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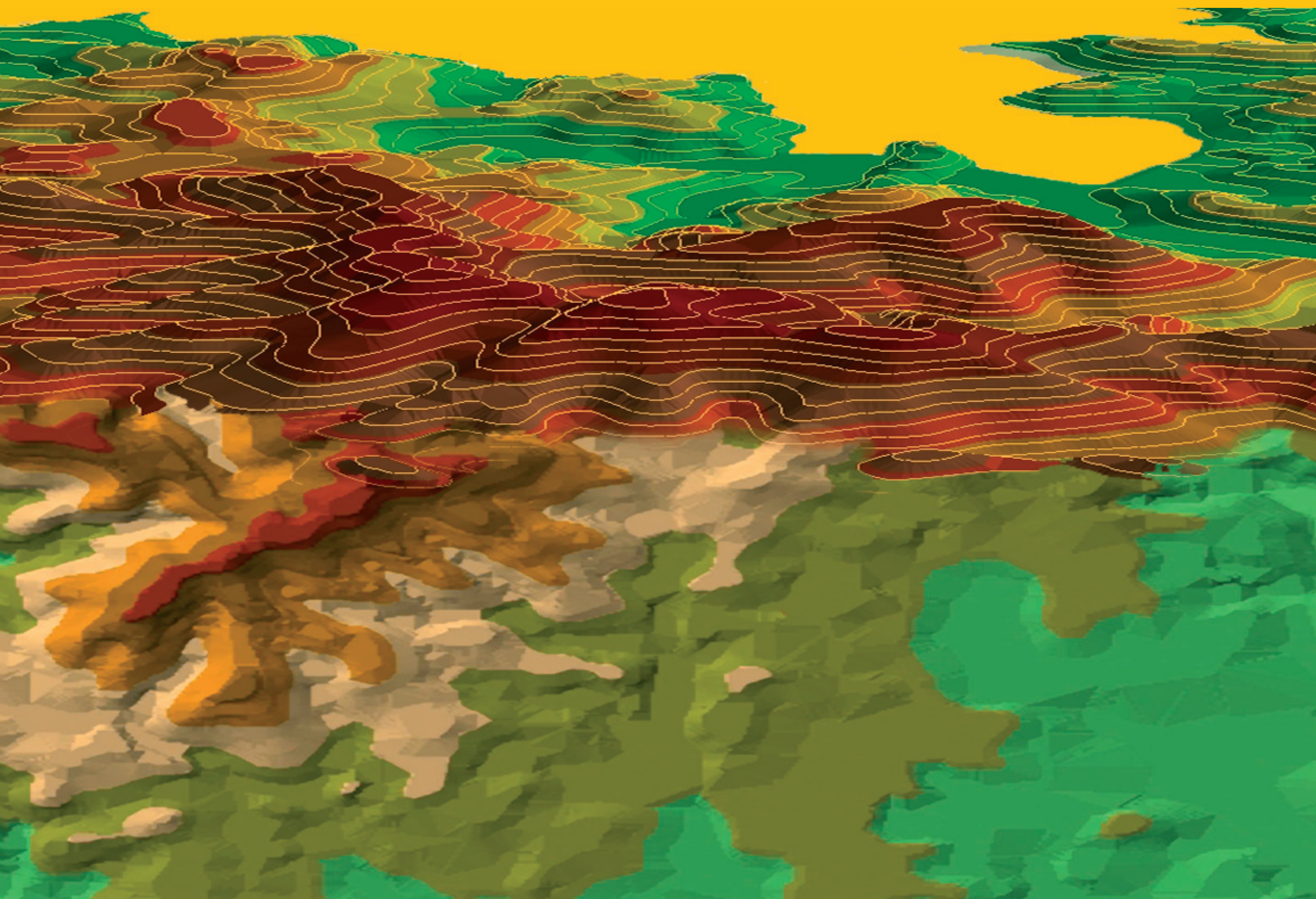

Fig. 1: Most lake – anthropogenic lake made during the recultivation of the Ležáky mine, the location of historical city of Most which was destroyed during 1970´s (Photo: B. Frantál))

Fig. 2: Opencast mine of the Czechoslovak Army (district of Most) – approaching the boundaries of the current ecological limits of mining (Photo: B. Frantál)

Illustrations related to the paper by B. Frantál and E. Nováková

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Articles:

Bohumil FRANTÁL, Martin J. PASQUALETTI, Dan VAN DER HORST
NEW TRENDS AND CHALLENGES FOR ENERGY GEOGRAPHIES: INTRODUCTION TO THE SPECIAL ISSUE 2
(Nové trendy a výzvy pro geografie energií: úvod do speciálního čísla)

Charles WARREN
SCALES OF DISCONNECTION: MISMATCHES SHAPING THE GEOGRAPHIES OF EMERGING ENERGY LANDSCAPES 7
(Měřítka diskonekce: nesoulady ovlivňující geografie rozvíjejících se energetických krajin)

Gerd LUPP, Olaf BASTIAN, Reimund STEINHÄUßER, Ralf-Uwe SYRBE
PERCEPTION OF ENERGY CROP PRODUCTION BY LAY PEOPLE AND FARMERS USING THE ECOSYSTEM SERVICES APPROACH 15
(Výzkum vnímání produkce energetických plodin laickou veřejností a zemědělci s využitím přístupu ekosystémových služeb)

Jaroslav HOFIERKA, Ján KAŇUK, Michal GALLAY
THE SPATIAL DISTRIBUTION OF PHOTOVOLTAIC POWER PLANTS IN RELATION TO A SOLAR RESOURCE POTENTIAL: A CASE STUDY OF THE CZECH REPUBLIC AND SLOVAKIA 26
(Prostorové rozložení fotovoltaických elektráren ve vztahu k potenciálu solárního zdroje: případové studie České a Slovenské republiky)

Justyna CHODKOWSKA-MISZCZUK
SMALL-SCALE RENEWABLE ENERGY SYSTEMS IN THE DEVELOPMENT OF DISTRIBUTED GENERATION IN POLAND 34
(Malo-měřítkové systémy obnovitelné energie v rozvoji rozptýlené výroby v Polsku)

Markus SEIWALD
THE (UP)SCALING OF RENEWABLE ENERGY TECHNOLOGIES: EXPERIENCES FROM THE AUSTRIAN BIOMASS DISTRICT HEATING NICHE ... 44
((Up)scaling technologií obnovitelné energie: zkušenosti z rozvoje dálkového vytápění biomasou v Rakousku)

Bohumil FRANTÁL, Eva NOVÁKOVÁ
A CURSE OF COAL? EXPLORING UNINTENDED REGIONAL CONSEQUENCES OF COAL ENERGY IN THE CZECH REPUBLIC 55
(Prokletí uhlí? Zkoumání nezamýšlených regionálních důsledků uhelné energie v České republice)

Dan VAN DER HORST
LANDSCAPES OF LOST ENERGY: COUNTERFACTUAL GEOGRAPHICAL IMAGINARY FOR A MORE SUSTAINABLE SOCIETY 66
(Krajiny ztracené energie: kontrafaktické geografické imaginárno pro udržitelnější společnost)

NEW TRENDS AND CHALLENGES FOR ENERGY GEOGRAPHIES: INTRODUCTION TO THE SPECIAL ISSUE

Bohumil FRANTÁL, Martin J. PASQUALETTI, Dan VAN DER HORST

In 1961, the Canadian geographer John D. Chapman recognized the rapid growth in demand for inanimate energy and the role geographers could be playing in explaining its patterns and importance in the growing world economy (Chapman, 1961). Fifty years later, Karl Zimmerer (2011) introduced a Special Issue of the Annals of the Association of American Geographers by noting that not only had Chapman's prediction come true but that geographers were studying even a wider spectrum of energy challenges than Chapman could ever have imagined (see e.g. Dorian et al., 2006; Florini, Sovaccol, 2009).

Many of those energy challenges were underscored at last year's G20 summit in Saint Petersburg, Russia. Particular attention was paid to four concerns considered as crucial for global energy (OECD, 2013): phasing out fossil fuel subsidies (which encourage wasteful consumption, disproportionately benefit wealthier countries and sectors, and distort energy markets); price volatility (understanding and reducing temporal fluctuations and regional differences in commodity prices); market transparency (a necessity for accurate and timely energy data); and – last but not least – options of mitigating climate change (as the source of two-thirds of global greenhouse-gas emissions, the energy sector is crucial for achieving any climate change goals).

By 2035, the world is projected to consume one-third more energy than today, while electricity demand should increase even by more than two-thirds (IEA, 2013). The centre of gravity of global energy demand will move decisively towards emerging economies such as China, India or Brazil, which should account for more than 90% of net energy demand growth. At the same time, however, it is estimated there will still be one billion people without access to electricity and 2.7 billion without access to clean cooking fuels in 2035, mostly in Asia and sub-Saharan Africa (ibid.). The current global energy market is characterized by rising differences in regional energy prices (depending on the availability of domestic resources and regional position within international energy flows), which have led to major shifts in energy and overall trade balances, as well as to energy expenditures taking a growing share of household income (IEA, 2013). The current political crisis in Ukraine and Russia´s chess operations with the supply of natural gas, have again emphasized the role of energy as an effective tool to influence international relations and maintaining political influence.

During the last two decades, environmental and security concerns have led to a rapid and far-flung development of renewable energies. Modern wind power development, for example, now is found in over 100 countries, and solar power deployment is – in one form or another – in many more. Reaping the benefits of renewable sources has become a global ambition for several reasons, ranging from anxieties about climate change and energy security to the dangers of the atom. Indeed, the generous feed-in tariffs that Germany used to stimulate renewable energy development have been so effective that Chancellor Merkel was able to renounce Germany's nuclear program after the Fukushima nuclear accident in 2011 (The Economist, 2011). Nonetheless, renewable energy development has been uneven around the world. Despite rapid and substantial growth in countries such as China, Germany, Spain and the United States, it still represents but a small amount of generation in most countries. For this reason, governments still need to consider other options, including cleaner use of fossil fuels, nuclear power, and new technologies such as shale gas fracking.

All energy sources are characterized by potentially negative impacts, direct or indirect, manifesting themselves at different spatio-temporal scales. The economic costs of resources and the reliability of their supply are no longer the only criteria shaping political decisions and public opinions. Rather, perceptions of energy landscapes from renewable energy resources can be significant factors affecting: (1) national energy policies and their support by the general public (Leiserowitz et al., 2013); (2) acceptance of new energy facilities by local communities (Frantál, Kučera, 2009; Frantál, 2014; Pasqualetti, 2011a; Pasqualetti, 2011b; Soland et al., 2013, etc.); and even (3) customer loyalty in liberalized residential energy markets (Hartmann, Ibanez, 2007).

The concept of what we call the "energy landscape" is one of the most intriging, important and challenging themes of the new geography of energy. Energy landscape is a term that has been commonly used for decades in physics and organic chemistry. In recent years, however, it has acquired a new meaning in the field of geography and landscape ecology (Pasqualetti, 2012). An energy landscape is a landscape whose images and functions (be they natural, productive, residential, recreational, cultural, etc.) have been significantly affected by energy development. Traditional energy landscapes include mines, canals, refineries and power plants, transmission lines, well fields and waste disposal sites, but more recently they have come to include expansive, whirling wind turbines and even the glare of solar central receivers in places like Ivanpah Dry Lake California (e.g. Nadai, Van der Horst, 2010; Zimmerman, 2014). In the broadest context, the range of what can be called an energy landscape is particularly expansive, though it may be used in the context of all branches of energy production and consumption with a geographic expression.

Projects like wind farms, solar power plants, the cultivation of energy crops, biogas stations and other innovative technologies, have become effective means of realizing officially declared state-subsidized support for clean and sustainable energy. These projects, as well, can be objects of entrepreneurial interest among investors and developers, a potential source of income for communities involved (often located in less-favoured rural areas), and an alternative type of land use and source of profit for farmers. In the eyes of objectors, however, they can also be considered visual polluters of scenic landscapes, degraders of arable land, potential threats to local tourism, and a privileged lobby business thought to be unable to compete without subsidies.

Renewable energy sources – such as wind and some types of solar – are often spatially dispersed, requiring substantial land resources in comparison to conventional energy sources such as coal, oil or gas. For this reason, they may be mostly undertaken in rural areas hitherto unaffected by large-scale industrial development. Only recently the ´brightfield´ projects (brownfield lands converted into a newly usable lands by implementation of renewable energy technologies) have been developing (Kunc et al., 2011, 2014). The problem of balancing both the real and perceived advantages and disadvantages of projects (taking into account such diverse considerations as global climate issues, the energy security strategies of national governments, regional development policies and local community economic benefits, while also on the other hand stressing the significance of nature and landscape protection, calling for a restoration of productive farming, and the preservation of local cultural identity), often provokes political and social conflicts arising from differing values and varying conceptions of land use (Boholm, Löfsted, 2004; Devine-Wright, 2011).

As renewable energy projects grow in frequency and scale, new forms of local opposition have emerged, and coal and nuclear power plants are no longer the only energy facilities people do not want built in their backyards. Opposition has increased most rapidly to wind power, but opposition to solar is on the rise as well. So concerned is it to this unwelcome trend that the International Renewable Energy Agency recently formed a group to provide factual balance to many of the misconceptions to renewable energy. It takes the name The Coalition for Action to Bolster Public Support for Renewable Energy (Irena, 2014). Such public responses range from impacts on archaeological sites and desert tortoises to accelerated erosion and visual glare, and they receive substantial attention in the press. At worst, such responses to landscape impacts have provided fodder for those who would wish to slow down renewable energy expansion in favour of maintaining the status quo. Many opponents to solar have been recommending that the development of large solar installations blatantly misses the major advantage of the resource, i.e., that is naturally distributed. They have advocated more distributed installations, such as covered parking, rooftops and community-scale projects.

Attention to the landscape impacts of energy transitions is just one of the many themes catching the attention of academic geographers. The geography of energy has been significantly progressing from being simply just another descriptive sub-discipline of industrial geography that focused on analyzing patterns of energy supply and demand. The new geographies of energy are encompassing all economic sectors, from primary to quaternary, covering a very wide range of current topics beyond the basic economic issues. Problems investigated in this field range from the uneven distribution of primary energy resources and patterns at all scales and the geopolitical impacts of diverging energy policies and international security issues, through to the issues of global climate change, air pollution and sustainable development, land use conflicts and adaptive management strategies within landscape planning and facility siting, problems of agricultural restructuring and food insecurity, including issues of energy poverty and social injustice and the broader socio-cultural contexts of energy transitions, even encompassing topics such as energy literacy and energy education (Solomon, Pasqualetti, 2004; Pasqualetti, 2011c).

Petrova (2014) summarized the recent Annual Meeting of the Association of American Geographers in Tampa, Florida with the title "Energy Geographers Take Over". The 25 paper sessions on the topic of Energy, comprising more than 100 papers presented, indicated that energy-related topics have increased in importance for both human and physical geographers, demonstrating the growing importance of geography to energy studies. While most of the energy sessions were supported by the AAG Energy and Environment Specialty Group, many papers were presented as a part of thematically broader sessions (e.g., Climate Change and Indigenous People). The energy geography contributions employed many traditional geographical concepts such as spatial fix, material energy flows, metabolism, and territory and territoriality, but also more novel interrogations of infrastructure, assemblages, vulnerability, resilience, community, landscapes, justice, etc. (Petrova, 2014).

The aim of this Special Issue of Moravian Geographical Reports is to contribute to current knowledge and debates about the spatial scales and social dynamics of on-going energy transition processes in the European context, and to highlight the role of geography in identifying and addressing current energy dilemmas. The origin of this issue lies in the international conference on New Trends and Challenges for Energy Geographies, organized by the Institute of Geonics, Academy of Sciences of the Czech Republic in Brno, August 6–8, 2013, in the context of the research project: "Energy Landscapes: Innovation, Development and Internationalization of Research (ENGELA)", Reg. No. ESF OP CZ.1.07/2.3.00/20.0025. This research project was developed with the objective of accelerating international collaboration in the research on emerging energy landscapes. This Special Issue comprises selected, revised and updated original papers from the conference, supplemented by some further contributions. These introductory editorial comments emphasise the key topics and coherence of the overall work.

New energy landscapes are forged when and where energy transitions meet rural transitions. Of course, energy was always part of the rural landscape and economy, but recent decades have seen some profound changes in the way that rural landscapes are utilized, perceived and governed. The European rural landscape is no longer simply the dominion of farming for food (as was the priority in the post-World War 2 era – on both sides of the former Iron Curtain), but is increasingly designed to accommodate alternative or new agricultural and industrial services and tourism activities (Frantál et al., 2013). With Ecosystem Services becoming a mainstream policy narrative (in some countries more quickly than in others), some of these changes are typified as shifts in 'services' provided by specific landscapes towards multi-functional land uses, that include more cultural services (e.g. recreation) or regulating services (e.g. flood control, climate control). Other policy narratives are at play as well and especially popular is the portrayal of renewable energies as an important opportunity for sustainable rural development. There remains the question, however, of the extent to which the political narratives of a new role for farmers as competitive entrepreneurs and "energy producers", accord with farmers' attitudes and their daily practices.

The papers collected in this volume address many of the core issues in the "landscape – energy nexus", from questions about what a landscape is for, and who has what stake in particular patterns of economic developments related to energy, to measures of efficiency, problems of scalability and questions of governance and justice, in case studies on Europe's energy transitions, old and new.

In the first paper, Charles Warren illustrates – by presenting a case study investigating the attitudes of Scottish farmers to policy proposals for extensive conversion of farmland to perennial crop production – how the networked nature of current energy systems produces "geographies of disconnection". The strong antipathy expressed by most farmers to energy crops exemplifies some of the wider socio-political and socio-cultural mismatches and geographical disconnects. Warren's discussion demonstrates that these disjunctions not only affect energy geographies but also raise questions about the ability of current governance structures and liberal democratic systems to deliver effective action in response to current global challenges.

On a related topic, Gerd Lupp, Olaf Bastian, Reimund Steinhäußer and Ralf-Uwe Syrbe explore perceptions of energy crop production as a result of energy policies in Germany. While many German farmers see themselves as being responsible for providing many ecosystem services and prefer a regional scale of energy crop cultivation based on conventional crops, lay people do not consider energy crop production as an important ecosystem service. Rather, they are interested in diverse agricultural landscapes that provide food, wildlife habitat and aesthetics, with at best a minor role for crop residues to be used for bio-energy production.

Over the last few years many European countries have experienced a boom in photovoltaic power plants (PVs), which resulted in controversies related to the economic efficiency and environmental sustainability of solar energy being driven by political interventions (see, e.g. Williams, 2010). The very strong spatial and temporal variability of solar resources and subsequent electricity production, poses new challenges for power grid system reliability and predictability. In the paper by Jaroslav Hofierka, Ján Kaňuk and Michal Gallay, recent data on the development of PVs in the Czech Republic and Slovakia are analyzed with a focus on their spatial distribution patterns. Observing that the spatial pattern of adoption of photovoltaic installations does not correlate with the spatial distribution of solar resource potential, their findings demonstrate that the policy is inefficient and that its design opens the door to many individual investment decisions that are not necessarily in the best public interest. They illustrate the ineffective trade-offs between resource policies that are strongly spatially targeted to maximize benefit-cost ratios, and policies that ignore resource geography by offering financial support everywhere, and therefore to every land owner.

One of the most recent, most efficient and environmentally friendly trends in the development of energy sectors in many European countries, is the so-called distributed energy system. The paper by Justyna Chodkowska-Miszczuk discusses small-scale renewable energy systems in the context of the development of distributed generation in Poland. One of the important dimensions of this process is the creation of micro- and small-power producers using renewable, locally available energy sources. The author notes that the development of small-scale renewable energy producers takes place in two ways, which are spatially differentiated. One is through small hydropower plants, which are the aftermath of hydropower development in areas traditionally associated with water use for energy purposes (northern and western Poland), and the second is through other renewable energy sources, mainly biogas and solar energy, primarily in southern Poland in highly urbanized areas.

Austria has long been a European leader in the green economy, excelling in diverse sub-sectors from biomass heating systems to organic farming. The socio-spatial diffusion of clean technologies, however, has not been automatic and without problems, even in this country. The contribution by Markus Seiwald unpacks the notion of the "up-scaling" of successful green technology adoptions, and challenges the underlying assumption that technology diffusion processes follow a linear trend from small-scale pilot plants to industrial-scale facilities. As Seiwald demonstrates through an analysis of the historical development of the Austrian biomass district heating niche, the socio-technical configurations are usually implemented at a variety of scales simultaneously. In a valuable contribution to the literature on energy transitions, he identifies four dominant designs that shape the diffusion dynamics of the technology.

Throughout modern history, coal has played a key role in human development and it still vitally powers global electric grids. Coal-powered development, however, has come with tremendous environmental and social costs. As emphasized by McKibben (2003, cited in Freese, 2003), given the particular chemistry of global warming, it is possible that the decisions we make about coal in the next two decades may prove to be more important than any decisions we have ever made as a species. The paper by Bohumil Frantál and Eva Nováková explores the long-term 'unintended' regional consequences of coal energy production in the Czech Republic, in terms of the 'environmental injustice' and 'resource curse' theories. Their empirical case study identified significant associations between the spatially uneven distribution of coal power plants and indicators of environmental and socio-economic quality of life (including population vital and health statistics, socio-economic well-being and social capital indicators), as well as recent development trends.

In the final paper, Dan van der Horst makes the case for a counterfactual geography of energy, inviting geographers to use their imaginations to project a view of their geographical area as if it was performing just like the 'best practice' cases found in the world today. He argues that this comparative analysis of the relative underperformance of "our bit" of the planet can serve to highlight the unacceptable non-sustainability of our current status, to familiarise ourselves with the normality of better practices found elsewhere right now, and to 'nudge' us into becoming more creative and ambitious in seeking to achieve a transition to a society that does not externalise its greenhouse gas emissions for the dis-benefit of future generations.

In summary, the world has changed since Chapman (1961) promulgated a "Geography of Energy" as essential for Geography as a discipline, in terms of its potential contributions to society, writ large. In the intervening fifty years or so, the investigations of energy landscapes recently have provided many important and useful insights into the geographic and socio-political effects of societal change with respect to energy, at once narrowing the focus to specific locales and at the same time acknowledging the overwhelming importance of the global grounding of local response. The contributions to this Special Issue of the Moravian Geographical Reports illustrate both the theoretical and empirical aspects of these important politico-economic and socio-spatial changes over the last fifty years, and of the responses to such changes by geographers.

In summary, Geography as a discipline has changed, to reflect the world as inhabited – but also the world as desired.

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SCALES OF DISCONNECTION: MISMATCHES SHAPING THE GEOGRAPHIES OF EMERGING ENERGY LANDSCAPES

Charles R. WARREN

Abstract

The networked nature of energy systems produces geographies of connection, but the focus of this paper is on geographies of disconnection, exploring the multi-scalar processes which shape the context in which energy landscapes emerge. It does so, first, by presenting a case study of farmers' attitudes to perennial energy crops in south-west Scotland. Their strong antipathy to converting farmland to short-rotation coppice, and the reasons for their negative attitudes, exemplify some of the wider mismatches and disconnects which the paper goes on to discuss. These include socio-political and socio-cultural mismatches, and a range of essentially geographical disconnects which are scalar in nature, such as the familiar local-global tension and the mismatch between the scales (both temporal and spatial) at which environmental and human systems organise and function. The discussion shows how these disjunctions not only affect energy geographies but also raise far-reaching questions about the ability of current governance structures and liberal democratic systems to respond swiftly and effectively to global challenges. The way that these mismatches are negotiated will mould both the character of future energy landscapes and the speed at which they take shape.

Shrnutí

Měřítka diskonekce: nesoulady ovlivňující geografie rozvíjejících se energetických krajin

Síťová podstata energetických systémů produkuje geografie spojitosti, nicméně tento článek se zaměřuje na geografie diskonekce, když zkoumá multiúrovňové procesy, které utváří kontext, v rámci něhož se rozvíjí energetické krajiny. Nejdříve je prezentována případová studie postojů zemědělců k víceletým energetickým plodinám v jihozápadním Skotsku. Jejich silný odpor k přeměně zemědělské půdy pro pěstování rychle rostoucích dřevin a důvody jejich negativních postojů ilustrují některé z obecnějších nesouladů a diskonekcí, které jsou v článku diskutovány. Tyto zahrnují sociopolitické a sociokulturní nesoulady a řadu v jádru geografických diskonekcí, které jsou z podstaty skalární, jako známé napětí mezi lokálním a globálním a nesoulad mezi měřítky (časovými i prostorovými), na kterých jsou postaveny a fungují environmentální a sociální systémy. Diskuze ukazuje, jak tyto disjunkce nejenom ovlivňují geografie energií, ale vyvolávají otázky schopnosti současných vládních struktur a liberálně-demokratických systémů rychle a účinně reagovat na globální výzvy. Způsob, jakým jsou tyto nesoulady řešeny, bude formovat charakter budoucích energetických krajiny, ale i rychlost, s jakou se budou rozvíjet.

Key words: *energy crops, mismatches, scale, governance, energy landscapes, energy geographies*

1. Introduction

Energy geographies now loom large within environmental management discourses, driven by the familiar 'troika' of climate change, energy security and peak oil, and by intense socio-political debates in many countries over the landscape impacts of renewable energy technologies (Warren et al., 2012). Even from this opening sentence it is immediately apparent that debates about energy geographies integrate numerous contentious and complex issues, all of which interconnect and interact on diverse spatial and temporal scales. They therefore constitute 'wicked problems' (Churchman, 1967), in that they resist resolution due to their complexity, they are multifaceted and interconnected, and large numbers of people and opinions are involved. Energy use has long been influential in the structuring of identities, territories and landscapes, and is likely to be the primary driver of landscape transformation in the present century (Nadai and van der Horst, 2010). Consequently, energy has emerged as a major governance challenge, not least because energy questions cross-cut many other policy concerns. Indeed, according to Zimmerer (2011, p. 705), energy is "far and away the most significant international resource system and political economic nexus", and energy questions are fuelling "a general social-ecological crisis of now major proportions".

This paper focuses on the essentially geographical dimension of this challenge by discussing the multiple scales – temporal and spatial – through which energy geographies are constructed, both conceptually and practically. It argues that a clearer recognition of this multiscalar reality can help us to understand why the debate is characterized by mismatches and disconnections, and why resolutions prove perennially elusive. In turn, this geographical framing may help to create discursive spaces for constructive debate.

In order to root these conceptual constructs in a real world context, the paper uses a case study about perennial energy crops to illustrate and exemplify how some of these issues play out in a specific geographic locale, namely south-west Scotland. Although the Scottish context is only one of many from which relevant examples could be drawn, it does provide a rich setting for exploring issues surrounding renewable energy and emerging energy landscapes (Warren, 2009). There are several reasons why this is so:

- the country is abundantly endowed with renewable energy potential, most notably in terms of hydro, wind (onshore and offshore) and marine renewables, but also in biomass;
- there is strong political will to harness this potential, demonstrated in the adoption of world-leading targets

(e.g. the aim of generating the equivalent of 100% of electricity demand from renewables by 2020). Scotland's First Minister has said that he wants the country to become 'the Saudi Arabia of renewable energy' (Carrell, 2011);

- as a consequence of these first two points, recent years have seen dramatic rates of deployment, especially of onshore wind farms, accompanied by intense public debate and also by extensive research into social acceptance and the dynamics of opinion formation (Warren and Birnie, 2009; Aitken, 2010); and
- finally, several widely-debated issues come into especially sharp focus in the Scottish uplands, including: (i) the spatial coincidence of sites with power potential and internationally famous landscapes of high value for tourism, such as Loch Ness; (ii) landscape debates concerning the upgrading of energy grids required by new renewable generation capacity in peripheral areas; and (iii) the role of community ownership in facilitating the energy transition.

In this paper, I first outline a case study of energy crops and then shift to a much broader perspective, discussing wider questions about the disconnections which affect the geography of energy landscapes. Where appropriate, aspects of the case study are used to exemplify these broader issues. Recognising that one single case study could not effectively illustrate all the wide-ranging issues considered, however, the subsequent discussion draws on examples from other technologies and other regions.

2. Energy crops, bioenergy landscapes and farmers in south-west Scotland

Much of the public debate in Scotland surrounding renewable energy and landscape impacts has centred on the iconic landscapes of the Scottish Highlands, and has revolved around proposals for onshore windfarms, hydropower plants and grid upgrades (Warren, 2009). By contrast, the case study summarised here addresses perennial energy crops (PECs) in south-west Scotland, an energy source and a region which have received comparatively little attention. PECs have been actively promoted to Scottish farmers as a means of diversification during difficult economic times, and official projections envisage the conversion of large areas of farmland to PECs, both in Scotland and across the UK (DfT/DECC/DEFRA, 2012). The main policy drivers are the potential of such crops to produce a carbon-neutral fuel, while also offering a wide range of ecosystem services (Rowe et al., 2009). The combination of strong policy support and projections of large-scale expansion led Coleby et al. (2012, p. 374) to assert that energy crop production is "set to drive the most extensive changes in land-use in Britain since the 1950s". If this prediction proves correct, the rapid creation of extensive bioenergy landscapes will represent a novel departure for UK energy geographies.

The reaction of the public to such a potential transformation in land use and landscapes, and the social acceptability of such changes, has begun to be investigated in recent years (Karp et al., 2009; Dockerty et al., 2012), but a necessary precondition of any large change taking place clearly would be the widespread adoption of PECs by the farming community. Simply put, if such crops are to fulfil the dramatically expanded role envisaged by policy makers, large numbers of farmers will need to plant them. But because very few British farmers have any experience of PECs, most are wary of them (Sherrington and Moran, 2010; Convery et al., 2012), and this may help to explain the stark contrast between the official optimism about energy crops and the limited area planted to date: by 2011, the total area established in the entire UK was just 0.01 Mha (DfT/DECC/DEFRA, 2012). This 'implementation gap' is one of the issues addressed in this case study.

The zone targeted for PEC expansion by policy makers is land which can be described as the 'squeezed middle' – not top quality agricultural land which is protected for arable cropping, nor poor, exposed upland areas, but intermediate quality farmland, sometimes referred to as 'marginal land' in this context (Shortall, 2013). It is dubbed the 'squeezed middle' because this zone is simultaneously targeted by several policy objectives (including forestry expansion, public access, renewable energy and conservation), and this area cannot fully accommodate all these diverse ambitions. The Scottish Government's innovative Land Use Strategy (LUS) is an attempt to provide a 'strategy of strategies' to chart a way through such tensions by facilitating holistic land use decision making. Launched in 2011, the LUS sets out a framework and broad principles for reconciling the many competing demands on land, utilising the familiar 'three pillars' framing of sustainable development (Scottish Government, 2012). It is too soon to know how effective it will be.

The dominant land uses in south-west Scotland at present are dairy farming and forestry, but the region's soils and climate offer significant biophysical potential for PECs, especially for willow grown in short rotation coppice (SRC). This was a key reason why the energy company E.ON decided to build a 44MW CHP biomass power station at Lockerbie in the Dumfries & Galloway region, the UK's first biomass power station. Commissioned in 2009 and costing £90m (c. €104.4m), it requires 480,000 tonnes of wood fuel per annum (E.ON, 2012). The company's stated aim at the outset was to source 20% of this total from willow grown by farmers within a 60-mile (c. 97 km) radius, requiring the establishment of some 4,000 ha of SRC. Because this represented a potentially valuable alternative market for the region's farmers at a time of economic volatility, offering an opportunity for diversification and a secure local market, E.ON's assumption was that many local farmers would plant SRC willow to supply the Lockerbie plant. The case study tested this assumption by investigating farmers' attitudes to willow SRC via questionnaire surveys in 2009 and 2011 (n = 218).

From previous studies, there were several reasons to suspect that E.ON's assumption was flawed:

- PECs involve cultivation techniques with which farmers are unfamiliar, involving new skills and different machinery;
- energy crops present farmers with new risks and uncertainties (e.g. a multi-year time frame which limits business flexibility);
- in contrast to much of mainland Europe, a deep and long-established cultural 'apartheid' separates farming and forestry in Scotland (Morgan-Davies et al., 2003), and this may prejudice farmers against perennial woody species; and
- PECs are situated in a policy context which is alien to most farmers, sitting outside the 'food and farming box' at the interface between policies concerning climate change, energy security and food security (Sherrington and Moran, 2010).

The methodology and the results of the study are presented and discussed in full by Warren et al. (2015). Only the key results are presented here, focusing on those which illustrate and exemplify the themes in the discussion which follows.

The primary, overarching finding is that most farmers are strongly negative towards converting their land to SRC. The three most frequently stated reasons for their opposition are that SRC:

- is not suitable for existing farming practices and/or for the land (33%);
- introduces inflexibility (18%); and
- is associated with price uncertainty (13%).

To explore the influence of economic factors on attitudes, farmers were presented with a pair of hypothetical questions about the profitability of SRC willow:

1. *Would you consider growing willow if profit margins were equivalent to existing operations?*
2. *Would you consider growing willow if it offered greater profits than current practices?*

Only 4% answered 'yes' to the first question. Unsurprisingly, the prospect of increased profits generated a more positive response to the second question, but still 40% answered 'no' and just 21% were potentially interested. When farmers were asked to identify a single factor which might persuade them to establish SRC, the two equal highest scoring factors, both with 32%, were 'profitability' and 'nothing'; thus for almost a third of respondents, no foreseeable factor would persuade them to consider planting willow on their farms.

