic growth indicator in the hope of upward-sloping tendencies, which are synonymous with better times ahead in their view. This situation is well captured by Jackson's term *the dilemma of growth* (Jackson, 2009), which means that modern societies have become heavily dependent on economic growth in order to secure social stability, employment and welfare institutions, despite mounting research which suggests that economic growth has undesirable effects on the planet (Wackernagel et al., 2002, Weinzettel et al., 2013, Wiedmann et al., 2015). Thus, the dilemma of growth encompasses two conflicting concerns: continued economic growth and global environmental havoc. The first can justly be termed as being top priority for states and governments, whereas the latter takes up a less prominent spot further down the list of government priorities and is often represented by publics less connected to the core operations of the state and its government.

Since the early seventies, it has become increasingly apparent that energy is a vital component of economic growth, societal order and stability. However, the use of energy, especially fossil fuels, for this purpose comes with severe environmental disadvantages such as carbon emissions and climate change (IPCC, 2014). Hence, the issue of energy encompasses the same concerns as the dilemma of growth, in relation to which the state and its government historically has been mostly interested in energy as a means for securing economic growth and stability, while those concerned with environmental issues have focused on the adverse effects of energy consumption.

In this respect, energy has, since the emergence of the first oil crisis in 1973, become an increasingly important political issue and the subject of perpetual policy-making and dispute (van Daalen et al., 2002). This increased political interest has also led to inquiry into the energy issue, which began to make use of *computational*[2] macroeconomic modelling already in the early seventies. The treatment of energy by this type of modelling is a key theme of the present article. By tracing the joint enterprises behind such modelling activities, this article provides insight to the apparatus behind the creation of *energy policy imaginaries*. This is achieved by addressing the following research question: *how has macroeconomic energy modelling been developed as an instrument for energy policy in Denmark since 1973, and what can be learned from this story about the role of macroeconomic modelling in Danish energy policy?*

The treatment of this question reveals a tension between the aforementioned concerns regarding economic growth, but also between different epistemic traditions, where mainstream macroeconomics is a tradition in favour of continued economic growth, while thermodynamics and system dynamics have been favoured by academics who are growth-

* A. C. Meyers Vænge 15, 2450 København, Denmark.
E-mail address: urhammer@plan.aau.dk.

[1] In fact, much more is needed; however, due to the limited scope of this article, I mainly focus on energy system issues.

[2] Computational, as opposed to theoretical, means that the model consists of a set of equations, which is solved by a computer, thus providing a numerical result. Since all the models treated in this article are computational, this will not be stated explicitly.

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antagonists (Georgescu-Roegen, 1971, Meadows et al., 1972). Mainstream macroeconomics conceptualises energy as a market good and a substitutable factor of production (Andersen et al., 2010), while the antagonistic perspective emphasises the systemic and entropic aspects of energy. The former perspective explains economic growth by enhanced factor productivity as a result of technological progress (Solow, 1956), whereas the latter holds that energy - or more precisely *exergy*[3] - is the key term in understanding economic growth (Ayres and Warr, 2005). Furthermore, the latter perspective points to the entropic consequences of economic growth, which means that maintaining low entropic societal order and stability (especially by means of fossil fuels) comes at the price of high entropic environmental degradation (Georgescu-Roegen, 1971).

The epistemic divide between mainstream economics and growth antagonistic perspectives is also key to understanding the title of the present article, which is inspired by macroeconomic modelling language. In this language, it is common to speak of an appendix model to a macroeconomic[4] model as a *satellite*. Hence, the macroeconomic model can be seen as a *celestial body* around which various satellites, such as energy models, orbit and whose gravity they have to obey. Taking an exergy view on this metaphor, however, requires a radically different explanation in which the role of celestial body is played by exergy, while the economy is a satellite under its command.

The analyses of this article are a combination of sociology of science and policy analysis with an inclination towards the former. This means that the article does not attempt to trace the influence of modelling on concrete policy-making, but rather investigates the historical development of a specific type of modelling as a certain mode of inquiry with the ability to produce energy policy imaginaries. Even though the article relates to several strands of literature, one of its main purposes is to contribute to on-going discussions of politics as a matter of *issues*, *publics* and *imaginaries* (Dewey, 2012 (1927); Marres, 2005, 2007; Brown, 2009, 2015; Jasanoff and Kim, 2009, 2013). Epitomising these strands of analysis, Marres has emphasised the significance of issues and publics to politics and democracy (Marres, 2005, 2007; Brown, 2015), while Jasanoff and Kim (2009, 2013) have highlighted the important role of sociotechnical imaginaries in policy-making. However, these two perspectives have, to my knowledge, not yet been merged together, which is what I do in the following.

Also of interest to this article are two different literary strands covering two different kinds of modelling: *macroeconomic* and *energy/environmental* modelling. The former investigates the role of macroeconomic modelling in various contexts of political decision-making (Andersen and Madsen, 1995; Evans, 1997; den Butter and Morgan, 2000; Henriksen, 2013; Reichmann, 2013), while the latter does the same for energy/environmental modelling (Midttun and Baumgartner, 1986; Baumgartner and Midttun, 1987; Hogan, 2002; van Daalen et al., 2002; Nilsson et al., 2011; Upham et al., 2015). Even though they discuss two different types of modelling, these two strands are closely connected since discussing one makes it hard to ignore the issues and concerns which motivate the other. Thus, energy has become part of macroeconomic modelling and macroeconomics has become part of energy modelling. For the purpose of elaborating on this relationship, this article puts the connection between macroeconomic and energy modelling at the centre of attention and investigates activities of developing a discipline which I have labelled *macroeconomic energy modelling* (MEM). Denmark – one of the leading renewable energy nations of the world – was chosen as the case for this historical investigation. Due to its compelling history of energy system transformations, Denmark provides an interesting case of entangled grassroots mobilisation and governmental policy intervention (Jørgensen and Karnøe, 1995, Karnøe, in progress). This article focuses primarily on the governmental policy side of the matter and investigates how macroeconomic modelling has been mobilised as a tool for articulating energy policy imaginaries in Denmark.

