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Abstract

To achieve a low-carbon transition in the electricity sector, countries combine national-scale policies with regional renewable electricity (RES-E) initiatives. Taking Austria as an example, we investigate the economy-wide effects of implementing national-level feed-in tariffs alongside local-level 'climate and energy model (CEM) regions', taking account of policy externalities across the two governance levels. We distinguish three types of CEM regions by means of a cluster analysis and apply a sub-national Computable General Equilibrium (CGE) model to investigate two RES-E scenarios. We find that whether the net economic effects are positive or negative depends on three factors: (i) RES-E potentials, differentiated by technology and cluster region; (ii) economic competitiveness of RES-E technologies relative to each other and to the current generation mix; and (iii) support schemes in place which translate into policy costs. We conclude that the focus should mainly be on economically competitive technologies, such as PV and wind, to avoid unintended macroeconomic side-effects. To achieve that, national support policies for RES-E have to be aligned with regional energy initiatives.

JEL codes: Q42; R13; C68

Keywords: Energy transition; Computable General Equilibrium (CGE); national support policies; regional energy initiatives; policy externality

1. Introduction

In October 2014, EU leaders agreed on the 2030 policy framework for climate and energy, which set the GHG reduction target of 40% compared to 1990 (European Commission 2014), and in December 2018 the so-called “RES Directive” defined a binding target for renewable energy sources (RES) for the European Union for 2030 of 32% with an upwards revision clause by 2023 (Council of the Europian Union and European Parliament 2018). Yet the implementation of this target is left to member states, and different paths are taken in different member states. At the national level, most European countries support specific types of renewables by means of quotas or renewable portfolio standards, or set feed-in-tariffs with differentiated rates by technology (Ortega-Izquierdo and del Río 2016).

Climate change mitigation and RES targets, often settled at the national level, are usually implemented at the local or regional level. In addition to technology-specific support, some countries have decided to support local communities in devising plans and implementation strategies for achieving ambitious RES targets. The idea of supporting local communities in RES projects dates back to the 1970s when countries like Denmark and Austria financially supported local wind and biomass projects (Walker et al. 2010). In the late 1990s, the approach started to spread to other countries, such as the UK Rural Community Energy Fund (WRAP 2012), the German bioenergy villages (Ruppert et al. 2008), and Swiss energy regions (Ribi et al. n.y.). The main activities of such community RES programs are the development of energy plans, education and awareness raising of citizens, and public actions to lead by example and to foster learning, such as the implementation of biomass heating in public buildings (van der Schoor and Scholtens 2015).

In Austria the national targets are implemented at the regional level through the ‘climate and energy model (CEM) regions’ mechanism, which is seen not only as an implementation tool to scale up RES deployment but also as a tool to stimulate regional socio-economic development by attracting financial sources, both private and public, into deployment of RES technologies. The idea behind the CEM regions is to support regions on their way to becoming independent of fossil fuels by 2050. The goal should be reached by expanding RES, increasing energy efficiency, and supporting a low carbon transition in economic sectors that can be targeted at the regional level, such as agriculture, housing and mobility. This goal is pursued by the development of a regional implementation concept (available at Climate and Energy Fund 2019) and the installation of a CEM manager. As of 2019, 95 regions participate in the CEM program – covering more than 800 communities in Austria, most of them rural and structurally weak (Climate and Energy Fund 2017, 2019). The CEM process reflects a mixed modus of governance. The Climate and Energy Fund together with a number of Austrian national ministries administers the process at the national level. At the state and the provincial level the main stakeholders, such as regional development agencies and provincial government, are shaping the implementation of the CEM process. At the CEM-regional level, the CEM manager is the main driving force behind the CEM process and is responsible for the design and implementation of concrete energy transition measures. At the local level, there are representatives of different municipalities as well as, in some CEMs, energy groups, which help to engage interested stakeholders but also inhabitants into decision-making processes (Komendantova et al. 2018).

From the perspective of a region, the expectation of regions to become a CEM region is to enhance regional economic development. In earlier years, Austrian CEM regions concentrated on expanding bioenergy (biomass and biogas), particularly in rural regions with a large agricultural sector. More recently, also semi-rural and urban regions have become CEM regions, with smaller potentials for bioenergy and larger potentials for wind and photovoltaics (PV). One of the questions this paper therefore addresses is how different types of regions (rural, semi-rural, suburban) are able to benefit in terms of regional economic development and how this benefit (or cost) depends on the implementation strategy (focus on bioenergy or on wind and PV).

Despite these expectations in the policy arena, the majority of studies focuses on the economic effects of energy transitions at the national level, while studies on the regional level tend to focus on questions of regional development and governance of the energy transition (Balta-Ozkan et al. 2015). The economy-wide effects, taking into consideration macroeconomic policy spillovers across governance levels, economic sectors, and the private and public sector, have received relatively little attention so far. The present paper intends to address this gap by assessing the economic effects of energy transition at the local level, taking account of feedback effects from and to the national economy.

The limited research on the impacts of RES expansion on regional economic development has found mixed results. Even if the direct (regional) economic impact e.g. on employment is positive, the net effect on the economy-wide level might not necessarily be positive and tends to be in general small (OECD 2012). Moreover, the effect on regional employment may be transitory (i.e. during the investment phase) but not permanent (i.e. during the operation phase) (Komendantova and Patt 2014; Okkonen and Lehtonen 2016). Finally, positive effects for some sectors might be outweighed by a general reduction in household income and a regressive distributional effect (Többen 2017).

The promotion of renewable energy leads to several benefits and costs in three domains, i.e. the energy system level, the macroeconomic level, and distributional effects (Ortega-Izquierdo and del Río 2016). Another common distinction is between direct effects and indirect effects which emerge because of sectoral spillovers and feedback effects. Examples of direct effects of the deployment of renewables on the energy system are the crowding-out of conventional electricity, higher generation and system costs, and reduced greenhouse gas emissions of the energy sector (Frondel et al. 2010; Hirth et al. 2015; Ortega-Izquierdo and del Río 2016). In addition to these direct impacts, macroeconomic effects may arise on economic growth, disposable income, and employment or the redirection of investment to renewables from other non-renewable sectors (Bachner et al. 2019; Hoefnagels et al. 2013; Blazejczak et al. 2014; Többen 2017). Finally, the costs of support schemes, such as feed-in tariffs, are passed on to consumers mostly through higher electricity prices and this may have a disproportionate burden on low-income households (Böhringer et al. 2017).