It was apparent from the nature of the responses that antipathy to SRC was closely linked with farmers' self-identity and with a strong attachment to their way of life. The following selection of statements by respondent farmers concerning their attitudes towards short rotation coppice and the proposal that they might establish SRC on their farms, exemplify this association:

- *"[SRC] is useless! Our job is producing food, not fuel."*
- *"It [growing SRC] is not what we do. We produce FOOD!"*
- *"We would never grow energy crops. [Dairy farming] is a way of life, our way of life."*
- *"We are livestock farmers, not tree farmers."*
- *"No amount of money would ever encourage me to grow willow because I am a farmer!"*

Some clear conclusions emerge from the data. Firstly, despite a reliable local market (the E.ON power station), SRC is perceived as an 'alien' threat to farmers' socio-cultural identity and way of life. Secondly, there is a serious disconnect between the goals of policy-makers and the perceptions of farmers who are at the 'sharp end' of policy delivery. As one farmer put it, *"some suit-wearing office boy must have thought that the hill-billy farmers of south-west Scotland would just subside, sell half their herds and plant willow."* Thirdly, and more generally, if these results are representative, they imply that energy crops are unlikely to become a significant part of the renewable energy transition in the UK uplands in the way that policies and official projections envisage.

3. Mismatches and disconnects shaping energy landscapes

The above findings are now used to illustrate a broader discussion of different scales and types of disconnection, and to explore some of the ways in which these mismatches can shape the geographies of emerging energy landscapes. The networked nature of energy systems produces geographies of connection, notably in very material ways (e.g. the spatial forms of electricity grids and their temporal evolution). By contrast, the focus here is on geographies of disconnection. While these disconnects are, in themselves, mostly immaterial, they have very tangible implications for landscapes and society.

3.1 Socio-political and socio-cultural disconnects

This sub-section highlights the disconnections between policy makers and stakeholders. Such stakeholders may be active (i.e. people who are expected to implement policy, such as the farmers in the above study), or passive, such as communities which are asked or forced to 'host' developments in their 'backyard'. A disconnect between stakeholders and policy makers is strikingly apparent in the Lockerbie results. These findings, when combined with other studies of farmers' responses to government policy initiatives, and also with research on the social acceptability of wind power, show that technocrats ignore socio-cultural realities at their peril (Burton et al., 2008; Greiner and Gregg, 2011; Convery et al., 2012; Huber et al., 2012). Policy makers in the UK and elsewhere have often been perplexed to discover that technical assessments identifying suitable sites do not translate either simply or easily into renewable energy projects. All too often, only lip service is paid to the social science dimensions of energy debates, and yet these frequently turn out to be critical. Policy making and policy implementation require an understanding of the 'full geography'.

In itself, this is hardly a new insight. Over two decades ago, Twidell and Brice (1992, p. 477) noted that "limits to renewable resources are not the potential in the environment, but the institutional factors and collective personal response of the public", and this observation has been repeatedly proved by subsequent experience. Because it is a truth which is continually overlooked and contributes to the common phenomenon of policy 'implementation gaps', however, it remains an important live issue to highlight. It is also a contributory factor in the so-called 'social gap' between broad public support for a policy and public opposition to specific proposals, a much-researched issue which has recently been revisited by Bell et al. (2013). They argue that understanding such gaps is important not only for the fulfillment of renewable energy ambitions but, more broadly, to explicate "the relationship between public opinion and political outcomes in democratic politics more generally" (Bell et al., 2013, p. 116). The importance of the social science dimensions of policy implementation is also stressed by Warren et al. (2012), who suggest that, whereas the sustainability challenge was once thought to consist of persuading a soft and malleable society to adjust to 'hard facts', it would now appear that the inverse situation of 'soft facts' and 'hard society' is perhaps closer to the truth: facts are contested, whereas social norms and practices prove resistant to change. The story of the development of wind power policy nicely exemplifies this inversion (Szarka et al., 2012), as does the resistance of Lockerbie farmers to PECs despite the existence of positive economic and technical 'facts'.

Thus, socio-political and socio-cultural disconnects can powerfully shape energy geographies by 'frustrating' energy policy. The way that this emerges in the Lockerbie study is characterised by Warren et al. (2015) as constituting a disconnect between 'suits and boilersuits' (boilersuits being work clothing worn by many farmers); in other words, a perceptual gulf separates the policy makers from the 'ground level' actors with responsibility for implementing policy. Quotes such as the one above about 'some suit-wearing office boy…' show that the farmers themselves are keenly aware of this disconnect. Official projections by 'the suits' envisage a major expansion of PECs, yet take-up by 'the boilersuits' has been minimal. This policy failure can partly be understood as a lack of understanding by policy makers of the values and goals of 'policy deliverers'. This links with the idea of 'place attachment' discussed below.

The gulf that this failure creates is, regrettably, all too common. For example, attitudes strikingly similar to those held by farmers around Lockerbie are documented amongst Australian farmers by Hall et al. (2013, p. 205), one of whom they report as saying: "We should decide what happens. We don't want city slickers coming down and telling us what's what". There are also strong parallels here with the well-documented disconnect that exists between agri-environmental policies and farmers' values and motivations (Burton et al., 2008; Greiner and Gregg, 2011). This literature highlights the fact that land use managers "stand at the point where abstract policy imperatives collide with concrete realities" (Constable, 2012, p. xi). Landscape change is, in practice, the product of myriad local decisions made by individual stakeholders. As Cope et al. (2011, p. 855) observe, policy makers "typically focus on biophysical and economic criteria that influence farmers' land use decisions at the expense of 'intrinsic' socio-cultural motivations". This further emphasises the point that understanding these socio-cultural dimensions of decision making and policy adoption is critical if the socio-political gulf and the 'implementation gap' are to be bridged.

3.2 Scalar disconnects: temporal and spatial mismatches

A number of significant disconnects are scalar in nature (at both spatial scale and temporal scale), and here we are in quintessentially geographical terrain. As Bridge et al. (2013, pp. 332–333) observe: *"The goal of a low carbon transition… is slowly emerging as a question of which geographical futures will be created… Meeting the challenges of climate change and energy security is, therefore, fundamentally a geographical project."*

The temporal dimension has received significant attention via the concept of 'the energy transition' itself, whereas the ways that spatial processes influence energy systems have been studied less. These interlocking scalar issues can be introduced via the simple graphic in Figure 1, which shows a three-dimensional 'decision space' with priority axes. This illustrates the potential for scale-related disconnects to arise. Whether a particular strategy or policy is judged to be good or bad will depend – amongst many other factors – on the different priorities attached to the various dimensions of this decision-making matrix. Debates surrounding energy futures have repeatedly revealed the differential weightings attached by diverse protagonists to (i) present concerns versus those of our descendants, (ii) local versus international perspectives, and (iii) the importance of human concerns versus the value of non-human nature. For example, to risk adopting stereotypes, members of rural communities might give high priority to the present concerns of local people (Point A in Fig. 1), while members of international conservation organisations might situate themselves at the other end of all three axes (Point B) by emphasising the long-term significance of natural systems from a global perspective. Tensions flowing from different spatial and temporal priorities lie at the heart of many energy controversies (Pillai et al., 2005; Szarka et al., 2012). Judgements about these priorities are themselves formed in diverse and contested ways, depending on people's beliefs and value systems, their political outlook, and, for example, the importance they attach to scientific approaches as opposed to other grounds of knowledge and decision making.

There are several mismatches to highlight here. The first, already alluded to, is the familiar tension between local and global. Arguments supporting renewables often rest on global and national concerns such as climate change and energy security, whereas the arguments of opponents typically focus on the specificities of local places and landscapes (Warren and Birnie, 2009). Conflict is exacerbated by the contrast between the seemingly abstract, invisible, diffuse benefits of the energy transition and the highly tangible local impacts of, for example, PECs, wind turbines or grid upgrades. The perception that the global environment is being saved by sacrificing the local environment fuels opposition.

The second mismatch is that between the rapid pace of change (in energy technologies and energy landscapes) and the slow rate at which public attitudes evolve, especially in relation to landscape aesthetics. Throughout history, the changing energy needs and choices of society have frequently been major drivers of landscape change, from prehistoric tree felling for fuel, to coal mining, hydropower dams and electrification. During the ongoing transition to renewables, energy has again emerged as a significant agent of landscape change (Nadai and van der Horst, 2010), notably through the construction of windfarms, solar farms and the associated upgrades of electricity grids, and these are set to rival or exceed the landscape impacts of previous energy technologies. Although social norms concerning landscape aesthetics do evolve, often quite radically, such changes typically take place slowly, over generations. The sharp dichotomy between the urgency of the need for an energy transition and the slow rate at which public attitudes towards landscape aesthetics evolve is explored insightfully by Selman (2010). For many people, the "energy transition is experienced as the transformation of landscape" (Bridge et al., 2013, p. 335) – often swift and dramatic in the case of modern windfarms - and the speed,

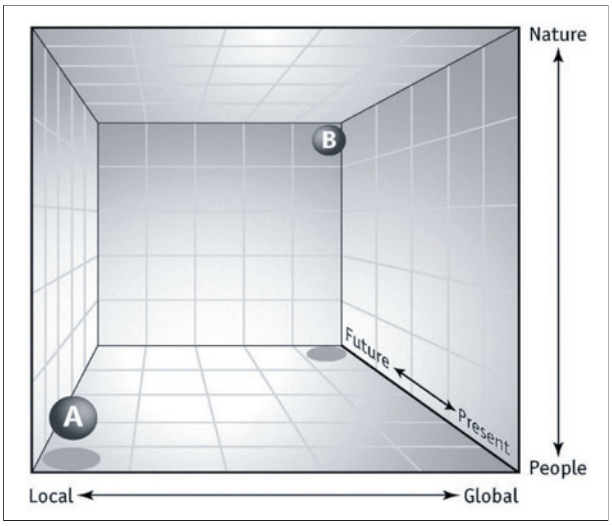

Fig. 1: Priority axes in environmental decision-making (See text for explanation: after Warren, 2009)

magnitude and nature of change is far greater than the pace of aesthetic adaptation will enable many people to accept. It is akin to 'future shock'. Landscape concerns often feature prominently in debates over renewable energy proposals, as revealed tellingly in the names of anti-windfarm groups such as Australia's 'Landscape Guardians' and England's 'Country Guardians'. Although history and some recent evidence suggests that society may eventually "learn to love the landscapes of carbon neutrality", and that an "acquired aesthetic" could develop concerning renewables technologies, this may take a generation or more because "the social production of taste associated with landscape is quite slow, and preferences tend to be conservative, generally making it difficult for us to accept change" (Selman, 2010, pp. 157, 160). In the meantime, this mismatch will continue to act as a social brake on the implementation of renewable energy policy. It is clear, for example, that farmers in the Lockerbie region are not minded to embrace PECs either quickly or easily.

A third mismatch comprises a socio-psychological disconnect in the way that locations are socially constructed - a mismatch between 'sites' and 'places'. In the context of renewable energy, this has been revealingly explored by Devine-Wright (2009, 2011). It comprises a conflict between the top-down perspectives of politicians, planners and developers, and the perceptions of local residents. The former typically conceptualise locations which have development potential (whether for energy crops, wind power or other renewable energy technologies) as impersonal 'sites', whereas the latter tend to see and relate to them as 'places' which are imbued with symbolic and emotional meaning. Local opposition to renewable energy proposals has been shown to be strongly linked to 'place attachment' (a concept closely allied with the geographical idea of topophilia (Tuan, 1990) and to the mobilisation of 'place protectors' (Devine-Wright, 2009; Bell et al., 2013). In other words, opposition is not simply a defence of landscape aesthetics, but of places from which individuals and local communities derive meaning, value and identity. So the scale dimension here is constructed by and operates through the perceptions of the actors involved. This disconnect is well illustrated by the Lockerbie results which show that farmers perceive PECs as incompatible with – and even a threat to – their identity and way of life. Their opposition to PECs is clearly motivated by the contrast between, on the one hand, the policy makers' detached, homogenising construction of 'intermediate land' as an ideal site for bioenergy production and, on the other, the farmers' own intimate understanding of the specificities of that land as a valued local place.

A fourth and final mismatch simply comprises a straightforward clash in scales between the large size of some renewable energy technologies (notably modern wind turbines) and the scale of the components of many rural landscapes – both natural (topography, trees) and cultural (field boundaries, buildings and settlements). Rapid technological development in pursuit of ever greater efficiencies, resulting in today's giant turbines, has meant that the technology has progressively outgrown the landscape and no longer fits comfortably within it. The industrial scale of modern turbines, and their out-of-scale dominance in the landscape, is frequently cited by opponents as a factor motivating their opposition. Scale is "one of the main controversial dimensions" because contemporary installations "ignore the principles of harmony and fitness" (Selman, 2010, p. 165). The impressive gains in efficiency have come at the cost of ever greater aesthetic intrusiveness as they have grown to dwarf their surroundings, becoming visible from great distances. To a lesser extent, this applies to PECs too; even though such crops are, in themselves, both natural and relatively small in scale, the policy aspirations for their widespread adoption represent a potentially large-scale transformation of the countryside, possibly the greatest change in British land use since the mid-20th century (Coleby et al., 2012).

3.3 Scale meets socio-politics

The above two groups of issues intersect and combine to create complex, many-layered disconnections that this paper can do little more than point towards, but they are integral to the emerging geographies of energy landscapes and socio-politics more generally. As shown below, while these disconnections stretch far beyond energy geographies and the energy transition per se, they are directly relevant to them, framing the evolving context in which energy decisions are made. Two examples of this multi-faceted and intricately woven terrain may suffice. Both are familiar examples which are used here to illustrate how geographical perspectives can enhance our understanding of the challenges of negotiating the energy transition, and how scaling, as an analytical lens, can illuminate significant aspects of energy geographies (Bridge et al., 2013). This final section, of necessity, leaves behind the regional case study of farmers' attitudes to PECs which has exemplified the above discussion, because the issues are broader in scope and more conceptual in nature.

The first example is the frequently noted and sharp discontinuity between the short time-scales of politics and the much greater temporal scales not only of climatic and environmental change, but also of the time that it will take for the energy transition to run its full course. Proverbially, 'a week is a long time in politics'. The time horizons in most democratic systems rarely stretch beyond a few years at best, and frequently decisions are taken on the basis of much shorter-term considerations. A policy which will yield no political dividends before the next election – indeed, which may only have measurable benefits over time-scales of decades or centuries - has limited political traction, and yet, compounding the difficulty, the costs of mitigation policies and strategies are borne in the present (Edmondson and Levy, 2013). This important "mismatch between the scales at which natural and human systems organize" is profoundly counter-productive, because it leads to these kinds of "failures in feedback when… benefits accrue at one scale, but costs are carried at another" (Carpenter et al., 2006, p. 257). One response to this problem has been the promotion of the concept of 'the Long Now' (Robin and Steffen, 2007). A damaging consequence of this disconnect is that short-term criteria predominate in much political decision making. Ineluctably, this downgrades the priority of long-term issues – such as climate change, landscape evolution and the ultimate goals of the energy transition – in turn rendering policy making for 'the Long Now' an intractable political challenge within democratic systems. Even though policy making for climate change mitigation and renewable energy development stand out as exceptions in this regard, in that some governments have set legally-binding targets over time periods spanning several electoral cycles, this is still a much shorter time frame than the time-scale of the issues that such policies purport to address.

The second example is the mismatch between the spatial scale of the politics of nation states and the global scale of many energy and climate-related issues. Nation states are well-practised in the art of governance at national, regional and local scales, but cannot, acting alone, tackle supra-national phenomena. Yet many of the most urgent challenges are now global in scope. This is because, since the mid-20th century, the rapidly globalising world has become ever-more intricately and deeply interconnected (especially in terms of economics, communications, health and environmental governance), and because exponentially increasing human impacts have inaugurated the so-called Anthropocene era of human dominance (Steffen et al., 2007). The swift dawning of today's hyper-connected age, in which the "knock-ons" of local events can rapidly cascade globally (e.g. '9/11'; the collapse of Lehman Brothers), has given ever-greater prominence to global governance arrangements. In an insightful discussion of this trend, Hale and Held (2013, pp. 20, 23) reflect on Lorenzetti's famous 14th century fresco *The Allegory of Good and Bad Government*, depicting medieval city states, to highlight the transformation in scales of governance: *"The scale at which political institutions must be effective has expanded beyond cities and their surrounding fields to include countries, continents and, with globalisation, the world as a whole… Human activities anywhere on the planet now affect the climate in which every other person on the planet and their descendants must live."*

They show how, just as the success of medieval city states set in motion changes which rendered them obsolete, so the success of nation states has unleashed forces at supra-national scales which they are ill-equipped to address. In the words of Goldin (2013, p. 48): "the challenges of the global commons increasingly render domestic solutions inadequate".

Growing recognition of these and other scalar mismatches, and of the ineffectiveness of the international community's response to many critical global challenges, has led some to question whether our political systems and institutions are 'fit for purpose' for governance of the global village (Goldin, 2013). An increasing number of those who investigate this question are coming to the conclusion that they are not. For example, the verdicts of Shearman and Smith (2007) and Edmondson and Levy (2013) are encapsulated in the arresting titles of their respective books: *The Climate Change Challenge and the Failure of Democracy*, and *Climate Change and Order: the end of prosperity and democracy*. These authors argue that liberal democracy and the current consensus-building approach to international relations are incapable of delivering the swift and effective action required to decrease rates of greenhouse gas emissions, not least through the decarbonisation of the energy sector; they even go so far as to suggest that they are responsible for global climate change. Thus Shearman and Smith (2007, p. 11) contend that "liberal democracy is ecologically flawed as a social system because it leads to the tragedy of the commons". In a similar vein, Wainwright and Mann (2012, p. 9) argue trenchantly in their paper *Climate Leviathan* that *"if climate science is even half right in its forecasts, the liberal model of democracy… is at best too slow, at worst a devastating distraction"*.

These publications go on to construct a critique of economic growth, the fundamental engine of capitalism, and argue that achieving 'prosperity without growth' (Jackson, 2011) should instead be the over-riding goal. For, as the UNDP (2008, p. 27) recognises, climate change demonstrates clearly that "economic wealth creation is not the same as human progress". In the Anthropocene era, Gross Domestic Product is a narrow, inadequate yardstick of success (Robinson, 2012). Considerations of this kind lead to suggestions that new political visions and economic systems are needed to support viable futures (Edmondson and Levy, 2013). Such arguments, informed by a recognition of the temporal and spatial mismatches identified above, are resulting in a hard-nosed reassessment of the value and likely ability of today's democratic governance structures to address worldwide challenges in a timely and effective fashion. In the view of Hale and Held (2013, p. 20), *"global governance has become gridlocked [and]… the multilateral institutions we rely on to solve global problems are increasingly unable to do so"*. Both Goldin (2013) and Hale et al. (2013) show that institutionalised multilateral cooperation is failing at a time when the need for it has never been greater.

This "yawning governance gap" (Goldin, 2013, p. 3) is apparent in many spheres, but the example that is of most direct and pressing relevance for energy geographies is the continuing failure of global climate negotiations to deliver an effective global treaty. The gap in this arena is particularly stark. Widespread and growing disillusionment with the negotiation process, especially since the Cancún climate talks of 2010, is prompting a reversion to smaller-scale, more localised responses to the many challenges posed by climate change, including the energy transition and its landscape implications (New Scientist, 2013). As the prospect of agreeing to binding targets at the global scale has receded, so regional and municipal governments have increasingly opted to 'go it alone' - to give up waiting for top-down, multilateral solutions, and to set their own local targets and policies unilaterally. This is strikingly true at the city scale (Bulkeley and Broto, 2013). Recent statistics suggest that this trend of relocalisation is helping to decouple economic growth from emissions through reductions in carbon intensity (Pearce, 2013). Positive though this trend is, it is not a substitute for global agreements.

It is apparent even from this short discussion that any consideration of the disconnects and mismatches identified above swiftly leads to much broader and searching questions about governance, ultimate socio-economic goals, the sovereignty of nation states and the efficacy of liberal democracy, questions which far exceed the scope of this paper. Such destabilising and unpalatable challenges to the status quo are, unsurprisingly, gaining little public airing as yet: "the prospect that core political values are challenged as a result of global climate change impacts is a dawning realisation that few political actors readily accept and acknowledge" (Edmondson and Levy, 2013, p. 4). Unwelcome though this realisation is, it is nevertheless quite clear that the issues raised by the urgent need for an energy transition – as part of an effective response to global climate change – are unleashing questions which go far beyond energy geographies to challenge fundamental, normative assumptions about the structure and functioning of society. The ways in which these questions are addressed – or ignored – in the coming decades, will set the context in which energy geographies and energy landscapes develop.

4. Conclusion

A case study of the attitudes of farmers in south-west Scotland to the adoption of perennial energy crops has shown that, despite the area's technical potential for such crops and the existence of a local market, most farmers are strongly opposed to planting them. The findings of this case study have served to illustrate a range of mismatches and disconnects – socio-political, cultural, psychological and scalar – which can act as significant hindrances to the delivery of renewable energy policies, in turn influencing energy landscapes. These then feed into a set of high-level questions and challenges concerning modes and scales of governance, questions which are becoming more pressing in the context of global climate change and consequent efforts to reduce emissions from the energy sector.

Society's energy choices have always shaped landscapes, and there can be no doubt that "energy will be a driving force of future cultural landscapes" (Selman, 2010, p. 169). But it is striking that, through the link with climate change, the scale at which society's use of energy moulds landscapes has recently leapt from local to global: our energy choices now have planetary reach. Reciprocally, that spatial leap has also operated in reverse, as global concerns have increasingly come to influence local decisions – householders install low-energy light bulbs to save the planet, and local mayors wrestle with the carbon cycle. In energy geographies, as in so many other arenas, globalisation has blurred the boundaries between domestic and international issues (Hale and Held, 2013). As the simple graphic in Figure 1 above, illustrates, the sliding scales of spatial and temporal concerns create the scope for an almost infinite number of different but justifiable positions. For this reason alone (and there are many others), energy decisions are always likely to generate sharp debate.

The various mismatches and disconnections discussed in this paper play an important role in shaping energy landscapes by influencing both the nature and rate of change. It is clear that the 'disconnections' are not only figurative but also literal, and that the former affect the latter: disconnections postpone connections. In other words, the failure of policy makers to 'connect' effectively with stakeholders delays the creation of actual physical electrical connections with renewable sources of power, thereby impeding the transition to a renewables-based energy sector. The way that these mismatches and disconnects are negotiated will mould both the character of future energy landscapes and the speed at which they take shape.

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PERCEPTIONS OF ENERGY CROP PRODUCTION BY LAY PEOPLE AND FARMERS USING THE ECOSYSTEM SERVICES APPROACH

Gerd LUPP, Olaf BASTIAN, Reimund STEINHÄUßER, Ralf-Uwe SYRBE

Abstract

Perceptions of energy crop production are assessed in this paper. The Görlitz district (Germany) serves as a case study area for this purpose. Semi-structured interviews with farmers and standardized surveys among lay persons were conducted. Many farmers perceive themselves being responsible for providing many ecosystem services. Farmers prefer a regional scale of energy crop cultivation based on conventional crops. Improved legal frameworks and incentives would safeguard equal competition and ecosystem services. Laypersons think that drinking water, food production, biodiversity and pollination are the most important ecosystem services of agricultural landscapes. Providing biomass for renewable energy production is not considered to be an important ecosystem service. Laypersons believe that biomass production should be restricted to fields that are not needed for food production, and the use of residues or landscape management materials. According to laypersons, more money should be spent to halt the decline of ecosystem services.

Shrnutí

Výzkum vnímání produkce energetických plodin laickou veřejností a zemědělci s využitím přístupu ekosystémových služeb

V tomto článku je hodnoceno vnímání produkce energetických plodin. Jako případová studie slouží okres Görlitz v Německu. Byly uskutečněny semi-strukturované rozhovory se zemědělci a standardizovaná dotazníková šetření s laickou veřejností. Většina farmářů vnímá sama sebe jako poskytovatele mnoha ekosystémových služeb. Farmáři preferují pěstování konvenčních energetických plodin s podporou na regionální úrovni. Lepší legislativní nástroje a dotace by podle nich zajistily rovnou soutěž a ekosystémové služby. Laická veřejnost se domnívá, že pitná voda, produkce potravin, biodiverzita a opylení představují nejdůležitější ekosystémové služby, které poskytuje zemědělská krajina. Zajištění biomasy pro produkci obnovitelné energie není považováno za důležitou ekosystémovou službu. Laická veřejnost má za to, že produkce biomasy by měla být omezena na plochy, které nejsou potřebné pro produkci potravin, využití zbytkových produktů či management krajiny. Více peněz by naopak mělo být věnováno proti úpadku ekosystémových služeb.

Key words: *Energy crops, biomass, bioenergy, ecosystem services, perception, farmers, laypersons, Görlitz district (Germany)*

1. Introduction

The European Commission and the German government have set ambitious goals for future renewable energy production (EC, 2009; Bundesregierung Deutschland, 2010). The aim of the energy transition is to reduce carbon emissions as part of limiting climate change, and of achieving strategic goals to reduce dependency on such imported non-renewable energies as oil and natural gas. A target set for renewable-energy use by 2020 for the EU is 20% of total energy consumption (Commission of the European Union 2007). Germany's targets are an 18% share of total energy consumption to be supplied from renewable sources by 2020, 30% by 2030, 45% by 2040 and 60% by 2050 (BMU, 2010), although it is not defined if such energy would be produced abroad or from within the country. Biomass from wood and energy crops is considered an important factor in meeting these policy goals. For that purpose, the cultivation of biomass for energy production would have to be doubled by 2020 at the European level, as well as in Germany (Commission of the European Union, 2005; Kavalov and Petkeves, 2005; BMELV and BMU, 2009). To reach that policy objective, between 21% (Agentur für Erneuerbare Energien, 2012) and 30% (SRU, 2007) of all German agricultural areas would have to be used exclusively for energy crops, which would change German agricultural landscapes significantly. The increase in the cultivation of non-food crops would force food production to be intensified, resulting in more pressure on ecosystem services.

By 2012, energy crops were already being cultivated on 2,124,500 ha, or on more than 17.6% of Germany´s arable land. The most important crops in 2012 included rapeseed for biodiesel and blended fossil fuels, cultivated on 913,000 ha (the produced fuels, however, provide only a negligible share of demand in the German transport sector), and various crops for biogas production, on 962,000 ha (FNR, 2012), including 800,000 ha used for corn *(Zea mays)* (Deutscher Bauernverband, 2012). Energy derived from biomass accounted for 6.1% of electric power production (mainly biogas), for 10.1% in the heating sector (mainly wood biomass), and for 5.5% in transportation (mainly rapeseed oil, ethanol derived from grain and sugar beets) (Agentur für Erneuerbare Energien, 2013). The extent of the cultivation of energy crops and silage corn varies significantly by region. According to Maiskomitee (2012), corn is grown on about 20% of the farmland in most districts in eastern Germany, while in some districts of Lower Saxony, such as Ammerland and Wesermarsch, intensive livestock farming had already given rise to intense cultivation of corn for fodder, even prior to the boom of bio-energy. The biogas plants then led to a further increase in corn cultivation, such that corn covered more than 70% of the farmland in some of these districts in 2011 (Deutsches Maiskomitee, 2012).

Scientists, policy makers and various stakeholder groups have discussed the negative impacts of these developments on biodiversity, ecosystems and their services, vigorously. Various impacts on ecosystem services are already visible and would further increase if the regulation and steering of bio-energy production is not improved significantly in the future (Bastian et al., 2013). Intensive corn cultivation, in particular, can threaten such environmental assets as biodiversity, soil fertility, pollution control and water conservation (Lee et al., 2008; Greiff et al., 2010), and lead to uniform and monotonous landscape structures, resulting in dramatic changes in the character of the landscape. Corn needs high nitrogen inputs and shows significant nitrogen spill-over and high erosion rates. The cultivation of such water- demanding crops as corn is considered a problem, especially in view of the fact that climate change could cause a decline in water availability (Hall et al., 1996; Heidmann et al., 2000). Moreover, it has been observed that high natural value grasslands are being converted into fields for energy crops, or to replace fields used for their production (indirect land use change). In Germany, approximately 0.9% or 188,000 ha of grasslands were lost by conversion to farmland between 2005 and 2009 (Schramek et al., 2012). Grassland conversion to arable land for energy crop cultivation can lead to carbon emissions from the soils that outweigh the greenhouse gas reductions due to bio-energy use (McLaughlin and Walsh, 1998; Rowe et al., 2009).

On the other hand, such perennial crops as cup-plants *(Silphium perfoliatum)*, wood biomass (e.g. short-rotation coppice), or landscape management materials, are alternatives with higher net greenhouse gas reduction and less impact on many ecosystem services (ES) than conventional crops. According to Cherubini and Strømman (2011), biomass production based on perennial crops or material from landscape management (grasses, herbaceous plants, wood) allows for the minimization of such inputs as fertilizers, tillage or herbicide use. Short-rotation coppices also increase structures in intensively used agricultural areas, and provide space for nesting birds (Liesebach and Mulsow, 2003), and even some Red List species (Burger, 2006). They may also increase scenic qualities and contribute to a green infrastructure (Londo et al., 2004) in intensively-used agricultural landscapes. The existing incentives, particularly the German Renewable Energy Act (EEG) and the Common Agricultural Policy of the EU (CAP) and various legal frameworks and planning tools, however, are not powerful enough to support more environmentally-friendly crops like perennials, residues or wood biomass (Lupp et al., 2014).

In this paper, we examine the extent to which the cultivation of energy crops (especially corn) and their impacts on the environment, are issues among farmers and lay people. We analyse not only how they perceive the increasing share of energy crops, but also how the alternative, less harmful sources of biomass for energy-production purposes, such as landscape-management materials, short-rotation coppices or perennial crops, might be attractive options for farmers. We assess what conditions might be favourable from a farmer's point of view to support the cultivation of alternative dedicated energy crops, and what kind of policy support by incentives or regulations, would be necessary to make them an attractive option for cultivation. By questioning lay people, we tried to assess the attitude of the public to bio-energy production, and their perceptions of the state of agriculture and energy-crop production in their region. In particular, we asked whether an enhanced provision of different ecosystem services (ES) in agricultural landscapes would be appreciated, and which ES would be considered most important.

2. Material and methods

Due to the diversity of natural, geographical and spatial features, a research design using a case study at the landscape level is a very promising approach (Rode and Kanning, 2006). The case study approach allows precise investigations of actual effects, rather than only theoretically possible effects. For the case study, we developed an approach of actively involving such stakeholders as energy crop farmers, planners and decision makers in the research process, in order to incorporate their knowledge, preferences, views, values and attitudes. One of the main goals of the research project is to involve and motivate stakeholders to shape, suggest and decide about future biomass production for energy purposes, so that they may benefit directly from the research results. Our assumption is that a combination of different local and scientific knowledge sources will best be able to cope with uncertainties and presumptions. The results of this procedure will provide the basis for more robust decision making.

2.1 Study area: The Görlitz district

We have chosen the easternmost German district of Görlitz, in the federal state of Saxony, as our case study region (Fig. 1). With its rather continental climate, the

Fig. 1: The case study district of Görlitz and the district of Uckermark

district is characterized by warm, mild summers and cold winters. Its 210,620 ha area provides a cross section of many relevant physical regions typical of Central Europe; its population was 264,673 in 2012 (Destatis, 2013). The north of the district is part of the North German Plain, characterised by poor sandy soils, and large Scots pine *(Pinus sylvestris)* forests, but it has also been transformed by large-scale opencast lignite mining. The central and southern parts are characterised by very fertile hilly landscapes with loess soils. The city of Görlitz is the main urban area, with some 54,000 inhabitants (Zensuskarte, 2013). The southernmost part of the district is dominated by the low Zittau mountain range. The district has been affected by demographic change and is seeking new opportunities for the future, including the possibility of becoming an important producer of renewable energy in Germany.

2.2 Current situation of energy crops in the Görlitz district

It is somewhat difficult to analyse the actual share of energy crops in the Görlitz district. Since farmers usually sell their crops to middlemen, who decide on a day-to-day basis whether they are to be sold for energy production, feed, or to the food industry, it was not possible to ascertain the spatial extent of corn used for energy production by interviewing farmers, nor could we obtain such information from the middlemen. To assess the demand for corn silage for bio-energy use, we therefore marked all sites of operating biogas plants in the Görlitz district by GIS, using a database in which all biogas plants are registered. Under the law, the operators have to describe accurately what amount and type of raw materials they use in their power plants. To ascertain the amounts of renewable raw materials used in the power plants, we thus calculated the need for farmland, using yields per hectare and regional soil fertility, and factored in a minimum crop rotation, assuming 50% corn (cultivation of corn in every second year), which was considered a kind of minimum standard among farmers. Assuming that fields providing feedstock for the power plants are located as close to them as possible to avoid long and costly transport, we then assessed the amount of farmland that each biogas plant would need in its own vicinity, using a GIS algorithm (Fig. 2).

It seems likely that in some areas, especially in the south of the district, most of the fields are needed for biogas plants and therefore will be cultivated with corn regularly.

2.3 The concept of Ecosystem Services

To assess the consequences of increased energy crop cultivation, we use the concept of Ecosystem Services (ES) as a theoretical framework. This concept stresses the essential relevance of ecosystem structures and processes to human well-being. It encompasses both the supply of services, which is based on structures, processes and potentials of ecosystems, and the demand for these services by individuals, groups of stakeholders, or society as a whole. The attractiveness of the ecosystem services concept is its integrative and interdisciplinary nature, and the fact that it is seen as an innovative way towards more sustainable land use practices (BMBF, 2008; Weith et al., 2010). Therefore, the concept can play a role as an eye-opening metaphor and a tool for society and decision makers to think about the importance of nature and its degradation (Norgaard, 2010). The assessment of the demand for non-market goods (e.g. the demand for attractive sceneries) can be carried out by such methods as stated preference techniques, choice experiments, willingness to pay (WTP) to maintain biodiversity, target species, ecosystem services, landscape elements and aesthetic values (Schweppe-Kraft, 2009). Especially the ranking and weighting of ES has to date received only limited attention (Lamarque et al., 2011; Seppelt et al., 2012). In our work, looking at the impact of energy crop production, we have assessed the demand for ES by the lay public and farmers by using both quantitative and qualitative social science approaches.