The story focuses on three characteristic MEM collections from three different decades: the 1970s, the 1990s and the 2010s. Each of these decades saw events and were characterised by themes of special interest to MEM and, therefore, provide a good background for telling the story. The models of the seventies are called the IFIAS[5] models, EMMA[6] is the model of the nineties, while a model collection named IntERACT[7] represents the current decade.

The rest of the article is organised as follows: in Section 2, a brief account of the empirical material is given, while, in Section 3, some of the limitations of the research are considered. The theoretical framework is presented in Section 4, and Section 5 discusses macroeconomic modelling and national accounting. Section 6 unfolds the story; Section 7 discusses some aspects of the story, while a conclusion is provided in Section 8.

2. Empirical Material

The empirical material of this article consists of fifteen semi-structured, audio recorded and transcribed interviews, and one audio recording from a public seminar on multi-sector models[8] (see Appendix 1 for a list of interviewees and their institutional affiliation). This material conveys the worldviews and stories of key actors including economists, civil servants and energy system researchers involved in the story of MEM in Denmark. Since all the interviews were performed in Danish, I have translated direct quotes from the interviews to English. The interviews and the seminar are referred to in square brackets. To supplement the audio recorded material, I rely on academic articles and book chapters and a body of reports and documents from central agencies such as the Danish Energy Agency, Statistics Denmark[9] and the Danish Ministry of Finance.

3. Limitations

The following story naturally has several limitations, two of which are the missing treatment of the impact of computer technology on macroeconomic modelling, and the fragmentary ethnographic detail concerning the linkages between policy change and modelling. It is widely recognised that the evolution of digital computers had a tremendous impact on computational modelling, and I am convinced that this influence also provides an opportunity for interesting investigations in relation to macroeconomic models. Yet, due to the focus on issues, publics and imaginaries, this part of the story has been omitted, leaving a gap for further research. Regarding the linkages between policy change and modelling, it is not easy to acquire the desired ethnographic detail since these linkages require access to rather closed and secretive environments such as the Danish Ministry of Finance. Several times during the research, I realised that access to such sites was quite limited and often beyond my reach.

4. Theoretical Framework

In order to analyse the case at hand, a selection of different, yet kindred theoretical perspectives have been weaved together, the purpose being to highlight the relation between issues, publics, and imaginaries as an important nexus for energy policy, in which macroeconomic

[3] Ayres & Warr define exergy as 'available' or 'useful' energy, which means the potential for physical work contained in a given quantity of energy (Ayres and Warr, 2005). The high exergy content of fossil fuels is, thus, key to understanding the rapid economic growth, which has taken place since the Second World War.

[4] To be more precise, satellites are developed for so called macro-econometric models, which are a special type of macroeconomic model.

[5] The International Federation of Institutes for Advanced Study.

[6] Energy and eMissions Models for ADAM (Annual Danish Aggregate Model).

[7] INTegrated Economic eneRgy Applied Computational Tool.

[8] All together comprising approximately 24 h of audio recordings.

[9] The Danish National Bureau of Statistics.

modelling plays a significant role. Thus, one of the main observations of the article is that macroeconomic modelling cuts across this nexus by being commissioned and commanded by certain publics, by participating in the articulation of issues, and by being used in the drafting of energy policy imaginaries. In the following, a more elaborate description of the theoretical perspectives deployed to develop this argument is provided.

The first thread in the patchwork is the concept of *issue articulation*, which according to Marres, is a constituent element of politics and democracy (Marres, 2007). Roughly speaking, issue articulation concerns the construction of objects by means of associating material circumstances through activities such as data collection, measurement, and calculation. In this sense, issues, such as the oil crisis in 1973, can be seen as objects which enter our common world through socio-material associations and acquire specific traits and qualities depending on how they are measured, calculated, and by other means expressed. As the following story hopefully reveals, macroeconomic models are able to participate in such socio-material articulations, and, hence, they can be understood as effective instruments of issue articulation.

The next perspective in the patchwork is Dewey's idea of the public as a pivotal notion in understanding democracy, societal change and the transformation of the state. In order to explain the public, Dewey takes indirect consequences of conjoint human actions as his point of departure: “The public consists of all those who are affected by the indirect consequences of transactions to such an extent that it is deemed necessary to have those consequences systematically cared for” (Dewey, 2012:48). Thus, a public is a social group which emerges as people who are affected by the consequences of conjoint actions engage in systematically caring for and dealing with these consequences.

In her contemporary reading of Dewey, Marres translates the indirect consequences of conjoint actions into *issues* and suggests that, “issues spark a public into being” (Marres, 2005:title). Using this phrasing, Dewey's theory of societal change becomes a theory of how specific social groupings named publics are called into being by emerging issues and how these organise and act in order to respond to these issues. Along these lines, it is important to emphasise that Dewey considered the state and its government to be a public (Dewey, 2012); a public in which multiple modes of organisation have turned into stable institutions and regimes of regulation in order to care for and handle a multitude of issues. In this perspective, societal change is highly dependent on how the state reacts to emergent issues and on interactions between the state and new publics called into being by these issues.

In the following, tensions between two publics dubbed the *traditionalist* and the *environmentalist* public (or simply the *traditionalists* and the *environmentalists*) constitute a fulcrum for telling the story of MEM in Denmark. The traditionalist public is anchored in core ministries of the Danish state, such as the Ministries of State, Finance and Commerce, whose main economic concerns are strongly tied to national accounting, whereas the environmentalist public is constituted by research groups, NGOs, and grassroots movements called into being by the environmental consequences of economic growth.