In this paper, we combine a cluster analysis with a sub-national Computable General Equilibrium (CGE) model to assess the economy-wide effects of pursuing ambitious RES targets at the local level in CEM regions. The CGE method is well established for assessing the economic consequences of RES expansion, both on the national scale, and on the local and regional scale. For both levels, current research focuses on specific technologies such as biofuels and biomass (Trink et al. 2010; Arndt et al. 2012; Wianwiwat and Asafu-Adjaye 2013; Hoefnagels et al. 2013; Philippidis et al. 2016), PV, or wind (Graziano et al. 2017), on policies to promote RES technologies such as the German Renewable Energy Act (EEG) (Frondel et al. 2010; Blazejczak et al. 2014; Többen 2017; Böhringer et al. 2017), and on broader energy transition (Jägemann et al. 2013). By focusing here on renewable electricity generation (RES-E), we address the following research questions: (i) What are the consequences of 100% RES-E in the Austrian CEM regions for the public budget and local electricity generation costs? (ii) What are the economy-wide (net) benefits or costs of RES-E self-sufficiency in the CEM regions? The novelty of our analysis is to focus on the policy externality from local to federal levels, i.e. the macroeconomic feedback effects which stem from RES-E policies set at the federal level, such as the Austrian feed-in tariff scheme, but implemented at the local level, such as the Austrian CEM regions.

2. Materials and methods

To investigate ambitious RES-E strategies in Austria's CEM regions, we develop a multi-regional, multi-sectoral sub-national Computable General Equilibrium (CGE) model (Figure 2). To capture the energy and economic characteristics of the different CEM regions in Austria as well as the specifics of different RES-E technologies, our sub-national CGE model builds on a comprehensive cluster analysis (Figure 1) of 78 existing CEM regions (Bramreiter et al., 2016), technology cost estimates from a bottom-up electricity sector model (EEG, 2016) and an existing RES potential scenario analysis for Austria (Stanzer et al., 2010).

2.1.Cluster analysis of Austria's 78 CEM regions

We carry out a cluster analysis on 78 Austrian CEMs[1] in order to more effectively assess the regions characteristics and differences. The cluster analysis uses economic and energy data available at the municipal level to identify three homogeneous clusters. The economic indicators comprise population density (inhabitants/ha), gross value added per capita (€/capita), and employees in the primary, secondary and tertiary sector. The energy indicators are energy consumption (MWh/capita), potential electricity self-sufficiency (local supply/local demand), and potential heat self-sufficiency (local supply/local demand). For details on the methodology, see the Annex.

According to this cluster analysis three CEM clusters can be distinguished: a "suburban", a "semi-rural" and a "rural" cluster. Since the CEM program targets by design peripheral Austrian regions, there is no urban cluster. They are distributed across Austria's municipalities as shown in Figure 1. Six CEM regions are assigned to the suburban cluster, 37 to the semi-rural and 35 to the rural CEM cluster.

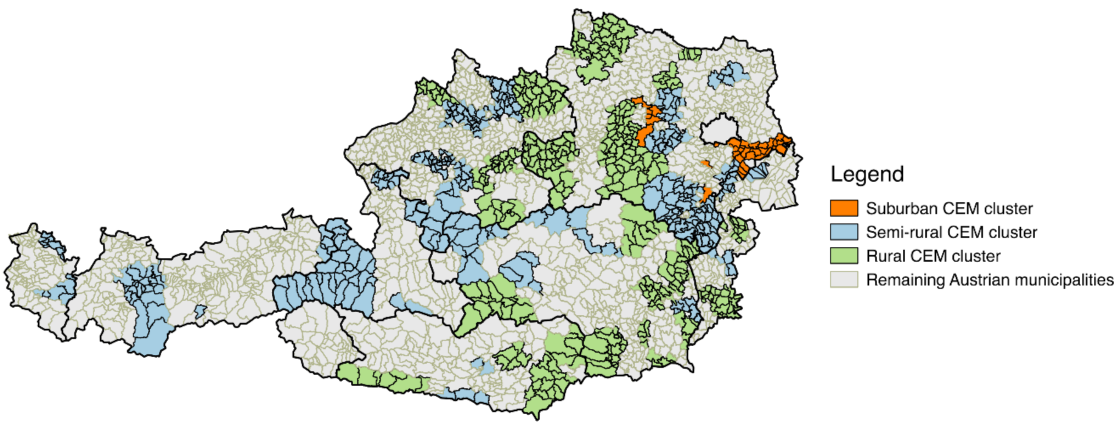

Figure 1: Figure. Mapping of the CEM clusters

[1] Of the 82 analysed implementation concepts (as of November 2016), four could not be included in the cluster analysis due to lacking data on energy demand in the respective CEM region concepts (Bramreiter et al. 2016).

The suburban cluster is characterized by a high population density and the highest gross value added per capita of the three clusters. Regarding sectoral structure, the suburban cluster is dominated by the tertiary sector, while the employment shares of the primary and secondary sectors are very small. The current energy consumption per capita is also highest in the suburban cluster. Suburban CEMs have on average quite low potentials to cover their energy demand, which correlates with the higher absolute demand. The semi-rural and rural clusters are more similar to each other. The population density in these clusters is lower than in the urban cluster, but due to the much larger number of municipalities, total population is almost four times larger in the rural and semi-rural cluster than in the urban cluster. For the same reason, gross value added is twice as high in the rural and semi-rural cluster as in the urban cluster. The main difference between the semi-rural and the rural cluster relates to gross value added and the sectoral structure. The semi-rural cluster has a larger gross value added per capita and the share of employment in the tertiary sector is larger and the share in the primary sector is smaller than in the rural cluster. The current energy consumption per capita is smaller than in the urban cluster. In contrast, the RES potentials for the semi-rural and rural clusters are highest. According to these numbers, both rural and semirural CEMs could even become net electricity exporters (see Table A1 in the Annex for detailed results).

2.2. The sub-national CGE model

We develop and implement a CGE model by employing the programming software GAMS/MPSGE (Rutherford 1999) within a comparative static scenario approach based on the Austrian IO-table of 2011 (Statistics Austria 2015a). The CGE model comprises of four sub-national model regions – representing the three CEM clusters presented above and the remaining Rest of Austria – each comprising twelve economic sectors. As illustrated in Figure 2, each of the four representative private households (of the three CEM types and of the rest of Austria) receives factor income by providing capital and labor to the sub-state production sectors via a national factor market (i.e. production factors are perfectly mobile across model regions). The private households receive transfers, unemployment benefits, and other transfers from the national government, which in turn collects tax income from different sources (capital, labor, production, and others) to ensure a balanced budget.