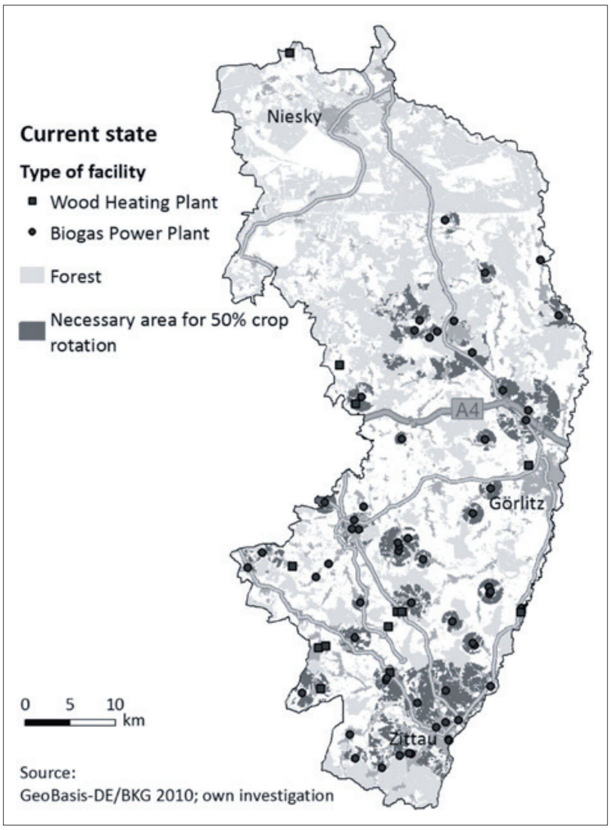

Fig. 2: Spatial extent of corn plantations for the existing biogas plants

Stated preference analyses reveal not only the amount that people may be prepared to pay, but also the conditions or developments in the environment, which they desire, or want to avoid. In recent years, a growing number of contingency studies were undertaken worldwide, e.g. Degenhardt et al. (1998); Elsasser et al. (2009); Meyerhoff et al. (2010); Tacconi (2012).

Stated preference analyses are applied to determine the appreciation of visitors for particular qualities of nature and the landscape. Such assessments are considered useful to verify the positive effects of nature conservation economically, including in monetary terms (e.g. Gantioler et al., 2010; Woltering, 2012). In a workshop in December 2010 with some two dozen key regional stakeholders from regional planning, biomass production, agriculture – both farmers and representatives of the farmers' association – bioenergy production, conservationist groups, and also representatives of the Saxon State Agency for the Environment, Agriculture and Geology, forestry authorities, the Upper Lusatian Heath and Pond Landscape Biosphere Reserve (the director) and others, some 14 ecosystem services were selected as important for detailed analysis:

1. *Provisioning services*

- Drinking water
- Food production

- Raw materials for industrial demands such as fibre
- Bioenergy
- Feed for livestock

2. *Regulating services*

- Habitats for plants and animals
- Pollination
- Flood prevention
- Erosion control
- Carbon storage

3. *Socio-cultural services*

- Landscape aesthetics
- Outdoor recreation
- Inspiration for hobbies
- Religion/spiritual inspiration.

2.4 Method for assessing the attitude of farmers toward energy crop production and the provision of ecosystem services

To address farmers, we opted for a qualitative approach (Atteslander, 2003). A small sample was chosen to develop a more in-depth understanding of human behaviour and the reasons for it. Semi-structured interviews were developed (Marshall and Rossman, 1998). Farmers to be interviewed were selected by using the concept of maximum contrasts (Hunziker, 2000) to encompass the entire range of attitudes and opinions of all types of farms found in the Görlitz district. At the end of an interview, the person was asked if he or she could name someone with an opposing opinion or from a different type of farm, who therefore might have a different view of these issues. Not all of those initially contacted reacted to our approach, and some refused our request for an interview. Almost all farmers were sceptical about being surveyed, but finally twelve persons agreed to be interviewed under this procedure (Tab. 1). One person from the regional planning authority and eleven representatives from different types of farms – large cooperatives and small family-owned farms, and also from organic farms and those planting genetically modified crops – were interviewed. Almost all interviewees rejected having the interviews recorded, although anonymity and privacy were assured.

Since most farmers refused to allow the recording of their interviews, two interviewers were present and noted the statements. These two handwritten records were used to create a single digital file that was analysed using content-analysis methods (Atteslander, 2003; Mayring, 2000) to obtain answers to the key questions of our semi-structured interviews. The text was edited, shortened and structured to render the key statements comprehensible.

2.5 Attitudes and perceptions of lay people

In order to obtain a broad perspective of the population in the Görlitz district, a quantitative approach was chosen (e.g. Degenhardt et al., 1998; Atteslander, 2003). We used short questionnaires with four questions, plus queries on demographic data. Answers were to be check-marked; only one choice per question was allowed. In the questions involving monetary value (WTP), we wanted

Interview number	Interviewee	Description of the farm/institution
# 1	Regional planner	Regional planning authorities, for an external view
# 2	Owner	Organic family-owned farm in the southern part of the Görlitz district, 50 ha of agricultural land and 40 ha of forest; the owner operates his own solar-power plant mounted on a stable, his own wind turbine and a small biogas plant (70 kW electricity generation capacity) using manure
# 3	Manager	Organic farm enterprise in the centre of the district with 320 ha: 189 ha of farmland, 20 ha of forest, 92 ha of grassland; value adding convenience products sold in whole-food/ health-food shops; 50 kW of heat energy generation capacity) wood heating
# 4	Manager	Agricultural cooperative of 1,200 ha in the north of the Görlitz district, 1000 ha of farmland, 100 ha of grassland, 450 livestock units; co-operative is interested in operating a biogas plant
# 5	Manager	Limited liability company in the southern part of the district with 500 ha (25% owned, 75% rented), 230 ha of grassland, 270 ha of farmland, including 90 ha of corn; dairy cattle; own biogas plant using manure, slurry and silage from the grassland
# 6	Manager	Agricultural co-operative in the southern part of the Görlitz district, 800 ha with major share in permanent grassland; dairy cattle; own biogas plant using silage from grassland, and slurry
# 7	Manager	Agricultural co-operative in the northern part of the Görlitz district, operating on 3,200 ha, 1,600 ha of farmland, 600 ha of grassland; biogas plant began operation in 2012
# 8	Manager	Agricultural co-operative in the centre of the Görlitz district operating on 1,250 ha, 1,000 ha of farmland and 250 ha of grasslands; 500 dairy cattle units; own biogas plant
# 9	Entrepreneur	Farm enterprise in the centre of the Görlitz district, 240 ha agricultural land, seed production, no livestock; operates wood-gasification plant
# 10	Owner	Family-owned farm in the Upper Lusatian Heath and Pond Landscape Biosphere Reserve breeding Galloway cattle, 270 ha
# 11	Owner	Small family-owned farm in the Upper Lusatian Heath and Pond Landscape Biosphere Reserve, 18 ha, 12 ha of farmland, 6 ha of grassland, recently taken over from parents
# 12	Owner	Family-owned farm in the southern part of the Görlitz district, 2/3 owned, 1/3 rented land, 325 ha of farmland, 30 ha of grassland; 1,900 feeding pigs

Tab. 1: Interviewees and a brief description of their farms

to know whether the respondent would be prepared to pay a predefined amount of money. Open-ended questions involved their willingness to pay (amount in Euros), and their opinion as to where to cut budgets to obtain money for conservation measures. Since the region is characterized by demographic change, there is a large proportion of elderly persons, and many long-distance or weekend commuters to the district. To get a good cross-section of interviewees, we decided to carry out "market-square surveys", choosing frequented places – a shopping centre and two festival events – on weekends, so as to reach more inhabitants. With this approach, rather than sending questionnaires, we intended to avoid a bias in favour of respondents more interested in nature, who might respond more frequently than others.

We validated our interviews by using a second interview site in Templin (16,237 inhabitants in 2011, according to the 2013 Census Map) in the district of Uckermark, in the neighbouring state of Brandenburg. The Uckermark district, with 305,841 ha (Destatis, 2013), is a different kind of region physically, located entirely in the North German Plain. The two regions are to some extent comparable from a socioeconomic point of view, in that both are peripheral regions with high unemployment and decreasing population, and are dominated by the agricultural sector.

Our selected interview sites and the number of collected interview sheets can be found in Table 2. Altogether 249 interview sheets were completed.

Post-modern sociological theories posit a pattern of individualization with a wide range of options for designing one's life. Schulze (1997), however, contends that socialization leads to similarities in behaviour patterns in terms of groups – his so-called "lifestyles" – which can be observed, sharing values, norms, tastes and preferences. Some studies indicate that value orientations (Müller and Job, 2009; BMU, 2009; UBA, 2009), or "lifestyles", strongly influence perceptions, consciousness and attitudes towards the environment (UBA, 2009). In this study we used Schulze's Lifestyle-Group Concept: five groups with specific behaviour patterns (Tab. 3). The five groups are defined by education level and by age (above and below age 40, respectively). According to Schulze (1997), persons tend to revise their behaviour patterns between 40 and 45.

Despite its tendency toward stereotyping, and some fuzziness in assigning individuals to certain lifestyles, Schulze's Lifestyle-Group concept helps provide an understanding of the everyday lives and realities of people. It covers many aspects regarding communication channels, general preferences and the home leisure-time activities of different groups.

Since our questions contain nominal and ordinal scales, we had to use non-parametric tests. We opted for a post-hoc analysis of our data to detect possible differences or correlations between different subgroups of our sampled population. We tested the results according to these different groups, as well as between the two different districts, to examine the statements from Görlitz district in comparison to the Uckermark District results, using Chi-square tests in pairwise comparisons and Anova Scheffé tests for the different lifestyle groups.

3. Results

3.1 The farmers' perspectives

3.1.1 Self-perception of farmers

All farmers perceive themselves as modern entrepreneurs, producing according to market conditions, no matter what

Interview site	Date	Duration	Completed sheets	Estimated response rate
Görlitz, downtown shopping centre	Saturday, March 10, 2012, a day when an education fair and exhibition was being held at the centre	10:00-16:00	71	25%
Nochten Music Festival	Friday, April 27, 2012	16:30-18:00	26	70%
Löbau, Saxon Horticultural Festival and Exhibition Area	Thursday May 18, 2012 (public holiday weekend)	10:00-16:00	113	80%
Templin, downtown shopping area	Saturday, April 28, 2012; the day of the annual spring district fair (validation for the Görlitz results)	10:00-16:00	39	30%

Tab. 2: Interview sites, dates, duration of collecting interviews, completed sheets and estimated response rate

Lifestyle-group	Age	Correlating everyday leisure behaviour patterns	Level of formal education
Unterhaltung ("Entertainment")	< 40	Listening to rock, pop, easy listening music, reading tabloids, watching quiz shows	Low
Selbstverwirklichung ("Self-fulfilment")	< 40	Listening to rock, pop, classical music, going to theatre performances, reading quality newspapers	High
Harmonie ("Harmony")	> 40	Listening to easy-listening music, reading tabloids, watching quiz shows	Low
Integration ("Integration")	> 40	Listening to classical music, easy listening music, watching quiz shows,	Medium
Niveau ("High-Class")	> 40	Listening to classical music, going to theatre, reading quality newspapers	High

Tab. 3: Lifestyle-Group Concept, following Schulze (1997)

type of farm they operate. They do emphasize, however, the importance of tradition – they want to be perceived as food producers. Most of our interviewees do not really like being called "energy farmers". In their opinion, energy should be just one of their farm products, and should not gain too much importance in their portfolios. The production of bio-energy should be directly connected with operating a farm. Interestingly, although we had some famers experienced in cultivating or using genetically modified plants on our panel, only two interviewees (#s 4 and 12) saw genetic engineering as an appropriate solution to a range of problems, from feeding humankind to energy production; # 8 and all the other farmers were critical of GMOs.

At the beginning of the interviews, without any questions being posed, or the concept of ES even being mentioned, some farmers already referred to their commitment and responsibility to provide other goods and services for the sake of society, or non-commodity outputs beyond food and energy (#s 1, 2, 6 and 9). In their self-image, they see themselves as providers of ES, although they do not use this term.

3.1.2 Land use conflicts

The biggest problem for all interviewees was the rise in prices and rents for farmland, due to speculation and land grabbing by non-agricultural investors, which is seen as a general trend unrelated to the bio-energy boom (#s 3, 5, 7, 8 and 10). In particular, the owners of small farms feel disadvantaged when trying to rent fields. Besides demand for biomass production, farmers complain of significant land loss without compensation due to opencast lignite mining (interviewees in the north of Görlitz district #s 4, 7 and 8), reforestation programs and excessive construction of infrastructure and housing, although the Görlitz district lost 25% of its inhabitants between 1990 and 2011 (Statistisches Landesamt, 2012). For the organic farms (#s 2 and 3), and also the seed-producing company (# 9), the increasing cultivation of GMOs is perceived as an existential threat. One of the interviewees (# 3) described the immense efforts needed to protect the farm from contamination by these organisms. Some of the interviewees stated that the increased conflict between biomass cultivation and food production is just a media issue, not a real one, and that the impacts upon the landscape are largely aesthetic (#s 4, 5 and 7).

The two organic farm interviewees (#s 2 and 3) did identify increased bio-energy production as a major threat to the success of their business model, e.g. due to contamination by GMO pollen. These two persons also mentioned the negative impact on soil carbon storage and pollination. All interviewed farmers saw the limits of energy crop cultivation.

Rising groundwater levels caused by abandoning lignite mining and converting the former open-cast mines into lakes is a major issue for many interviewees, especially for those in the northern part of the district (#s 3, 4, 7, 8, 10 and 11). All of them want an institution responsible for maintaining the ditches in order to restore a functioning landscape water regime. Two conventional farmers (#s 4 and 7) see a necessity for further drainage, while the manager of the organic farm (# 3) thought that short-rotation coppice could be a possible alternative for his sites affected by stagnant moisture.

3.1.3 Climate change and adaptation

With the exception of three interviewees (#s 8, 10 and 11, all located in the south, on better soils), all farmers see themselves confronted with the need to adapt to a changing climate. Climate change is perceived primarily in terms of extreme weather events: examples included extremely rainy phases in early spring, followed by an early summer drought, and then extreme summer rain, causing soil erosion, flooding, often combined with damage due to hail, etc. The interviewees had different coping/adaptation strategies. Wells for sprinkle irrigation (#s 2 and 4), experiments with more drought resistant crops (#s 2, 3, 5 and 7), or alternative cultivation systems, such as plough-free farming. One of the organic farmers (# 2) even mentioned experiments with viniculture, due to the warmer climatic conditions in recent years. Two of the conventional farm managers stated that GMO plants would not solve the problems arising from climate change (#s 5 and 7).

3.1.4 Importance of regional planning and subsidies

Regional planning is not considered relevant for farmers. Its position would improve if it was used to identify and allocate regions for certain types of subsidies (# 1). With respect to subsidies and dependency on EU payments, as well as to the importance of payments from the operation of biogas plants, the farmers gave evasive answers. It can be assumed that direct CAP payments (around € 300/ha/year in Germany by 2012) and the revenues gained by providing electricity to the grid under the Renewable Energy Act, are important pillars of their income structure. Interestingly, a number of interviewees (#s 2, 4, 5, 6, 8 and 9) from all different types of farms stated that they would prefer free markets, if the general framework for agriculture were established differently, e.g. if prices for food were fair and such external effects as direct or indirect subsidies like those to the transportation sector, were ended. Also, recent EU Cross-Compliance regulations involving considerable paperwork and controls, which the interviewees saw as time-consuming and extremely complex, may have affected these responses. It can be assumed that environmental programs are also an important source of income, but four farmers mentioned a lack of consistency and the long-term character of these programmes (especially #s 2, 4 and 8). The regional planner (# 1) stated that regional planning should be better combined with environmental programs, so as to provide better effects for biodiversity and Ecosystem Services.

3.1.5 Bio-energy and farming

Bio-energy is important for all interviewees. Many of the farmers have already their own wood heating (#s 2, 3 and 9) or biogas plant (#s 5, 6, 7 and 8), or are considering to install one (# 4). Corn is the most important feed, but manure, slurry and silage grasses are used as well. One of the farms (# 7) was experimenting with switch grass (Panicum virgatum) at the time of the interviews. Most of the interviewed farmers used the cultivated energy crops themselves and only two (#s 2 and 4) sold it to other entrepreneurs. The farmers were unable to tell whether their wheat or rapeseed was used for energy purposes or not. Vendors or middlemen decide whether the products are sold for food or fuel production, and the farmers can virtually never ascertain what happens to their crops.

All of the interviewees felt that bio-energy production should always be associated with a farm, and that the size of a biogas plant should correlate with the amounts of raw material that could be delivered from the surrounding area. Also, transport distances should be limited to 10 km around the biogas plant, and transport costs should also include the costs paid by society in general (e.g. wear and tear on roads due to heavy trucks).

3.1.6 Perennial crops, wood biomass and landscape management residues

All except four of the interviewed famers rejected perennial crops and short-rotation coppice. On the one hand, it was perceived as being incompatible with farming. On the other, these cultures cause severe problems when plants are replaced in favour of others, since root penetration is intense. Also, compared with other crops, short-rotation coppice and dedicated energy crops have few marketing options. Only two interviewees had generally positive attitudes: one (# 4) stated that the examples in the regions for short-rotation coppice are not convincing, while another (# 10) could imagine cultivating willow and poplar plantations as a second independent enterprise. Also, farmer # 7 felt positively about growing Miscanthus, and farmer # 9 was in favour of such crops on the former lignite opencast mines. The organic farmer (# 2) stated that only residues and material from landscape management are suitable sources for bio-energy. Many other interviewees shared this view, but aside from the organic farmers (#s 2 and 3), only one other farm owner systematically planted hedgerows (# 4). Most of the interviewees stated that it would be difficult to manage these structures with the existing machinery.

3.2 Lay people's perspectives

Looking at our sample data, younger persons less than 18 years of age are underrepresented, while persons in the age groups between 41 and 65 are overrepresented, when comparing them to the official census data (Zensus, 2011). Persons with a higher formal education background and their lifestyles are overrepresented in our sample. As in other surveys, persons with lower formal education levels tend not to participate or refuse more frequently (some discussion about this can be found e.g. in Schulze, 1997 and BfN, 2011).

On a preference scale from 1 (not important) to 5 (very important), the provision of drinking water, food production and biodiversity (referred to as "wild animals and plants" in our questionnaire) were considered the most important ecosystem goods and services (Fig. 3). In the perceptions of people from the Görlitz district, flood prevention was considered significantly more important than it was in the Uckermark, where floods were not perceived as a major risk. This can be explained by two severe floods along the Lusatian Neisse (the district's eastern border with Poland) in 2010 and 2011.

Significant differences between lifestyle groups were found mainly among younger persons with higher formal education ("Self Fulfilment"). They tend to attach less importance to such services as outdoor recreation opportunities, inspiration for hobbies, flood prevention, feed for livestock, landscape aesthetics and erosion control. While landscape aesthetics, outdoor recreation, erosion control and flood prevention tend to become more important for lifestyles characterized by older age people, inspiration seems to be less important for those characterized by higher education.

Most respondents, by far, want to limit biomass production to areas not needed for food production, with the focus on residues and landscape management materials (Fig. 4, only one selection possible). There were no significant differences between Templin and Görlitz district interviewees in this respect, or between different lifestyle groups. A large majority (85% of the interviewees) demanded better conditions for biodiversity and ES provision on agricultural land. Here, too, there are no significant differences between interviewees in the two districts or between the lifestyle groups.

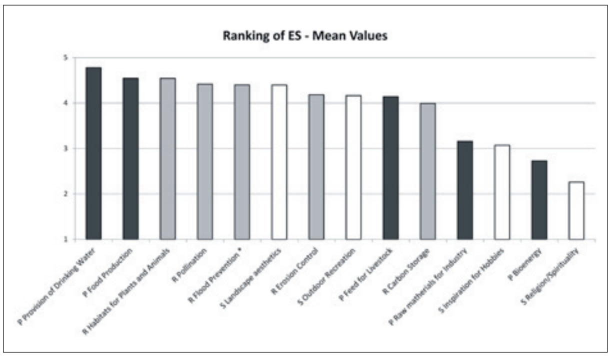

*Fig. 3: Values of ecosystem services by surveyed lay people on a scale from 1 (not important) to 5 (highly important). Colours and abbreviations: Black; R = Provisioning Services, Grey; R = Regulating Services, White; S = Socio-cultural Services, * significant difference between the Görlitz and Uckermark District interviewees*

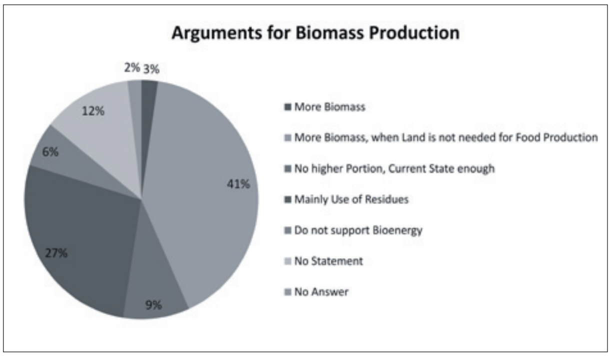

Fig. 4: Responses of surveyed lay people to the question of whether biomass production should continue to be supported/support be increased

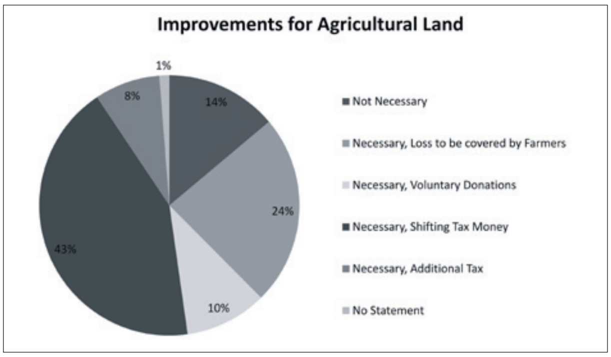

Fig. 5: Responses of surveyed lay people to the question of spending money for the improvement of ecosystem services on agricultural land

While roughly one quarter of interviewees stated that possible extra costs and potential losses should be covered by farmers, a majority of interviewees wanted to spend more money to support ES by shifting more tax money (mainly defence, if interviewees named a budget item where money might be cut). However, a number of participants were also willing to pay more in taxes or voluntary donations. The amount which those willing suggested as payment averaged €13.25, which would be roughly €0.85 per capita per year and would sum up to nearly €225,000 in the Görlitz district.

4. Discussion

It is difficult to assess the extent and location of areas needed for energy crop cultivation. With the aid of GIS, we have a tool to describe at least partially the spatial impact of corn production for biogas plants. Compared to German regions like Ammerland with a 70% share of corn (Deutsches Maiskommitee, 2013) on arable land, relatively small amounts of corn are grown in the Görlitz district, and an even smaller amount is used for energy production. If the ambitious political targets set for energy derived from biomass production and regulation are not changed, this increase would be based mainly on a few annual energy crops, especially corn (FNR, 2012). Due to its negative effects, there is a need for better regulation of the cultivation of energy crops, for the support of farmers who opt for less harmful crops, and for the promotion of alternatives, and a diversified crop rotation.

Key stakeholders see biomass production as still of minor importance in the Görlitz District, as compared to the other parts of Germany, especially in the states of Lower Saxony and Schleswig-Holstein. Therefore, biomass cultivation in the study area could still be somewhat increased from this perspective (Fleischer and Syrbe, 2013). But it should be realized with wood biomass and non-edible energy plants. Strictly speaking, transport and other energy inputs such as fertilizers should be restricted, and humus loss must be avoided in order to keep the carbon balance of bio-energy within the positive range (Leopoldina, 2012). Farmers interviewed in this project also strongly supported such a future course. Almost all of them demanded stricter regulation, as well as laws and incentives to promote better spatial regulation of biomass cultivation and to avoid intensive cultivation of energy crops in sensitive areas, such as protected areas or slopes prone to erosion. There is a strong feeling that binding rules to secure sustainability and some minimum standards are necessary, and should apply to everyone participating in the bio-energy sector. The options for that exist in the Renewable Energy Act according to article 64b, but are not used yet.

Lay people have a critical attitude toward an unrestricted increase of biomass production, which is primarily forced by subsidies or quota regulations for a target share of renewable sources of energy. From lay perspectives, most people prefer that biomass production focus on areas not necessary for food production, with a stronger focus on residues, landscape management materials or waste. The relatively slight importance that lay people attach to bio-energy production is in line with other studies. In the Europe-wide study Eurobarometer (2010), for example, 56% of interviewed persons identified the production of healthy food and 25% environmental protection, as core goals for farming activities; only 8% named biomass production for energy purposes. The fact that the result in the Görlitz and Uckermark districts are similar is especially notable, since our surveys were carried out after the Fukushima nuclear accident, which sparked a shift in German energy policy towards renewable energy sources, so that these sources thus received much media attention.

The surprisingly high appreciation for such assets as "habitats for plants and animals", "pollination" or "landscape aesthetics" is comparable with the results of other recent studies in Germany (cf. BfN, 2011; Grunewald et al., 2012). It can be stated that there is a high acceptance and even an expressed demand for biodiversity and nature protection among all groups in society. Many other surveys on nature consciousness also indicate a huge demand of high environmental standards and a great relevance for environmental protection throughout society, especially by persons characterized as trendsetters and role models (Lupp and Konold, 2008; BfN, 2009; Sinus Sociovision, 2009; UBA, 2009). The BfN study (BfN, 2009) also indicates a demand among many groups in society for stricter laws to better protect ES, and to provide offset payments for the destruction of nature. It is questionable, however, whether the expressed willingness to pay would gain such high acceptance if a new tax were to be implemented, or donations were to be made to permit agricultural land to be used for recreational purposes.

5. Conclusions

Although the majority of surveyed laypersons may not be familiar with energy derived from energy crops and their impacts on ES and the environment, they feel the ambiguity of this energy source with respect to its side effects. Bio-energy will only gain acceptance if the focus is placed on the use of residues and other non-food crops in the future. Dedicated energy crops, which can benefit ES, may therefore be the basis for a strategy which could gain acceptance, especially for intensively-used agricultural landscapes. They could improve the ecological situation and landscape scenery, and win greater acceptance than corn or rapeseed. Not only lay people, but also farmers set great value in providing and enhancing ES. Improved legal frameworks and incentives are appreciated as safeguards for equal competition while maintaining and enhancing ES. The use and cultivation of alternative crops has to be started however. Strong regional networks between operators of biomass plants and farmers can be one key strategy to overcome the problem of the very limited marketability for perennial crops or residues.

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THE SPATIAL DISTRIBUTION OF PHOTOVOLTAIC POWER PLANTS IN RELATION TO SOLAR RESOURCE POTENTIAL: THE CASE OF THE CZECH REPUBLIC AND SLOVAKIA

Jaroslav HOFIERKA, Ján KAŇUK, Michal GALLAY

Abstract

Over the last few years, many European countries experienced a rapid growth of photovoltaic (PV) power plants. For example, more than 20,000 new PV power plants were built in the Czech Republic. The high spatial and temporal variability of the solar resource and subsequent PV power plant production, poses new challenges for the reliability and predictability of the power grid system. In this paper, we analyse the most recent data on PV power plants built in the Czech Republic and Slovakia, with a focus on the spatial distribution of these installations. We have found that these power plants scarcely follow the solar resource potential and, apparently, other factors affect decisions for their location. Recent changes in the support schemes for solar applications also influence these patterns, with new installations mostly confined to built-up areas. These changes will require new tools to assess the appropriate locations of PV systems.

Shrnutí

Prostorové rozložení fotovoltaických elektráren ve vztahu k potenciálu solárního zdroje: případové studie České a Slovenské republiky

V mnohých evropských zemích byl v posledních několika letech zaznamenán rapidní nárůst počtu fotovoltaických elektráren. V České republice bylo například vybudováno více než 20 tisíc fotovoltaických elektráren. Velká prostorová i časová variabilita solárního zdroje a následná produkce fotovoltaických elektráren přináší pro spolehlivost a předvídatelnost systému elektrovodné sítě nové možnosti. Příspěvek analyzuje nejnovější údaje o fotovoltaických elektrárnách vybudovaných v České republice a na Slovensku, přičemž se soustřeďuje na prostorové distribuční systémy těchto instalací. V rámci našeho výzkumu jsme zjistili, že se tyto elektrárny jen velmi zřídka řídí možnostmi zjištěného potenciálu solárního zdroje a že rozhodování o jejich lokalizaci je ovlivňováno dalšími faktory. Systémy nových instalací jsou nedávnými změnami ve schématech podporujících solární aplikace většinou omezovány na zastavěná území. Tyto změny budou vyžadovat pro posuzování vhodných lokalizací fotovoltaických systémů nové nástroje.

Keywords: *solar energy, photovoltaic power plant, geographic information systems, Czech Republic, Slovakia*

1. Introduction

Solar energy plays an increasingly greater role in the production of electricity in many countries around the world. Leaders in using solar energy for photovoltaic (PV) applications include Germany and Italy, the United States of America and several Asian countries (EPIA, 2013). The rapid development of these applications has been supported by various support schemes such as guaranteed feed-in tariffs, tax incentives, etc. The European Union supports the use of renewable energy including solar energy via its commitment to increase the share of renewables in the electricity production of its member states. Many countries have adopted this policy through a feed-in tariff support scheme that fixes the buy-back price of electricity produced by the solar power plant for a specific period (e.g. 15–20 years). The rapidly decreasing costs of PV power plant construction and relatively high buy-back price levels guaranteeing profits have led to a PV power plant construction boom. In the period from 2009 to 2012, more than 2,100 MWp (megawatt-peak) of new PV power capacity was built in the Czech Republic, and more than 491 MWp in Slovakia. The nominal power capacity of installed PV power plants varies from 1 kWp to tens of MWp. The Czech Regulatory Office (ERÚ) has approved more than 20,000 PV power plants (October 2013), and 1,179 PV power plants were approved by the Slovak Regulatory Office for Network Industries (ÚRSO) (September, 2012). This resulted in 17,754 locations with such power plants in the Czech Republic and 635 locations in Slovakia. With the ever-increasing installed power capacity of PV power plants, it has become increasingly important to understand the spatial distribution of these installations and the consequences for power grid management, as well as for electricity production and consumption in various parts of the countries.

Solar radiation available on the Earth's surface is highly variable, spatially and temporally. Therefore, exploring the true potential at particular locations is a complex task requiring knowledge and expertise in various disciplines. This variability also affects the predictability and manageability of national power grids. The PV systems can be connected to a power grid supplying electricity to various customers, or off-grid when the producer consumes the electricity directly. In both cases, the operation of the national power grids is affected. Šúri et al. (2011) analysed the stability of the Czech power grid system using a hypothetical random distribution of PV power plants with a total nominal capacity of 1,000 MWp under various meteorological scenarios. They concluded that temporal variations are manageable at the national level. Problems may arise locally, though. Thus, accurate data on the spatial distribution of PV power plants are needed for this type of analysis.

Hofierka and Kaňuk (2011) analysed the correlation between the spatial distribution of power plants built in Slovakia and the actual solar potential assessed from the solar radiation database derived by Hofierka and Cebecauer (2008). It was shown that the installations of PV power plants built before 2012 took into account the solar potential of the country only partially. It was concluded that the profitability of the PV project under the support scheme valid at the time of installation was sufficient, even at locations with a lower solar potential. The economic efficiency of these projects and supporting schemes, however, is rather low. The criticism of high electricity costs for consumers has led to a substantial reduction of support in many European countries, eliminating the development of new large solar power plants. The support for new PV power plants is limited only to smaller installations mounted on a roof or a building facade. For example, Slovakia has recently limited the support to systems of up to 100 kWp power capacity and a lower limit of 10 kWp is also considered. It is clear that future PV installations will be smaller and confined mostly to built-up areas.

Assessing and planning PV installations in built-up areas is much more complex than in open areas. Various methodologies have been developed. Some of them are coupled with geographic information systems (GIS) to address the complex urban environment (Littlefair, 2001; Pereira et al., 2001; Gadsden et al., 2003; Compagnon, 2004; Robinson and Stone, 2004). Hofierka and Kaňuk (2009) proposed a methodology for assessing the PV potential in built-up areas using the r.sun solar radiation model and PV GIS online estimation utility (http://sunbird.jrc.it/pvgis/). Recently, findings relevant for the analysed sample areas were extrapolated to other built-up areas identified using the Corine Land Cover database (Kaňuk et al., 2009). Residential areas with blocks of flats and industrial areas were identified as the most effective.

This summary emphasizes the importance of analysing the spatial distribution of existing PV power plants in two neighbouring countries, in which similar changes in legislation recently caused different behaviours in locating the power plants and in the use of the electric energy they produce. Therefore, the aim of this paper is to analyse the spatial distribution of existing PV power plants in the Czech Republic and Slovakia in relation to the solar resource potential and land cover classes identified by the Corine Land Cover 2006 (CLC, 2006) database, and to present future trends in the sector.

2. Spatial and temporal variations in the solar resource potential

Incident solar radiation at any location on the Earth's surface results from the complex interactions of energy between the atmosphere and land or ocean surfaces. On a global scale, the latitudinal gradients of radiation are caused by the geometry of the Earth and by the Earth's rotation and revolution around the Sun. On regional and local scales, the land surface creates strong local gradients that modify the basic pattern of global radiation fields (Hofierka, 2012).

Seasonal and daily variations primarily caused by well-predictable astronomic factors (via solar altitude) are strongly modified by changing atmospheric conditions (e.g. clouds, aerosols, water vapours and ozone). In Central Europe, for example, the monthly sum of global solar radiation striking a horizontal surface in December is about five times lower than in July, which is the month with the highest monthly sum of solar radiation. During the winter season, clear-sky radiation is greatly reduced by cloudiness, especially at lower altitudes. More rain (and cloudiness) in June usually also lowers the monthly sum of solar radiation in spite of the fact that solar altitude in this month is higher than in July (Hofierka and Kaňuk, 2011).