The question of how the state and new publics react to emergent issues leads to Dewey's notion of inquiry, which is a certain instrumental mode of knowledge production that regards the clarification of indeterminate situations, instances of ambiguity and confusion (Brown, 2009). As such, inquiry plays an important role as articulator of emergent issues and devisor of ‘appropriate’ responses (Marres, 2007). As Brown explains, “[i]nquiry begins with the desire to respond to [a] disturbed and troubled situation, followed by the transformation of the indeterminate situation into a “problematic situation”, and then into a specific “problem” to be solved” (Brown, 2009:153). By virtue of this ability to transform a troubled situation into a specific problem, inquiry is core to determining what can be thought of, planned and chosen (Dewey, 2012). In the story which follows, macroeconomic models are investigated as instruments of inquiry, which help to transform troubled situations into solvable problems by providing frameworks for articulating energy issues and drafting energy policy imaginaries.

Continuing along these lines, the final theoretical thread I wish to add to the patchwork is an emphasis on the imaginary; in this case visions of the future Danish energy system. For this purpose, I draw inspiration from Jasanoff and Kim, who use the term *sociotechnical imaginaries* to describe “collectively imagined forms of social life and social order reflected in the design and fulfilment of nation-specific scientific and/or technological projects” (Jasanoff and Kim, 2009:120). In a later article, Jasanoff & Kim use the case of energy system transformations to exemplify sociotechnical imaginaries as important guides for energy policies (Jasanoff and Kim, 2013). Adding to this line of research, the present article investigates macroeconomic inquiry engaged in the articulation of energy policy imaginaries for the purpose of governmental decision-making regarding the transformation of the energy system in Denmark.

5. Macroeconomic Modelling and National Accounting

Adding to the previous reflections on issues and issue articulation, it is interesting to observe that, ever since their inception, macroeconomic modelling and energy modelling have been engaged in the articulation of emergent issues from the Great Depression to present day climate change. To exemplify this, the world's first computational macroeconomic model was developed by Tinbergen in a response to the hardships following the Wall Street crash in 1929 (Zalm, 2000), while the first large-scale energy models in the USA came as a response to skyrocketing oil prices in 1973, which very quickly became a national security issue for the US government (Hogan, 2002). This modelling mobilisation can be interpreted as publics – in this case nation states – responding to emerging issue by incorporating modelling inquiry in their perception of these issues and their responses to them.

This connects to Dewey's notion of inquiry or more precisely a specific instrumentality of inquiry named, national accounting, which serves as a foundation for macroeconomic modelling (Bjerkholt, 2000). Thus, one way to understand macroeconomic modelling is that it concerns causal relationships between national accounting variables and the investigation of other forces which cause national accounting variables to change. Modern systems of national accounting date back to the Great Depression, which called for tangible accounts of the economic status of nation states (Vanoli, 2008). Since then, national accounting has gradually been formalised and harmonised such that most countries employ comparable standards (Vanoli, 2008). This institutionalisation has also induced a very strong political focus on national accounting, such that emergent issues which affect, or merely threaten to affect, these indicators have the potential to become issues of great concern to governments.

Cast in the vocabulary of this article's theoretical framework, this can be interpreted as an example of traditionalist issue articulation, which at least partly explains the need for macroeconomic models in policy-making since such models provide frameworks for imagining the future status of national accounting variables and the effects of various policy proposals on these variables. Having this in mind, it is noteworthy that macroeconomic forecasts are notoriously flawed, yet they are used for multiple political purposes (Evans, 1997). One explanation for this is that they provide consistent, non-contradictory frameworks in which fundamental national accounting identities are respected (Smith, 2000). In Denmark, the macroeconometric model, ADAM, maintained by Statistics Denmark and operated by the Ministry of Finance, plays an important role in this regard. Since the late seventies, it has been the main celestial body for managing the macroeconomic concerns of shifting Danish governments.

6. The Story

6.1. The Pioneers

The story begins in 1973 on November 25th with the introduction of *car free Sundays*, a government intervention banning all car driving[10] in Denmark[11] on Sundays. A complex situation in the Middle East, spurred by the Yom Kippur war, had led to skyrocketing oil prices in the wake of which followed disturbing national account articulations such as an increasing balance of payment deficits, decreasing consumption and growing unemployment (Bjørnholm et al., 1976; Handelsministeriet, 1976; Issawi, 1978; Meyer, 2000). This threatened economic growth[12] and stability in the West and left many oil importing countries in a state of emergency; also articulated as the first oil crisis (Tennant, 2013). The Danish government needed to act, and car free Sundays aimed at immediate cuts in oil consumption. However, probably more than anything else, car free Sundays was a moral statement telling the Danes to stand together in this critical situation [Bjørnholm].

The year before, in 1972, another important event had taken place: the publication of the first Club of Rome report named *Limits to Growth* (LtG) (Meadows et al., 1972). LtG was based on computations performed on a system dynamics model named, *World3*, which, "[…] became an important vehicle in bringing the new problem perception of a global ecological crisis to national and international policy attention" (van Daalen et al., 2002:5). Even though LtG was not the first publication to problematise perpetual economic growth, its global scope and far-reaching narrative marked the advent of a 'new' issue and called an international environmentalist public into being.

The concerns of this public immediately turned out to be in stark opposition to the concerns and interests of the traditionalist public for whom continued economic growth, employment and societal stability were the primary political priorities. These two publics carried the potential for severe conflict, and soon after its publication, LtG became subject to aggressive attacks from traditionalists, and heated discussions broke out [Meyer].

In spite of this controversy, the LtG issue had the ability to mobilise both competent business leaders and long-haired students [Bjørnholm]. Along these lines, Bjørnholm explains how the LtG issue influenced the Rockefeller Foundation and the Nobel Foundation to establish a scientific network called, IFIAS, which involved high-ranking research institutes from several countries. The basic idea of this initiative was to see whether international, interdisciplinary research collaborations could lead to useful responses to the complex, multifaceted future challenges articulated by LtG and other related studies [Bjørnholm]. The famous Niels Bohr Institute for theoretical physics in Copenhagen was invited to join IFIAS and the invitation was accepted. Using Dewey's vocabulary, the IFIAS community can be understood as a public which brought the traditionalist and environmentalist together around a somewhat common agenda.