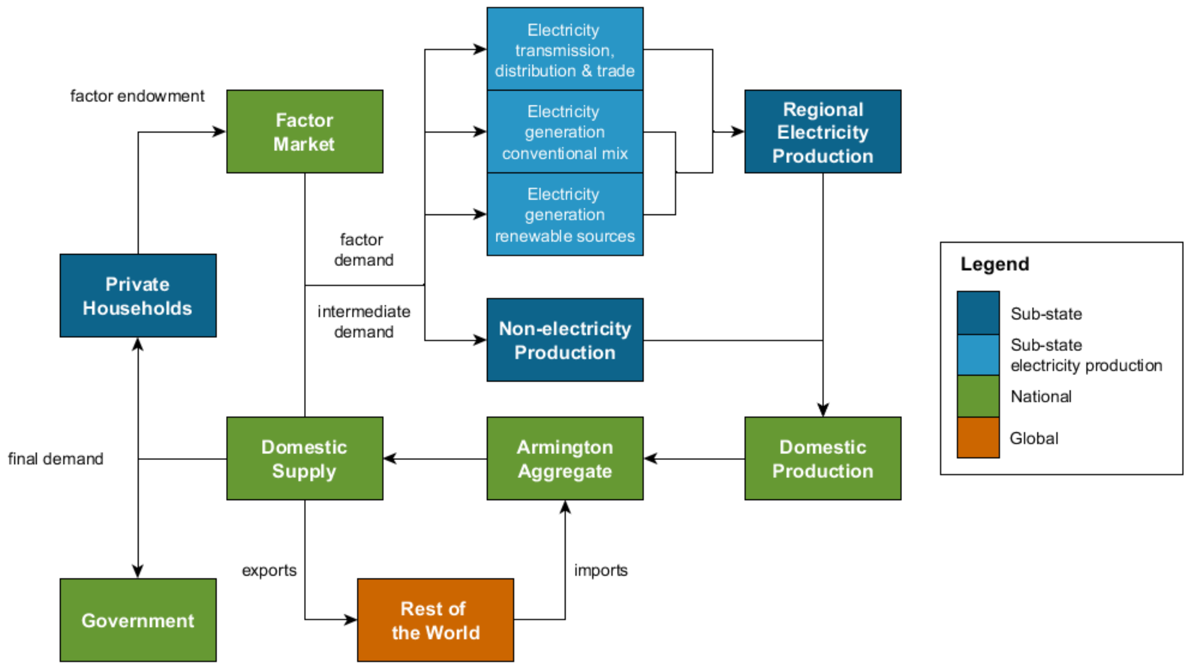

Figure 2: Diagrammatic structure of the subnational Computable General Equilibrium (CGE) model for Austria

The twelve economic sectors produce, subject to constant elasticity of substitution (CES) production functions, in each model region at the sub-state level for the national market. They can be divided into 11 regional non-electricity production sectors and one regional electricity production sector. In the three CEM model regions, the electricity sector itself is further disentangled to explicitly represent different RES-E technologies (wind, biogas, hydropower, solid biomass, PV roof small and PV roof large; see Table A2 in the Annex). Trade with the rest of the world is represented by making use of the small open economy and Armington trade assumption. Imports from the rest of the world are combined with the domestic production good as imperfect substitutes with sector specific Armington elasticities of substitution, adopted from Bachner et al. (2015), to a single Armington good for each sector. This Armington good then feeds the domestic supply at the national level, which is consumed as domestic intermediate and final demand, and for national exports, sold to the rest of the world, by again using sector specific Armington elasticities of transformation. The exports to the rest of the world generate foreign exchange reserves, measured at a single world price, which are subsequently used to finance imports. The four representative sub-national households and the national government spend their income on the purchase of domestic supply goods to maximize their utility subject to their preferences, represented by a nested CES consumption function, and income constraints.

2.3. Sub-national economic and technology data

The sub-national CGE model is calibrated to the Austrian IO-table of the year 2011 (Statistics Austria 2015a). The economic sectors of the Austrian IO-table are classified according to the ÖNACE 2008 classification. The sub-national breakdown of the Austrian SAM requires different regional secondary data, such as data concerning population and employment (Statistics Austria 2014a, 2015b; STATcube 2015), gross value added (Statistics Austria 2014b), household consumption (Statistics Austria 2011), and international and inter-regional trade flows (Statistics Austria 2014b).

Table 1: Electricity generation costs by RES-E technology in 2020

Projection 2020 (medium costs) [€/MWh]	Fuel costs	Operating costs	Investment costs	Levelized costs of electricity	Feed-in tariff 2016	Subsidy (% of LCOE)
Electricity production						
Wind power	0.00	15.83	38.02	53.85	90.40	59.48%
Biogas	28.57	24.00	51.51	104.08	161.50	99.09%
Solid biomass	100.00	19.64	40.14	159.77	133.90	47.27%
PV roof small [a]	0.00	9.52	68.28	77.80	82.40	30.89%
PV roof large [a]	0.00	10.00	54.41	64.41	82.40	37.31%
Hydropower (small-scale)	0.00	13.33	33.68	47.02	64.35	12.72%
Reference technology: Gas-steam power plant	44.75	3.64	9.99	58.37		

[a] *Note: For PV technologies we employed low cost estimates. Source: Own calculations based on cost estimations from Held et al. (2015)*

To derive the desired energy sector level detail of the original IO table sector "electricity, gas, steam, and air conditioning supply", we use data provided by Eurostat (2016) concerning lower level sectoral production shares for the sectoral disaggregation into four energy sectors by deploying the RAS method (Deming and Stephan 1940; Bacharach 1970; Trinh and Phong 2013), a SAM balancing procedure. Additionally, six renewable electric power generation sectors are established, which are restricted in local production levels by the RES-E potentials derived by Stanzer et al. (2010) and based on technology cost estimates from Held et al. (2015). Current fuel costs are based on data from Statistics Austria (2015c). Cost developments for each technology are based on Held et al. (2015), which includes scenarios for technology diffusion and learning rates and their impact on cost reductions for renewable energy sources up to the year 2030. Table 1 presents the breakdown of projected levelized costs of electricity (LCOE) generation for each RES-E technology, as well as a reference gas-steam power plant, into fuel, operating and investment costs for the year 2020. The discount rate for all technologies was assumed to be 4%. For the calculation of levelized costs typical lifetimes and full load hours for each technology were assumed (for more details see Held et al. 2015).

