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Handling uncertainty in bioenergy policy design – A case study analysis of UK and German bioelectricity policy instruments

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ABSTRACT

In designing policies to promote bioenergy, policy makers face challenges concerning uncertainties about the sustainability of bioenergy pathways (including greenhouse gas balances), technology and resource costs, or future energy market framework conditions. New information becomes available with time, but policy adjustments can involve high levels of adaptation costs. To enable an effective steering of technology choices and innovation, policies have to strike a balance between creating a consistent institutional framework, which establishes planning security for investors, and sufficient flexibility to adapt to new information. This paper examines implications of economic theory for handling cost and benefit uncertainty in bioelectricity policy design, focussing on choices between price and quantity instruments, technology differentiation, and policy adjustment. Findings are applied to two case studies, the UK's Renewables Obligation and the German feed-in tariff/feed-in premium scheme. Case study results show the trade-offs that are involved in instrument choice and design – depending on political priorities and a country's specific context, different options can prove more adequate. Combining market-based remuneration with sustainability criteria results in strong incentives for bioenergy producers to search for low-cost solutions; whereas cost-based price instruments with centrally steered technology and feedstock choices offer higher planning security for investors and more direct control for policy makers over what pathways are implemented. Independent of the choice of instrument type and technology differentiation mechanism, findings emphasise the importance of a careful policy design, which determines the exact balance between performance criteria such as cost control, incentive intensity, planning security and adaptive efficiency.

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1. Introduction

Bioenergy use in the electricity sector plays an important role in meeting renewable energy expansion and greenhouse gas (GHG) mitigation targets in many EU member states [1]. Due to a lack of commercial competitiveness with fossil fuel-based technologies, the uptake of bioelectricity technologies relies heavily on policy incentives. From an economics perspective, the rationale for policy intervention on behalf of bioenergy lies in the correction of market failures. For one, negative GHG externalities of fossil fuels distort competition with renewable energy sources (RES). Furthermore, bioenergy can make a positive contribution to the public good "secure energy supply" [2], by substituting fossil fuel imports from geopolitically instable regions [3], or by providing systemic benefits in an electricity system with high shares of volatile RES, where bioenergy can act as a renewable option for balancing fluctuations [4]. At the same time, investments in innovative technologies and learning generate knowledge spillovers as positive externalities. The existence of multiple market failures justifies the use of a policy mix combining instruments like the European Emissions Trading System (EU ETS), which sets a price on GHG emissions, and direct support instruments aimed at promoting RES diffusion, like renewable quotas or feed-in tariffs [5,6]. To ensure an effective innovation system for low carbon technologies, demand-pull measures such as these need to be further combined with instruments promoting the supply of innovative technologies and knowledge creation, such as research and development support [7–10]. Functioning knowledge exchange networks and economic and political framework conditions which are conducive to innovation are further elements of effective innovation systems [7,8]. The focus of policy interventions, meanwhile, needs to be aligned with a technology's stage of commercial maturity. For bioenergy use in the electricity sector, deployment support is of particular relevance, because major technologies such as biogas and solid biofuel-based combined heat and power (CHP) production have reached a comparatively high level of technological maturity, even though potentials for incremental innovation remain [11,12]. The EU ETS as an indirect support instrument fails to create a level playing field for competition with conventional energy technologies, which benefit from economies of scale, past learning effects and persistently low levels of emission allowance prices [13,14]. Moreover, current market framework conditions set only limited incentives for the provision of flexible capacities, even though their systemic importance is growing as shares of volatile RES increase [15–17]. In this context, direct deployment support is necessary to further develop bioenergy technologies as part of a diverse RES portfolio, and reflect bioenergy's option value as a dispatchable, low-carbon RES in the future electricity mix.

Meanwhile, the heterogeneity of technology–feedstock combinations and associated environmental and socio-economic impacts makes it a difficult task to design policy instruments which incentivise cost-effective contributions of bioenergy to RES and GHG mitigation targets while also ensuring the sustainability of developments [18]. Particularly problematic for bioenergy policy design is the pervasive existence of uncertainty about the costs and benefits of various pathways. While uncertainty about the private cost characteristics of RES plants and future learning curve effects is a well-researched phenomenon [19,20], the heterogeneity of bioenergy pathways and their dependency on biomass and land resources adds several dimensions to the problem of policy design under uncertainty (see Table 1).

Firstly, the future costs of bioenergy provision depend not only on the extent of cost reductions associated with technological progress and learning by doing, but also on resource cost developments, which are in turn influenced by the demand for competing biomass uses; as a result, the future competitiveness of bioenergy pathways can be associated with large uncertainties [21]. Moreover, bioenergy production can give rise to external costs (e.g. through negative impacts on biodiversity, soils, water quality and availability), which depend on the pathway in question as well as on local and regional circumstances [22]. On the benefit side, not only the level and slope of the aggregate marginal benefit function of GHG mitigation is uncertain [23,24], but also the extent of emission reductions associated with different bioenergy pathways, because estimates of GHG balances require numerous assumptions [25–27]. The complexity of estimating GHG mitigation benefits grows, once indirect land use effects of an increased biomass demand are taken into account [28,29]. Also, it is difficult to assess benefits related to the security of electricity supply; those relating to the substitution of imports depend on which fuels are replaced by bioenergy, whereas the value of systemic benefits of flexible bioenergy provision depends on the future availability of low carbon alternatives, such as storage systems, and their competitiveness.

Finally, given the existence of multiple externalities, policy makers face the challenge of how to weigh external costs and external benefits of a given pathway against each other and solve associated trade-offs. Moreover, uncertainties do not only apply to bioelectricity pathways, but also to the use of biomass in transport, heating and material applications in the growing bioeconomy. The optimal future allocation of scarce biomass resources remains unknown, because the future availability of alternative, non-biomass GHG mitigation options in the different sectors determines where biomass use would generate the largest benefits.

In the implementation phase, a further dimension of uncertainty applies to the response of actors to policy incentives. An important influence factor on market actors' behaviour is the degree of policy uncertainty they perceive: the profitability of investments depends heavily on policy incentives, so that market actors will only be willing to carry them out if they have sufficient safeguards and confidence in their continued existence [20,30,31]. Policy makers therefore face a trade-off: over time, as the policy is implemented, new information becomes available and learning takes place, reducing some of the uncertainties named above. The flexibility to adjust the policy, however, results in an increase in policy uncertainty. On the other hand, policies which create very stable expectations and ensure high planning security reduce uncertainty about how market actors will respond to them, but flexibility to correct errors and respond to new developments is lost. In this paper, we explore what answers economic theory has to offer for dealing with this trade-off, and apply findings to the analysis of two case studies.