At the first IFIAS meeting in Copenhagen in February 1973, it was decided that the Danish contribution would be a pilot study of energy issues in Denmark. Later that same year, the oil crisis emerged and pushed the Danish IFIAS project up the political agenda. Thus, the oil crisis became a factor in turning the project focus towards the concerns of the traditionalists, such that the main question for the Danish project became: *how to become independent of oil from the Middle East?* Denmark was the perfect case for such a study due to its utter dependence on foreign energy and the availability of well-ordered statistics in many categories [Holm].

The oil crisis and the economic concerns of western nation states thus became factors which directed the Danish project focus towards energy supply security and increased the government's attention, to such an extent that the project was subject to continuous interest from high-ranking officials in the Danish ministries of State, Finance and Commerce; the latter being responsible for national energy issues at the time [Holm]. The high priority status of the project was also reflected in the appointment of Thorkil Kristensen – the first secretary general of OECD and former Danish Minister of Finance – as the public face of the project.

The daily work of the IFIAS group consisted of talking to representatives of a wide range of professional capabilities within the energy industry and gathering energy system data from every corner of the country in order to build a model strongly grounded in empirical data [Holm]. This work was facilitated by the high priority status of the project, which made almost anything possible, or as Holm expresses it, "all doors were open so to say, and if information existed at all, it was accessible to us".

However, as Holm also remembers, they needed a framework for the figures: "we had plenty of data for houses, gasworks and oil burners, but needed a framework in order to say something about the overall economy and energy consumption". For this purpose, it was decided, under the influence of the economist, Bent Thage, a high-ranking official from Statistics Denmark, that a macroeconomic model would be built based on the Norwegian Multi-Sector Growth (MSG) framework [Holm]. Hence, Holm, the programmer of the group, reconstructed the Norwegian MSG model to fit Danish data. As the work progressed, the IFIAS group developed a joint instrument consisting of two models: MSGE (E for energy), an energy demand model, and ESM (Energy System Model), an energy supply model. This description exemplifies issue articulation as a process of associating material circumstances – houses, gasworks, and oil burners – by means of data collection and the incorporation of these data into a wider framework of macroeconomic calculation.

Using the article's theoretical patchwork to express the procedure of operating the IFIAS models, one could say that the interests and economic concerns of the traditionalist public came to dominate the operation. To begin the procedure, MSGE would receive an exogenous input, which was the official economic growth forecast provided by the Ministry of Finance. Based on this input, MSGE would calculate the total amount of energy needed to achieve the level of production forecasted by the ministry. By means of an input-output[13] (IO) matrix, MSGE would disaggregate the total energy demand into sectors and energy sources. ESM was then used for exploring energy system opportunities and developing scenarios of less oil-dependent energy system configurations able to meet this demand. There was no programmatic feedback from ESM to MSGE. Thus, ESM had no direct influence on the total energy demand or the disaggregation into energy sources demanded by industry and households [Holm]. Based on this procedure, the IFIAS group produced and published energy system scenarios for the purpose of policy debate and decision-making, thus articulating imaginaries in agreement with the traditionalists' economic growth priority.

The theoretical interpretation of the preceding section is that it exemplifies the role of macroeconomic calculation in a nexus between issues, publics and imaginaries: an issue – the oil crisis – emerges and is articulated by means of national accounting. The traditionalist public reacts by making the IFIAS project a high priority, which leads to inquiry into the Danish energy system and macroeconomic articulations with the purpose of informing governmental decision-making and public debate.

6.1.1. Publications and Confrontations

The Danish IFIAS project terminated in 1976 when two group members were headhunted to work in the Ministry of Commerce on energy

[10] There were some emergency exceptions to the law, and it was possible to acquire a permission to drive for certain vital purposes.

[11] Actually, this intervention was also introduced in other European countries.

[12] At that time, growth had in fact already been declining for some years (Midttun and Baumgartner, 1986), which only made the crisis more disturbing for the government.

[13] An IO matrix is a mathematical subdivision of the economy into sectors of production and final consumers. For more information, see Leontief (1970).

issues. Even though the project finished abruptly and the work of the group has now been more or less forgotten, the project must be recognised as a pioneer project. As an economist, who was later involved in similar projects, puts it, "the IFIAS group started a tradition" [Morthorst].

A part of this tradition was to publish energy policy scenarios, and the year 1976 witnessed no less than three such publications. First came the IFIAS scenarios (Bjørnholm et al., 1976), then the first official energy plan of Denmark (Handelsministeriet, 1976), and finally, a so-called alternative energy plan (Blegaa et al., 1976) authored by growth sceptical members of the environmentalist public. The IFIAS scenarios and the official plan were actually more or less identical - reflecting the high level of coordination between the IFIAS project and the Ministry of Commerce (the publisher of the official plan) – whereas the alternative energy plan especially deviated on one specific issue: nuclear energy.

The IFIAS scenarios and the official plan both relied on the introduction of nuclear energy (amongst many other very well-considered technical solutions, which would later prove to be successful) to reduce the oil component of the overall energy mix. However, the introduction of nuclear energy was a highly controversial issue in Denmark (Meyer, 2000), and in spite of the fact that most of the authors of the alternative plan held strong antagonistic views on economic growth, they accepted this priority in order to fight the battle against nuclear.

They did this by first explicitly denouncing the economic growth imperative, although they accepted the overall projections of economic growth presented in the official plan in order to show that it was possible to make an energy system scenario which was able to saturate the overall demand for energy projected in the official plan without nuclear. For this purpose, the alternative plan relied on coal and, to a much greater extent than the two other plans, on renewable energy. As history has shown, nuclear has not been introduced in Denmark and the country has since witnessed what could reasonably be termed a renewable energy revolution (Karnøe, in progress). The growth sceptical authors of the alternative energy plan (and the environmentalist public more generally) thus ended up as winners of the nuclear power battle, albeit at the cost of accepting the economic growth imperative. Since nuclear has not yet become part of the Danish energy system, the preceding exemplifies how the battle over nuclear in Denmark was always a battle of imaginaries, and how imaginaries can be understood as strong political forces able to determine actual decision-making.