2.4. CGE model scenarios

Applying the sub-national CGE model outlined above, we strive to investigate the macroeconomic effects of pursuing ambitious sub-national RES-E targets in comparison to a Baseline scenario. As depicted in Figure 3, we assess two exogenously specified RES-E technology scenarios in which CEM clusters pursue 100% RES-E generation (on a net yearly balance) by 2020. To isolate the local and national economic effects of ambitious RES-E upscaling in Austria's CEM regions, we assume for both scenarios that Rest of Austria does not increase its RES-E shares. The scenarios differ in terms of RES-E technologies employed and their relative shares. While the first scenario reflects RES shares based on a bottom-up potential analysis (Stanzer et al. 2010), the second scenario focuses only on "new" renewables, which are more cost efficient than the first generation RES-E technologies, biomass and biogas (Held et al. 2015). Both scenarios are compared to a Baseline scenario according to which the base year (2011) generation mix of Austria is maintained in all model regions.

Scenario 1: RES-E mix in CEM clusters based on a broad portfolio of RES technologies: hydro, PV, wind, biogas, biomass (relative RES-E technology shares according to Stanzer et al. 2010).

Scenario 2: RES-E mix in CEM clusters consisting only of "new" renewables hydro, PV, and wind, but not biomass and biogas.

The CGE model is calibrated to the Austrian IO-table for 2011 (Statistics Austria 2015a). For calculating the 2020 Baseline scenario, the Austrian economy is exogenously up-scaled by assuming a GDP increase of 0.94% per anno until 2020, based on a forecast by the International Monetary Fund (2016).

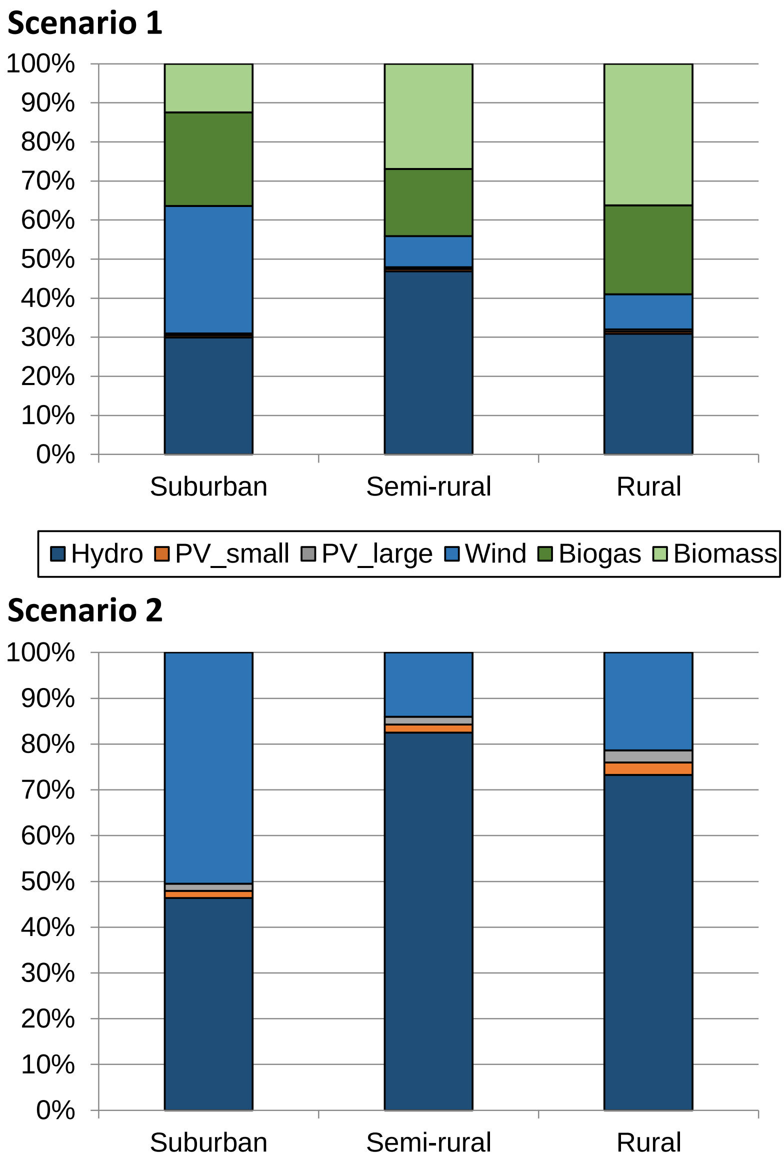

Figure 3: 100% RES-E scenarios in CEM regions. Scenario 1: RES-E mix including biogas, biomass. Scenario 2: RES-E mix of hydro, PV and wind.

3. Results

In this section, we investigate two questions: (i) What are the consequences of 100% RES-E in the CEM regions for the public budget and electricity generation costs? (ii) What are the economy-wide (net) benefits or costs of RES-E self-sufficiency in the CEM regions?

3.1. 100% RES-E in CEM regions: policy costs & and electricity generation costs

The support for RES-E expansion in Austria differs substantially across generation technologies (Table 1, two most right columns). The highest feed-in tariffs are granted to biogas, solid biomass and wind, with subsidies being almost as high as the LCOE for biogas (99%), and almost half of LCOE for solid biomass (47%) and wind (43%). Feed-in tariffs for small scale and large scale roof-top PV correspond to 25 and 30% of LCOE and subsidies for small scale hydro correspond to 13% of LCOE.