Detailed knowledge of the primary solar energy resource is needed for any solar power system including a PV power plant. Clearly, the analysis of available solar energy resources is a part of the efforts to integrate solar energy into energy systems in many countries. For example, Šúri et al. (2007) created a database of solar radiation maps and other climatic parameters for Europe. To account for the spatial variations of solar irradiation in different geographical conditions, solar radiation models integrated with GIS were developed. The solar radiation models use ground-based or satellite data and digital elevation models as inputs into physically-based empirical equations to provide estimates of irradiation over large regions, while considering terrain inclination, orientation and potentially also shadowing effects. New web-based tools, such as PVGIS, were developed to provide an access to solar databases and to assess the performance of PV systems (Šúri et al., 2005; Šúri et al., 2007; Huld et al., 2012).

Šúri and Hofierka (2004) developed a comprehensive GIS-based methodology to compute solar radiation for any geographical region and for any time moment or period. This solar radiation methodology was implemented in the r.sun module of GRASS GIS (Neteler and Mitasova, 2004). The r.sun module can be used to compute clear-sky or real-sky radiation using several basic input data sources. These include digital elevation models, measured global and diffuse solar irradiation from ground stations and a map of the Linke turbidity coefficient. The measurement of global and diffuse solar irradiation is needed to assess the ratio of real-sky and clear-sky radiation represented by the clear-sky index and its direct and diffuse components used to derive real-sky irradiation on inclined planes. The clear-sky irradiation can be computed relatively easily using the r.sun model; however, the real-sky irradiation is more dependent on local meteorological conditions (cloudiness) which reduce the amount of available irradiation for energy applications.

Hofierka and Cebecauer (2008) applied this methodology to derive a solar radiation database for the territory of Slovakia. The database consists of spatially distributed raster-based maps representing monthly and annual long-term averages of daily radiation sums in $kWh/m^2/day$. While the long-term averages of solar radiation provide valuable information on the available solar radiation for energy applications, the annual, seasonal and intra-day variability may still pose a major problem for the reliable planning and use of solar energy.

The solar radiation database developed by Hofierka and Cebecauer (2008) can also be used effectively to assess the solar resource potential for PV installations. The efficiency of solar radiation conversion by solar cells ranges from 10% to 20% depending on the solar cell technology. In the case of Slovakia, the annual electricity yield from the standard 1 kWp PV system ranges from 850–1,050 kWh (Hofierka and Kaňuk, 2011). The optimum tilt angle of solar panels maximizing the energy yield ranges from 36 ° to 44 °. However, the actual inclination of the panels also depends on the preferred energy output. For example, a standard PV system with the inclination of panels optimized for annual production generates four times more electricity in summer than in winter (Hofierka and Kaňuk, 2009).

The territory of the Czech Republic is covered by several solar databases such as the free PVGIS online solar database with a spatial resolution of 1 km, or the commercially available SolarGIS database with a spatial resolution of 80 m. The methodology used in these databases is based on the satellite-to-irradiance model developed by Perez et al. (2002), as further enhanced by Šúri and Cebecauer (2010). In this study, we used the solar database developed by Hofierka and Cebecauer (2008) for the territory of Slovakia and the SolarGIS database for the territory of the Czech Republic, to evaluate the correlation of solar resource potential with installed power capacity for the locations of PV power plants.

3. Spatial distribution of photovoltaic power plants

The massive development of PV power plants in the Czech Republic and Slovakia started in 2009, with the highest capacity installed in 2010 and 2011. The boom resulted from the generous governmental support in the period from 2008 to 2009, which was later gradually reduced to levels that were more reasonable. For example, the feed-in tariff in the Czech Republic was 13,460 CZK/MWh (about 538 EUR/MWh) in 2008 for any new installation, 7,500 CZK/MWh in 2011 for new installations up to 30 kWp, 5,900 CZK/MWh for installations 30–100 kWp and 5,500 CZK/MWh for above 100 kWp of installed capacity (ERÚ, 2013). Since 2012, no new installations above 30 kWp have been supported. Moreover, the Czech Republic introduced a so-called solar tax in 2011 for PV power plants with a power capacity over 30 kWp installed in 2009 and 2010, and similar measures were considered in Slovakia in 2013. In Slovakia, the highest support in 2009 with the feed-in tariff set to 448.12 EUR/MWh for any new installation was later gradually reduced to 119.11 EUR/MWh in 2013, only for new installations mounted on buildings with an installed power capacity of up to 100 kWp (ÚRSO, 2013). The main difference in the regulation policies of the two countries affecting the installations has been the restricted number of approved licences in Slovakia that were capped by the announced limit of total available capacities. No such restrictions had been imposed in the Czech Republic.

It can be concluded that the early support schemes (up to 2010) indirectly supported mainly large ground installations with lower costs per installed kWp capacity, compared to building-mounted systems with higher installation costs. Recent changes in the support schemes of both countries have effectively eliminated the development of new large PV power plants. Since 2012, only small systems have been supported. In some countries with an excellent solar resource potential, such as Spain and Italy, however, solar energy has become increasingly competitive with some other energy sources, even without generous governmental support. This is helped by a substantial reduction of the PV technology costs, especially in the segment of solar cell components (EPIA, 2013).

3.1 The spatial distribution of photovoltaic power plants in Slovakia

Hofierka and Kaňuk (2011) presented the spatial distribution of PV power plants built in Slovakia up to 2011, based on data provided by the Slovak Regulatory Office for Network Industries ÚRSO. The total installed power capacity at that time was 489 MWp in 569 locations. It has been shown that there was only a weak correlation (Pearson's r = 0.24) between the location of installed PV power plants and the actual solar resource potential, identified using the solar radiation database published by Hofierka and Cebecauer (2008). The solar radiation database was derived using the methodology that synthetically expresses the influence of various factors affecting the potential, such as latitude, elevation, land surface forms and long-term atmospheric conditions.

According to slightly updated data provided by the Slovak Regulatory Office for Network Industries ÚRSO, valid for 2012, the installed power capacity increased to 492 MWp in 635 locations (Fig. 1). The textual addresses of the power plants were manually geo-located using aerial orthophotomaps and field mapping. The GIS data were further processed in the ArcGIS v.10.1 software. The

CLC 2006 CODE	CLC 2006 level 2 class	All locations		Locations of <0.3 MWp		Locations of >1 MWp	
		Count	Sum of installed power [MWp]	Count	Sum of installed power [MWp]	Count	Sum of installed power [MWp]
11	Urban fabric	404	93.227	311	12.798	1	2.997
12	Industrial, commercial and transport units	22	19.190	14	0.600	4	14.658
13	Mine, dump and construction sites	2	7.089	1	0.026	1	7.063
14	Artificial, non-agricultural vegetated areas	5	0.225	5	0.225	0	0.000
21	Arable land	148	342.366	28	1.498	86	310.183
23	Pastures	11	2.929	8	0.116	0	0.000
24	Heterogeneous agricultural areas	40	25.694	25	0.662	8	18.394
31	Forests	1	0.004	1	0.004	0	0.000
32	Scrub and/or herbaceous vegetation associations	2	1.022	1	0.009	1	1.013
	Total	**635**	**491.746**	**394**	**15.938**	**101**	**354.308**

Tab. 1: Distribution of PV power plants within the CLC2006 classes in Slovakia
Source: ÚRSO (2013) and EEA (2007)

correlation between the PV power plant locations and the solar resource potential represented by the solar database developed by Hofierka and Cebecauer (2008) was again very weak (Pearson's r = 0.24).

To identify the spatial relation of the PV power plant location to the land cover in a particular location, we used the CLC 2006 database in a raster data format of 100 metres cell size, widely used in many environmental studies, which fully covers the territory of both countries. The advantage is that the CLC 2006 database had been created using a uniform methodology and had recorded the land cover prior to the construction of the first PV power plants in both assessed countries. There are also drawbacks of this database, however, mainly the mapping scale of 1:100 000 (EEA, 2007). This issue is discussed further below. A comparison of the spatial distribution of installations in Slovakia in relation to CLC2006 level 2 land cover classes can be found in Table 1. Most installations (404 locations) are located in built-up areas (code 11: Urban fabric) dominated by smaller PV power plants (below 0.3 MWp), with a total capacity of 93 MWp. Larger power plants (over 1 MWp) are located mostly in agricultural areas (21: Arable land, 23: Pastures, 24: Heterogeneous agricultural areas). PV power plants located in the agricultural areas have a total capacity of 371 MWp (75% of the total PV power capacity in Slovakia). We have also analysed the spatial relationship of PV power plant installations to the solar resource potential within the CLC 2006 land cover classes. Dominant installations in the agricultural areas have a slightly higher correlation (r = 0.26) to the solar resource potential than installations in the built-up areas (r = 0.17). Globally, large installations over 1 MWp follow the solar resource potential (r = 0.3) better than small installations (r = 0.08).

3.2 The spatial distribution of photovoltaic power plants in the Czech Republic

More than 20,000 PV power plants approved by the Czech Energy regulatory office ERÚ are distributed in 17,754 locations across the Czech Republic (Fig. 2). The data provided contained the textual addresses of the power plants but not the exact

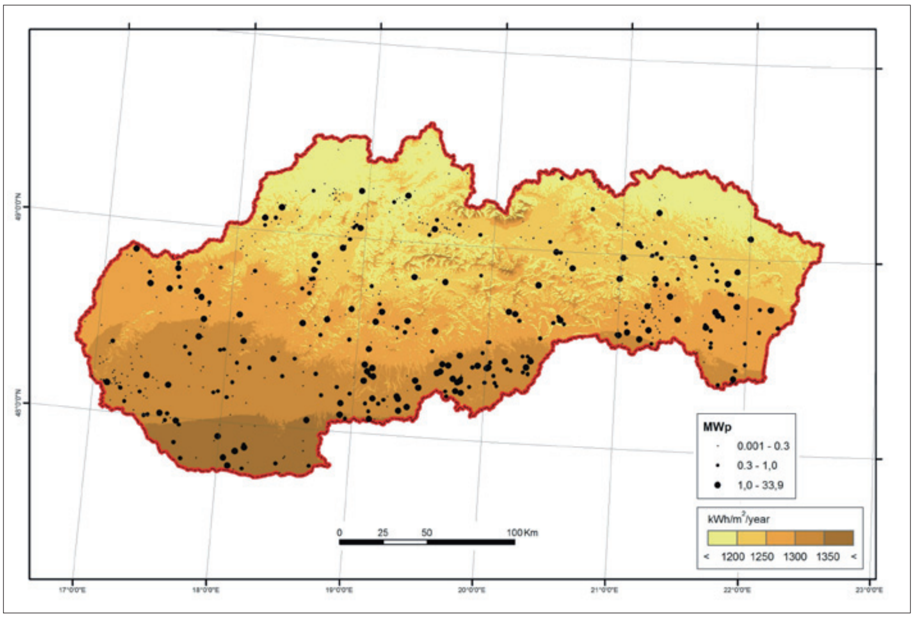

Fig. 1: Spatial distribution of PV power plants in Slovakia in 2012

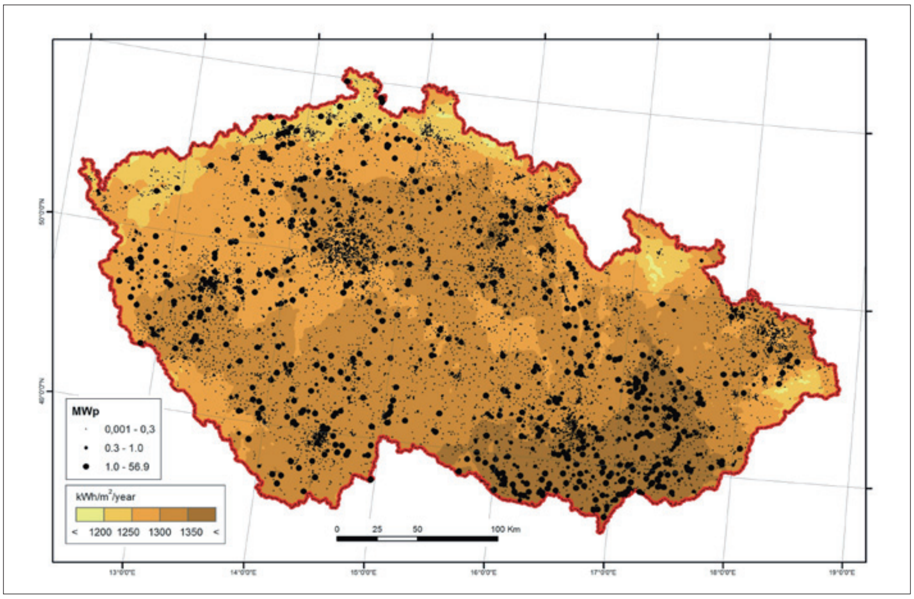

Fig. 2: Spatial distribution of PV power plants in the Czech Republic in 2013

spatial coordinates. The online BatchGeo utility was used to geo-locate these installations. The accuracy of geo-location in built-up areas was very high, but in open space areas only the centroids of the respective villages were identified. The actual positions of larger power plants were verified manually (on-screen) and corrected using orthophotomaps available at www.mapy.cz and the WMS service of the Czech Surveying and Cadastral Office (ČÚZK, http://geoportal.cuzk.cz), and further processed in the ArcGIS v.10.1 software.

The correlation of the PV power plant locations and the solar resource potential represented by the SolarGIS database in the Czech Republic is even weaker than in Slovakia (Pearson's r = 0.093). A closer look at the distribution reveals a few spatial trends, however. Small PV installations with installed capacities less than 0.3 MWp are concentrated in built-up areas dominated by large urban agglomerations, such as Praha (Prague), Brno, Plzeň (Pilsen), České Budějovice and the Ostrava region. The distribution of installations in relation to CLC 2006 level 2 land cover classes and total sums of installed power capacities is shown in Table 2. The highest number of installations can be found in the areas of 11: "Urban fabric" class, with a dominance of very small installations. Some PV power plants in built-up areas are quite large (1 MWp and more), however, mostly located in industrial areas (code 12: Industrial, commercial and transport units). The largest share of the total PV power capacity (70%, 1,348 MWp) is located in agricultural areas (21: Arable land, 22: Permanent crops, 23: Pastures, 24: Heterogeneous agricultural areas) dominated by large PV power plants (more than 1 MWp). Unlike the situation in Slovakia, installations in the agricultural areas have a much higher correlation (r = 0.22) with the solar resource potential than installations in the built-up areas (r = 0.04). However, large installations over 1 MWp follow the solar resource potential (r = 0.02) very poorly, and smaller installations are only marginally better (r = 0.05).

It should be noted that the number of installations found in the particular CLC 2006 classes is slightly influenced by the lower level of detail (a minimum mapping unit of 25 ha) and the spatial accuracy of the CLC 2006 database. In particular, some smaller PV power plants found in smaller settlements can sometimes be classified in agricultural or forest area classes. Such inaccuracies, however, do not substantially affect the overall picture of the distribution of the PV power plants within the major CLC 2006 classes.

4. Transition from large-scale to small-scale installations

Urban areas are very important for solar energy applications. It is assumed that future massive thermal and photovoltaic (PV) applications will involve urban areas primarily. More than 80% of inhabitants of the most developed countries live in an urban environment. In urban areas, energy is consumed and, at the same time, a large portion of green-house gases is produced. Šúri et al. (2007) point out that, in theory, the electricity consumption in many countries could be completely covered by the utilization of solar radiation from a relatively small area (for example, using only 1% of the territory in some countries). This assumption has been corroborated by recent changes in the Slovak support scheme, confining the installation of future PV power plants only to building-mounted systems with a maximum installed capacity of 100 kWp.

The global and regional solar resource databases with spatial resolutions ranging from 100 m to 1 km are of limited applicability in urban areas. The complex nature of the urban environment includes the 3-D morphology of buildings, urban greenery with parks, and isolated trees casting shadows on facades and roofs. All of these factors greatly modify the available solar radiation throughout the day and year. Recently, virtual 3-D city models have become an integral part of many urban studies. Hofierka and Kaňuk (2010) provide an example. The production of 3-D city models is also stimulated by new 3-D mapping technologies such as LiDAR, pictometry and digital photogrammetry, as well as by the development of 3-D tools in GIS technologies that enable 3-D data processing and visualization.

CLC 2006 CODE	CLC 2006 level 2 class	All locations		Locations of <0.3 MWp		Locations of >1 MWp	
		Count	Sum of installed power [MWp]	Count	Sum of installed power [MWp]	Count	Sum of installed power [MWp]
11	Urban fabric	12,175	363.590	12,000	212.571	41	72.651
12	Industrial, commercial and transport units	1,033	338.795	901	36.646	58	260.113
13	Mine, dump and construction sites	16	8.150	15	0.369	1	7.781
14	Artificial, non-agricultural vegetated areas	91	2.762	89	1.196	0	NA
21	Arable land	1,882	1,069.994	1,437	35.483	310	949.027
22	Permanent crops	29	10.720	23	0.442	3	8.970
23	Pastures	446	116.801	393	8.070	31	94.114
24	Heterogeneous agricultural areas	1,849	150.527	1,778	31.726	35	93.754
31	Forests	211	5.931	210	4.931	0	NA
32	Scrub and/or herbaceous vegetation associations	22	33.291	16	0.300	6	32.991
	Total	**17,754**	**2,101.000**	**16,862**	**332.00**	**485**	**1,519.00**

Tab. 2: Distribution of PV power plants within the CLC 2006 classes in the Czech Republic
Source: ERÚ (2013) and EEA (2007)

Hofierka and Kaňuk (2009) have developed a methodology for assessing the photovoltaic potential of urban areas using the 3-D city model, r.sun solar radiation model and PVGIS photovoltaic estimation utility available at http://re.jrc.ec.europa.eu/pvgis/. The methodology can be effectively used for any urban area with a 3-D city model and known rooftop parameters. The assessment of the urban areas of two towns in Slovakia, Prešov and Bardejov, has shown that urban zones of the blocks of flats and industrial zones have the highest potential for future rooftop PV power plant installations (Fig. 3). A study by Kaňuk et al. (2009) further extrapolated the estimated PV potential for residential areas with the blocks of flats identified using the Corine Land Cover database to 138 cities in Slovakia. The study concluded that the estimated annual photovoltaic potential of these cities is around 960,000 MWh.

It should be noted that this methodology can only be applied to the rooftops (i.e. 2-D surfaces) and many parameters must be assessed manually. Since no real 3-D tools had been available until recently, vertical surfaces such as facades usually had to be excluded. Recently, Hofierka and Zlocha (2012) developed new 3-D tools for assessing the solar radiation distribution in morphologically complex urban areas. The new v.sun module for GRASS GIS is based on the solar methodology developed for the r.sun module. The 3-D surfaces of buildings are segmented using a combined voxel-vector approach, allowing for a more accurate assessment of the solar resource potential even on vertical surfaces such as facades (Fig. 4). The applications of the v.sun module go beyond the PV applications and may include an analysis of light and thermal conditions of buildings and open urban areas.

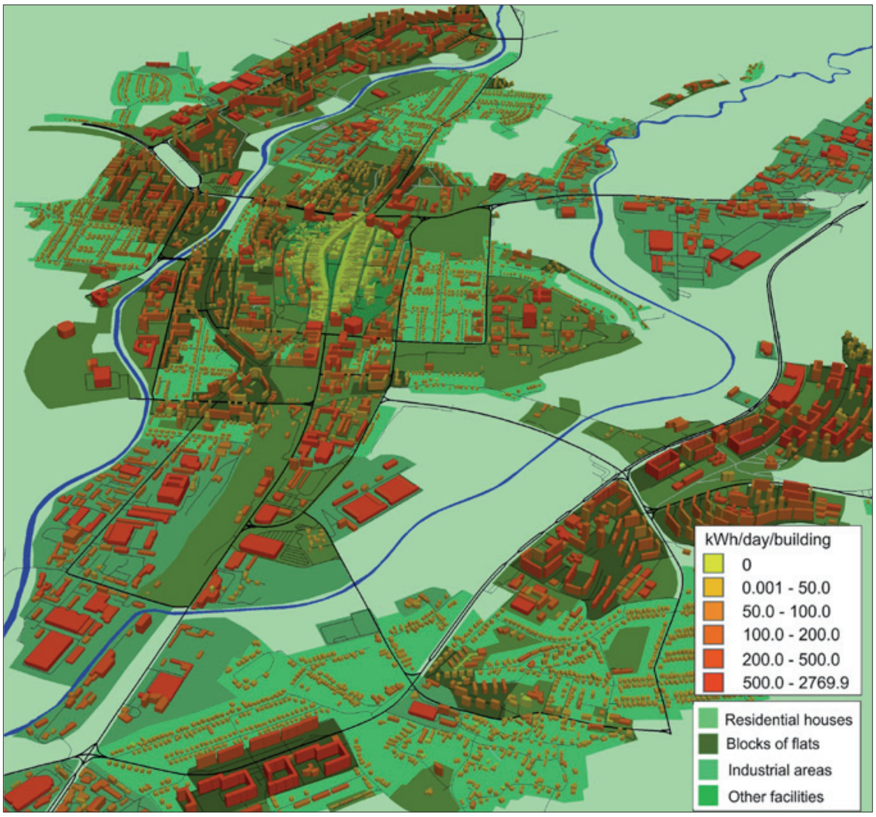

Fig. 3: Assessment of photovoltaic potential in the urban area of Prešov

Fig. 4: 3-D solar radiation modelling using the v.sun module

5. Conclusions

Solar energy has become an integral part of energy resource mixes of many countries, including the Czech Republic and Slovakia. The generous support schemes in both countries, as well as the decreasing costs of new PV power plant installations, caused a massive boom in the area of PV power plant construction in the period 2009 to 2012. More than 20,000 new PV power plants were built in the two countries, but the consequences included higher electricity prices paid by consumers. Recent changes in the support schemes for new PV installations, however, will shift the focus to smaller systems in built-up areas. In this paper, we have analysed the spatial distribution of existing PV power plants. We have found that these power plants scarcely follow the solar resource potential represented by solar databases developed by Hofierka and Cebecauer (2008) and the commercially available SolarGIS (Šúri and Cebecauer, 2010). Smaller installations (less than 0.3 MWp) are concentrated mostly in the built-up areas (these are often rooftop installations); larger installations are usually located in open agricultural areas, with a few exceptions found in industrial areas or in quarry areas (former extraction of minerals).

Recent changes in the support schemes for new PV installations will also affect these patterns, with new installations mostly limited to built-up areas. These changes will require new tools to assess the appropriate locations of the PV systems. The complex environment of built-up areas will require new 3-D tools, integrated with the spatial databases and modelling techniques of GIS. Several examples have been presented, assessing the solar resource potential in a built-up area using a virtual 3-D city model and new 3-D solar radiation tools developed for GRASS GIS.

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SMALL-SCALE RENEWABLE ENERGY SYSTEMS IN THE DEVELOPMENT OF DISTRIBUTED GENERATION IN POLAND

Justyna CHODKOWSKA-MISZCZUK

Abstract

Small-scale renewable energy systems in the context of the development of distributed generation, are discussed for the case of Poland. A distributed energy system is efficient, reliable and environmentally friendly, and is one of the most recent trends in the development of the energy sector in Poland. One of the important dimensions of this process is the creation of micro- and small-power producers based on renewable, locally-available energy sources. It is clear that the development of small-scale renewable energy producers takes place in two ways. One of these is through small hydropower plants, which are the aftermath of hydropower development in areas traditionally associated with water use for energy purposes (northern and western Poland). The second is through other renewable energy sources, mainly biogas and solar energy and located primarily in southern Poland, in highly urbanized areas (e.g. Śląskie Voivodship). In conclusion, the development of small-scale renewable energy systems in Poland is regarded as a good option with respect to sustainable development.

Shrnutí

Malo-měřítkové systémy obnovitelné energie v rozvoji rozptýlené výroby v Polsku

Článek pojednává o malo-měřítkových systémech obnovitelné energie v kontextu rozvoje rozptýlené výroby v Polsku. Systém rozptýlené produkce je efektivní, spolehlivý a šetrný k životnímu prostředí a je jedním z nejnovějších trendů rozvoje energetického sektoru v Polsku. Jednou z důležitých dimenzí tohoto procesu je vznik mikro a malovýrobců na bázi obnovitelných, lokálně dostupných zdrojů. Malo-měřítková produkce obnovitelné energie se rozvíjí dvěma směry. První je prostřednictvím malých vodních elektráren, které jsou pokračovatelem rozvoje vodní energie v oblastech tradičně spojených s využíváním vody pro energetické účely (severní a západní Polsko). Druhý je prostřednictvím dalších obnovitelných zdrojů, zejména bioplynu a sluneční energie, převážně ve vysoce urbanizovaných oblastech jižního Polska (Slezské vojvodství). Z článku vyplývá, že malo-měřítkové systémy výroby obnovitelné energie jsou vhodnou volbou z hlediska trvale udržitelného rozvoje.

Key words: *distributed generation, small-scale renewable energy, Poland*

1. Introduction

The socio-economic development of a country is determined principally by both the production of and demand for electricity. In today's world, as many as 2 billion people have no access to electricity, of which 98% live in developing countries (Suberu et al., 2013). Energy security is equally important for post-communist countries that are still in the process of economic transition. One of these countries is Poland, where the domination of obsolete power stations and power grids is accompanied by a steadily-expanding demand for electrical energy. The Polish Energy Group (Polska Grupa Energetyczna) estimates that in the years to come, the demand for electricity will be increasing in Poland at a rate of 1–1.7% per year (www.ure.gov.pl). As a European Union (EU) Member State, Poland is also required to modernize its power sector in line with the laws in force. European policymakers are expressing clear political support for a move to a low-carbon society. The expected changes range from a wider use of renewable energy sources and improved energy efficiency, to reduced emission of CO_2 (known as the 20-20-20 targets) and decarbonization energy sector by 2050 (Klose et al., 2010; Ruester et al., 2013). Given the urgency of these regulations, including carbon emission reductions, Poland faces a major challenge in its energy sector. Taking into account electricity production in Poland, over 85% is based on a coal (both hard coal and brown coal), while renewable energy sources provide less than 10% (Statystyka Elektroenergetyki Polskiej, 2012).

A relatively limited supply of electricity in Poland in the near future may emerge, even though some modernisation works and new projects, although to an insufficient degree, have been launched and there are some on-going deregulation processes in the power sector. The Energy Regulatory Office (ERO) estimates that after 2015, Poland may be short of as much as 5,000 MW. One solution to this huge problem for the country's economy is distributed generation, based on local renewable sources of energy, which is more efficient than a centralised system (Moriarty, Honnery, 2011). As planned, in Poland, the expansion of domestic micro generation systems is to generate 1.9 GW of new power by 2020 (http://biogazownierolnicze.pl).

In the face of this on-going process of transformation of the energy sector in Poland, including the development of distributed generation, there is a need to enumerate and evaluate the current situation. This is because, in Poland, where the energy sector is highly centralized and the issue of distributed generation is still new, there is a need for research considering the current use of small-scale renewable energy. Furthermore, an extremely important context for these studies is to establish the first legal regulations to support electricity production via micro-installations, i.e. the law known as the Energy Three Pack. Another good reason to address this issue is the lack of this kind of research related to the situation in Poland. This is especially important because this problem is a part of a wider scientific and public discussion about the possibilities, directions and conditions for the development of distributed generation and energy production in small-scale installations.

The aim of this article, then, is to outline and evaluate the current situation regarding micro- and small-renewable energy systems in the context of distributed generation, the popularity of which has been recently growing in Poland. This objective will be achieved by analysing the electricity production from energy sources such as water, wind, solar radiation and biogas in small-scale installations (to 200 kW); according to Polish law the total installed electrical capacity of a small-scale installation is not higher than 200 kW (Ustawa z dnia 26 lipca 2013). The purpose is to indicate the most prospective renewable energy sources that may be most appropriate for electricity production in small-scale installations in Poland. In addition, the aim is to identify regions in Poland with the greatest potential for distributed generation development, in relation to small-scale renewable energy systems. A final aim is to identify the possibility of using solar energy in urban and suburban areas, such as the supply of thermal energy in multi-family buildings and single family-houses.

This research project is based on the Energy Regulatory Office data on small-scale renewable energy systems generating electricity in Poland (as of 31 July 2013). The Energy Regulatory Office is the government institution which carries out assignments relating to the power sector in Poland, including electricity production. As a government agency, it has reliable and complete data on electricity production in small-scale renewable energy systems.

This study is carried out at the poviat[1] level, but some research results are presented at the voivodship[2] level. Moreover, based on a case study, the production of thermal energy from solar energy is analysed. The generation of thermal energy is illustrated by a case study of solar technologies applied to multi-family buildings managed by housing cooperatives in Bydgoszcz and Toruń (the two major cities of Kujawsko-Pomorskie Voivodship) as of 2012. These cities (Bydgoszcz and Toruń) were among the first in Poland where solar technologies were applied to multi-family buildings. The experiences of these cities can be very useful in other similar projects, especially in the context of using the small-scale installations in thermal energy production.

2. Distributed generation – the concept and main issues

Currently, the energy system is based on particular assumptions related to sustainable development. In accordance with the principles of the contemporary energy hierarchy the priority is energy conservation, the next is sustainable production (primarily from renewables), and the lowest option is energy generation from fossil sources. In this context, distributed generation enables the implementation of the main objectives of a sustainable energy system, including improving energy efficiency, increasing the use of renewable energy sources and reducing energy production from fossil sources (Wolfe, 2008). Generally, distributed generation (DG) includes the generation of electrical energy, thermal energy and liquid fuels based on decentralised small-scale power technologies serving mainly local needs (Energetyka rozproszona, 2011). It must be noted that there are many definitions of distributed generation (Ackermann et al., 2001; El-Khattam and Salama, 2004; Pepermans et al., 2005; Purchala et al., 2007; Wolfe, 2008). On the one hand, distributed generation is defined in terms of generation capacity (cf. Dondi et al., 2002). On the other hand, a definition of distributed generation refers to connection and location (cf. Ackermann et al., 2001). Generally, definitions suggest that small-scale generation units connected to the distribution grid are to be considered as part of distributed generation. Besides, generation units installed close to the load or at the customer side of the meter are also commonly identified as distributed generation (Pepermans et al., 2005).

Considering generation capacity, distributed generation is a small source of power – typically ranging from less than one kW to tens of MW (Dondi et al., 2002), including, for example, 30 MW (Chambers, 2001). Generally, in Poland distributed generation utilises power generation systems of installed power capacity to around 200 kW. The systems are subdivided into micro systems (of the total installed capacity (electrical and thermal) of, respectively, 40 kW and 70 kW) and small systems (installed electrical capacity of 40–200 kW and thermal capacity of 70–300 kW (Więcka et al., 2012), which are the most frequently used by households, farms and small firms. Their operators can sell the generated power and/or utilise it to meet their own needs. People who use small-scale renewable energy systems to produce energy as well as consuming their output are called prosumers. Their current population in Poland exceeds 220,000, with every second Pole declaring their interest in the systems, mainly in technologies allowing the energy of solar radiation to be converted into power (http://biogazownierolnicze.pl).

DG was the most common solution in the early period of the global power industry, i.e. in the late 19th century. Over time, however, it started giving way to centralised power generation. As a result, by the end of the 20th century DG systems were mainly used for back-up purposes or by small, autonomous off-grid users. Between the early 20th century and 1990 the percentage of independent power producers (IPPs) decreased in the world market ten times, from around 30–40% to 3–4% (Energetyka rozproszona, 2011).

At the end of the 20th century, the significance of IPPs for the global, and also European power industry slowly started to grow following the implementation of deregulation processes in the world markets (Carley, 2009), a trend that can be observed in Poland too. According to Bell and Cloke (1990), deregulation resembles liberalisation and consists of the withdrawal of government control over various sectors of the economy, including the power industry. The process aims to create a competitive market for power, now recognised as a commodity. Because a market cannot be really competitive without a diverse ownership structure of the players, incentives for the establishment of IPPs are created, etc. (Luchter, 2001). An equally important aspect of deregulation is that it drives the diversification of energy sources, such as a wider use of locally available sources of renewable energy.

All these changes lead to the emergence of small-scale renewable energy systems (Solomon et al., 2006). Nevertheless, deployment of small-scale renewable energy systems has so far progressed slowly in Poland, as in other post-communist countries such as Lithuania (Miskinis

[1] poviat – administrative region of the 2nd order

[2] voivodship – administrative region of the 1st order

et al., 2011). The Polish energy market is still dominated by centralized generation (over 90% of the energy market for electricity) (Energetyka rozproszona, 2011).

Development of distributed generation – as a part of the energy system – is conditioned by particular implementations noted on the stage of energy production, distribution and legal regulation. The first issue is to indicate the most promising renewables, which can be used in distributed generation. The further consequences refer to the technological and infrastructural aspects of energy production and distribution, including energy transport, storage and networks (Woodman and Baker, 2008; Wolfe, 2008; Barry, Chapman, 2009; Wolsink, 2012). For instance, in the context of energy transport there is the question related to the connection of individual energy users to the national energy system (Pecas Lopes et al., 2007; Wolfe, 2008). Apart from distributed generation and energy storage, another aspect of a decentralised energy system is a more active involvement of consumers through demand response. Demand response does not necessarily save energy, but rather shifts energy loads around in time. This is very important since it potentially avoids the need to shed excess energy supply at times of low demand or high supply (Decentralised Energy Systems, 2010). In addition an increasingly decentralised energy system could offer substantial opportunities for the storage of energy (including on-site energy storage options) and reducing energy losses (Wolfe, 2008; Basak et al., 2012).

The distribution networks will also have to evolve increasingly towards smart grids (Jiayi, XuRong, 2008; Wolfe, 2008; Barry, Chapman, 2009; Wolsink, 2012; Zhang et al., 2014). Smart grids are active and dynamic electricity networks where the smart grid functions as a facilitator for active end-users as opposed to the traditional passive top-down (uni-directional, producer-to-consumer) power system (Decentralised Energy Systems, 2010). At the same time it can facilitate the achievement of a renewable electricity future by integrating distributed renewable resources locally, while providing greater flexibility for managing resources to respond to varying grid conditions (Newcomb et al., 2013).