The authors behind the alternative energy plan belonged to a group of researchers[14] centred at the Technical University of Denmark, spearheaded by the physics professor and economic growth antagonist, Niels I. Meyer. As was also the case for the LtG authors, Meyer's group was occasionally met by attacks from mainstream economists and a general distrust from the traditionalist public. This is exemplified by one of the former group members in the following way: "we operated in a hostile environment and were often met by hard feelings" [Anonymous]. This indicates a sharp divide between the traditionalist and the environmentalist public. However, this is not entirely precise since the boundaries between the two were blurred by multiple crossing and interrelations. An example of this is the fact that some members of Meyer's group actually ended up working in state organisations such as the Energy Agency, while Meyer himself chaired various governmental renewable energy committees and councils from the seventies and several decades onwards (Meyer, 2000).

Regarding the energy issue more generally, the members of Meyer's group held an entirely different view than most mainstream economists. In mainstream economics, energy was, and for many practical purposes still is, considered one of the less influential factors of production, whereas a former member of Meyer's group emphasises how the energy crises revealed energy as a key socio-economic factor having multiple environmental implications [Josephsen].

6.2. The Golden Age

In the early eighties, the energy question was, from a traditionalist perspective, still mainly a question of security of supply, while environmental problems in relation to energy consumption was a marginal concern (Meyer, 2000). This changed in the late eighties with the emergence of the international sustainable development discourse, spearheaded by the publication of the Brundtland Report in 1987 (Hajer, 1995; Blok, 2005; Røpke, 2005). As opposed to LtG, the sustainable development discourse was more in line with the traditionalist agenda since it promised a reconciliation between environmental concerns and the unquestionable economic growth imperative. Thus, the Brundtland Report became a turning point, which marked an increased interest in environmental issues in Danish policy-making (Miljøstyrelsen, 2015).

The increased interest led, amongst many other things, to the establishment, in 1992, of the Strategic Environmental Research Programme, the objective of which was to provide environmental knowledge for policy-making in Denmark (Blok, 2005). Amongst many research projects, the programme also funded a project with the purpose of creating a modelling tool for the coherent assessment of economy-environment relations in Denmark (Andersen et al., 1998). This project resulted in the development of a collection of models named EMMA, which is still used by different state agencies for energy demand forecasting today [Andersen, Pedersen].

The main organisations involved in developing EMMA were the sectoral energy research institute, Risø, and Statistics Denmark. Risø employed an interdisciplinary energy systems group (also including economists), while Statistics Denmark commanded a macroeconomic modelling group (comprising only economists). Economists in the Risø group had previously been involved in MEM projects funded by the European Community (Fenhan and Morthorst, 1981; Bâtiment, 1993), while the group at Statistics Denmark were in charge of maintaining and developing the macroeconometric model ADAM used by the Danish Ministry of Finance for forecasting and policy assessment. The connection between the groups at Risø and Statistics Denmark has been vital to the MEM community in Denmark, not least due to the fact that most of the economists involved in the development of this discipline received their training in either one or both of these groups.

The relatively long history of EMMA indicates how changing policy issues and public interests are able to influence the development of a model. Even though I do not possess all the ethnographic detail and empirical pieces to fully explain this, I argue that there is a connection between the sustainable development agenda, the environmental issues it brought along, and the demand for further macroeconomic inquiry for which purpose EMMA was developed. Indicating this, the first version of EMMA[15] was merely a single energy demand satellite to ADAM [Andersen], while during the nineties, EMMA evolved into a collection of ADAM-satellites able to couple several environmental issues, such as CO_2, SO_2 and NO_x emissions, to ADAM's macroeconomic machinery.

An important force in this development was the then Minister of Energy and Environmental affairs, Svend Auken, who had a strong voice in the centre-left government (1993–2001) and was able to bring environmentalist concerns further up the traditionalist agenda. This resulted, amongst other things, in the passing of a law which dictated environmental assessments of policy plans and the annual budget (Andersen, 2000). The environmental assessments of the annual budget quickly became subject to heavy criticism, and they were abandoned already after three years. However, they left an imprint on EMMA by being the catalyst for its expansion and elaboration in terms of environmental detail. This development required much time and labour, however, according to one of its designers, EMMA was actually capable of handling the assessments at the time of the abandonment [Andersen].

[14] This group based their understanding of economic growth and energy systems on, amongst other things, systems dynamics and thermodynamics.

[15] This was before the model was actually dubbed EMMA during a naming session involving two model builders and a bottle of red wine [Grinderslev].

Broadly speaking, EMMA is a collection of energy specific satellites to ADAM. In concert, this setup is able to perform three core articulations: first to quantify industry and household energy consumption and disaggregate it into different energy types[16], second to model the energy supply sector's conversion of fuels into other forms of energy, and finally to calculate the total amount of CO_2, SO^2 and NO_x emissions due to energy consumption[17] (Andersen and Trier, 1995). In order to do so, EMMA is dependent on an exogenous projection of economic growth (provided by the Ministry of Finance using ADAM). In this respect, EMMA can be seen as an energy/emissions extension of the macroeconomic concerns of the traditionalist public.

Even though the IFIAS models and EMMA thus exhibit a basic similarity, there are still quite a few differences between the two. First of all, the development of EMMA reveals an interesting double movement: *increasing interest in environmental issues* and a *gradual take over by the economics discipline*. The first aspect has already been treated, while the second refers to the fact that the IFIAS project was an interdisciplinary project characterised by a mix of physics, engineering and economics competencies, whereas EMMA was developed by economists, who incorporated energy systems engineering knowledge in their framework. This is indicative of how economists gradually expanded their sphere of influence on the inquiry into the energy issue, which is also exemplified by the fact that the IFIAS collections was a combination of a macroeconomic and an energy systems model, whereas EMMA is solely macroeconometric. In other words, IFIAS's energy system model was a mathematical model based on an engineering approach to the energy system, whereas EMMA is based on estimated behavioural equations (and IO-matrices) determined by mainstream economic theory.