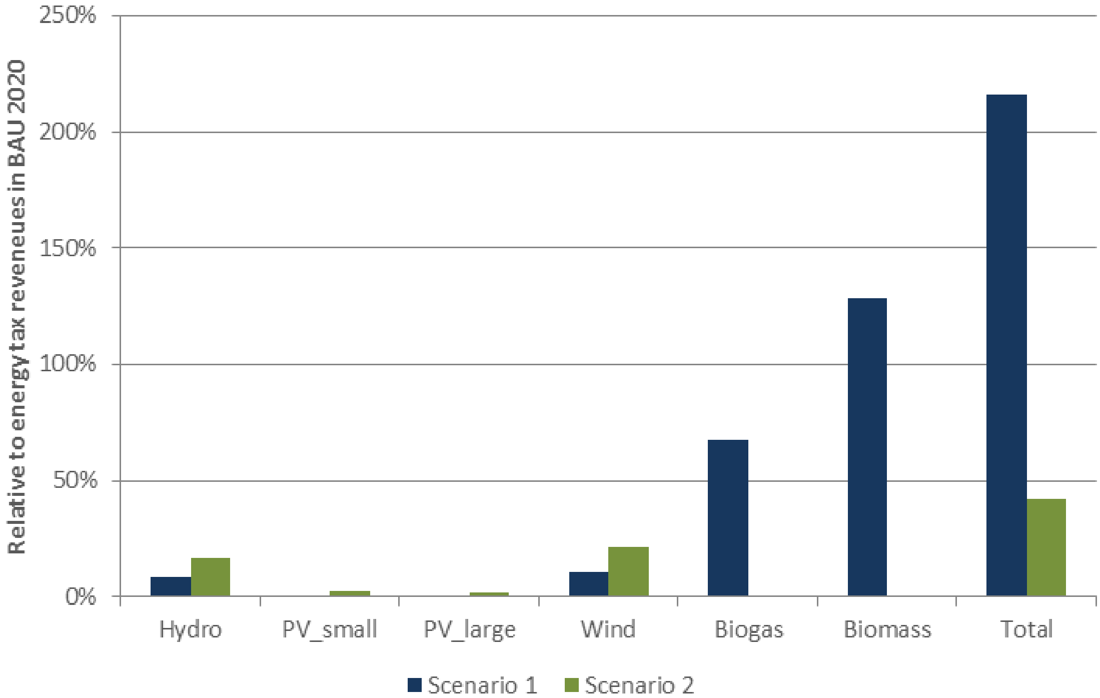

Figure 4: Required subsidies by type of technology and scenario, relative to electricity output tax revenues in the Baseline (2011 generation mix)

Figure 4 illustrates that this RES support leads to considerable expenditures for the public budget, particularly in scenario 1 that is characterized by a strong focus on biogas and biomass. While electricity generation and distribution leads to net tax revenues in the Baseline scenario, in which the base year (2011) electricity mix is employed, additional expenditures on feed-in tariffs (for each technology set at the respective level presented in Table 1) for RES-E expansion in scenario 1 are more than twice as high as these tax revenues from electricity generation and distribution in the Baseline. In scenario 1, electricity generation and distribution therefore do not generate a net revenue, but a net expenditure, for the public budget (of approximately equal size as tax revenues from electricity generation and distribution in the Baseline scenario). In scenario 2, which focuses on wind, PV, and hydro, expenditures on feed-in tariffs correspond to 42% of tax revenues from electricity generation and distribution in the Baseline scenario, thus the net contribution from electricity to the public budget remains a revenue (approximately half of the size as in the Baseline scenario).

Taking the generation costs by technology (after accounting for producer subsidies) and considering generation mixes by region, we find that the resulting composite electricity generation costs differ by region (Figure 5). Two factors determine whether the regional composite electricity generation costs increase or decrease in the different model regions: (i) the generation mix for the different CEM regions and (ii) whether the technology specific LCOE are above or below the reference technology (gas-fired power). In scenario 1, the rural and the semi-rural CEM regions have a comparatively larger share of biogas and biomass than the sub-urban region which has a comparatively larger share of wind (Figure 3). Since the LCOE of biogas and biomass are twice as high as the LCOE of the reference technology but the LCOE of wind is slightly below the LCOE of the reference technology (Table 1), the regional electricity generation costs increase in the rural CEM region but decline in the suburban and semi-rural CEM region. In comparison to scenario 1, scenario 2 does not include biomass and biogas but has a larger share of wind and PV and in particular of small-scale hydro. Since LCOE of small scale hydro are below the costs of the reference technology, regional composite electricity generation costs decline in all CEM regions.

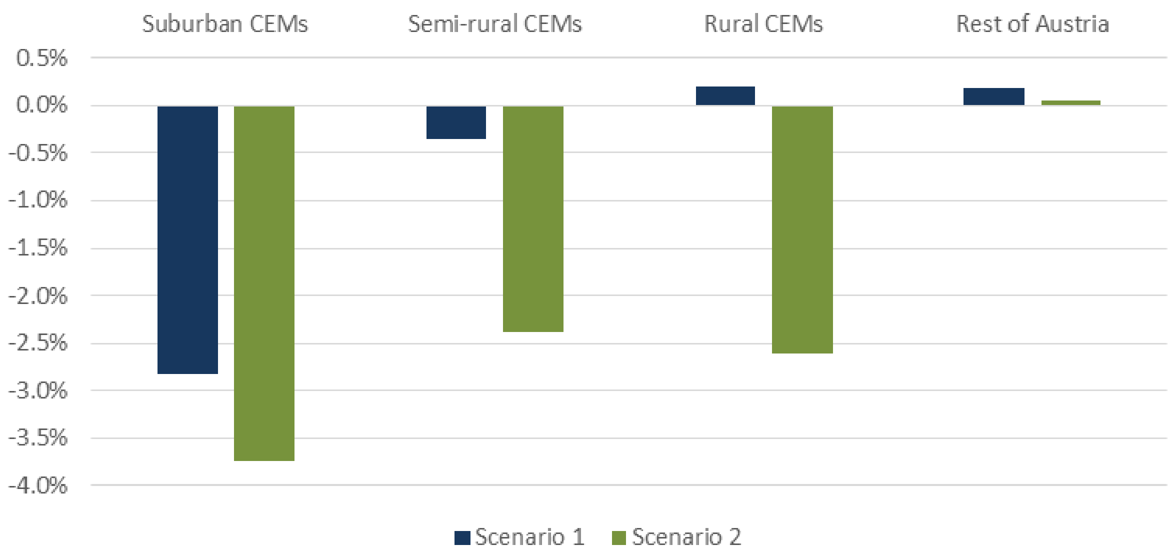

Figure 5: Composite electricity generation costs (after accounting for producer subsidies) across the four model regions relative to Baseline

3.2. The economy-wide costs and benefits of 100% RES-E in CEM regions

In scenario 1, the only benefiting sector is agriculture, output declines not only in the mining and gas manufacturing and distribution (MD_GAS) but also in energy intensive sectors such as construction (CO_WAT), energy intensive and other manufacturing (MANU_C; MANU_E), transport, and the service sectors (FIN_TD). Aggregate output therefore declines by 0.14% (Figure 6).