It is also necessary, however, to develop an effective and innovative business model as an additional tool to support the process of a decentralised energy system (Gordijn, Akkermans, 2007; Klose at al., 2010; Eghtedarpour, Farjah, 2012; Richter, 2013), including supply demand models, regional models, resource models and the application of energy management systems (Jebaraj, Iniyan, 2006; Hiremath et al., 2007; Basak et al., 2012; Herran, Nakata, 2012). The one of the essential conditions for increasing the use of renewables is also social acceptance of renewable energy, for instance wind energy (Frantál, Kunc, 2011).

It should be mentioned that in Poland, as in other countries, besides the infrastructural and technological implications related to a decentralised energy system, an important factor restricting the development of distributed generation is unstable energy policy. Many researchers emphasize (cf. Barry and Chapman, 2009; Wolfe, 2008; Vogel, 2009; Rydin et al., 2011) that only if policy support is provided, will small-scale renewable energy systems be able to play a useful role in the power sector.

Renewable energy technologies, including small-scale systems, are a relatively recent innovation for the planning system and have placed new demands on policy guidance at national and local levels. Both government and local policies for renewables are still evolving (Hull, 1995), especially since (EU) Member States are required to modernize the power sector in line with the laws in force, which means a wider use of renewable energy sources and improved energy efficiency to reduced emission of CO_2. It is difficult for countries where the energy sector is highly centralized and mostly coal-based (as in Poland). In such cases, the modernization of the power sector might be related to the increased use of renewable energy sources as well as clean coal technology. Clean coal technology, which could be one of the key ways to reduce greenhouse gas emissions, might enable fossil fuels to remain an integral part of the energy mix in the EU (The Future of Carbon Capture and Storage in Europe, 2013). It should be mentioned that many industrialized countries have achieved limited success in addressing their reliance on fossil fuels (Cirone, Urpelainen, 2013). According to the International Energy Agency (IEA), in 2010 less than 60% of the IEA energy efficiency recommendations were implemented (even in these countries that are most proactive on energy).

The effects of renewable electricity policies are more pronounced before 1996 as well in developed and emerging countries. Moreover, policy effectiveness varies by the type of renewable electricity policy and energy source. The main barrier for the development of a renewable energy system is its high fixed costs (privately, unprofitable) compared to non-renewable electricity, including clean coal technologies (Verrbrugen et al., 2010; Aalarbes et al., 2013). As a result, only investment incentives and feed-in tariffs are found to be effective in promoting the development of all types of renewable energy sources for electricity (also distributed and micro generation) (Steenblik, Coroyannakis, 1995; Dong, 2012; Zhao et al., 2013). Besides, a large presence of non-governmental organizations and green residential customers facilitate the transmission of renewable energy policies (Delmas, Montes-Sancho, 2011; Stokes, 2013). There is a need for coalitions, mediators and proponents of renewables projects (Stokes, 2013).

Furthermore, decentralisation of the energy system is also a challenge for system planning and the management of energy infrastructure. A central government cannot direct this process although it can seek to provide incentives. The onus for promoting, delivering and coordinating energy decentralisation is likely to fall on local government. Because they tend to be smaller, decisions can be taken quickly and their structure can adapt more quickly to new situations, as compared to larger and more bureaucratic national governments (Puppim de Oliveira, 2009). A major role for local planning will be to monitor the evolving nature of energy decentralisation in their areas, looking across public, private and third sector schemes and taking a broad view of energy systems as encompassing generation, distribution and consumption (Rydin et al., 2011).

In Poland, energy policy is being transformed, as national laws are adapted to European Union regulations. One of the dimensions of this process is the government document "Energy Policy of Poland until 2030" (Polityka energetyczna Polski do 2030 r.). According to the "Energy Policy...", the development of the Polish energy sector includes the diversification of energy sources (increased use of renewable energy sources) and the use of clean coal technologies. Furthermore in this document DG development is treated as a central factor in the improvement of the country's energy efficiency. In addition, in July 2013, the national regulations related to the energy sector were partly amended (through the law known as the Energy Three Pack). The Energy Three-

Pack is mainly aimed at implementing into the Polish legal system the provisions of the so-called Gas Directive (2009/73/EC) and the Electricity Directive (2009/72/EC). Although the main part of the Energy Three Pack is dedicated to gas market regulations, it sets out the support scheme for small and micro renewable energy installations (i.e. energy sources with total installed electrical capacity not higher than 200 kW, interconnected to the grid below 110 kW, or of the total installed heat capacity not higher than 600 kW). It must be noted that the act introduced preferential conditions for connection to the national grid micro-installations (less than 40 kW). In accordance with the law, the owners of micro-installations of electricity production do not need formalize economic activities related to the electricity production, which means that they are exempt from the obligation to establish and run the business. Besides, this electricity will be bought at a price equal to 80% average selling prices of electricity in the previous year (Ustawa z dnia 26 lipca 2013). These rules allow for the creation of the financial support for the development of micro-installations, such as PV or wind turbines. It must be noted that this line of power sector development has also been incorporated in the draft of the new law on renewable energy sources.

The development of DG provides a range of benefits to the local economy, communities and the national power sector (Zahedi, 1996; Ackermann et al., 2001; Barry, Chapman, 2009; Encouraging Renewable Energy Development, 2011; Herran, Nakata, 2012). A. Lovins et al. (2002) have compiled a list of more than 200 benefits (social, economic, ethical and psychological, etc.). According to the aforementioned forecasts, a wider use of DG may cut the present consumption of energy by 20% in the EU alone (Bańkowski, Żmijewski, 2012). Moreover, DG following from the implementation of sustainable development principles, also promotes environmental protection and pro-environmental attitudes (Watson, 2004; Alanne, Saari, 2006; Akorede, Pouresmaeil, 2010; Kaygusuz et al., 2013).

3. Micro and small renewable energy systems and production of electricity in Poland

The total installed capacity of micro and small renewable energy systems in Poland accounts for 0.25% of the total installed capacity in Poland (www.ure.gov.pl). The average installed capacity of 84.2 kW per system shows that most of them are small (from 40 to 200 kW). There are differences in the spatial distribution of micro and small systems in Poland. They are present in over 63% of rural poviats and in almost 34% of cities with poviat status. In northern voivodships and in the Opolskie Voivodship they generate power in more than 85% of rural poviats, but in the Mazowieckie, Podlaskie and Wielkopolskie Voivodships their rates do not exceed 40% (see Fig. 1).

The micro and small systems are least common in areas where electricity shortages occur already today – in north-eastern Poland. The environmental and socio-economic conditions (low density of population, a considerable proportion of rural areas, etc.) make this part of the country one of the most conducive to the development of distributed generation. The relatively low number of micro- and small-systems in the Wielkopolskie Voivodship is due to the prevalence of large-scale renewable energy facilities, including wind power plants.

When the segment of micro and small electrical energy producers in Poland is analysed by source of renewable energy, we find that the sources of energy driving its development include the energy of water, wind and solar radiation, and biogas.

As far as the first source of energy, water, is concerned, small hydropower plants prevail and, unlike large hydropower facilities that have been steadily losing their position as providers of electrical energy since c. 2005 (Chodkowska-Miszczuk, Szymańska, 2011), they play an important role. A strong indication of this is their presence in over 45% of all Polish rural poviats and in 87% of poviats where small-scale renewable energy systems are used. Most of these areas have a long-standing tradition of harnessing the energy of rivers, dating back to the period of the Prussian partition, i.e. the turn of the 19th and 20th centuries (Luchter, 2000).

Although hydropower plants constitute a majority of small-scale facilities, they only represent just over 40% of the total installed capacity of all micro- and small-renewable energy systems in Poland. This is the case because over 30% of the analysed hydropower plants are micro-hydro systems (of installed capacity to 40 kW); the average installed capacity of the considered hydropower plants is 70.4 kW. Hence the installed capacity of micro and small hydropower systems stands at 0.5% of the installed capacity of all hydropower plants in Poland.

It is important to note that small hydropower plants not only perform social and economic functions (create jobs, generate electricity, attract tourists), but also enormously benefit the natural environment because of their water retention function.

Another source of renewable energy utilised by the micro and small systems is biogas (obtained from dump sites and sewage treatment plants). Biogas power plants are present in over 15% of poviats with small-scale renewable energy systems, mainly in the Śląskie and Mazowieckie Voivodships. Their total installed capacity accounts for almost 46% of the installed capacity of all small-scale electricity producers in Poland (the biogas power plants analysed have a considerable installed capacity of 148.5 kW on average) and for almost 4% of the installed capacity of all biogas power plants in Poland. The installed capacity of the smallest of the investigated biogas power plants was 75 kW, meaning that all of them are small systems, without any micro facilities present.

An analysis of the micro- and small-renewable energy systems may not omit those using the energy of wind and the energy of solar radiation. They belong to the primary renewable energy sources for electricity production in the world (Boreland and Bagnall, 2008, Tavner, 2008). While in Poland, systems based on these two sources of energy are few: wind power plants and solar power plants are present, respectively, in somewhat more than 5% and 3% of the investigated poviats.

Most wind power plants in Poland are large facilities, so it is not surprising that micro and small systems account for only 0.03% of the installed capacity of all wind power plants in the country. The average installed capacity of the investigated wind power plants was 81.5 kW and one third of them were micro systems.

Solar power systems (photovoltaic) are still at the early stage of their expansion in Poland. The systems are generally relatively small. Those analysed in the research account for over one-fifth of the installed power of all photovoltaic cells in the country. The average installed capacity of micro and small solar power systems (36.2 kW) is the lowest among all investigated systems and 75% of them are classified as belonging to the micro category (see Fig. 2).

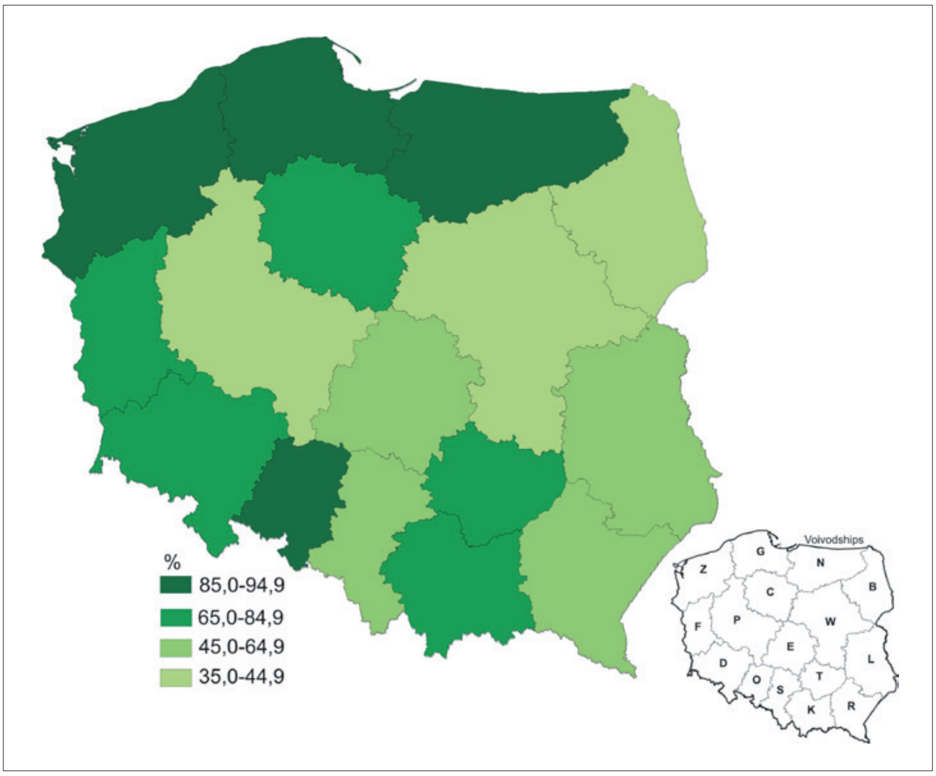

Fig. 1: Rural poviats with micro and small renewable energy systems as percentages of all rural poviats in the voivodships in Poland as of 31 July 2013. Explanation: Voivodships: B – Podlaskie; C – Kujawsko-Pomorskie; D – Dolnośląskie; E – Łódzkie; F – Lubuskie; G – Pomorskie; K–Małopolskie; L – Lubelskie; N – Warmińsko-Mazurskie; O–Opolskie; P – Wielkopolskie; R – Podkarpackie; S – Śląskie; T – Świętokrzyskie; W – Mazowieckie; Z – Zachodniopomorskie. Source: developed by the author based on data available at ERO

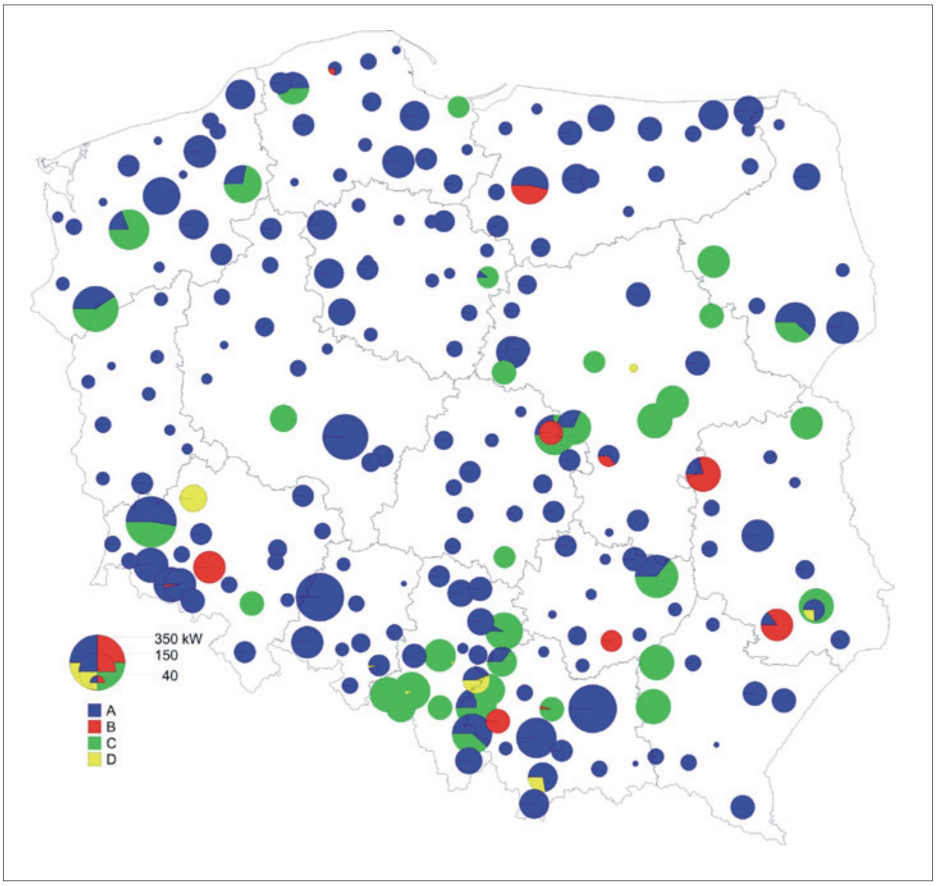

Fig. 2: The structure and the installed capacity of small-scale renewable energy systems in Polish poviats as of 31 July 2013. Explanation: A – hydropower plants; B – wind power plants; C – biogas power plants; D – solar power plants. Source: developed by the author based on data available at ERO

An analysis of the small-scale systems by source of renewable energy shows two trends in their development. One is the prevalence of small hydropower plants following from the development of hydropower generation in areas that have the tradition of harnessing the energy of water (northern and western Poland). The other is the expanding number of systems utilising other energy sources, mainly biogas and the energy of solar radiation. The two sources of energy typically occur in southern Poland, usually in strongly urbanized areas. As far as solar energy is concerned, photovoltaic cells are most common in areas with the highest numbers of companies producing and/or distributing solar technologies, i.e. in southern Poland (Chodkowska-Miszczuk, Szymańska, 2012).

4. Solar technologies and the development of distributed generation in Poland – examples of application

A huge market segment offering opportunities for distributed generation to expand is construction, the most power-intensive sector of the economy, which accounts for over 40% of final energy consumption in Poland. Special attention should be given to housing, because in 2012 as much as 30% of final energy consumption in the country was attributed to households (Efektywność wykorzystania energii, 2013). That great amount of energy is mainly used to deliver heat and hot water, which respectively account for 69% and 15% of all energy used by housing in Poland (ibid). With the floor area of housing units growing larger and larger and with the spreading use of air conditioning systems, energy consumption may rise still higher.

Among the small-scale renewable energy systems used in the Polish housing sector those based on solar energy technologies are the most common, despite their relatively short history. Systems converting the energy of solar radiation (solar collectors and photovoltaic cells) into usable power are usually located the closest to energy producers and users (Chodkowska-Miszczuk, 2012), are the most environmentally friendly among the power generation technologies, and do not affect the architectural design or aesthetics of the buildings (Chwieduk, 2010). Moreover, projects involving the use of solar radiation energy are eligible for wide financial support from both domestic and EU sources.

In analysing the applicability of solar technology to a building, it is important to consider the building's age, state of repair and architecture. In existing buildings, a number of alterations improving heat circulation and retention must be made for a renewable energy system to be effective. This means that it is much easier to install such systems in new buildings, for instance in single-family houses. A pattern can be observed that in places where the number of new residential buildings is systematically growing (mainly in the suburban areas of large cities (Biegańska, Szymańska, 2013), the number of investments in solar technology projects, mainly solar collectors but increasingly often also photovoltaic systems, is rising too.

Depending on the manner of applying a photovoltaic system to a building, which is determined by whether the building is being designed or already in existence, the Building Integrated Photovoltaics (BIPV) concept or the Building Applied Photovoltaics (BAPV) concept is adopted. The BIPV is one of the most innovative solutions where the photovoltaic system is designed into a building, mainly as an alternative to traditional roof or elevation elements, such as roofing sheets and glass systems. Under the BAPV approach, the building is provided with a non-integrated photovoltaic system (see Fig. 3). The BAPV approach is the most common in the market today; because the BIPV is a relatively new solution, its share in the global photovoltaic market stands at around 1% (Pietruszko, 2009).

A notable factor in the development of solar energy systems is the high capacity of multi-family buildings in Polish cities to receive them. What makes solar energy technologies (solar collectors and BIPV and BAPV photovoltaic systems) appropriate for the urban built environment that offers few opportunities for modifications, is that they intrude the least on the fabric of buildings and are cost-effective (http://www.urbansolplus.eu/pl/urbansolplus-w-polsce).

My own study into housing cooperatives in Bydgoszcz and Toruń (the principal cities of the Kujawsko-Pomorskie Voivodship) has shown that installing solar collectors, photovoltaic cells and heat pumps, as a triad, increases the efficiency of individual devices. These small-scale power systems are applied to meet tenants' demand for energy. Depending on the multi-family building, their total installed capacity may range from 100 to 150 kW. As Kaygusuz et al. (2013) noted in buildings, the energy mixing strategy is very useful for the integration of hybrid renewable energy and the grid energy to meet site power demand. It is worth adding that the systems are mainly installed in multi-family buildings comprising new, modern housing estates (see Fig. 4).

Solar collectors allow hot water to be supplied to the tenants (a modern housing estate has several hundred tenants on average) at much lower cost, an average saving being estimated at 30–40% annually. Heat pumps considerably lower the cost of heating cost. Photovoltaics is currently in the experimental stage; the most efficient uses of the electrical power that it can generate are still being sought.

Compared with buildings without renewable energy systems, flats in buildings powered by solar collectors, etc., attract much more interest from potential buyers, even though the technology involves additional costs. Solar technologies in multi-family buildings add to the quality of space, and property managers use them for marketing purposes.

5. Conclusion

The development of small-scale renewable energy systems provides a range of benefits to environmental protection and the socio-economic development of regions and communities. This research has shown that environmental, social and economic considerations make distributed generation utilising renewable, locally available sources of energy one of the most desirable directions in the development of the power sector in Poland. Unlike the implementation of large power generation facilities, the growing use of small-scale renewable energy systems neither drastically affects the landscape nor changes the way it is perceived, but furthers the socio-economic development of regions and municipalities. Investing in technologies based on renewable energy sources brings passive income and guarantees that the steadily increasing demand for power among the population will be satisfied (not least through the development of prosumer power generation).

Distributed generation in Poland is at the initial stage of its development. One of the key characteristics of distributed generation is the presence of small-scale renewable energy systems (up to 200 kW of installed capacity). Among these,

Fig. 3: A single family-house with solar collectors in Czarnowo – a suburban area of the Bydgoszcz–Toruń agglomeration (Kujawsko-Pomorskie Voivodship) – an example of the BAPV system. Source: author

Fig. 4: A multi-family building with solar collectors managed by Spółdzielnia Mieszkaniowa "Budowlani" in Bydgoszcz (Kujawsko-Pomorskie Voivodship). Source: author

hydropower plants are the most important, which have been found in 87% of poviats using small-scale renewable energy systems. Most of the poviats have a long tradition of harnessing water to generate power (northern and western Poland).

Second in the ranking are biogas power plants (using biogas generated at dump sites and sewage treatment plants). These installations occur in more than 15% of the analysed poviats, mainly in the Śląskie and Mazowieckie Voivodships. The installed capacity of the biogas power plants is relatively high; micro installations (to 40 kW) have not been identified. A source of renewable energy whose importance for electricity production in Poland is growing despite a relatively short history of use is solar radiation. The most common are micro photovoltaic systems averaging 36.2 kW in installed capacity.

According to the research outcomes, distributed generation is of crucial importance to the housing sector. The most frequent source of renewable energy used in the sector is solar radiation (converted into energy by solar collectors and photovoltaics cells). Solar energy systems are increasingly being integrated into residential buildings. Their use is more common in areas with growing numbers of new housing estates consisting of single-family houses and multi-family buildings, for instance in the suburban areas of large cities. Solar energy technologies applied to single-family houses and multi-family buildings improve their standard, so property managers frequently refer to them for marketing purposes.

The global trends in the development of the power generation sector combined with technological, legal and financial factors make it probable that small-scale renewable energy systems will be used increasingly often in Poland. The range of the most promising renewable energy sources has the traditional hydropower plants at one end and increasingly popular solar technologies (photovoltaic cells and solar collectors) at the other.

It must be mentioned that this study generates future research in this area. There is a need for further interdisciplinary research on distributed generation and development of small-scale renewable energy systems in Poland. The information on the structure and the installed capacity of small-scale renewable energy systems in Poland, which are included in this article, determine the future research related to directions for the development of the energy sector in Poland. This issue requires further studies especially in the context of the deficient supply of electricity in Poland. Deficits of electricity supply will be particularly noted in the rural areas of eastern Poland (the most depopulated area of the country). In this case, the most appropriate solution is the development of distributed generation based on locally-available energy sources.

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THE (UP)SCALING OF RENEWABLE ENERGY TECHNOLOGIES: EXPERIENCES FROM THE AUSTRIAN BIOMASS DISTRICT HEATING NICHE

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Abstract

The successful diffusion of sustainable technologies is termed "upscaling" in the transition studies literature. This paper maintains that upscaling is an ambiguous notion that suggests that technology diffusion processes follow a linear trend from small-scale pilot plants to industrial-scale facilities. On the ground, however, socio-technical configurations are implemented at a variety of scales, simultaneously. These issues are demonstrated in this paper by analysing the historical development of the Austrian biomass district heating niche. Drawing on secondary statistical data and primary qualitative semi-structured interviews, it is possible to identify four generic socio-technical configurations or dominant designs that, in conjunction, shape the diffusion dynamics of this technology in Austria.

Shrnutí

(Up)scaling technologií obnovitelné energie: zkušenosti z rozvoje dálkového vytápění biomasou v Rakousku

Úspěšná difúze udržitelných technologií je v literatuře zabývající se studiem přechodů označována termínem "upscaling". Tento článek dokládá, že upscaling představuje nejednoznačný pojem, sugerující, že procesy šíření technologií sledují lineární trend od malých pilotních elektráren k velkým průmyslovým zařízením. Nicméně ve skutečnosti jsou socio-technické konfigurace implementovány simultánně na různých úrovních. Tato problematika je demonstrována analýzou historického vývoje trhu dálkového vytápění biomasou v Rakousku. S využitím sekundárních statistických dat a kvalitativních semi-strukturovaných rozhovorů byly identifikovány čtyři generické socio-technické konfigurace neboli dominantní vzorce, které ovlivňují dynamiku šíření této technologie v Rakousku.

Key words: *energy transitions, scale, biomass, district heating, Austria*

1. Introduction

Research on sustainability and energy transitions is an expanding scientific field, as a growing number of publications and special issues in journals show (Markard et al., 2012). Recently, economic geographers have proposed a series of conceptual points of departure to elaborate the spatial aspects of sustainability and energy transitions (Coenen et al., 2012; Bridge et al., 2013), and one of the most prominent concepts is scale. In the sustainability transitions literature, the establishment and especially expansion of novel socio-technical configurations[1] is termed the Upscaling of Technological Niches: "Upscaling is defined as increasing the scale, scope and intensity of niches experiments by building a constituency behind a new (sustainable) technology, (...)" (Coenen et al., 2010, p. 296, emphasis added). Actors that participate in a local project share their experiences with other projects. They compare and aggregate lessons and thereby contribute to the creation of an emerging technological trajectory (Schot, and Geels, 2008). The approach of Strategic Niche Management thus uses the notion of upscaling as a shorthand symbol for deliberate technology diffusion. The underlying picture is one of a rather linear development trajectory, pushed by a homogenous community and resulting in a continuous increase in artifact size for the realization of economies of scale. In this article, I suggest that this notion of upscaling represents an overly simplistic view of technology diffusion. I maintain that a technology can be divided into several generic socio-technical configurations or dominant designs. Each dominant design consists of a particular combination of technical (hardware) and institutional (software) components and follows its own life cycle. The successful diffusion of the wider technology results from the aggregated implementation rates of the individual dominant designs, and cannot be reduced to the realization of large-scale industrial facilities that intensify energy production.

To illustrate this contention I analyse the development of the Austrian biomass district heating (BMDH) niche which experienced high diffusion rates throughout the 2000s. The number of installed plants increased four-fold to over 2,000 from 1999 to 2010 (Rakos, 2001; Mayerhofer and Burger, 2011), while the amount of fed-in heat increased five-fold to approximately 37 PJ, thereby covering around 45% of the overall district heating output (Statistik Austria, 2012). The spatial distribution of these plants is shown in Figure 1. Although no technology-specific goals exist for a further expansion of capacities, diverse supply- and demand-side policies at the national and the provincial scale support

[1] A socio-technical configuration is understood as a certain combination of technological artifacts, actors that use and maintain those artifacts, and institutions that govern the relations between actors and between actors and artifacts (Markard et al., 2012).

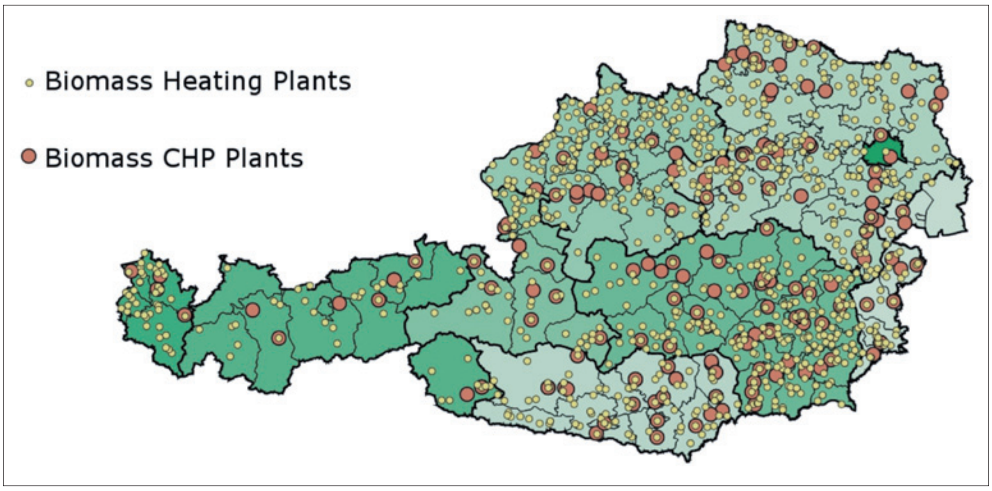

Fig. 1: Biomass Heating and Combined Heat and Power Plants in Austria 2010[2]
Source: Austrian Biomass Association, 2013

the ongoing diffusion. These policies are listed in the Austrian Renewable Energy Action Plan submitted to the European Commission as key contributions to increase the amount of renewable heating and cooling to roughly 175 PJ by 2020 (Karner et al., 2010). This currently rather successful example of technology diffusion serves as a case study to answer the following questions: Which actors and institutions shaped the dynamics of technology diffusion? What were the consequences of these dynamics for the physical size of technology implementation and the interrelated organizational patterns of plant operation? What conclusions can be drawn for the concept of niche "upscaling"?

The paper is structured as follows: Section 2 briefly introduces the concept of scale with respect to transitions in the energy system and connects it to the hardware/software scheme proposed by Walker and Cass (2007), as well as the Technology Life Cycle approach (Taylor and Taylor, 2012). The following section describes the methodology for empirical data collection and analysis. Drawing on the approach by Walker and Cass (2007), the dominant designs for BMDH in Austria are classified according to typical combinations of hardware and software components. In a second step, the current phase of the Technology Life Cycle (TLC) is identified for each dominant design. Section 4 delineates the system of interest and briefly discusses the particularities of the BMDH value chain. The next section focuses on the historical trajectory of BMDH in Austria and identifies the relevant actors and institutions that had a strong influence on the (up)scaling of the niche. Section 6 combines the theoretical perspective with the historical case study data and quantitative material to develop a classification of dominant designs in the Austrian BMDH population. The final section concludes the paper and proposes lines of inquiry for future research.

2. Theoretical departures

2.1 Energy transitions and the concept of scale

In a recent contribution, Bridge et al. (2013) review a set of geographical concepts that might help to better understand the transition from fossil to renewable fuels. They argue that this alleged transition might have similar social and geographical implications as the shift to coal as the primary energy source in the 19th century. Currently, however, the sustainability transitions literature is mainly concerned with temporal processes, though its proponents stress geographical metaphors like local and global niche or upscaling. Bridge et. al. (2013) intend to move space to the centre of the discussion. They discuss a number of geographical components of transitions with scale as one of them. From a geographical perspective, scale can be conceptualized in at least two different ways (ibid., p. 337f): (i) as levels of governance with a specific geographical reach that are interrelated to each other; and (ii) as the physical aspects of a phenomenon in combination with its organizational structures. The first concept in particular is widely discussed in the geographical literature (Brenner, 2001; Marston et al., 2005). A thorough account of this rich discussion does not fit within the scope of this paper, especially as I intend to focus on the second of the mentioned conceptualizations.

On the other hand, some insights of the discussion about scale as the relation between governance levels might be helpful for the purpose of this paper. As Swyngedouw (2004) emphasizes, scalar levels of governance – such as local, regional or national – must not be taken as predetermined, nor as organized in a fixed hierarchy where the higher levels rule the lower ones. Scalar levels are instead actively produced by powerful actors who may adapt the level they are operating in to fit it to their interests. Similarly, the "right" capacity of energy production facilities is not predetermined but depends on a number of external structural circumstances as well as the needs and interests of stakeholders. In the case of Biomass District Heating (BMDH), the preferred scale of heat production may for instance vary according to the views of a local farmer cooperative which wants to sell a certain amount of wood from its forest, the municipality which wants the facility to supply all households within its territory, or an energy utility that operates the plant and strives to optimize heat sales to large customers. Thus it seems appropriate to refer to scaling as a deliberate activity in its verb form and not to scale as a given characteristic. In the context of this article, I will refer to scaling as a strategy that actors deliberately apply to match the physical size and the mode of governance of a socio-technical configuration to their needs and interests.

[2] AUSTRIAN BIOMASS ASSOCIATION (2013): Bioenergie. Basisdaten 2013. Österreichischer Biomasse-Verband. [cit. 30.10.2013]. Available at: http://www.biomasseverband.at/publikationen/broschueren/?eID=dam_frontend_push&docID=2019

To properly characterize the latter two dimensions, Walker and Cass (2007) develop a scheme for the categorization of socio-technical systems in the energy sector. They directly link the physical aspects of the energy system – like plant capacity or geographical extent of the infrastructure – to questions of operation and governance. They distinguish between the hardware and the software of a socio-technical configuration, the hardware being the engineered artifacts of the infrastructure in question, while software comprises its social organization. Considering the hardware, Walker and Cass (ibid., p. 460) stress the "hypersizeability" of renewable energy technologies, i.e. the possibility to realize plants from a macro- (e.g. the Three Gorges Dam, offshore wind farms) to a micro-scale (e.g. a micro- turbine inside a drinking water pipe, roof-top wind turbines). Each implementation size is characterized by different relational qualities of physical presence, connection to other infrastructure, degrees of mobility and the potential for environmental impact that comes with a certain size. The software side comprises the specific arrangements between actors and institutions. Walker and Cass propose to characterize the software component by its function and service (What is the energy used for and who uses it?), ownership and return (Who owns the technology and what benefits are returned as a consequence?), management and operation (Who manages the hardware and to what extent and through what mechanisms is management regulated?), and infrastructure and networking (What is the scale of the network the energy is fed into and how is it managed?). Hardware and software as two aspects of a socio-technical configuration have to be seen as co-dependent and co-evolving. This means that one might expect to observe a certain path dependency in the development of a new technological niche. A range of possibilities for viable configurations exists for every technology, but not every combination of hardware and software matches specific needs at a given point in time and space.