As opposed to the IFIAS models, feedback from EMMA to ADAM is technically possible (Andersen et al., 2010). However, interviews reveal that this is a slightly tricky business, and such iterations can easily go astray [Andersen]. Over the years, the emissions and supply satellites and the feedback possibility of EMMA have not been employed for many practical purposes (Energistyrelsen, 2015). EMMA has, thus, always been mainly used for imaginary purposes such as the articulation of energy demand forecasts.

6.2.1. More Energy Plans

During the eighties and nineties, new energy policy imaginaries in the form of three official energy plans – *Energy Plan 81* (Energiministeriet, 1981), *Energy 2000* (Energiministeriet, 1990) and *Energy 21* (Miljø- og Energiministeriet, 1996) – where published. These three plans were exponents of the changing policy focus described in the preceding. Thus, Energy Plan 81 was mainly concerned with energy security (Meyer, 2000), whereas the latter two plans exhibited an increased emphasis on the concerns of the environmentalist public, especially climate change. However, all the plans still consisted of imaginaries which complied with the official economic growth forecasts provided by the Ministry of Finance using ADAM.

Providing a more nuanced perspective to this general tendency, it is interesting to observe that the 81 plan actually presented a so-called low growth scenario, which halved the official future economic growth rate to 1.5% and relied on tighter government control of energy system developments. The reason for incorporating this imaginary was, most likely, parliamentary pressure motivated by the concerns of the environmentalist public (Meyer, 2000). That said, Energy 81 emphasised that the low growth approach would substantially affect the balance of payments and employment negatively. Furthermore, it was emphasised that the low growth projection of GDP was not the Ministry of Finance's official forecast (Energiministeriet, 1981).

Finally, it should be mentioned that the official 81 plan was followed by the publication of a very elaborate alternative plan in 1983 (Hvelplund et al., 1983), authored by a group including several of the authors of the first alternative plan (Meyer, 2000). This plan was characterised by a holistic systems perspective with serious attention paid to renewables, which inspired the makers of Energy 2000 seven years later (Meyer, 2000). Once again, this exemplifies the ability of imaginaries, to exercise influence; influence which is traceable in actual policy and energy system transformations.

6.3. Present Trends

During the 2000s, Denmark witnessed a policy shift from a willingness to an aversion to financially support state institutions to care for the environment [Holten-Andersen]. The main protagonist of this shift was Anders Fogh Rasmussen, head of the right-wing government, which came into office in 2001. According to public myth, one of Rasmussen's aims was to demolish Auken's empire. This aim was carried out, amongst other things, by shutting down several environmental boards and councils [Holten-Andersen], (Jerking, 2009) and establishing a new institute of environmental assessment headed by the now notorious climate action obstructer, Bjørn Lomborg (Jerking, 2009).

As a consequence of Rasmussen's low concern for environmental issues, his reign became a dark era for the environmentalist public [Holten-Andersen]. However, during his second term, Rasmussen changed his attitude towards climate change, and not long after[18], an interdisciplinary climate commission to explore the possibility of achieving a zero-carbon energy future by 2050 was commissioned. This shift in political attention characterises the present day where the focus on climate change and a zero-carbon future dominates the public debate on environmental issues.

Not least thanks to impressive grassroots activities and innovative entrepreneurship, Denmark is, at least for the time being, one of the leading renewable energy nations in the world (Karnøe, in progress, IEA, 2011). This status makes it realistic for Danish politicians to discuss the possibility of a zero-carbon energy system in 2050. Even though the coming into office of a new right-wing government in 2015 has added serious doubts to the feasibility of this ambition, the Danish Energy Agency still possesses a large selection of instruments with which to explore this issue. As the main agency handling the government's energy concerns, the Danish Energy Agency thus provides an appropriate site for an account of energy models currently in use for energy issue articulation and the drafting of energy policy imaginaries.

At the beginning of the story in 1973, the energy concerns of the state were more or less handled by two people, who kept track of coal imports in the Ministry of Commerce [Holm]. With the outbreak of the first oil crisis, it quickly became apparent that the number of employees and level of expertise was insufficient. Hence, in 1976, the Danish Energy Agency[19] was established, and since then, the agency has expanded dramatically, to the extent that it has approximately 300 employees today.

In the early seventies, the general selection of energy models was sparse (Hogan, 2002), whereas today a diverse array of such models is in use at university departments and sectoral research institutes. This is also the case for the Danish Energy Agency, which has a large model selection including energy models for areas such as transportation, housing, district heating and electricity [Pedersen]. This reflects a very different situation from the situation in which the IFIAS models operated. The IFIAS project consisted of a small group of people who had two models at their disposal, whereas the models in the Danish Energy

[16] In the 1997 version, the six energy types were: transport fuel, electricity, natural gas, district heating, solid fuel and liquid fuel. A subsequent version included seven types: gasoline, electricity, gas, district heating, coal, oil and biomass (Andersen et al., 2010).

[17] The disaggregation into energy types is necessary in order to provide a good description of emissions since each fuel type has a specific emission intensity and results in the emission of different pollutants.

[18] At that time, however, Rasmussen had left office to become the new Secretary General of NATO.

[19] The Danish Energy Agency is now a part of the Ministry of Climate, Energy and Housing.

Agency are distributed amongst several areas of responsibility. This is indicative of an increase in modelling capabilities, which has taken place over the years and has led to a situation where the energy agency is able to respond to many different political requirements using its models either separately or in concert. In the latter case, the agency's selection of models is a fairly streamlined apparatus held together by a so-called compilation model. This apparatus regularly provides an elaborate baseline forecast of the energy situation in Denmark approximately ten years ahead in time [Pedersen].