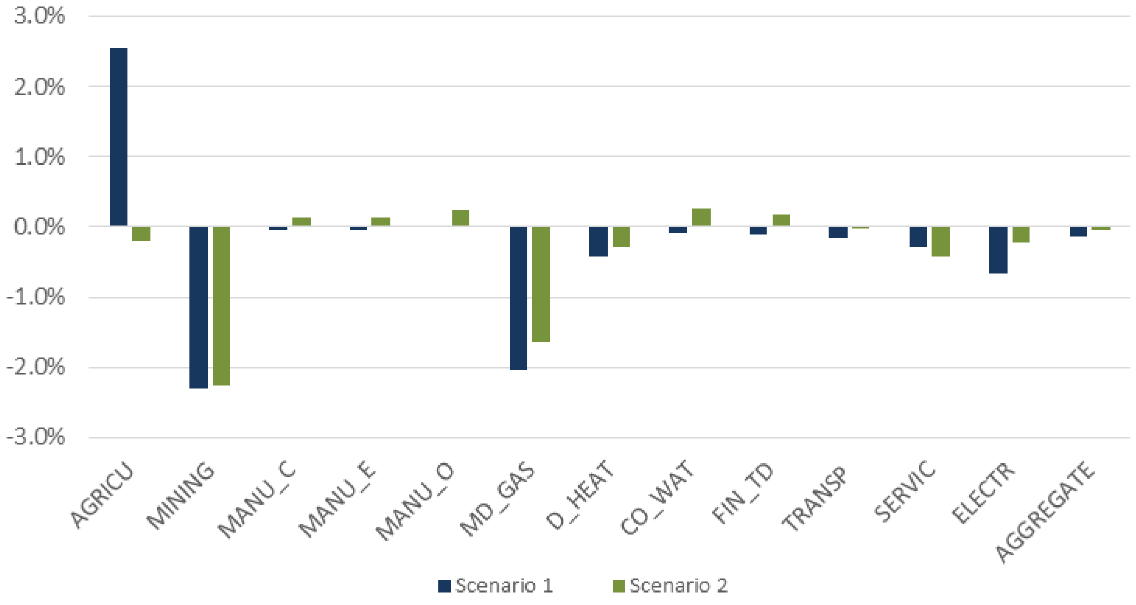

Figure 6: Sectoral and aggregate output effects at the Austrian scale relative to Baseline. Note: AGRICU… Agriculture, forestry, and fishing; MINING… Mining and quarrying; MANU_C… Manufacturing of coke products; MANU_E… Energy intensive manufacturing; MANU-O… Other manufacturing; CO-WAT… Construction and water supply; FIN-TD… Financial, insurance, real estate, and trade activities; TRANSP… Transportation and storage; SERVIC… Other service sectors; ELECTR…Electricity

Due to negative effects on aggregate output in Scenario 1, government revenues decline by 0.5% relative to the Baseline. To balance public expenditures with costs, the government is therefore forced to cut other expenditures. One the one hand, this relocation of public expenditures to less labor-intensive electricity generation sectors (compared to public service sectors), reinforces the decline in government revenues. On the other hand, reduced public transfers lead to negative consequences for household disposable income. Moreover, the consumer electricity price[2] increases by 10% and further reduces households' purchasing power. In total, welfare (measured in terms of consumption possibilities) therefore decreases in the rural and semi-rural CEM regions (Figure 7). In the suburban CEM region, however, welfare increases because of a comparatively higher capital income share which counteracts the negative impacts of higher electricity prices. Also, the expenditure for electricity is lower in the suburban CEM than in the two other CEM regions. The welfare effect in the Rest of Austria remains negligible. Overall, welfare gains and welfare losses balance each other across the four model regions.

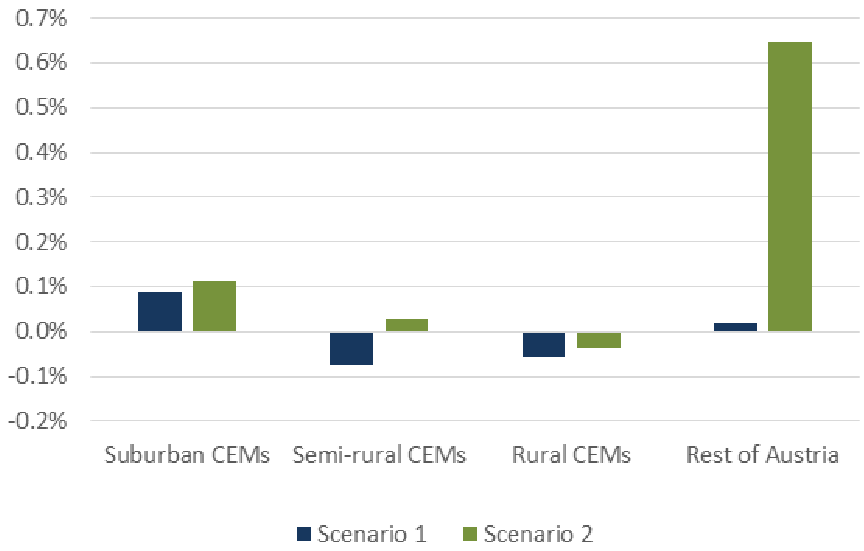

Figure 7: Welfare effects across the four model regions relative to Baseline

In Scenario 2, when taking all model regions together, welfare increases by 0.5%. This result is driven by considerably lower expenditures in RES support, declining electricity prices (by -0.38%), and positive output effects for energy intensive sectors (MANU_C; MANU_E) and other manufacturing sectors (MANU_O), construction water supply (CO_WAT), and the service sectors (FIN_TD; Financial, insurance, real estate, and trade activities) (Figure 6). This leads to an overall positive effect on GDP and therefore government expenditures increase by 0.07%. When comparing across model regions, we find that both the suburban cluster and the Rest of Austria experience significant welfare gains, the semi-rural CEM experiences a slight welfare gain (in contrast to the welfare loss in scenario 1) and also the welfare loss for the rural CEM is smaller than in scenario 1.

[2] While electricity generation costs differ by region, there is a nation-wide electricity market (see Figure 2). Therefore, the electricity price is uniform across all four model regions.

The differences in results across regions is again driven, as explained above, by varying shares of capital and labor income as well as the share of electricity expenditures in total household expenditures.

4. Discussion, conclusions and policy implications

Previous research was mainly assessing the consequences of RES expansion for regional development at the local and sub-national scale. The economy-wide effects, taking into consideration macroeconomic spillovers across economic sectors, governance levels and the private and public sector, have received relatively little attention so far. We address this research gap by assessing effects not only for regional economic development but also by taking account of macroeconomic feedback effects from and to the national economy. Taking into consideration these feedbacks from the national economy, both via linkages to upstream and downstream sectors (crowding out effects) and via policy costs of support schemes such as feed-in tariffs, we find that even though certain economic sectors and sub-national regions may benefit, aggregate output and welfare effects may point into a different direction. If regional energy autarky is achieved by a substantial support of national scale policies, such as feed-in tariffs for bioenergy in Austria, the net benefit of regional energy autarky could turn negative at the national scale because these support policies have to be financed out of the tax system. It is important to note that in our macroeconomic modeling we focus on annualized long term effects of RES-E deployment and do not only, in contrast to partial and short term economic assessments, focus on the short-term effects during the investment phase. Our results indicate that the mix of RES-E technologies is the most crucial determinant of whether achieving high shares of RES-E at the sub-national region eventually leads to economy-wide (net) benefits or costs. More precisely, we find that whether the net economic effects are positive or negative depends on three factors: (i) renewable electricity potentials, differentiated by technology and region, because different technologies affect different sectors; (ii) competitiveness of renewable technologies relative to each other and to the current generation mix; and (iii) support scheme in place which translates into policy costs. These insights from have strong implications for energy policy in Austria and beyond