2.2 The evolution of socio-technical configurations through the Technology Life Cycle

Sandén and Hillman (2011) use a value chain approach to delimitate technologies for alternative transport fuels and identify crucial interaction points between them. Using a very broad definition of technology, they identify physical objects, organizations, knowledge and regulation as elements of socio-technical systems that are organized in value chains (ibid., p. 404). In a similar way, Taylor and Taylor (2012) search for a viable methodology to delimitate the boundaries of a technology for the foundation of a better understanding of the Technology Life Cycle (TLC). They start by classifying the generic category of "technology" into four types: from a simple product without any separable components (like glass or cement) to complex open assembled systems that have no clear boundaries, are made up of distinct subsystems and artifacts that are linked through interface technologies, and are delivered through a network of multiple organizations. The authors state electricity supply as an example for such an open assembled system. Each of its subsystems or artifacts is subject to its own individual life cycle along which it evolves. To follow these individual cycles is virtually impossible. Thus, Taylor and Taylor (ibid., p. 545) propose to define such complex technologies at an aggregated level according to their application. The overarching application usually can be divided into different paradigms. Paradigms for their part follow their own life cycles which may be consecutive or may overlap in time. They can be divided further into different generations. Taylor and Taylor provide "technology for music playback" as an example of an application and divide it into the dominant paradigms: "analog-phonographic", "analog-magnetic" and "digital". They finally define different generations like "record", "compact cassette", "compact disc", or "MP3". How can we now apply this approach for a better understanding of the Austrian BMDH niche?

BMDH plants can be seen as an appropriate example of an open assembled system in the sense of Taylor and Taylor. The overarching application can be defined as "centralized heat generation for distribution via a pipe network". The paradigm of interest in this article is "biomass-based heat generation". This basic principle might be adapted and modified to meet the needs and interests of different actors. These modifications often have the character of a trial and error search process. Actors that engage along the value chain of BMDH search for a satisfying combination of hardware and software. If they succeed in establishing a socio-technical configuration that delivers performance (within the local circumstances), this configuration might be regarded as a best-practice example and become copied elsewhere. It has to be emphasized, though, that a mere imitation of a successful example without adaptation to the local conditions is condemned to failure.

Nevertheless, generic configurations might develop over the years that shape the path dependent evolution of a technology. Each of these generic configurations can be regarded as one dominant design[3]; a further sub-level of the paradigm that follows its own life cycle. The ideal type of the life cycle follows an S-shaped curve with time plotted on the x-axis and a performance or diffusion indicator (such as total sales) plotted on the y-axis. The life cycle can be divided into different phases. During the embryonic or formative phase, growth is slow due to uncertainties at the producer- and user-side and childhood diseases of the technology. In the growth phase, technology diffusion accelerates, a dominant design emerges and technological change tends to be incremental. In the maturity phase, diffusion slows down again as cumulative technology adoption reaches saturation (ibid., p. 550ff). Drawing on these theoretical concepts, I argue that the open assembled system BMDH, in the Austrian case, followed a complex innovation pathway that encompassed several dominant designs that overlapped in time. I reject the idea of a linear trend from small-scale to industrial-scale plants that is driven by a group of actors that share the goal of technology diffusion. The question then arises: how can these dominant designs be delimitated, and what is their effect on the diffusion of the broader technology application, in other words, the "upscaling" of the niche?

3. Methodology

The empirical quantitative data presented in the following sections were collected from different primary and secondary sources. The distinctions between the consecutive phases of the life cycle are based on quantitative data published by the Austrian Statistical Office (Statistik Austria, 2012), the Chamber of Agriculture (Furtner and Haneder, 2013), the

[3] Compared to the classification by Taylor and Taylor (2012), the notion of "generation" is not considered because it suggests a continuous progress from one generation to another, which is not necessarily the case for different socio-technical configurations. Thus, I use the term "dominant design" instead of "generation".

Ministry for Traffic, Innovation and Technology (Biermayr et al., 2013), and the Federal Government of Lower Austria. Section 5.1 briefly sketches the formative and early growth phase of the niche. It draws mainly on research that was conducted by the Institute for Technology Assessment Vienna, the Austrian Energy Agency and the University of Natural Resources and Life Sciences Vienna. Section 5.2 describes the developments during the growth phase of the TLC.

The qualitative data were collected in several ways:

- in a series of 17 semi-structured interviews with staff of the national and provincial subsidy departments, lobbying organizations, plant operators and research organizations (see Tab. 1);
- by an analysis of studies and reports by federal agencies, research and lobbying organizations; and
- attendance at five conferences (Tab. 2) on bioenergy with a strong focus on district heating.

The semi-structured interviews lasted 1 to 2 hours, were recorded, transcribed and added to a database. The guiding issues for the interviews were: (i) the general development of the niche during the last 15 years; (ii) the business model used in cases where the interviewee was a plant operator; (iii) normative and cognitive institutions that guide the actions of the interviewee (good practices, common problems and bottlenecks, future possibilities for the technology, etc.); and (iv) the strategies of other actors with respect to competitors that operate plants.

4. The value chain of biomass district heating – processes, actors and spatiality

The basic process steps along the value chain of BMDH plants are shown in Figure 2. One reason for actors to dedicate themselves to an emerging business field might be that they have a strong relation to at least one of the crucial activities along the value chain. An expansion to upstream or downstream activities might then seem obvious to increase value creation and capture. The core business of the agricultural and forestry sectors, for instance,

	Organization	Position	Date
1	Austrian Biomass Association	CEO	28.11.2012
2	Lobbying Organization for Natural Gas and District Heating	Referee	28.11.2012
3	Austrian Energy Agency	Scientific Staff	28.11.2012
4	Lobbying Organization of Electricity Producers	Referee	30.11.2012
5	Federal Forestry Agency	Executive Director of former Bioenergy Division	30.11.2012
6	ESCO	CEO	24.01.2013
7	Subsidy Administration	Referee	24.01.2013
8	Syndicate Small Scale Biomass District Heating	Referee	07.02.2013
9	Energy Utility	Executive Director Renewables	22.02.2013
10	Energy Utility / ESCO	Executive Director Heatcontracting	06.03.2013
11	Energy Utility	Executive Director Heat Executive Director CHP Executive Director Networks	12.03.2013
12	ESCO	CEO	07.05.2013
13	Small Scale District Heating Plant	Administration	14.05.2013
14	Medium Scale District Heating Plant	CEO	14.05.2013
15	Provincial Scale Lobbying Organization and Planning Office	CEO	29.05.2013
16	Medium Scale District Heating Plant	Chairman	06.06.2013
17	Provincial Subsidy Administration	Referee	11.06.2013

Tab. 1: Qualitative field interviews

1	Biomass Days 2011	Biomass Association	16.–18.11.2011
2	Biomass Days 2012	Biomass Association	22.–24.10.2012
3	Energy Symposium	Chamber of Agriculture	25.01.2013
4	INREN Wood Gasification Conference	AgrarPlus	21.02.2013
5	Renewable Heat – Key for the Energy Transition	Biomass Association	08.05.2013

Tab. 2: Conferences attended

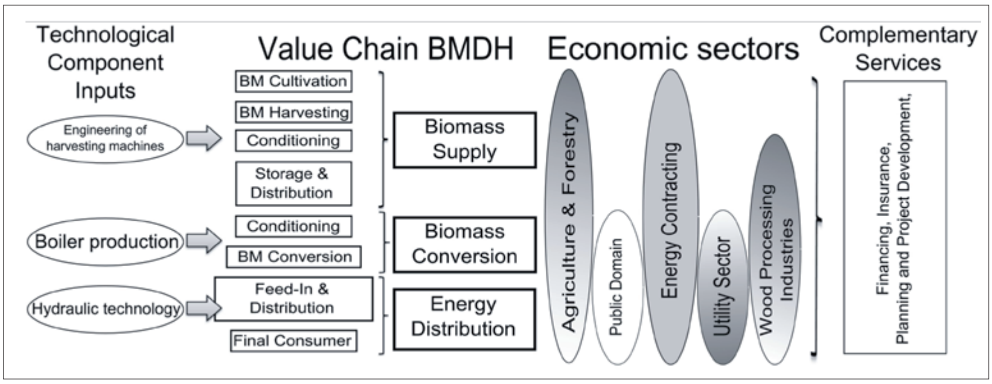

Fig. 2: The value chain of biomass district heating plants. Source: Author

lies in biomass cultivation, harvest, conditioning and distribution. In Figure 2 these core activities of an economic sector are depicted in dark grey shading. Newly-developed business segments are depicted in light grey to white. In the case of BMDH, actors from agriculture and forestry expanded their activities further downstream into biomass conversion and energy distribution. Likewise, the wood processing industries – especially the sawmill industry – expanded downstream from their core activities of biomass conditioning and distribution. Energy utilities have always been concerned with the feed-in and distribution of the final product (heat and/or electricity), but were somewhat hesitant with their commitment to biomass-to-energy conversion. They mainly stick to their core competencies and do not extend their activities further upstream.

The public domain is mainly represented through municipalities, which play a central role in most projects. On the one hand, they maintain buildings in the village or town centre that are important customers for most district heating networks, e.g. schools, retirement homes or public swimming pools. On the other hand, they act as a project initiator in many cases, and sometimes even as a plant owner and operator. As BMDH plants spread throughout Austria, energy supply contracting emerged as an independent business field consisting of heterogeneous actors. Energy contracting firms, also called energy service companies (ESCOs), are usually involved in a number of projects. ESCOs can be run by planning offices, mergers of freelancers, or subsidiaries of energy utility companies. Thus, the distinction between traditional economic sectors is fuzzy. Additional to the organizations that operate along the value chain, planning offices and project developers played and still play a key role for the development of the niche. They provide similar services to those of the ESCOs (pre-studies, site selection, application for subsidies, etc.), but do not finance or operate plants.

The specific spatiality of BMDH derives from the particularities of biomass cultivation at the upstream end of the value chain and district heating at the downstream end. Considering the scale of facilities for bioenergy production (the hardware component of the socio-technical configuration), Jack (2009) emphasizes the trade-off between economies of scale for the conversion of biomass to energy and the dis-economies of scale for biomass collection and transportation. Compared to fossil fuels, biomass has a lower energy density. Thus, transportation over long distances is not economically feasible. Nevertheless, biomass must be collected from extensive cultivation areas to provide feedstock for processing and conversion. Assuming simplifications like an equal distribution of feedstock and homogenous road tortuosity throughout a region, Jack demonstrates technology-specific economic optima. Even within the same class of technology – heat-only boilers – demands for feedstock characteristics vary according to boiler scale: smaller boiler classes require a higher feedstock moisture content to avoid excessive temperatures during combustion, and thus are not suited to burn dry wood waste. Large-scale facilities with a high feedstock demand, on the other hand, require more complex logistics that raise costs.

The regional characteristics of biomass distribution, transport routes and potential alternative value chains for material use thus have a very strong influence on the optimal scale of biomass-to-energy conversion. Regardless of these regional characteristics, Roos et al. (1999) detected dis-economies of scale for biomass combustion facilities in Austria. Their main reason was increasing specific investment costs per kW capacity of larger plants. Large-scale boilers are not standardized products but usually are custom solutions for specific projects that raise costs. Environmental legislation also has an influence; emission thresholds for large-scale facilities are lower, which requires the equipment of more efficient and expensive filters. The picture becomes even more complex when district heating is added to the socio-technical configuration as an important commercialization pathway for the produced energy. In contrast to mainly rural biomass cultivation, district heating systems usually can be found in urban areas, because of the need for a high customer density. Heat is distributed via networks of pipes filled with hot water. Losses in distribution rise very quickly with increasing length of the network, with decreasing heat density per pipe running meter.

Considering the scale of district heating, smaller networks are associated with lower costs for digging and pipe installation as well as for project planning (Rakos, 2001). Networks with a higher number of customers also require more frequent hydraulic maintenance measures, which touches the issue of organizational scaling, i.e. the software component of the socio-technical configuration. Many small- to medium-scale BMDH plants are operated as a sideline by farmer cooperatives (see Section 5.1). Such farmers often invest unpaid working hours into the operation of their plant. Large-scale plants connected to extensive networks, on the other hand, need a dedicated workforce for maintenance, feedstock acquisition, customer service, on-call duty and the like. This workforce has to be paid according to wage agreements, which results in significantly higher operational costs for commercially-owned large-scale plants.

The results of these physical and organizational preconditions along the value chain are tensions between the de-centralized character of biomass supply and the

Spatial aspects	Centralized biomass combustion for the distribution of heat via a pipe network	
Different geographies of supply and demand	Biomass → low energy density, extensive cultivation, long transport distances not cost-efficient	District Heating → high losses in long networks, high consumer density needed
Sectors that act at the respective end of the value chain	Forestry Sawmill industry Agriculture	Municipalities Public housing Industry Tourism (hotels, thermal baths)

Tab. 3: The spatiality of BMDH

centralized character of demand in district heating networks. Actors that combine the two technologies and operate BMDH plants have to cope somehow with these different spatial characteristics. This has major consequences for the geography of BMDH – for plant localization as well as for its physical and organizational scaling. Table 3 summarizes the spatial aspects and lists actors that typically engage at the respective ends of the value chain.

5. The historical development of the biomass district heating niche in Austria

5.1 The formative and early growth phase

Several scholars (Rakos, 1996, 2001; Weiss, 2004; Madlener, 2007) have analysed the formative phase of the BMDH niche in Austria. Their findings provide a valuable basis for further research. The history of the niche actually started with the imperfect material and energy flows in the sawmill industry. As Rakos (1996, 2001) explains, sawmills "discovered" the wood waste that accrued in the course of their production process as a source of cheap energy. They established biomass combustion to exploit this undeveloped potential for wood drying purposes. This trend was given further incentives by the effects of the 1970s and 1980s oil crises. By the beginning of the 1980s, the first innovative sawmill owners had the idea to commercialize their surplus heat by adding district heating systems to the technological configuration. This organizational innovation combined two existing technologies and altered their application. It transferred district heating technologies spatially from urban to rural areas where biomass was available. As sawmill operators are usually strongly locally embedded at their plant site, however, they were not suited to foster the further geographical diffusion of BMDH.

During the 1980s, the agricultural sector became aware of the possibilities that existed for farmers to commercialize logging debris from their forestry activities by establishing BMDH plants on their own. The farmers usually teamed up in cooperatives to cope with the high investment costs. The focus of these newly-emerging organizations was not so much on generating profits by selling heat to the final customer, but on creating demand for logging debris. Weiss (2004) detects a second organizational innovation here: namely the de-coupling of the BMDH system from sawmill locations where wood waste is readily available. The diffusion of the new socio-technical configuration, "agricultural cooperative for the operation of district heating networks in rural village centres", subsequently gained the interest of policy makers, who aimed to contribute to environmental protection by replacing fossil fuels and to regional development by providing incentives for the utilization of wood debris from forestry activities – at one stroke. Subsidy programs for the initial investments were first established at the provincial level and later became harmonized across Austria. Loans at reduced interest rates for operators from the agricultural sector and subsidies directed at the final consumers for the connection to the district heating network, complemented supportive measures (Rakos, 1996).

The agricultural sector became very active in promoting and lobbying for BMDH throughout the second half of the 1980s and the 1990s, for example through the chamber of agriculture or the newly-founded biomass associations. Additionally it created new networks that actively promoted knowledge diffusion and supported farmer cooperatives with planning activities. Weiss (2004) characterizes these developments as a strong transfer of key responsibilities from actors operating on the regional scale to entities operating on a sectoral base. It is also safe to say that the chamber of agriculture had a significant influence on policy development at the provincial level, especially in some of the pioneering provinces like Lower Austria, Upper Austria and Styria. In summary, the different activities carried out by the agricultural sector to support technology diffusion can be seen as quite successful. These efforts in the beginning, however, focused on one very specific socio-technical configuration: "village heating". Around the turn of the millennium this changed as a consequence of two developments: (i) the introduction of feed-in tariffs for electricity generated from biomass in 2002; and (ii) the entry of new actors into the business field and the interrelated development of new business models. These developments were the basis for an accelerated diffusion of BMDH and can be placed at the beginning of the growth phase of the Technology Life Cycle.

5.2 The growth phase

Spurred by international and national discourses, the Austrian government in 2002 issued the first Green Electricity Law. The law allowed for feed-in tariffs of electricity from solid biomass differentiated by plant size. These circumstances triggered an increased involvement of new, financially strong actors like the National Forestry Agency, or some of the incumbent integrated energy utilities. The latter were traditionally founded as public enterprises at the provincial level and became partly privatized during the 1990s. The introduction of feed-in tariffs for electricity from biomass provided an incentive for utilities to engage in biomass-based activities again, after some discouraging experiences with technically immature pilot plants during the 1980s and early 1990s. The first issue of the Green Electricity Law, however, did not impose a minimum threshold for overall energy efficiency. This led to a retrospectively politically undesired outcome. A series of large- (around 30 MW thermal capacity) and medium-sized (around 10 MW thermal capacity) CHP plants was installed all over the country where biomass was readily available. Many investment decisions were based on the historically low prices for wood fuel that prevailed from the early 1990s. With a guaranteed price for the produced electricity and in the absence of a minimum threshold for energy efficiency, operators had little incentive to develop plants with well-elaborated concepts for heat distribution and, in many cases, chose locations without any regard for the basic requirements of district heating networks, e.g. green field sites with missing or little demand for process heat or room heating.

The government finally introduced a threshold of 60% overall energy efficiency as a minimum criterion for a subsidy grant in 2006. At that time, however, many plants already were in operation and put enormous demand pressure on the wood fuel market. Due to the high investment costs for electricity production, CHP plants are bound to burn biomass all-year-round, regardless of the actual heat demand. For instance, in the province of Styria, 16 CHP plants burn nearly the same amount of biomass as 657 heating plants (Metschina, 2012, p. 124). The high demand for biomass by CHP plants led to a strong increase of prices from 2005 to 2011 (7% on average per year, according to Waldverband Niederösterreich, 2013). This turned many CHP plants into a loss-making business, as electricity feed-in tariffs were not indexed but remained constant over a time-frame of 13 years. Summarizing, many large- scale CHP plants that were constructed during the first hype about biomass electrification between 2002 and 2006, did not pay attention to a proper utilization of waste heat via district heating networks, and consequently must be assessed as both ecologically and economically unsustainable.

Besides the early efforts by the agricultural sector and the later activities in CHP production by financially strong actors like energy utilities, energy service companies (ESCOs) emerged as a third dominant organizational form to engage in BMDH. As already mentioned, the population of ESCOs is very heterogeneous. Some are made up of mergers by freelancers, while others are subsidiaries of bigger energy utilities. The first specialized ESCOs were founded around the turn of the millennium. Many of them originally focused on the realization of renewable energy projects for single facilities like hotels or public buildings. Some firms then decided to extend their activities and search for partners for the realization of larger district heating projects. Networks that provided services and knowledge to potential operators had existed for some time, but these organizations usually did not get involved as shareholders of the plants. This changed to some extent with the diffusion of the energy contracting model. Trans-locally active firms started to cooperate with local partners to establish and continually operate projects. Some especially successful enterprises are involved in up to 50 BMDH-networks today.

The ambitions and abilities of these professional operators differ from those of the locally- embedded actors like farmers or municipalities. The cooperation with ESCOs thus renders a series of advantages to the locally-embedded actors. ESCOs provide the necessary technological and managerial know-how for project realization. Compared to stand-alone planning offices, the involved ESCOs are liable with their investment in the project and have a strong interest in establishing an economically suitable plant design. Additionally, ESCOs can put into practice valuable experiences considering plant operation, which is absent from planning offices that never actually operated their designed plants. This renders advantages for the on-going optimization of the plant, which is critical for the economic and ecological sustainability of the project. During the last 10 years, ESCOs have played a critical role in the expansion of the Austrian BMDH niche. They often occupy an intermediary bridging position between feedstock providers, local plant operators and heat customers with respect to performing central tasks like customer service and billing. Most ESCOs focus on the realization of small- to medium-scale district heating systems, as well as on micronets for residential complexes or holiday resorts.

6. Identifying life cycles and corresponding dominant designs

The overall development of the Austrian BMDH capacity followed the typical life cycle S-shaped curve, roughly passing through the phase of introduction during the 1980s and 1990s, experiencing exponential growth during the 2000s, and showing abrupt signs of maturity and saturation from the beginning of the 2010s. This overall life cycle can be subdivided into several dominant designs or generic socio-technical configurations with their own sub-cycles. Drawing on statistical data (Statistik Austria, 2012), we can roughly match the advent of the growth phase to the turn of the millennium and distinguish it initially into two dominant designs that followed different life cycles – combined heat and power (CHP) and heating plants. Figures 3a and 3b show the amount of heat from biomass that was fed into district heating networks on a yearly basis. The figures for CHP plants (Fig. 3a) are rather unambiguous in their interpretation. Plant numbers and fed-in heat began to rise very rapidly after the introduction of the Green Electricity Law in 2002, which guaranteed fixed feed-in tariffs for electricity from renewables. The installed capacities for electricity production increased five-fold in the period from 2002 to 2006 and subsequently stagnated (see Fig. 4a below, green curve), while fed-in heat from CHP plants rose from 2 Petajoule (PJ) in 2003 to over 14 PJ in 2008 (Statistik Austria, 2012). The continuing increase in Fig. 3a after 2006, compared to CHP saturation in Fig. 4a, can be interpreted as the result of rising biomass prices that forced plant operators to maximize their heat sales to stay profitable. The graph in Fig. 3a is split into energy utilities and plants attached to private enterprises as operator classes, with fed-in heat by the latter recently being on the rise. This might indicate a slightly differentiated timing of technology diffusion for distinct socio-technical configurations within the CHP segment. The data for fed-in heat from heating plants (Fig. 3b) are more difficult to interpret than those for CHP plants. We can observe a relatively strong increase from 2000 to 2003, from 2003 to 2007 fed-in heat stagnated, but another strong rise followed from 2007. The stagnation probably mirrors the strong expansion of CHP capacities in that period. A better interpretation of these changes might be possible by drawing on the data shown in Figures 4a and 4b.

Figure 4a splits biomass heat only boilers into two different classes. Considering large-scale boilers, a slight slowdown in sales can be detected which indicates the advent of the maturity phase for this capacity class. Medium-

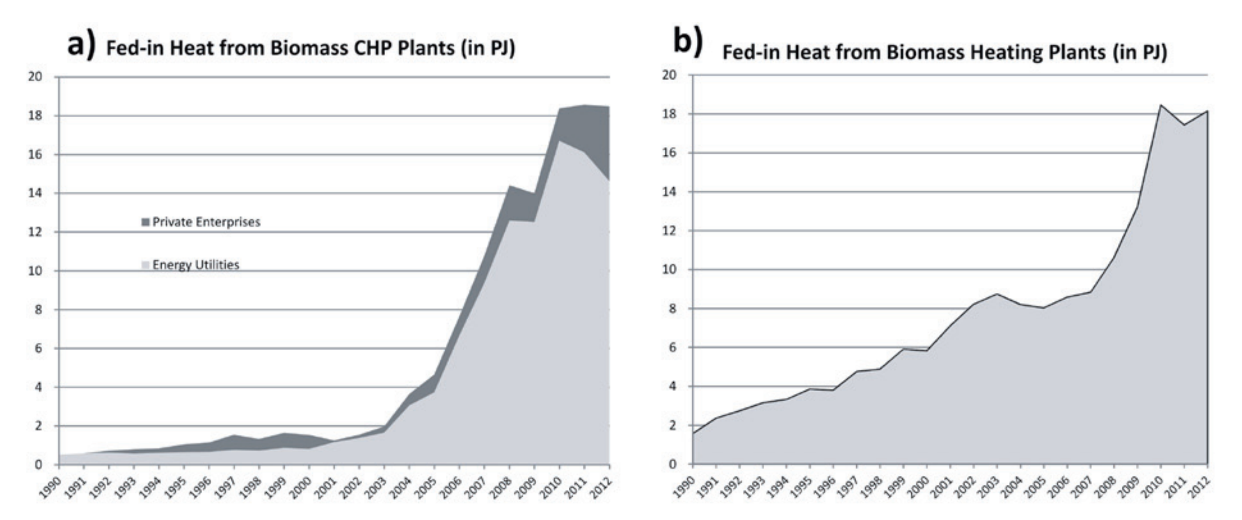

Fig. 3: Fed-in Biomass Heat 1990–2012 – a) CHP and b) Heating plants
Source: Statistik Austria 2012; Author's compilation/design

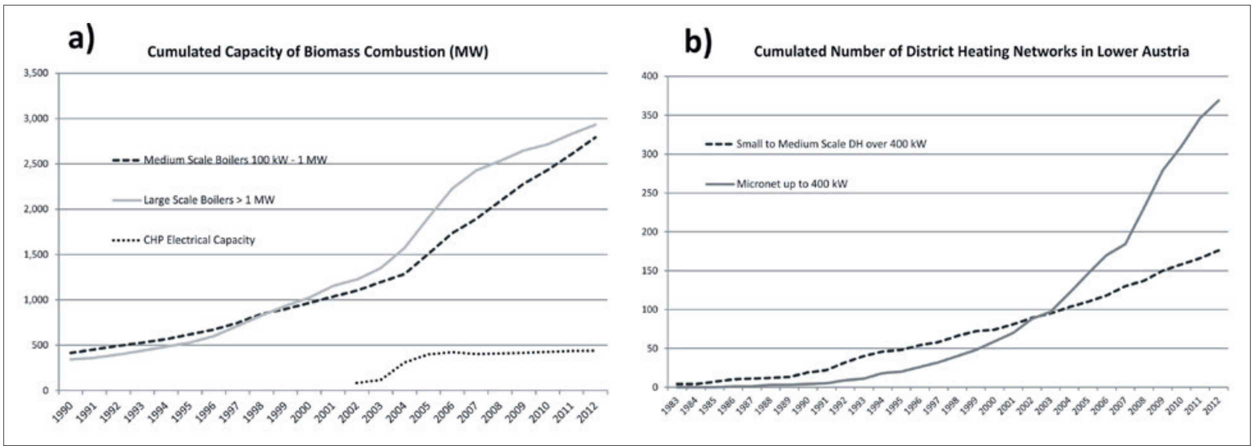

Fig. 4: a) Capacity of Biomass Combustion in Austria; b) District Heating Projects in Different Size Classes in Lower Austria. Source: Biermayr et al., 2013; Furtner and Haneder 2013; Federal Government of Lower Austria; Author's compilation/design

scale boilers, on the contrary, still experienced increasing sales and remained in the growth phase of the life cycle. Unfortunately, the data for Figure 4a is only available at an aggregated level with pre-determined size classes. Figure 4b, however, is based on data from the Federal Government of Lower Austria that allowed a manual classification[4]. It shows the comparatively late introduction of micronets in relation to traditional small- to medium-scale "village heatings". We may assume that the accelerated increase of fed-in heat after 2007 in Figure 3b (above) was carried at least partly by the more frequent implementation of micronet projects.

Some caution should be exercised, however, in that the amount of fed-in heat can only be estimated due to difficulties and vagueness in data collection for biomass compared to fossil fuels (Statistik Austria, 2011: 29f). Thus the initial analysis of the quantitative data was complemented by the qualitative expert interviews. Each dominant design is characterized by a series of attributes and arrangements along the value chain for the production and distribution of energy from biomass. These characteristics were identified by analysing the qualitative interview material. Table 4 summarizes the different dominant designs following the hardware-software scheme by Walker and Cass (2007). On this basis, it is possible to distinguish at least four distinctive dominant designs.

Put into chronological order, the first dominant design that spread throughout the country was the idea of "village heatings" – small- to medium-scale heating plants for the provision of heat to buildings in rural centres. These plants are often operated by agricultural cooperatives that aim to generate profits for their members through biomass sales. The underlying discourses that support the establishment of this kind of plant are the goals to increase regional value creation and to contribute to climate change mitigation. With over 2,000 district heating networks installed in 2,354 Austrian municipalities (Mayerhofer Burger, 2011), small- to medium-scale networks are close to saturation. The co-production of heat and power in large- and medium-scale plants as the second and third dominant designs was spurred by the introduction of the Green Electricity Law in 2002 and reached saturation within only four years. These two dominant designs share many characteristics. They focus on the production and feed-in of electricity for the generation

[4] District heating networks up to 400 kW capacity are termed "micronets" by Austrian administrative bodies. They typically supply only a limited number of facilities and have different criteria with respect to operating licenses and subsidy programs.

	Generic Plant Type/ Paradigm	Micronet	Small to medium scale district heating	Medium scale CHP with ORC process	Large scale CHP with steam turbine
Hardware	Capacity/plant size	Up to 400 kW	Up to several MW, usually around 1 MW	Up to 10 MW thermal and 2 MW electrical	Up to 65 MW thermal and 15 MW electrical
	Feedstock	Pellets Forest wood chips	Forest wood chips	Forest wood chips Industrial wood waste	Industrial wood waste Black liquor
Software	Management and operation	Agricultural cooperative (AC), ESCO, Energy utility	Agricultural cooperative (AC) ESCO Small sawmills	ESCO Energy utility Sawmills	Energy utility, Paper and pulp industry Sawmill industry
	Customers/ function and service	Heat for: • Public buildings • Housing associations • Hotels and baths	Heat for: • rural centre (public buildings, private households)	Focus on electricity production for the grid. Heat for: • Internal industrial processes • Semi-urban district heating	
	Ownership and return	• AC: revenues from wood supply • ESCO, energy utility: heat sales	• AC: revenues from wood supply • ESCO, sawmill: heat sales	• Private heat demand for industry • Electricity (and heat) sales	
	Motivation/discourse	• Green image • Legal provision (public housing) • Local monopoly (utility sector) • Outsourcing to experts	• Supply with heat from regional origin • Green image	• Corporate social responsibility/green image • Optimization of internal material and energy flows • Flagship projects	
	Life cycle phases	• Formative phase late 1990s and early 2000s • Growth phase from around 2004	• Formative phase late 1980s and early 1990s • Growth phase from late 1990s • Saturation reached around 2010	• Quick growth phase from 2002 to 2006 • Some remaining potential in private enterprises	• Quick growth phase from 2002 to 2006 •Saturation reached
	Typical location	• Peri-urban areas • Dense residential zones	Rural areas	• Business parks • Small towns	• Industrial sites • Medium towns

Tab. 4: Dominant designs in the Austrian BMDH system
Source: Author, after Walker and Cass (2007)

of private profits. Heat is used all-year-round for industrial processes or primarily during winter for district heating in small- to medium-sized towns. CHP plants passed through the whole TLC very quickly. They reached saturation around 2006 – most locations that guarantee all-year-round heat demand and high efficiency were equipped by that time. There is still some remaining potential for medium- scale CHP plants attached to private enterprises however (Lang and Tretter, 2011). The main rationale for the realization of CHP plants is the optimization of material and energy flows within wood processing enterprises. Further motives can be the realization of flagship projects as a showcase, and the demonstration of corporate social responsibility.

According to interview participants, the fourth dominant design – micronets – shows the highest potential for future development. The development of this market segment is supported by the reissue of the EU Directive on the Energy Performance of Buildings (2010/31/EU) that foresees a high share of renewables for newly-constructed buildings. Micronets are the traditional business area for ESCOs. In response, however, actors from the agricultural sector reacted to the trend with a series of strategies, one of which was the creation of a centralized contact point for housing associations as new key customers. Energy utilities that previously concentrated on the implementation of large-scale projects, also became aware of the trend towards micronets and increasingly have focused on this market segment. They have also increasingly switched the feedstock for the boilers: wood pellets are a standardized product and thus are easier to handle compared to wood debris from forestry, and they do not require complicated arrangements with local suppliers. The main rationale for integrated utilities to engage in micronets is to keep their long-standing customer relations that often resemble a local monopoly, considering that these utilities also provide electricity and telecommunication services, besides serving the heat market via natural gas and BMDH. The primary growth areas for micronets are the rather densely populated peri-urban zones around large cities, especially Vienna, and to a lesser extent regions with high levels of tourism that are not yet provided by "village heatings".

7. Conclusions

The Austrian BMDH case suggests that diffusion processes for socio-technical configurations in the renewable energy sector are not necessarily driven by a homogenous group of niche actors. Rather, technology "upscaling" was carried by a diverse range of actors that did not follow the same set of cognitive and normative beliefs and visions. At best, an alignment of visions regarding the development of the technology happened between a limited number of actors as a consequence of the lobbying activities initiated by regional chambers of agriculture and biomass associations.

Furthermore, "upscaling" processes do not imply an increase of capacities or plant size, i.e. they do not necessarily rely on economies of scale and an intensification of production. On the contrary, many mistakes that led to economically unsustainable outcomes during operation were related to the 'over-dimensioning' of different components. According to interview participants, two particularly frequent mistakes were: (i) a wish to connect all village households to the district heating network to guarantee the inclusiveness of the socio-technical configuration, regardless of the regionally available feedstock and heat losses in long-distance networks; and (ii) the installation of CHP plants with a focus on electricity production combined with a neglect of the district heating component, which led to high amounts of unutilized waste heat in the first place, and subsequently to economic problems when feedstock prices started to rise. Another critical issue in relation to scale was the organizational establishment of operator companies. Micronets and small-scale plants are relatively easy to maintain and, in many cases, can be serviced as a sideline by locally present individuals – be they farmers, caretakers or municipal employees – while larger facilities require costly professional supervision.

The central task for BMDH plant operators from a techno-economic standpoint is to fit the scale of production, i.e. the boiler and network capacity, to bridge the gap between the locally available biomass potential and the local heat demand. By adapting the scale of renewable energy plants to local circumstances, the scope of technology diffusion can be increased. In retrospect, however, it becomes clear that every switch in the scale of district heating (and thereby an expansion to previously unsupplied areas and customer groups) was not only a question of technological issues, but was linked to changes in the organizational arrangements along the value chain – a switch of scales on the hardware side can only work if it is accompanied by corresponding modifications in the software. "Upscaling" thus should not be conceptualized as a linear trend from small-scale pilot and demonstration plants to large-scale industrial facilities, but rather should be seen as a much more nuanced process. Successful scaling activities result in a number of generic socio-technical configurations or dominant designs that, in conjunction, shape the diffusion patterns of technologies.