As was also the case for the previously described models, the models in the Danish Energy Agency can be grouped according to an economic conceptualisation of the energy issue. A central distinction in this regard is made between supply and demand models. On the demand side, EMMA is responsible for the overall energy demand forecast, which is dependent on the official macroeconomic forecast provided by the Danish Ministry of Finance. This reveals a one-directional demand forecasting procedure, where the agency's energy models are not in a position to provide any feedback to ADAM.

In relation to this ‘deficiency’, it is noteworthy that a new integrated modelling collection is currently under construction at the Energy Agency. This collection is called IntERACT[20] and is supposed to become a supplement to the model selection already in use at the agency [Termansen]. The decision to initiate the IntERACT project was part of a parliamentary energy agreement from 2012 (under a centre-left government 2011–2015), in which it is stated that 15.2 million Danish Kroner has been earmarked for the, “[d]evelopment of a general equilibrium (GE) model for modelling the energy system and economic system to identify effective policies and future regulatory initiatives” (Termansen et al., 2013).

As a part of the energy agreement from 2012, the objective of which is to push in the direction of making Denmark fossil-free by 2050, IntERACT is designed to articulate the effects of a transition to a zero-carbon-future on the Danish economy. IntERACT consists of two integrated models: a computable general equilibrium (CGE) model and an energy supply model named TIMES-DK[21]. The CGE model is based on neoclassical assumptions such as rational economic behaviour, utility and profit maximisation (consumers and firms respectively) and perfect information. These assumptions combined with the mechanics of prices and market forces make it possible to obtain a general equilibrium solution for the entire economy, where all markets achieve equilibrium simultaneously (Termansen and Gersfelt, 2013).

TIMES-DK, on the other hand, is a very detailed linear programming energy systems model, which optimises a single objective function under a number of constraints. The objective which TIMES-DK optimises is: *how to deliver a specified amount of energy services in the most cost-efficient way?* To answer this question, TIMES-DK uses a rich technical description of the Danish energy system.

Even though both models operate by optimisation, they are considered to represent two opposite approaches: top-down (CGE) and bottom-up (TIMES-DK). According to Termansen, integrating the two is not straight forward. In intERACT, the integration goes through energy services such as heating, light and transportation. The basic idea is that the CGE model provides an overall demand for energy services, while TIMES-DK calculates how this demand can be met ‘at the lowest cost’[22] under specified constraints [Termansen].

Unlike the two previously described model collections, feedbacks between the energy system and macroeconomic variables are of high priority to IntERACT, and the collection is designed to perform iterations between the two models. The iterative loop starts in the CGE model, which is calibrated according to the latest national account figures from Statistics Denmark. Based on these figures, the model provides an energy service demand output, which is fed into TIMES-DK, which then performs its optimisation and feeds the result back into the CGE model, which reacts by adjusting prices and, consequently, the entire macroeconomic output from total production and energy services to unemployment and export. The new demand is then fed into TIMES-DK and so on. Termansen refers to a similar Swedish model when he states that it will take three to four iterations before convergence is established[23].

Basically, IntERACT is designed to calculate the ‘costs’ of a transition to a zero-carbon future, which is calculated by means of a comparison between IntERACT scenarios and the Energy Agency's baseline forecast [Termansen]. The deviation between the baseline projection and the scenarios determines the overall future societal costs (or benefits) in terms of GDP. This procedure is indicative of a very common approach to articulating the future costs to society of sustainable energy transitions (or any other economic policy proposal for that matter). The procedure is not well known to the public and the end result is often communicated as if it was scientific fact, which reveals how mainstream macroeconomic articulations are so ingrained in economic policy that they have become solid reality which is hardly ever contested. This is a good example of ‘successful’ issue articulation.

Comparing IntERACT with the two previously described models reveals a stronger resemblance to the IFIAS models than EMMA. As was the case with the IFIAS models, IntERACT also consists of a combination of a CGE model and a technical energy systems model. However, the IFIAS models were not designed to investigate feedbacks, and its energy systems model was not based on linear optimisation. Furthermore, the range of research questions which characterised the IFIAS project also deviated from IntERACT. Thus, the main focus of the IFIAS project was energy security and independence from the Middle East regarding oil, while the cost of a renewable energy transition is the main focus of IntERACT.

6.3.1. The Climate Commission

Since the publication of Energy 21, Denmark has not seen any new official energy imaginaries. However, in 2010, the aforementioned Climate Commission published the results of its study (based on several models, two of which was ADAM and a model similar to IntERACT) of the possibility of achieving a fossil-free energy future in Denmark. More precisely, the research question was as follows: *is it possible for Denmark to reduce its greenhouse gas emissions by more than 80% by 2050?* (Klimakommissionen, 2010b:18). The commission concluded: yes it is possible, and the ‘costs’ will be modest; an uplifting imaginary, but in my view, it has not been as strong and influential as the authors probably hoped it would be.

What the authors actually mean by costs in the report is the *welfare loss* induced by higher energy prices (Klimakommissionen, 2010b:79), where welfare loss simply means negative effects on GDP (the mainstream macroeconomic proxy for societal welfare). Thus, the welfare aspects of the energy transition were assessed by means of GDP, the traditionalist's value metric par excellence. Once again, this reveals the ability of the economic growth imperative to determine and assess energy policy imaginaries. This imperative is further highlighted by the fact that the commission's mandate, decided by government, explicitly stated that the commission had to take continued high economic growth rates as a given (Klimakommissionen, 2010a:16). Thus, economic growth entered the imaginary policy space and constrained it by only allowing growth imaginaries.

[20] The IntERACT project had a time frame of three years and the initial funding terminated in 2015.

[21] TIMES is one of the modelling tools of the Energy Technology Systems Analysis Program (ETSAP), a consortium, under the International Energy Agency (IEA), which includes a large number of member countries.

[22] The quotation marks are inserted to stress that what is considered the lowest cost depends on the context and the regime of valuation in use.

[23] Convergence means that the difference between output t and t_1 remains within a predefined numerical interval.