National support schemes, such as feed-in tariffs, play an important role in fostering RES-E deployment at the regional scale. In order to ensure macroeconomic efficiency, subsidies have to be set at the right level for specific technologies. Relatively high subsidies for otherwise not cost-competitive technologies (e.g. biogas or biomass in the case of Austria) will lead to higher electricity generation prices, higher direct and indirect costs for the average consumer and reduced government income. If energy policy instruments, such as feed-in tariffs, are designed based on the goal to eventually foster regional economic development in certain sub-national areas and/or individual economic sectors, this could come at net-costs at the national level. Our results highlight the need for aligning policies supporting RES-E deployment with those supporting regional development. Policy makers should therefore address the question of who should eventually benefit from an energy transition at sub-national level (such as the CEM regions in Austria): the agriculture sector in economically and structurally weak regions or the national economy as a whole? In addition, the public perception survey in two case study CEM regions has shown that citizens actually prefer those technologies that require low public subsidies and have become cost competitive with conventional fossil fuel based technologies by now.

It is important to note that those RES-E technologies we identified as being cost-competitive today, have required higher financial support in their initial phases of deployment to foster technological progress via learning-by-doing. This calls for an iterative adjustment of RES-E support schemes linked to the cost competitiveness trajectories of specific technologies. The design of technology support schemes should be flexible enough to allow for dynamic updates over time. In doing so, unforeseeable technological breakthroughs leading to substantial cost decreases (for instance in the case of PV) or changes in fuel costs (for instance biomass) can be tackled, as also recently recognized by the European Commission Guidance for the Design of Renewable Support Schemes (European Commission 2013). For Austria, an energy and climate strategy is currently under development (BMWFW and BMLFUW 2016). It remains to be seen whether there will be also a change from the currently predominant feed-in tariff system to instruments, for which lower policy costs are expected.

One such alternative support instrument that is currently being introduced in some countries are RES-E auctions (also known as competitive bidding or tenders). One of the countries that are now transitioning to a support system for renewable energy based on auctions is Germany (IRENA 2017). The potential strengths of auctions are that they allow the government to better control the amount of new installed capacity and that competitive bidding in the right setting may push down costs for supporting RES-E (IRENA and CEM 2015). Despite the potential to reduce policy costs, the recent move in Germany towards RES-E auctioning also led to a heavily polarized debate (Amelang, et al. 2016). The most prominent concerns comprise that an auctions system will disadvantage and decrease private citizens' initiatives to invest in RES-E, will lead to an overly slow installation of new RES-E capacity and may not lead to cost-effective outcomes. In addition, policy makers have to be aware of new risks and uncertainties the transition to an auctioning system might impose on potential investors. While under a feed-in tariff scheme RES-E investments could have been considered a rather safe investment, auctions now increase the complexity of the investment process and require resources and time that could become sunk costs if the bid is not successful. An auctions support scheme could also have distributional consequences with a bias towards large scale institutional investors, since they generally have more resources available to handle the bureaucratic requirements and are less sensitive to losing on one single bid. To circumvent the potential systemic disadvantage of small scale investors, countries could include exemption clauses for specific investor groups in their RES-E legislations. Germany, for example, granted citizens energy cooperatives that win in the auction, to be paid the highest winning bid, regardless of their actual bid; all other winning actors are paid their submitted bid only (Appunn 2016; EEG 2017).

In addition to regional economic development, a key objective of CEM managers is to ensure that deployment of RES happens in accordance with expectations of inhabitants of CEM region. These expectations are expressed in terms of public support. If previously people perceived infrastructure projects as drivers for economic development, nowadays inhabitants want to participate in decision-making processes that affect their community. If an infrastructure project is facing public opposition, protests from inhabitants can delay realization of such a project for several years or even lead to its cancellation. The results of a large scale survey (N=1600) we conducted in addition to the macroeconomic modeling in two rural Austrian CEM regions show that inhabitants have a particularly positive attitude towards "new" RES-E technologies, compared to lower levels of public support for biomass and biogas technologies (see Komendantova and Neumueller (under review) and the Annex A3 for further details on the methodology and results of the survey). This empirical insights regarding the public acceptance of RES-E, even though not representative for the whole of Austria, tend to underpin our macroeconomic results.

In summary, our results indicate that large-scale RES-E deployment is not only environmentally effective in terms of reducing GHG emissions from fossil fuel combustion, but can also become macro-economically efficient in the longer term if the focus of RES-E strategies is on economically competitive technologies. In particular, our analysis illustrates that policy costs are much lower for solar photovoltaics, small-scale hydro and wind than they are for biomass and biogas, leading to net welfare gain on the national scale if these "new" renewables are used for RES-E generation. The positive macroeconomic effects could potentially be even larger if a level playing field with conventional fossil fuel based technologies can be achieved, e.g. by internalizing external costs with a CO_2 tax. An assessment of the macroeconomic effects associated with the introduction of a CO_2 tax in addition to a feed-in tariff scheme constitutes a fruitful topic for future research. It is therefore important that national RES-E support policies as well as other climate and energy policies are aligned with regional energy initiatives, and provide the right incentives to achieve regional energy autarky at least costs. Otherwise, costly RES-E support measures might – even though they promote the economic performance of the agricultural sector in certain sub-national regions – limit the macroeconomic feasibility of ambitious RES-E implementation targets and eventually even slow down the important low-carbon energy transition. Public acceptance, which tends to be higher for some "new" RES-E technologies than for traditional bioenergy, might be a leverage to steer regional energy transition in the right direction. Our assessment provides valuable insights for the Austrian CEM program, in particular to carefully select the proposed technology targets in the implementation plans. The insights are, however, also of great value for other countries that aim at combining bottom-up initiatives at the local level with top-down policies and are therefore confronted with similar policy overlaps and multi-level governance challenges.

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Annex

A1. Cluster analysis

The variables used for the cluster analysis are listed in Table A1. The cluster analysis relies on standardized values, so that variables with different ranges are treated equally.