Consequently, the recently published FTI Roadmap for BioHeating and Cooling by the Ministry for Traffic, Innovation and Technology calls for the development of innovative business models that integrate new feed-in and storage technologies for heat, and broker between consumers, providers and producers (Wörgetter et al., 2012). For the establishment of these new arrangements, intermediary organizations that translate and mediate between feedstock providers, plant owners and customers will probably play a central role. Rohracher and Späth (2008) have already emphasized the role of this type of organization for the BMDH niche in Austria, and Hargreaves et al. (2013) further stress their importance for the expansion of niches in the community energy sector generally. From a policy perspective, then, future research should focus on identifying already successful intermediary actors in the field, and on analysing their organizational arrangements and future possibilities to develop new innovative approaches for the distribution of heat via networks.

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A CURSE OF COAL? EXPLORING UNINTENDED REGIONAL CONSEQUENCES OF COAL ENERGY IN THE CZECH REPUBLIC

Bohumil FRANTÁL, Eva NOVÁKOVÁ

Abstract

Focusing on coal energy from a geographical perspective, the unintended regional consequences of coal mining and combustion in the Czech Republic are discussed and analysed in terms of the environmental injustice and resource curse theories. The explorative case study attempts to identify significant associations between the spatially uneven distribution of coal power plants and the environmental and socioeconomic characteristics and development trends of affected areas. The findings indicate that the coal industries have contributed to slightly above average incomes and pensions, and have provided households with some technical services such as district heating. However, these positive effects have come at high environmental and health costs paid by the local populations. Above average rates of unemployment, homelessness and crime indicate that the benefits have been unevenly distributed economically. A higher proportion of uneducated people and ethnic minorities in affected districts suggest that coal energy is environmentally unjust.

Shrnutí

Prokletí uhlí? Zkoumání nezamýšlených regionálních důsledků uhelné energie v České republice

Autoři se zaměřují na energii uhlí z geografické perspektivy, analyzují a diskutují nezamýšlené regionální důsledky těžby a spalování uhlí v České republice v kontextu teorií environmentální nespravedlnosti a prokletí zdrojů. Explorativní případová studie se snaží nalézt signifikantní vztahy mezi prostorově nerovnoměrným rozšířením uhelných elektráren a environmentálními a socioekonomickými kvalitami a vývojovými trendy dotčených území. Výsledky indikují, že uhelný průmysl přispěl k mírně nadprůměrným mzdám a penzím a širšímu rozšíření určitých technických služeb, například centrální vytápění. Tato pozitiva však lokální populace zaplatila vážnými environmentálními a zdravotními dopady. Nadprůměrná míra nezaměstnanosti, bezdomovectví a zvýšená kriminalita také indikují, že ekonomické benefity nebyly rovnoměrně distribuovány. Vyšší procento nevzdělaných lidí a etnických minorit v dotčených lokalitách naznačuje, že energie z uhlí je environmentálně nespravedlivá.

Keywords: *coal energy, environmental injustice, resource curse, spatial analysis, Czech Republic*

1. Introduction

"The coal business is archaic. It was good for the past, but it doesn't fit with the future. It's polluting, and it's polluting some more, and it's polluting some more beyond that."

(Vernon Lee, Moapa Paiute tribe member, Nevada, USA)[1]

Growing concerns over global climate change, future energy sustainability and energy security, have led to growing interest in the last few decades to develop domestically available renewable energy sources. Coal still plays a vital role in electricity generation worldwide, however. Coal-fired power plants currently provide about 40% of global electricity, but in some countries coal fuels more than fifty percentage of electricity production, e.g. South Africa (93%), Poland (87%), China (79%), Australia (78%), Kazakhstan (75%), Serbia (72%), India (68%), Israel (58%), including the Czech Republic at 51% (IEA, 2012). It has been even assumed (ibid.) that coal's share of the global energy mix will continue to rise, and by 2017 it will come close to surpassing oil as the world's primary energy source. It is expected that coal demand will increase in every region of the world except in the United States, where coal is being 'pushed out' by natural gas. These trends are close to peaking, however, and coal demand in Europe by 2017 is projected to drop to levels slightly above those in 2011 due to increasing renewables generation and the decommissioning of old coal-fired plants (IEA, 2012). On the other hand, the World Resources Institute identified some new 1,200 plants in the planning process across 59 countries, with about three-quarters of those projects in China and India, and 130 projects in Europe (Yang, Cui, 2012).

Even though the actual cost of renewable energy has already fallen below the cost of fossil fuels in some countries (e.g. in Australia, see BNEF, 2013), conventional public perceptions, perhaps supported by the coal industry lobby, prevail: that renewable energy is expensive and needs to be subsidized, while fossil fuels are cheap. It is necessary to differentiate between two principal issues: (a) the price of coal in the energy market that is, at the present, decreasing (being affected among other factors by the shale gas revolution in the USA and cheap exports of their

[1] Lee, V. (2012): The Cost of Coal. Sierra Club Photo Essay. Available at: http://www.sierraclub.org/sierra/costofcoal/nevada/vernon-lee.aspx

coal), but expected to increase in the future (as a result of limited and overrated resources and growing demand from developing economies, such as China or India (Heinberg and Fridley, 2010)); and (b) the cost of electricity generated from coal, which should include increasing transportation and construction costs (Schlissel et al., 2008; McNerney et al., 2011) and especially the so-called externalities in the form of the different disruptive influences of coal extraction, transportation and processing exerted on the physical and social environment (Budnitz, Holdren, 1976).

In this sense, environmental economists distinguish between the apparent (explicit or internalized) costs and the hidden (secondary or externalized) costs, which together comprise the "true" social cost of energy (Butraw et al., 2012). Social costs arise when any costs of production or consumption are passed on to third parties, like future generations or society at large (Hohmeyer, 1988). In market economies, the structure and decisions of the energy system are usually determined by market prices and politics. If substantial cost elements are not reflected in the market prices of any energy technology, decision makers get wrong signals and take wrong decisions about energy use (Hohmeyer, 1988). Including all social, environmental and other costs in energy prices would provide consumers and producers with the appropriate information to decide about future fuel mix, new investments, and research and development (National Academy of Sciences, 1991; Viscusi et al., 1992). Then, one of the relevant energy policy instruments could be to introduce additional charges into the production cost of electricity that would reflect the cost of the associated impacts on human health, the built environment, and ecosystems (Mahapatra et al., 2012).

In this paper, we focus on coal energy not from the environmental-economic point of view but from a spatial or geographical perspective. The main objectives of our exploratory case study are to analyse unintended regional consequences of coal energy and to test the validity of the "resource curse" hypothesis (Ross, 1999), and the "environmental injustice of energy" hypothesis (Maxwell, 2004), in the conditions of the Czech Republic. Using a correlational analysis of regional data, we attempt to identify significant associations between the spatially uneven distribution of coal power plants and the environmental and socioeconomic qualities and development trends of related areas. In addition to population health characteristics, we focus also on locational attributes that have not been investigated in previous studies and that are hard to monetize, such as the quality of life, social capital and social cohesion.

Our case study area is the Czech Republic, which has been regularly among the three largest net exporters of electricity in Europe – in 2012 the net export exceeded 17 TWh, which became the historical maximum. This export represents approximately five million tons of brown coal being burned in Czech thermal power plants (Polanecký et al., 2010). Such electricity export can be considered a form of landscape commodification and exportation, which raises questions of environmental injustice or the uneven spatial and/or social distribution of benefits (economic profits for energy producers and stakeholders, available cheaper electricity for the general public) and costs (in the form of environmental, health, economic and social impacts) of electricity from coal. In the context of the Czech Republic, the question of negative consequences and the "true" social coast of coal energy is also relevant in practical terms for two on-going public debates: (i) about a possible change to the territorial ecological limits of brown coal mining in the North Bohemian coal basin; and (ii) about the potential adoption of a carbon tax for electricity which is produced from fossil fuels, and/or special taxes for electricity producers whose power plants do not achieve a set minimum of energy efficiency.

2. Theoretical background

Throughout modern history coal has played a key role in human development. Coal has transformed societies, expanded frontiers and sparked social movements, it has redefined the role of workers, changed family structures, altered concepts of public health and private wealth, crystallized debate over national values, and it still vitally powers electric grids (Freese, 2003). Coal-powered development has come with tremendous costs, however, including centuries of blackening both skies and lungs, and recently dramatically accelerating the global climate changes (ibid.).

The historical role of coal for industrialization and regional economic development is indisputable (e.g. Domenech, 2008; Latzko, 2011). The economic benefits of coal for host regions have been in the long term view outweighed by negative externalities, however, and they have been typically subject to "boom and bust" cycles (Black et al., 2005). In this sense, the coal industry is more often associated with the so-called "resource curse" hypothesis, suggesting that resource-dependent communities and regions whose development has been strongly dependent on the extraction of natural resources (specifically non-renewable resources like minerals and fossil fuels) and linked industries, are characterized by economic vulnerability, demographic instability, negative health impacts, higher poverty, increasing geographic isolation, imbalances of scale and power with respect to extractive industries, and the absence of realistic alternatives for diversified development (see, inter alia: Freudenburg 1992, 1998; Perdue and Pavela, 2012).

Coal mining traditionally took place underground. Since the late 1960s, surface mining methods have become more common, and today they account for more than half of total coal extraction (Maxwell, 2004). The methods of surface mining (including the strip mining, open-pit mining and mountaintop removal mining) have made the coal industry more effective (i.e. increasing production gained while reducing workforce), but they also drastically increased negative impacts on the topography, vegetation, and water resources of the affected areas. Although coal mining has always had a negative effect on the surrounding environment and people, surface mining has shown a notable increase in these ecologically damaging effects (Sipes, 2010). Subsequently, the massive coal combustion in modern thermal power plants has become the most polluting and extensive manner of electricity production (e.g. in the United States, coal produces just over 50% of the electricity, but generates over 80% of the CO_2 emissions from the utility sector, and 70% of overall rail traffic is dedicated to shipping coal (Epstein et al., 2011).

Environmental economists have applied different methods to account for externalities and to monetize the social cost of energy (Ottinger et al., 1990; Krewitt et al., 1999; Krewitt, 2002; Pearce, 2003; Rafaj, Kypreos, 2007; Mahapatra et al., 2012). Recently, Epstein et al. (2011) have provided the most comprehensive cost accounting for the life cycle of coal (from mining and transportation through combustion to waste disposal and electricity transmission), taking into account externalities, such as injuries and the mortality of mine workers, increased illness and mortality due to mining pollution, higher stress levels in communities proximate to mining, threats remaining from abandoned mine lands, particulates causing air pollution, infrastructure damage from mine blasting, impacts of acid rain resulting from coal combustion byproducts, water pollution, destruction of local habitat and biodiversity, loss of recreation availability in coal mining communities, loss of tourism income, lower property values for homeowners, damage to farmland and crops resulting from pollution, etc.

The impacts of coal energy production are cumulative, they extend well beyond the geographic locations of operating mines and power plants and bring about other direct, indirect and unintended consequences at higher spatial levels, from regional to global (Franks et al., 2010). Most of the impacts are also spatially and/or socially unevenly distributed, which raises questions of the environmental injustice of energy (Maxwell, 2004). Environmental justice has been defined as a "fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (EPA, 2004). The 'fair treatment' means that no group of people should bear a disproportionate share of negative environmental consequences resulting from industrial or other operations, programs and policies (i.e. distributional justice, including geographical/spatial justice). 'Meaningful involvement' is defined as situations in which potentially affected communities have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment, and that the concerns of all participants involved will be considered in the decision-making process (i.e. procedural justice; EPA, 2004).

The environmental (in)justice concept has been applied in the research of many current relevant topics, including the distribution and disposal of industrial toxics and hazardous wastes (Fisher et al., 2006; Oakes et al., 1996), transport planning (Forkenbrock et al., 1999), and the siting of nuclear power plants (Alldred, Shrader-Frechette, 2009), but topics also include renewable energy projects (Gross, 2007). Coal, as one the most concentrated and localized energy resources, can be regarded as a perfect subject of research into cumulative effects and environmental injustice. The proximity to energy resources was a significant location and development factor since the industrial revolution, powered by coal and steam. Many early industries began to set up in coalfield areas to minimize the transport costs of raw materials, and the clustering of industries around coalfields then led to the intensive development of neighbouring cities. Consequently the first coal-fired power plants were constructed near collieries to minimize the cost of transporting coal and to meet the energy demand of expanding industries and the increasing population of cities (Webb, 1967).

The existing literature dealing with environmental injustice related to coal mining and coal energy generation can be divided into two groups: (i) local case studies assessing the environmental, economic and socio-cultural impacts of coal mining on affected communities (e.g., Lockie et al., 2009; Petkova-Timmer et al., 2009; Shandro et al., 2011; Petrova, Marionova, 2013); and (ii) comparative studies mapping the spatial diffusion of air pollution and analyzing selected data about coal-affected and non-coal-affected populations (Armstrong et al., 2009; Higginbotham et al., 2010; Saha et al., 2011; Riva et al., 2011; Zullig, Hendryx, 2010; Weng et al., 2012). The majority of comparative regional studies, however, have only focused on negative health impacts of coal mining and coal combustion. The studies by Papyrakis et al. (2008) and Hajkowicz et al. (2011) involved selected socioeconomic indicators in their testing of the validity of the resource curse hypothesis in the USA and Australia, but their analyses dealt not exclusively with coal but with the regional abundance of different natural (mineral) resources.

3. Geographical context of the case study

The Czech Republic is a country with a significant coal mining and energy industry tradition (Kořan, Žebera, 1955; Smolová, 2008). During the socialist era (1948–1989), Czechoslovakia, as a member of the former East European COMECON group of countries, was designated the "forge of the socialist camp" with a dominance of metallurgical and energy-intensive heavy industries where coal was regarded the "life blood of industry" (Říha et al., 2005). Concentration on production with high energy consumption created a considerably higher demand for energy raw materials, namely brown coal. The production of brown coal increased about five times and electrical power generation about twenty times with respect to 1937 levels, whereas the production of bituminous coal increased by only 80% (Pešek, Pešková, 1995).

This planning orientation affected the overall national economy and resulted in the environmental devastation of several regions, especially in the Ostrava-Karviná black coal basin (part of the Upper Silesian basin, on the north-east border with Poland), and most extensively in the North Bohemian and Sokolov brown coal basins (located in the furrow along the Ore Mountains, which follows the north-west border with Germany). These regions were extensively developed on the basis of coal mining and linked industries at the expense of other economic activities, the natural environment, the existing built environment, social structures, and public health. The lignite surface mining, the construction of giant power plants and related infrastructural projects, eliminated human settlements (over 100 municipalities, including the historic city of Most, have been destroyed since 1949 – Fig. 1 – see cover p. 2), and over 90,000 people were relocated due to mining and related activities (e.g. the construction of dams). Several hundreds of square kilometres of cultural landscapes were destroyed, and drainage and water management systems, the ecological stability of landscape, and agricultural and forestry potential were disrupted (Říha et al., 2005). While land regeneration has been successfully carried out in many cases (e.g. the regeneration projects of a motor-racing circuit and hippodrome in Most city), the scope of devastation in the entire region is much greater.

After the fall of socialism in 1989, the newly-established Federal Ministry of Environment prepared programs to restore the environment of the North Bohemian and Ostrava-Karviná coal basins, the most environmentally affected areas. As a result, all operational coal-fired power plants were required to be desulphurized or shut down (the desulphurization program took place in the period 1992–1998, the most extensive and most rapid one in Europe (ČEZ, 2013)) and the so-called territorial ecological limits for mining were established (Government Decrees No. 331 and 444/1991). By restricting exploration, mining and other brown-coal mining-related activities beyond certain spatial limits, the government established a balance between economic and ecological interests, but it also ignited a fierce political debate that has been smoldering ever since (Kotouš, Jurošková, 2013).

Current Czech energy policy is still dominantly based on traditional resources. Primary energy consumption, which amounted to 62.9 Mtce in 2010, was supplied as follows: 41% coal (total 25.5 Mtce, of which hard coal 6.5 Mtce and brown coal 19.0 Mtce), 19% natural gas (11.7 Mtce), and 20% oil (12.9 Mtce). This primary energy mix is supplemented by nuclear energy with a 17% share (10.4 Mtce), as well as by renewables and hydroelectric power, which together account for some 6% (4.0 Mtce) (Euracoal, 2011). About 24,000 people were employed directly in the coal mining industry in 2010. The Czech Republic's dependence on energy imports has been quite modest to date (circa 27% of energy demand is met by imports); however, imports are structurally unbalanced (the dependence on oil is about 97%, and in the case of natural gas it is about 96%) (Euracoal, 2011).

Overall electricity production is based predominantly (57%) on thermal power plants (burning primarily brown coal [46%], black coal [5.5%], gas [4%] and other fuels), nuclear power plants (33%), and renewable energy sources (10%) (ERU, 2012). The share of coal power plants in electricity production decreased by circa 10% during the last decade primarily due to the decommissioning of old plants and increased installed capacity from renewable energy, but it still represents the dominant energy source in the country. The Czech Republic, however, is among those countries with the worst air quality in the European Union (the positive trend of improving air quality from the 1990s stopped at the turn of the millennium) (MŽP, 2012). The most significant contributors to the worsening air quality, apart from surface coal mining and coal combustion in power plants, are the metallurgic and heavy chemical industries, car traffic, and the burning of coal in local heating systems.

Most electricity, then, is produced from fossil fuels and almost one third of it has been exported (mostly to neighbouring Germany, Austria and Slovakia) which makes the Czech Republic regularly one the three largest net exporters of electricity in Europe. The historically largest national net export of electric energy in 2012 (more than 17 TWh) represents approximately the entire production of the Temelín nuclear power plant, or 5 million tons of brown coal being burned in thermal power plants (Polanecký et al., 2010). The majority of the coal power plants are owned by the ČEZ joint-stock company, a semi-public enterprise which is the dominant energy producer in the Czech Republic (the state remains the company's largest shareholder with a 70% stake in the stated capital).

Opponents to coal energy have stressed that such energy export is just a continuation of the commodification and exportation of the Czech landscape, with economic benefits for a few shareholders of coal mining and energy companies, and negative environmental and socioeconomic impacts on large populations in the regions affected by coal mining and combustion. The question of distributional injustice is closely related to the currently prominent topic of the possible lifting of territorial limits of brown-coal mining in the Northern Bohemian basin (Fig. 2 – see cover p. 2). The main arguments used by supporters of coal, promoting a change in the mining limits and a continuation with coal energy production, are as follows: (i) to prevent price increases in electricity and district heating (in the case of further development and subventions for renewable energy and substitution of coal by natural gas in the systems of heating plants); (ii) to maintain employment in coal mining regions; and (iii) to keep a traditional Czech industrial sector running and to contribute to the state budget. On the contrary, the objectors to changing the coal mining limits stress the following factors: (a) the negative environmental and socioeconomic impacts of coal mining and coal combustion; (b) a continuation of regional resource-dependency with negligible long-term effects on employment rates; and (c) the low energy efficiency of coal-fired power plants (suggesting to save the coal for the future when economically and technologically more effective processing will be possible – see Komise pro životní prostředí Akademie věd ČR; KŽP AV ČR, 2013).

A study realized by the Czech non-governmental organization Hnutí Duha (Kubáňová, 2007) documented that the Ústecký region (as the one most significantly affected by the coal resource curse) is, in comparison to other Czech regions, still characterized by many negative attributes, including the highest concentration of areas of deteriorated air quality, the lowest life expectancy, a higher than average occurrence of allergic diseases, the highest rate of abortions, the highest unemployment rates, the lowest percentage of people with university degrees, a lower than average percentage of business activity, etc. The Ústecký region is the least attractive tourist destination in the country according to the number of arrivals per capita and total area, with the number of tourist accommodation facilities decreasing continually since 2000. The Ústecký and Moravian Silesian regions were the only two regions with a higher number of emigrants than immigrants (ibid.).

In this paper the authors attempt to contribute to current knowledge about the unintended regional consequences of coal energy production by providing a more complex and more sensitive comparative analysis, focusing on the level of districts (NUTS4 / LAU1).

4. Data and methods

More than 70 thermal power plants with installed capacity of more than 10 MW were in operation in the Czech Republic as of December 31, 2010 (ERU, 2011). The overall installed capacity of thermal power plants was 11,793 MW. More than one half of the installed capacity was represented by power plants operated by the ČEZ company. For the purpose of this analysis, we created a database of selected power plants which met the following conditions: (a) have a total installed capacity of at least 100 MW; and (b) the major fuel is brown or black coal. Altogether 28 power plants are included in the database (see Tab. 1), with total capacity of 9,679 MW which is more than 80% of the overall installed capacity of thermal power plants in the country. The power plants are located in 19 different localities (municipality cadasters) within 15 districts. The largest numbers (4) of power plants are located in the Sokolov district, while the highest installed capacity (2,290 MW) is in the Chomutov district. One power plant is located in the capital, Prague; however, the capital city was not included in the statistical analyses since it is characterized by outlying values with respect to the majority of the socioeconomic indicators, which would skew the results.

The brown coal from the Northern Bohemian basin is still the dominant fuel for most thermal power plants. Three plants in the Ostrava-Karviná basin are powered by local black coal. In some plants biomass and natural gas are used as secondary fuels. It is evident from the map (Fig. 3) that almost all power plants have been constructed close to coal basins. The majority of the installed capacity of power plants is concentrated in areas where coal mining is still in operation, including the Sokolov basin (Sokolov district), the

Name	Municipality	District	Installed capacity (MW)	Year of commissioning	Fuel 1	Operator
Pruněřov II	Kadaň	Chomutov	1,050	1981–1982	BrC	ČEZ, a. s.
Počerady	Výškov	Louny	1,000	1970–1977	BrC	ČEZ, a. s.
Tušimice II	Kadaň	Chomutov	800	1974–1975	BrC	ČEZ, a. s.
Dětmarovice	Karviná	Karviná	800	1975–1976	BlC	ČEZ, a. s.
Chvaletice	Chvaletice	Pardubice	800	1977–1978	BrC	Elektrárna Chvaletice a.s.
Mělník III	Horní Počaply	Mělník	500	1981	BrC	ČEZ, a. s.
Pruněřov I	Kadaň	Chomutov	440	1967–1968	BrC	ČEZ, a. s.
Opatovice	Opatovice n./L.	Pardubice	378	1960–1997	BrC	Elektrárny Opatovice, a.s.
Vřesová I	Vřesová	Sokolov	370	1996	BrC, G	Sokolovská uhelná, a. s.
Kladno-Dubská	Kladno	Kladno	366	1976–1999	BlC, BrC, B	Alpiq Generation, s.r.o
Mělník I	Horní Počaply	Mělník	352	1961–1995	BrC	Energotrans a.s.
Ostrava-Kunčice	Ostrava	Ostrava	254	1957–2000	BlC, G	Arcelor Mittal Energy a.s.
Komořany	Most	Most	239	1959–1998	BrC, G	United Energy, a.s.
Mělník II	Horní Počaply	Mělník	220	1971	BrC	ČEZ, a. s.
Vřesová II	Vřesová	Sokolov	220	1967–1991	BrC, G	Sokolovská uhelná, a. s.
Ledvice II	Bílina	Teplice	220	1966–1968	BrC	ČEZ, a. s.
Tisová I	Březová	Sokolov	184	1959–1960	BrC, B	ČEZ, a. s.
Třebovice	Ostrava	Ostrava	174	1961	BlC, L	Dalkia ČR, a.s.
Litvínov T200	Litvínov	Most	166	1942–1955	BrC	ČEZ, a. s.
Poříčí	Trutnov	Trutnov	165	1957	BrC, B, BlC	ČEZ, a. s.
Trmice	Trmice	Ústí n/L.	158	1974–1976	BrC	ČEZ, a. s.
Plzeň	Plzeň	Plzeň	149	1984–2008	BrC, G, B	Plzeňská teplárenská, a.s.
Praha-Malešice	Praha	Praha	122	1963–1971	BlC	Pražská teplárenská a.s.
Štětí	Štětí	Litoměřice	113	1984–2008	BrC, L, B	Mondi Štětí, a.s.
Litvínov T700	Litvínov	Most	112	1963–1995	BrC	Unipetrol RPA, s.r.o.
Tisová II	Březová	Sokolov	112	1961	BrC	ČEZ, a. s.
Ledvice III	Bílina	Teplice	110	1967, 1998	BrC	ČEZ, a. s.
Hodonín	Hodonín	Hodonín	105	1951–1957	BrC, B	ČEZ, a. s.

Tab. 1: Coal-fired thermal power plants with installed capacity over 100 MW. Notes: 1 BrC – brown coal, BlC – black coal, G – gas, B – biomass, L – light fuel oil. Source: Energy Regulatory Office (ERU, 2011)

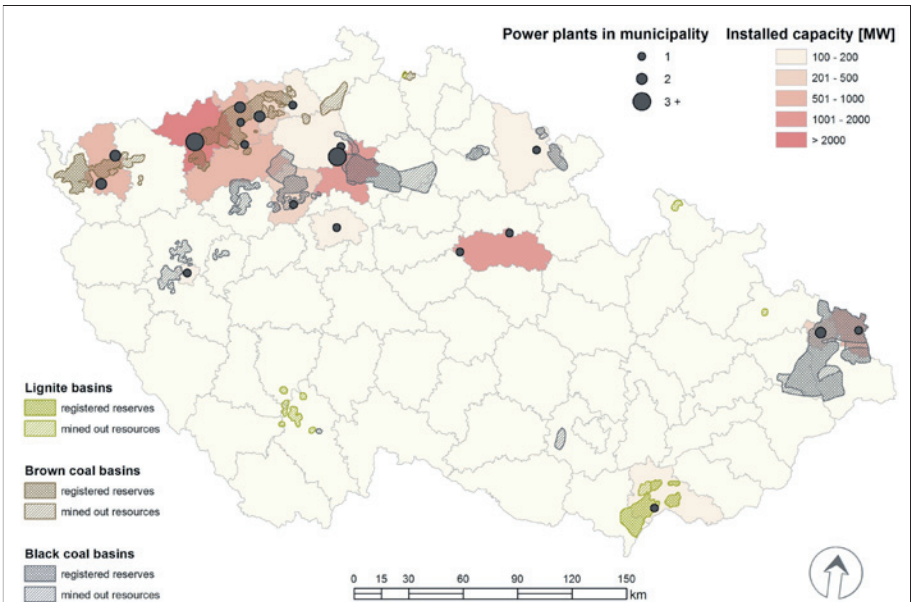

Fig. 3: Registered coal resources, functional large coal-fired power plants and their total installed capacity in districts of the Czech Republic. Source: Czech Geological Survey, Energy Regulatory Office;apping and design by authors

North Bohemian basin (districts of Chomutov, Most, Teplice, and partly also Louny and Ústí nad Labem), and the Ostrava-Karviná basin (Fig. 4 – see cover p. 4). Black coal mining had been already stopped in the districts of Brno-venkov (1992), Trutnov (1995), Plzeň-sever (1995) and Kladno (2002), and the lignite mining in Hodonín district was finished in 2009. The key location factors for five power plants (Opatovice and Chvaletice in Pardubice district, and three plants in Mělník district) have been proximity to good water resources (Labe river) and proximity to large cities (Hradec Králové, Pardubice and Prague), and/or specialized industries (i.e., factors of electricity demand and the use of heat in district heating systems as a plant by-product).

Subsequently we created a database of selected variables representing the most relevant characteristics of districts, including population vital and health statistics, quality of life indicators, labour market data, social capital and social cohesion indicators, and environmental indicators. The selection of indicators was determined by the availability of statistical data for the spatial level of districts in the Czech Republic and by the potential comparability of results with previous studies (Armstrong et al., 2009; Hajkowicz et al., 2011). For the complete list of 33 indicators, see Tab. 2.

The hypotheses that drive this study were defined as follows:

- H1: The areas affected by coal mining and coal combustion are characterized by worse environment, population health status and quality of life, and lower socioeconomic potential (resource curse hypothesis)
- H2: The areas affected by coal mining and coal combustion are characterized by higher concentration of ethnical minorities and/or socially deprived population (environmental injustice hypothesis)

Then we carried out statistical testing for relationships between the above listed indicators as dependent variables and the number of power plants within districts as the independent variable. The number of power plants was chosen as an adequate independent variable since it was

Factor	Indicator	Measure
Population vital statistics and health	Population increase	Annual population natural increase per 1,000 population
	Age index	{Number of persons (65+ years)/number of persons (0–14 years)} * 100
	Life expectancy	Male life expectancy at birth 2007–2011
	Abortion rate	Abortions per 1,000 population
	Divorce rate	Divorces per 1,000 population
	Infant mortality	Infant mortality [‰]
	Congenital anomalies	Congenital malformation per 10,000 live births
	Respiratory diseases	Deaths per 100,000 population of respiratory diseases
	Sickness rate	Average duration of annual incapacity for work (days)
Life quality	Health care	Health care establishments per 1,000 population
	Social care	Social service establishments per 1,000 population
	Average monthly wage	Average monthly wage in 2005 (CZK)
	Average monthly pension	Average monthly pension revenue (CZK)
	Car ownership	Number of cars per 1,000 population
	District heating	Percentage of inhabited flats with district heating
	Internet connection	Percentage of inhabited flats with PC/internet connection
	Property value	Average price of flats (millions CZK)
	Homelessness	Number of homeless people per 1,000 population
	Population density	Population per km2
Labour market	Unemployment	Unemployment rate [%]
	Job vacancies	Job applicants per vacancies
	Business activity	Total business units registered per 1,000 population
Social capital and social cohesion	Education level I	Persons with basic or no formal education [%]
	Education level II	Persons with university education [%]
	Political involvement	Turnout in regional elections in 2012 [%]
	Crime rate	Ascertained offences per 1,000 population
	Alcohol abuse	Car accidents due to alcohol abuse per 1,000 population
	Proportion of natives	People with permanent living at the place of their birth [%]
	Proportion of minorities	Number of Roma ethnic people per 1,000 population
	Net migration	Number of immigrants less number of emigrants per 1,000 pop.
Environmental restoration	Air quality	Main pollutant emissions (SO2+NOx+CO tones/km2)
	Environmental restoration	Environmental protection expenditure per 1,000 population
	Renewable energy development	Installed capacity of wind energy [MW]

Tab. 2: List of indicators included in statistical analyses
Source: Czech Statistical Office, Institute of Regional Information (data are relevant for 2011 unless otherwise indicated)

shown to have strong correlations to both the total installed capacity [MW] of power plants within districts (Pearson's R = 0.84**) and the current status of mining (active/finished) in the district (point bi-serial coefficient) (R = 0.74**). Statistical testing was carried out with the SPSS program, using a bivariate cross-correlation analysis of all dependent variables against number of power plants. The strength of association and statistical significance was tested using the classical Pearson's R correlation coefficient, and examining the p-value for each pair of variables. To better demonstrate the associations, we then provided a comparison of mean values of indicators that proved to be statistically significant within categories of districts (Tab. 3).

5. Results

Out of 33 indicators, we have found statistically significant correlations with the distribution of coal power plants for 19 indicators. The differences between district categories with their mean values of the relevant indicators are summarized in Tab. 3.

The most significant differences among districts are according to air quality, with respect to the concentration of basic pollutants. The highest mean values of pollutants are in the category of districts with two power plants, including the district of Ostrava city which reported absolutely the highest concentrations of pollutants (213.5 tones per sq. km) among all areas in the Czech Republic. Air quality in this area, however, is significantly affected by the location of the Arcellor Mittal steelworks factory which is considered to be the biggest polluter in the region.

There are significant associations between coal energy production and some population vitality and health indicators, including higher rates of abortions, higher infant mortality and lower male life expectancy. On the contrary, we have found no statistically significant differences among districts according to occurrence of congenital anomalies, respiratory diseases and the general sickness rate in terms of average days lost. The analysis also did not reveal any significant differences according to selected indicators of the population's socioeconomic well-being (measured by the provision of health care and social services establishments, availability of ICT in households, and personal car ownership). The coal industry has contributed to the fact that central (district) heating is more obvious in related districts. There is a significant negative association between the number of power plants within a district and the average price of flats; however, it cannot be regarded as direct evidence of better affordability or some worse quality of flats.

Significant differences among districts are related to one key labor market characteristic, the unemployment rate, which is higher in districts whose economy has been dependent on the coal industry. The results also indicate the unemployment rate is likely connected with other negative social phenomena such as the higher percentage of homeless people, higher rates of crime, divorces, and annual out-of-district migration. On the other hand, the higher than average incomes and pensions indicate that the coal industry has brought about positive economic effects to local employees. We can assume that the above-mentioned negative social phenomena indicate that economic benefits have been socially unevenly distributed. Moreover, although

Dependent variables[1]	District category according to number of plants (number of districts within category)				Pearson´s R^2
	0 (N = 61)	1 (N = 8)	2 (N = 3)	3+ (N = 4)	
Air quality	4.2	12.6	92.1	36.2	0.52**
Proportion of minorities	0.4	0.5	0.8	2.0	0.51**
Life expectancy	74.2	73.3	73.0	72.3	− 0.45**
Political involvement	38	35	34	31	− 0.44**
Crime rate	23	29	39	33	0.43**
District heating	70	73	75	81	0.42**
Abortion rate	3.6	4.1	4.1	4.9	0.41**
Renewable energy development	2.1	1.3	2.7	18.8	0.38**
Infant mortality	2.6	4.0	3.4	4.9	0.33**
Property value	1,303	1,138	0.995	0.780	− 0.32**
Education level I.	19	20	19	23	0.31**
Unemployment	8.9	10.9	10.0	12.2	0.30**
Average monthly wage	16,372	16,926	16,996	17,954	0.29*
Average monthly pension	10,134	10,259	10,294	10,320	0.29*
Divorce rate	2.6	2.8	2.8	3.0	0.27*
Homelessness	0.9	1.6	1.8	1.1	0.25*
Environment restoration	1.968	1.801	3.365	2.959	0.26*
Population density	131	300	486	163	0.22*
Net migration	1.75	− 0.23	− 0.37	− 0.33	− 0.21*

*Tab. 3: Relationship between distribution of power plants and mean values of selected indicators ([1]Dependent variables are listed according to their descending correlation value; [2]Correlations are significant at the levels of **0.01; *0.05)*
Source: Czech Statistical Office, Institute of Regional Information; calculations by authors

the differences in average incomes and pensions were shown to be significant statistically, they are negligible in terms of practical life.