7. Discussion

The empirical focus of this article is macroeconomic modelling involved in articulations of Danish energy policy imaginaries. An important observation in this regard is that MEM articulations are political and have concrete policy implications. An example of this is their ability to provide calculations for drafting energy policy scenarios, which define a spectrum of possible energy futures for politicians to discuss and decide upon. In this respect, MEM is part of determining what can be thought of, planned and chosen regarding the future energy system.

An important factor in these choices is the economic growth imperative, which must be preserved thereby ruling out any possible energy futures which violate this rule. This is indicative of the reciprocity of policy and modelling, where the former sets the conditions for the latter with the latter then producing results which determine the imaginary scope of the former. To describe this reciprocity, I show how concerned publics use instruments of enquiry such as national accounting and macroeconomic models in order to articulate troubling situations, turn them into well-defined problems and, finally, propose energy policy imaginaries (in the form of energy plans).

This leads back to the celestial bodies and satellites mentioned in the introduction and the epistemic divide between mainstream macroeconomics and inquiry which takes a thermodynamics perspective on energy systems (Illum and Gibson, 2006). In the preceding story, the role of celestial body was always played by a macroeconomic model (in most cases ADAM), which secured the top priority of traditionalist concerns such as economic growth, unemployment and the public balance of payments. This choice meant that energy system futures became subordinate to these concerns and had to conform to the demands of a growing economy, rendering no-growth energy system futures more or less unthinkable. Thus, the choice of celestial body is a political choice, which determines the range of energy policy imaginaries.

Conversely, choosing exergy as the celestial body changes the conditions for policy imaginaries and renders economic growth a subordinate of thermodynamic forces and concerns. This leads to precaution, serious attention to the environmental consequences of energy consumption and calls for energy system futures determined not first and foremost by the need for economic growth, but a deeper understanding of the thermodynamic aspects of energy systems (Illum and Gibson, 2006). More practically, such an approach emphasises collective energy system planning and allows for zero-carbon energy scenarios based not only on renewable energy and efficiency improvements, but also on voluntary simplicity (Heikkinen, 2015). Thus, such approaches contribute to the expansion of energy policy imaginaries and make alternative approaches to energy transitions thinkable. However, due to a non-existent anchoring in traditionalist strongholds such as the Ministry of Finance, exergy imaginaries are not very likely (not yet at least) to determine any concrete energy policy decisions.

8. Conclusion

In the preceding, a historical case for the promotion of two interconnected arguments – one theoretical and one empirical – has been presented. The first argument regards issues, publics and imaginaries as a nexus for energy policy, while the latter concerns the dominant role of economic growth in the articulation of energy imaginaries. A recurring pattern in the story is the emergence of issues, which publics respond to by means of articulation of these issues and imaginaries of how to deal with them. In this sense, energy policy can be seen as a battle of imaginaries, where environmentalists have achieved some significant victories over the years, yet have never been able to seriously challenge the dominance of economic growth over the imaginary space of energy system futures.

The answer to the research question proposed in the introduction is that macroeconomic energy modelling has been developed as an instrument for energy policy in Denmark as a result of a traditionalist public responding to energy issues in the need for imaginaries of the future energy system. Gradually, some of the concerns of another public – the environmentalists – entered the traditionalist policy agenda, which led to an expansion of modelling capabilities in relation to environmental detail. Ever since the early 1970s, economic growth has played a key role in the energy imaginaries by being incorporated as a basic precondition provided by the Danish Ministry of Finance.

The lesson to learn from it all is that macroeconomic modelling can be used as a powerful articulator of issues and imaginaries, and is, hence, to be understood as an effective instrument for constructing the realities confronting governmental decision-makers and the wider public. Thus, if someone wishes to change the world of economic policy, changing the models and the imaginaries they articulate might be a good place to start.

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Appendix 1. Interviewees and seminars

Interviewees

Andersen, Frits M.; professor of economics, Technical University of Denmark, Risø. Involved in the development of several macroeconomic models for energy and environmental analysis since the late 1970s.

Blegaa, Sussanne; high school teacher (retired). During the 1970s, employed at Technical University of Denmark.

Bjørnholm, Sven; senior lecturer of physics (retired), the Niels Bohr Institute, Copenhagen. Day-to-day head of the Danish IFIAS group from 1973 to 1976.

Grinderslev, Dorte; chief consultant, The Danish Council on Climate Change. At the time of the interview, consultant at the Danish Economic Councils.

Holm, Anders; senior lecturer of physics (retired), the Niels Bohr Institute, Copenhagen. Member of the IFIAS group in charge of coding and programming from 1973 to 1976.

Holten-Andersen, John; senior lecturer in engineering (emeritus), Aalborg University Copenhagen. Previously, head of the secretariat of the Danish Nature Council.

Jespersen, Jesper; professor of economics, Roskilde University.

Josephsen, Lars; consultant (retired), the Danish Ministry of Energy and Environment. Co-founder of the Danish environmental NGO NOAH. Previously, also involved in some of the IFIAS publications.

Knudsen, Dan; chief consultant in the macroeconomic modelling group at Statistics Denmark.

Meyer, Niels I.; professor of physics (emeritus), Technical University of Denmark. Key figure in the Danish alternative energy transition since the 1970s.

Morthorst, Poul E.; professor of economics, head of the systems analysis division at Technical University of Denmark, Risø. Involved in the development of several macroeconomic models for energy and environmental analysis since the late 1970s.

Nørgaard, Jørgen; senior lecturer in physics and engineering (emeritus), Technical University of Denmark.

Pedersen, Sigurd L.; chief consultant, the Danish Energy Agency.

Thomsen, Thomas; economist, self employed developer of solution algorithms for macroeconomic models.

Werner, Morten; chief consultant, Danish Economic Councils. At the time of the interview, consultant in the macro-policy centre at the Danish Ministry of Finance.

Seminars

Public seminar on multi-sector models, Danish Energy Agency, Copenhagen, Denmark, March 20, 2015. The seminar consisted of several presentations. I only refer to the presentation about IntERACT by Termansen, Lars B., specialist consultant, the Danish Energy Agency.

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