Our analysis has also demonstrated that districts with higher concentrations of thermal power plants are characterized by a higher concentration of ethnic minorities, specifically by the Roma minority. At the same time, the coal-affected districts are characterized by higher proportions of people with basic education and uneducated people ('Education level I'). On the contrary, there are no differences with respect to proportions of persons with university education.

A retrospective analysis of data (2005–2011) showed a positive development trend in relation to local air quality and most of the population health and socioeconomic indicators (see Tab. 4). The numbers still remain significantly worse compared to rest of the country, however. But the unemployment rate in coal-affected districts decreased while it increased slightly in the rest of the country. Whereas the number of workers in the coal mining industry has been continually decreasing during the last decade, this can be regarded a sign of economic diversification. Risk factors for further positive economic development of affected districts are the higher concentrations of low educated people and ethnic minorities. Lower social capital is also indicated by lower political involvement of people measured by the election turnout.

The positive development trends in air quality and population vital statistics were supported by higher investments in environmental protection (by business companies with registered offices in the districts) which have been continually increasing during the last four years. The significantly higher installed capacity of wind energy[2] can be regarded as demonstrating that local communities and decision makers living in environmentally affected areas are more likely to support alternative technologies (Fig. 5 – see cover p. 4). This finding is in accordance with studies of Toke (2005), Frantál and Kunc (2011) and others (Van der Horst, 2007, p. 2709), which found a relationship between the industrial character and environmental degradation of a location and the local population's more positive attitudes towards renewable energy projects.

6. Discussion and conclusions

The results of this case study support the hypotheses of the resource curse and environmental injustice of coal energy. Although the coal mining and coal combustion (together with linked industries) contributed to slightly above average incomes and pensions (which are actually significant statistically but not of practical relevance), and provided households with some technical services (district heating), these positives have come at high environmental and health costs paid by the local population, such as significantly worse air quality, lower life expectancy, higher rates of infant mortality, etc. Above average rates of unemployment, homelessness and crime also indicate that the economic benefits have been unevenly distributed. In this sense, our study has confirmed the findings from previous studies made at the regional level (Kubáňová, 2007).

As compared to the few foreign studies on the issue, our findings are partially in accordance and partially in conflict with results reported by Hajkowicz et al. (2011), which affirmed positive impacts of mining activities on incomes, housing affordability, communication access, education and employment across regions in Australia, but negative impacts on life expectancy. They did, however, highlight the fact that while their data were valid at an aggregate level, there is often an uneven income distribution within mining regions and that certain sub-groups in regional and remote communities are more vulnerable to mining activities (ibid.). Another Australian study (Taylor, Scambary, 2005, cited by Hajkowicz et al., 2011) reported that indigenous communities, resident in mining regions, in particular were excluded from the socio-economic benefits of adjacent mining operations.

This study detected a higher proportion of uneducated people and ethnic minorities in affected districts, which suggests that coal energy is environmentally unjust. This finding, however, does not confirm the theory of disproportionate siting, i.e. that polluting industries are proposed for areas with a high concentration of poor or minority residents (see e.g. Pastor et al., 2001). Most of the thermal power plants in the Czech Republic were constructed between the 1950s and 1980s, at locations within the main

Dependent variables	Coal-affected districts		Coal-free districts	
	2005	2011	2005	2011
Air quality	63.2	34.8	3.7	4.2
Life expectancy (2004–2008 / 2007–2011)	72.1	72.9	73.2	74.1
Political involvement	27	34	30	38
Crime rate	34	32	23	23
Abortion rate	4.6	4.3	3.8	3.7
Infant mortality	5.1	4.1	3.3	2.6
Unemployment	12.7	11.1	8.4	9.0
Environmental restoration	2.020	2.423	1.350	1.968
Population change (2005–2011) per 1000 population	+ 23.6		+ 16.4	

Tab. 4: Development trend in most relevant indicators (note: Coal-affected districts are all districts with at least one coal-fired power plant). Source: Czech Statistical Office; calculations by authors.

[2] The actual installed capacity of wind energy [MW] in districts correlates more strongly (R = 0.54**) with the actual installed capacity of coal energy [MW] than with the numbers of district realizable wind potential (R = 0.48**), as assessed by Hanslian et al. (2008).

coal basins (Northern Bohemian and Northern Moravian Regions). These border areas were typically characterized on the one hand by large depopulations due to the expulsion of the German population after WWII, and on the other hand by increasing demand for labour by massively expanding mining and metallurgical industries. As a result less educated minority populations have moved into extensively industrialized and urbanized areas (i.e. disproportionate minority in-migrants).

Finally, our findings have demonstrated a slightly positive trend in improving indicators of environment and population health. Regardless, the numbers still remain significantly worse compared to the rest of the country, even though the negative impacts are mitigated by increasing investments in environmental protection and the efficiency of thermal power plant technologies. In other words, the coal-affected regions still suffer from the historic "curse of coal". In the context of on-going public debates about possible changes to the current territorial limits of mining and about the potential adoption of a carbon tax for electricity produced from fossil fuels, our findings suggest that the actual long-term environmental and socioeconomic cumulative effects of coal mining and coal combustion should be taken into account more responsibly, and that market prices should reflect the real social price of coal energy to a greater extent. In terms of environmental justice, the economic profits from coal should be more fairly redistributed to compensate for the negative impacts in affected regions. As a final cautionary note, in terms of procedural justice, the residents of affected regions should have the last word in decision-making processes about future coal energy policy.

The main focus of this case study was at the regional level; however, the impacts of coal energy exceed regional and national levels. The emphasis paid to coal by McKibben (2003, as cited by Freese, 2003), given the particular chemistry of global warming, is instructive: it is possible that the decisions we make about coal in the next two decades may prove to be more important than any decisions we have ever made as a species.

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LANDSCAPES OF LOST ENERGY: COUNTERFACTUAL GEOGRAPHICAL IMAGINARY FOR A MORE SUSTAINABLE SOCIETY

Dan van der HORST

Abstract

The quest for sustainable energy, one of the greatest challenges of the 21st century, calls for more input from academics than 'simply' producing good science. Geographical imaginations are as old as storytelling and mapmaking, but this essay is neither about 'long ago and far away', nor about utopian energy futures. This is a call to geographers to engage with 'alternative present' energy scenarios, using the full range of analytical and discursive tools at our disposal. Drawing on a diverse tradition of imagined spaces and the awareness of absences (material, relational or otherwise), geographers should be able to contribute to the quest for a more sustainable society by assessing, envisaging, and communicating a counterfactual 'here and now', based on good practices existing right now, but not (yet) right here. We need to understand how much more sustainable our bit of the planet would be if we could just, environmentally speaking, 'keep up' with the best of our neighbours. This counterfactual present should be seen as neither radical nor utopian, because it only assumes the historic adoption of best practices which we now know to be feasible and successful. And if this alternative current scenario looks radically different from the 'real' state we are in, then this goes to show how radically unsustainable our business-as-usual approach has been.

Shrnutí

Krajiny ztracené energie: kontrafaktické geografické imaginárno pro udržitelnější společnost

Hledání udržitelné energie, které je jednou z největších výzev 21. století, si žádá od vědců více než „jen" produkovat kvalitní vědu. Geografické imaginace jsou stejně staré jako vyprávění příběhů a tvorba map, ale tato esej není ani o tom, co bylo „dávno a daleko" ani o utopické energetické budoucnosti. Je to výzva geografům zabývat se současnými alternativními energetickými scénáři s využitím všech dostupných analytických a diskurzivních nástrojů. Čerpáním z pestré tradice imaginativních prostorů a uvědoměním si nedostatků (materiálních, relačních či jiných) by geografové měly být schopni přispět k hledání udržitelnější společnosti pomocí zkoumání, hodnocení a komunikování kontrafaktického „tady a teď", založeného na příkladech dobré praxe, které existují právě teď, ale (ještě) ne tady. Potřebujeme porozumět tomu, jak by mohl být náš kus planety udržitelnější, pokud bychom mohli – ve smyslu environmentálním – „držet krok" s těmi nejlepšími z našich sousedů. Tato kontrafaktická přítomnost by neměla být nahlížena jako radikální ani utopická, neboť pouze předpokládá historické přijetí nejlepších příkladů praxe, o kterých nyní víme, že jsou proveditelné a úspěšné. A pokud se tento alternativní současný scénář zdá být radikálně odlišný od „skutečného" stavu, ve kterém se nacházíme, potom to ukazuje, jak radikálně neudržitelný náš přístup „dělat věci jak obvykle" je.

Keywords: *counterfactual, imagery, imagination, energy literacy*

1. Introduction

NASA's famous 'Earth at Night' picture shows the cities of the world shining like diamonds on a dark background map that only distinguishes land and sea. This picture is obtained from 'hard' satellite data, and yet it is a carefully manipulated mixture of empirical reality and visual imagination; the cloud cover has been removed, the planet is projected in two dimensions and the time zones are collapsed into a single night time. Geographers have long been obsessed by terrae incognitae (e.g. Wright, 1947) and 'seeing' in the night and seeing earth from space are two prime examples of Geographical Imagination. NASA's manipulated map may have largely been created for aesthetic purposes, but it has moral connotations as well; is it encouraging us to see the beauty in light pollution? Is it stereotyping Africa as the 'dark continent'? NASA's map could be interpreted as an indication of energy wastage in affluent countries and the shortage of basic lighting services in poorer parts of the world.

The broad scientific consensus about anthropogenic climate change is now a generation old. Students graduating this year with a Ph.D. in climate science were not even born when the problem was already identified and widely agreed upon by those with the appropriate disciplinary expertise. It is thus not the lack of science which has caused the lack of action. But that does not mean to say that academics cannot do more to bring the need, urgency and options for adaptation and mitigation closer to the attention of various sections of society. There are very many studies of how much we need to do, how far off target we are, etc. but there is scope to do more than 'just' producing those estimates. For that matter, there is scope for doing more than 'just' theorising human-nature relations or critiquing capitalist accumulation. With 'Earth at Night', NASA's remote sensing experts demonstrated that they can combine their expertise with their imagination, and this paper calls for geographers to do the same. In previous publications

(Nadai, van der Horst 2010a; 2010b) we have called for more research on the landscape/energy nexus. This paper adds a new and distinct category of academic activity to that research agenda.

The aim of this paper is to promote critical engagement with 'our' energy system by imagining and examining the geography of 'lost energy'. The laws of physics stipulate that energy cannot be lost, but my framing of 'loss' in this paper is explicitly anthropocentric and normative; I want to draw attention to the energy that we failed to capture or utilise for our benefit. Although there are still some shameful cases of wastage of fossil fuels in the 21st century (e.g. continued gas flaring in the Niger delta; the Deepwater Horizon oil spill in the Gulf of Mexico), on the supply side the attention should go towards renewable energy. Fossil fuels are replenished over (a very long) time, whereas renewable energy sources like wind and waves are replenished over space. It would therefore require a more temporal strategy to deal sustainably with fossil fuels, and a more spatial strategy to deal sustainably with renewables. The energy flux of the wind and sunshine and flowing water that is not captured now is a lost resource, an opportunity that is gone forever. How can we justify such lost opportunities in a world threatened by anthropogenic climate change?

On the demand side, we can ask ourselves many critical questions about the amount of societal good that our energy consumption patterns have delivered. It is ironic that our conspicuous consumption of lighting services has created such externalities that we depend on NASA's eyes in the sky (satellites) and the artistic license of NASA's remote sensing experts, to internalise this energy wastage through the means of a visual aesthetic, bringing the light that we have carelessly spilled into space, back to earth for cultural consumption. This paper does not seek to deliver a dispassionate and novel contribution to knowledge. It is a call for imaginative and creative engagement with the energy/society nexus, highlighting some important contributions that geographers can make.

In general society is somewhat conservative when it comes to challenging the status quo, changing the system or upstaging the incumbent. This systemic bias in favour of the devil we know means that there is a need for creative approaches to help people think outside their familiar box. In this context, imagining is a necessary skill rather than a frivolous activity. The low carbon energy transition requires radical and systemic step changes rather than marginal and gradual alterations if we are to truly deal with the multiple energy challenges we face: the era of cheap fossil fuels seemed to have come to an end in 2008; most coal-fired and nuclear power plants across Europe are decades old and need to be either closed down or expensively refurbished to extend their life a little longer; there are concerns about the increased dependency on Russian gas or fossil fuel from the turbulent Middle East; and last but not least, a number of countries are formally committed to very radical cuts in greenhouse gas emissions. Short term, myopic business-as-usual approaches will block this transition, whereas imagination may aid it, by inspiring or by showing the way. And there is a lot of space for imagination and imagery in the geography of energy.

2. Energy, geography and absence

The relationship between energy and geography is both intimate and complex. Cheap and abundant energy is the nemesis of geographical constraints, helping (the more energy affluent amongst) humans to conquer space, overcome climate and 'globalise' our lives, economy and society. However, our 21st century energy dilemma is how to flourish as a society without using quite so much (conventional) energy. Using less energy means living with more geography; smart and selective (partial) re-localisation; finding better ways to live with nature. Before we can decide how to adapt, we need to understand, and agree on, the extent to which we are currently not doing it right. This question of the legibility of the sustainability implications of our behaviour comprises a challenge to thinkers, researchers and educators alike. This legibility may be pursued through theory and empirics, through lab, class and fieldwork. Images are widely used as a tool for legibility, from microscopic pictures of pollutants, to satellite images of algae bloom or deforestation. But there are ecological concerns that cannot be easily communicated by showing things as they are. Rachel Carson's (1962) influential book, Silent Spring, provides a powerful example; it was the absence of a sound, bird song, which she uses to make legible the nefarious impacts of pesticides on wildlife. More recently, several authors have referred to the absence of visual clues as a form of silence, including the deconstruction of geographical maps by revealing the counter narratives of subaltern groups (e.g. Vermeylen et al., 2012). Drawing attention to silence or absence can be an evocative tool to enhance our understanding of the unsustainability of certain socio-ecological conditions. The very same can be said of socio-technical conditions, as is evidenced for example by NGO efforts to assess and identify (for further protection) areas where the audio and visual impacts from the industrial age are relatively scarce, e.g. tranquillity mapping (Jackson et al., 2008) and 'Dark Sky Parks' designations (www.darksky.org), the latter providing a counterpoint to NASA's 'Earth at Night' imagery.

As geographers, there are many ways in which we can use imagination and imagery to increase the legibility of that which can be, but is not, here and now. One of our original disciplinary strengths is the making, studying and manipulating geographical maps. As an obvious early step in this quest, map-minded geographers could set out to examine how various kinds of energy-related maps can inform us of our existing energy practices and help us to think or imagine geographically better ways to configure and utilise our energy systems. This is not 'mapping the gap' of existing bio-physical supply of energy or socio-political demand of energy services or the mapping of utopian future scenarios, but the mapping of a 'lost present', i.e. the energy landscape we would be inhabiting now if we had been early adopters and adaptors in the transition to a low carbon society. We should seek to expose the counterfactual of insufficient environmental policies and actions within a landscape or region. In doing so, we would make a contribution to an already well-developed tradition of geographical imaginations, which may take up 'a location somewhere between the domains of the factual and fictional, the subjective and objective, the real and representational' (Daniels, 2011, p. 183). Moreover, imagining other and better energy worlds would constitute a rare effort to create something akin to 'spaces of hope' (Harvey, 2000, p. 33): "*What partially separates us human architects from bees, however, is that we are now obliged (by our own achievements) to work out in the imagination as well as through discursive debates our individual and collective responsibilities not only to ourselves and to each other but also to all those other 'others' that comprise what we usually refer to as 'external' nature ('external,' that is, to* *us).*" In the context of anthropogenic climate change, these 'others' include existing climate vulnerable communities, future generations and those who are doing more 'their bit' in climate change mitigation than we are.

It is not possible within the word limits of this essay to do justice to existing literature on geographical imaginations and geographical imagery. Moreover, there has been a recent upsurge in papers (mainly by geographers) on energy-related imaginaries of the state, private sector investors and NGOs (Perreault and Valdivia, 2010; Levidov and Papaioannou, 2010; Boamah, 2014; Shim, 2014). The Dictionary of Human Geography provides a useful potted summary, indicating not only the psychoanalytical origin of imagery as a concept, but also the 'co-mingling of culture and nature' implicit in the more landscape-oriented writings on geographical imagination. The title of this piece is consistent with the description in The Dictionary of geographical imagery as 'a taken-for-granted spatial ordering of the world' which human geography should seek to disclose and examine its 'often unacknowledged effects', but also with the modern take on geography as a discourse, whereby human geography is construed as 'a site where images of the city and space more generally are set up as reality' (Gregory et al., 2009; pages 282 and 284 respectively). Hence I propose that there is scope for a counterfactual geographical imagery as a discourse which challenges this 'taken-for-granted spatial ordering', by projecting a world that is remarkable for the absence of these unacknowledged effects[1].

The idea of a counterfactual is fully embedded in the practices and tools of policy appraisal and the accounting of externalities such as carbon emissions. For those types of uses, the counterfactual is the scenario of what would have happened in the absence of a particular policy or intervention: (agreeing on) the counterfactual is a prerequisite for determining how additional the project or policy is. For those purposes, the counterfactual is often established through a discursive approach that pays detailed attention to political, socio-technical and biophysical context, yielding a narrative that contains both qualitative and quantitative aspects. Whilst this kind of counterfactual has been of much applied academic interest (e.g. Begg and van der Horst, 2004) and subsequent critical interest (especially in the context of the commodification of nature debate, e.g. Lancing, 2010), this is not the kind of counterfactual that is of primary interest for this paper. More relevant, conceptually, is the literary tradition of alternative histories. Indeed, that tradition has given historians the inspiration to examine the idea of the counterfactual (see Tucker, 1999), which in turn has inspired historical geographers, culminating in a special issue in the Journal of Historical Geography (Gilbert and Lambert, 2010). That special issue actually contains a paper that is explicitly about counterfactual energy landscapes. In 'Landscapes without the car', Pooley (2010) examines a counterfactual historical geography of what Britain would look like if car ownership had been curtailed in the 20th century. As an exemplar of scholarship on the counterfactual geographies of energy, Pooley's paper opens the door to many similar studies (of other countries, or other energy technologies), potentially providing a bridge for a new type of engagement with the energy transitions literature, some of which is also strongly historical in nature (e.g. Turnheim and Geels, 2013). For the purpose of this paper, however, I am focusing my attention specifically on constructing a counterfactual geography of energy that asks less of what has happened in this location in the past, and more of what is happening in other places right now. The rationale for this focus is explored below.

3. Energy literacy

The history of human civilisations can be told through the energy lens (e.g. Pimentel and Pimentel, 1979; Smil, 1994), and energy also features strongly in discussions about the future of society. High energy prices and the fear of anthropogenic climate change have led to a quest for a more sustainable society in terms of energy and resource use, often phrased through narratives of 'transitions', 'escaping the lock-in', 'green innovations', and 'de-carbonising our economy'. Many of the technical, economic, institutional and social barriers to changing our energy use are linked to the peculiar physical characteristics and spatial configurations of our energy systems. Oil, gas and electricity are just about the only commodities (knowledge and data transfer not included) that are traded through grids, with pipes and wires running for thousands of kilometres, across national boundaries, along the sea-floor, over or through mountain ranges to connect multiple locations of production with (in the case of gas and electricity) a large number of dispersed consumers. Especially electricity is a commodity with unique space-time characteristics. It is produced in one location and instantaneously consumed in a multitude of other locations, i.e. it is (to simplify it a bit) a commodity that travels in space but not in time. Gas and electricity are more or less intangible and are mainly represented by the fixed physical infrastructure that enables their transport and utilisation. Oil, on the other hand, is a commodity that is largely used for transport, i.e. to observe its use is to observe the geographical movement of cars, trains and planes and the people and goods within them. We have not even touched upon the geopolitics of energy, and it is already very clear that our energy system cannot be understood in isolation from its geographical and political context.

On the supply side, the visibility of extractive technologies to local communities has often (simplistically) been portrayed as a fundamental reason for local opposition (e.g. van der Horst, 2007). On the demand side the very opposite can be found: energy has been largely 'invisible' in the consumptive choices of our daily life. There has been research on the level of 'energy literacy', especially of young people (e.g. Dewaters and Powers, 2011), and on the available methods to 're-materialise' energy use through improved monitoring and labelling (Burgess and Nye, 2008) and the use of smart energy monitors (Hargreaves et al., 2010). Whether the focus is on the indoor geographies of 'smart' homes, on the socio-political landscape of the auto-motive age, or on local, national and international level of energy use, this paper fits very much within this need to visualise and communicate energy issues as part of the agenda to move to a cleaner and more efficient energy system. In the same vein (if not necessarily with quite the same spiritual fervour) that the concept of 'earth literacy' is promoted by some educators (see www.earthliteracies.org), we must acknowledge the educational undertones of the

[1] For the sake of clarity, it is worth noting that my interest in counterfactual geography is very different from the recent work by Fall (2013), who explores the counterfactual of the development of geography as a discipline.

term 'energy literacy'. I would argue that there is a moral imperative for energy researchers to draw attention to poor energy policies and practices. Whilst we have not been elected to make policies, as academic citizens and knowledge workers for the common good who are largely sustained by general taxation and tuition fees, we have a moral obligation to speak truth[2] to power by providing critical reflections on existing policies and societal trends and the possible long-term repercussions of these. Whilst we are rarely in the position to (effectively) tell policy makers what we think they should be doing, we certainly have the capability and the right to inform society what 'now' would look like if different (and better) decisions had been made in the past. Counter-narratives play a central role in the societal remit of Human Geography as a discipline that is able and willing to critique incumbent regimes for power structures that reproduce inequality, or for institutional thickness that favours unsustainable business-as-usual practices. Counterfactual geographical imagery of more sustainable energy landscapes would add another strand to this tradition of counter-narratives.

4. Possible examples

So how can we go about imagining and making legible the more sustainable energy landscape that could have been, now? In a paper that calls for imagination, it would be rather inappropriate to offer prescription. Different sections of our discipline may be able to draw on entirely different methods and paradigms here, from map overlays and probabilistic modelling to the sensuous and performative. As a starting suggestion, and drawing on my own areas of relative expertise, I can envisage at least four aspects of energy use that lend themselves for counterfactual geographical imagining.

First we should seek the avoidance of zero and negative returns on energy consumption. Zero returns on energy consumption are common in everyday life; e.g. boiling more water than we need, leaving the lights or the heating on in empty rooms. This is the domain of where smart metering and feedback displays, the labelling of energy appliances and inbuilt and pre-programmed sensors (e.g. motion detectors in light switches) rub against human behaviour, habits and practices. At the level of individuals, households and the work place, there is now a substantial amount of social science research into awareness of energy consumption, energy practices and energy literacy. There are publications, animations, pictures and testimonials of 'the house of the future' and of ecologically-minded citizens cutting down their energy bills whilst still appearing healthy and happy. Some cars equipped with a voluntary setting for more fuel-efficient driving, provide the driver with feedback on the amount of fossil fuel saved, or the extra miles the car can go as a result of improved fuel efficiency. This is counterfactual baseline that shows how much more efficient the actual car is, in comparison to some sector average. It provides the driver with a positive message that s/he is saving fuel and money by driving a more fuel efficient car. The counterfactual I'm focusing on in this paper is equivalent to 'normal' cars having a sign on their dashboard saying how much fuel and money the driver would have saved if s/he had driven an energy efficient car instead. It would thus question how 'normal' the business-as-usual cars are.

What is perhaps less well-researched, is the extent to which we understand that energy consumption can have negative returns. Examples in the transport sector are an obvious start: would we have the same levels of 'road rage', 'food deserts' or obesity if our urban transport system and urban planning would have prioritised walking, cycling and public transport, thus opposing the hegemony of the private car and the associated super-concentration of food sales in huge supermarkets with huge car parks at the edge of town? Cycling in the Netherlands or car-free Venice, are well-known better practice examples, but they are often filed away as historic anomalies or cultural exceptionalism. How can we imagine and visualise a more local situation where these negative effects of excessive private mobility have been challenged? Some imaginative approaches have appeared over the years, e.g. car-free days in inner cities, organised bike rides, earth hour. These typically have a performative and even a festive character, and do not take place each and every day. It is not clear to what extent they are now perceived as a normalised tradition for some ('progressive') sections of society (i.e. embraced as they are) or seen as a continued political rallying call for an overhaul of car-friendly urban governance.

There is certainly scope for more geographical imaginations in this respect. In cities where cycling has long been neglected by planners and policy makers and largely abandoned by the public, the appearance of new maps with cycling routes are a great example of geographical analysis and imagination coming together to encourage local action for cleaner, healthier and more socially-inclusive transport. These maps often do not so much indicate what cyclists do at the moment, but what they could do. These maps feed the imagination and provide a prescription. In doing so, they encourage change to happen, i.e. for more people to cycle and for local authorities to plan more and better for the needs of cyclists.

Secondly, we should query the efficient and effective use of energy generation and waste management technology. One particular example from the United Kingdom springs to mind. Despite having a climate which necessitates the heating of buildings for most of the year, and despite widespread and systemic problems of fuel poverty, thermo-electric power plants in the UK waste most of the energy they generate, because they only seek to utilise the electricity, not the heat. The scaling-up of space heating technology, from heating individual rooms to heating individual buildings to heating city blocks, was a logical development that has been pursued in the city centres of most cold countries since the first developments of steam district heating in New York in the 1880s. Despite many early attempts by local councils to develop district heating in the UK (Russel, 1993), the UK has largely abandoned this technology, and its coal-fired and nuclear power stations are throwing out more energy into the atmosphere (in the form of steam) than they produce energy for the electricity grid. This very wasteful system is all the more painful to observe when the environmental justice literature shows us time and again that it is mainly the less wealthy who tend to live in the vicinity of power plants. An obvious example of geographical imagination would involve the identification of the areas surrounding the power plant which could be served by district heating from the plant, and

[2] I see the expression of 'speaking truth to power' in the context of Habermas' discourse ethics, which draws attention to the counterfactual conditions or presuppositions of un-coerced agreement. Within that context, academic truths are vital components of liberal democracy.

the assessment of the number of people who could be lifted out of fuel poverty if the waste heat of the plant was provided to heat the homes of nearby residents.

A related example concerns the lack of energy recovery from waste. In many countries, this lowest step of the waste hierarchy (after reduce, reuse, recycle) has long been ignored politically, because it is a difficult sell to local residents. And yet some countries have strongly embraced waste-to-energy district heating plants (e.g. Austria, Denmark and Sweden), and also in countries that seemed to oppose them we can find exceptions (e.g. the city of Sheffield). Talking of imagination, what better example can we find than the award-winning waste-to-energy plant feeding Vienna's district heating system: designed by the artist and architect Hundertwasser, it is perhaps the city's most famous building and the most famous operational thermal power plant in the world. District heating linked to waste management can be valuable beyond the recovery of calories and the destruction of harmful bacteria and substances. It has the potential to address local pockets of fuel poverty and to connect people with their own waste production. Unlike the invisibility of energy flowing through electric networks, heat networks provide a more concrete material link between the home and the power plant and a tangible benefit of living near an operational power plant. There is thus scope for a geographical imagination in seeing and communicating not only how much waste we produce, but also how it has been dumped into unsightly and noxious landfills in urbanised regions, where land is scarce and energy is expensive.

Thirdly, we should draw attention to the biophysical underutilisation of locally-available resources. This is not merely a call for reproducing maps with estimates of wind potential or biomass yield. Many such resource mapping studies have been commissioned and carried out in the last twenty years. There is scope for geographical imagination in identifying specifically which areas have not been developed, and asking critical questions about why that is. Examples could include the assessment of the wind potential along all major motorways, harbours and industrial areas, as these are locations where few people live, noise levels are already significant, the disruption of traditional or high-value landscapes has already been 'achieved' and potential near-by demand for energy and the opportunities for grid-connection are very high.

Further examples could include the opportunity cost of the full exclusion of wind farms from certain protected areas, such as protected landscapes, buffer zones around towns, or flight paths and military installations such as radar ranges. In the UK, national parks (which have their own planning powers) have not only consistently banned wind farm developments within their territory, but in some cases they have opposed the development of wind farms in the vicinity of the national park, thus extending their visual claim over the landscape far beyond their formal administrative remit. It could be argued that national parks should be run under a green agenda, which includes efforts to minimise and offset the emissions associated with the existence and functioning of the park. I would certainly not seek to argue that all national parks should be 'full' (whatever that might mean) of wind turbines, but I would welcome an assessment of (a) the amount of carbon emitted through cultural consumption of the amenities of the national park, by visitors and more economically-privileged residents alike (in the UK, property prices within national parks are considerably higher than those beyond the boundary), and (b) the amount of wind energy forgone by the nation because of the refusal of national parks to play host to this technology. Such a proposed assessment could open up imaginative debates about equity, tensions between local-global and short- and long-term nature conservation, the (changing) functions of national parks, and about possibilities for local off-setting of the carbon footprints of tourist hotspots.

Fourthly, we should consider the question of how policies perform. Ambitious targets may be unachievable due to weak support structures, and strong relative performance may be explained away by favourable conditions that have nothing to do with strong financial commitments or brave political decisions. For example, the UK was one of the very few western countries to achieve its Kyoto target, but this was not due to strong policies on renewables or energy conservation (the UK was a comparative laggard in both respects). Rather, it was an accidental by-product of privatisation, which resulted in a dash-to-gas (the cheapest technology). Furthermore, there is often a large discrepancy between the (loud) political and public debate about (say) renewable energy, and the (humble) actual size of the sector, in terms of KWh generated and in terms of money invested. This discrepancy is problematic because it can cause public impressions that much is being done and achieved, whereas the very opposite is true in terms of actual renewable energy production.

Rather than focusing on issues such as the level of public subsidies, or on ambitious targets set in a future that is far beyond a term in office, a geographical imagination of good energy policies should address the following sorts of questions: 'How much better would we perform if we were to do our fair share?'; 'How can we adopt and improve on the policies of those who are leading in this effort?'; and 'How can we work back from the energy future we want, to design and adopt the right policies today?'. A counterfactual geographical imagery of existing policies in the UK will show both failings and room for improvement. For example it might show all wind farm planning applications that were not granted permission, or it might create an interpretation on an annual basis of the legally binding 2050 UK government target to reduce carbon emissions by 80% of 1990 levels, and thus display by how much we have missed the target this year. This imaginary basically helps us to assess to what extent (other-wise bold-sounding) policies are actually delivering the goods.

Moreover, we could examine alternative policies altogether, from state-led and command-and-control to the far end of neo-liberal logic. Ideas could range from taxing real estate owners for heat waste or wind waste, to legalising wind- and water-squatting (right to install a mobile turbine on the land/in the water course of someone who is not harnessing that energy themselves), to selling the view by auction (so that local residents who do not like looking at wind farms, can chose to outbid a wind farm developer), to internalising carbon emissions in the cost of mortgages and car-leasing contracts, that in turn are used to fund off-setting projects within the local area.

5. Conclusions

This paper makes the case for a geographical imagination of a more sustainable here and now, more counterfactual in the 'here' than in the 'now'. I call for a visioning of better energy practices on the supply and demand sides, based not on some utopian ideals of society or scientific-economic arguments about the size and accessibility of energy resources, but on observations of existing good practices by some of this planet's more pioneering individuals, institutions or administrations. Rather than dismissing them as being far away in space and culture, our geographical imagination can help to reduce this othering, and portray our lives and our bit of the planet as if we had operated like them. This can help to bring us closer to those early adopters, challenge the lazy perception that this adoption accentuates their otherness and make us reflect on the strangeness of the situation in which nothing much was happening in our own bit of the planet, causing us to start lagging behind. I would argue that this alternative current scenario should be seen as neither radical nor utopian, because it only assumes the historic adoption of best practices which we now know to be achievable and workable. Looking at the mirror of a better here and now, can help drive home the message of how radically unsustainable our business-as-usual approach has been. Imagining the geographies of lost energy is an endeavour that, rather than highlighting imaginative solutions, seeks to normalise better practices through a critical counter narrative of society observed through the energy lens, thus exposing the under-imagined energy absurdities of extant policies, processes and practices.

As a final point, it is worth noting that such an idea of a counterfactual geographical imagery of the here and now can have relevance beyond energy. For example, issues around food wastage, hunger and obesity could be subject to a similar kind of analysis, helping to challenge complacency, to confront unambitious policies, to motivate citizens and policy makers and identify practicable next steps within our daily lives and local environment on the road to greater sustainability.

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MORAVIAN GEOGRAPHICAL REPORTS

Aims and Scope of the Journal

Moravian Geographical Reports [MGR] is an international peer-reviewed journal, which has been published in English continuously since 1993 by the Institute of Geonics, Academy of Sciences of the Czech Republic, through its Department of Environmental Geography. It receives and evaluates articles contributed by geographers and by other researchers who specialize in related disciplines, including the geosciences and geo-ecology, with a distinct regional orientation, broadly for countries in Europe. The title of the journal celebrates its origins in the historic land of Moravia in the eastern half of the Czech Republic. The emphasis at MGR is on the role of 'regions' and 'localities' in a globalized society, given the geographic scale at which they are evaluated. Several inter-related questions are stressed: problems of regional economies and society; society in an urban or rural context; regional perspectives on the influence of human activities on landscapes and environments; the relationships between localities and macro-economic structures in rapidly changing socio-political and environmental conditions; environmental impacts of technical processes on bio-physical landscapes; and physical-geographic processes in landscape evolution, including the evaluation of hazards. Theoretical questions in geography are also addressed, especially the relations between physical and human geography in their regional dimensions,

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Fig. 4: Počerady plant – the second largest coal-fired power plant in the Czech Republic (Photo: B. Frantál)

Fig. 5: Wind farm in Nová Ves v Horách (district of Most) – an alternative energy path for coal mining region (Photo: B. Frantál)

Illustrations related to the paper by B. Frantál and E. Nováková