The cluster analysis is based on the hierarchical Ward method using squared Euclidean distances, which are minimized between the CEMs in one cluster. The average values of the Ward clusters are then taken to perform a K-means cluster analysis based on the existing cluster mean values, and assigns all CEMs to the clusters by comparing the variables of CEMs with the respective mean values. The results of the cluster analysis are summarized in Table S1.

Table A1: Results cluster analysis

	Suburban	Semi-rural	Rural
	Average values		
Population density (inhabitants/ha)	5.2	0.8	0.7
Gross value added per capita (€/capita)	51,062	25,103	21,493
Employees in primary sector (%)	1.8	6.8	12.8
Employees in secondary sector (%)	19.7	30.3	29.6
Employees in tertiary sector (%)	78.4	62.9	57.7
Energy consumption (MWh/capita)	36.0	28.6	30.4
Potential electricity self-sufficiency (%)	77.6	128.3	125.3
Potential heat self-sufficiency (%)	29.4	48.7	83.5
	Sum		
Number of CEMs	6	37	35
Total population	239,531	909,308	920,262
Total gross value added (million €)	11,209	23,339	21,397

Data sources: Stanzer et al. (2010), Statistics Austria (2013, 2014a, 2014b, 2015a, 2015b), STATcube (2015), CEM implementation concepts (available at Climate and Energy Fund 2019).

A2. The CGE model

The eight electricity sub-sectors (1a-1h in Table A2), which produce subject to CES production functions, are “regional electricity transmission, distribution, and trade” (1a) and generation of electricity from different sources (1b-1h). In all model regions “electricity transmission, distribution, and trade” is combined with “production of electricity – conventional mix” by a Leontief production function. In the three CEM cluster model regions “electricity transmission, distribution, and trade” is additionally combined with a composite of electricity production technologies from different sources, including the conventional mix and RES-E technologies, via a Leontief production function. After aggregating the production of sector 1a-1h to a single regional electricity good, we finally end up with twelve regional production sectors, which are provided to the national market (1-12). The twelve regional production sectors, produced in every model region, are used as inputs in the national production and are combined in a Cobb-Douglas production function to twelve national production sectors, which provides a single national consumer price for each good.

For the four sub-national SAMs it is assumed that for each model region the production technologies of a certain economic sector (1-12 and 1a-1h), including intermediate inputs, factor inputs, subsidies, and taxes, are equal to the technologies of the national SAM of Austria. This means that production inputs of a certain sector are equal in the four sub-national SAMs, while the absolute values of production differ in accordance to their respective shares of gross value added.

The government income of a certain model region is obtained by the regions sum of all taxes. While the government and investments are modeled on national level within the CGE model, the demand of the government, taxes payed by the government, demand for investments, and the taxes for investments are nevertheless regionalized by the share of gross value added of a model region in a certain sector to achieve balanced regional SAMs. Additionally, the gross value added is used to calculate the capital endowment of a certain model region, as we assume that capital used for production is provided by the representative private household of each model region. Therefore, the capital endowment equals the capital inputs of production for each region. Labor endowment is broken-down to the sub-national level by the model region’s shares of Austria’s employed persons obtained by census data (Statistics Austria 2013b).

Table A2: Sectors of the subnational CGE model

No.	Activity / industry	Model code
	Regional electricity production	
1	Electricity	ELECTR
1a	Electricity transmission, distribution, and trade	EL_TDT
1b	Generation of electricity – conventional mix	EL_CON
1c	Generation of electricity by small scale hydro	EL_HYD
1d	Generation of electricity by large scale PV	EL_PVL
1e	Generation of electricity by small scale PV	EL_PVS
1f	Generation of electricity by wind power	EL_WIN
1g	Generation of electricity by biogas	EL_BGS
1h	Generation of electricity by biomass	EL_BMS
	Regional non-electricity production	
2	Manufacture and distribution of gas	MD_GAS
3	District heating	D_HEAT
4	Agriculture, forestry, and fishing	AGRICU
5	Mining and quarrying	MINING
6	Coke manufacturing	MANU_C
7	Energy intensive manufacturing	MANU_E
8	Other manufacturing	MANU_O
9	Construction and water supply	CO_WAT
10	Financial, insurance, real estate, and trade activities	FIN_TD
11	Transportation and storage	TRANSP
12	Other service activities	SERVIC

A3. Qualitative survey on perception of renewable energy technologies in two CEM regions

Background and methodology

The large-scale survey was conducted in the period from September 2016 to February 2017. The survey was conducted in two case study CEM regions, Amstetten and Freistadt. Both regions fall into the rural CEM cluster. Freistadt is a rural, agriculturally dominated region with 27 communes and 65.000 inhabitants and 42% of wooden area. Freistadt became part of the CEM program in 2010 and in 2012 Helios Sonnestrom GmbH, a solar power plant in crowdfunding, was established. Amstetten has 58.320 inhabitants and is also known for its high potentials for biomass production.

The reason for selecting these regions is that they have similar socio-economic characteristics, however different engagement of inhabitants. In Freistadt, several awareness raising initiatives were conducted for different groups of inhabitants. Moreover, so-called energy groups allowed interested inhabitants to decide jointly about distribution of financial support to different kinds of RES projects. Finally, inhabitants could financially participate in RES projects and companies, such as Helios GmbH. Amstetten, on the other hand, had a much weaker focus on awareness raising measures and measures facilitating engagement into decision-making processes.

The goal of the survey was to evaluate patterns of public acceptance among inhabitants of the two case study regions, regarding which kinds of RES technologies people are supporting mostly or if they are willing to use RES in their households. The first part of the survey was on attitudes towards different kinds of RES, asking for instance, "what is your opinion about solar, wind, biomass etc.?" Answers were given on a 5-point Likert scale ranging from "very negative" to "very positive", with "don't know" as an additional alternative. Another question was to indicate the share of RES which inhabitants are willing to use in their households. They could select between "no use at all" and then going up to "more than 75%".

Altogether 800 people participated in the survey in the two regions. Respondents were approached by local mass media questionnaires, through web survey and personally when a team of interviewers filled the questionnaires. The sampling was developed to ensure representability of different socioeconomic characteristics in the population (age, gender, education, household size).

Results

The survey showed that, in general, renewable energy sources enjoy high levels of support among inhabitants of the two case study CEM regions Freistadt (Figure A1) and Amstetten (Figure A2).

Over 60% of respondents support deployment of renewable energy sources and more than 70% completely reject nuclear energy as potential energy source. Amongst different RES-E technologies, solar energy is the most popular energy source, which is supported by respondents in both regions. Over 60% of all respondents in Freistadt and in Amstetten have in general a very positive attitude towards solar power.

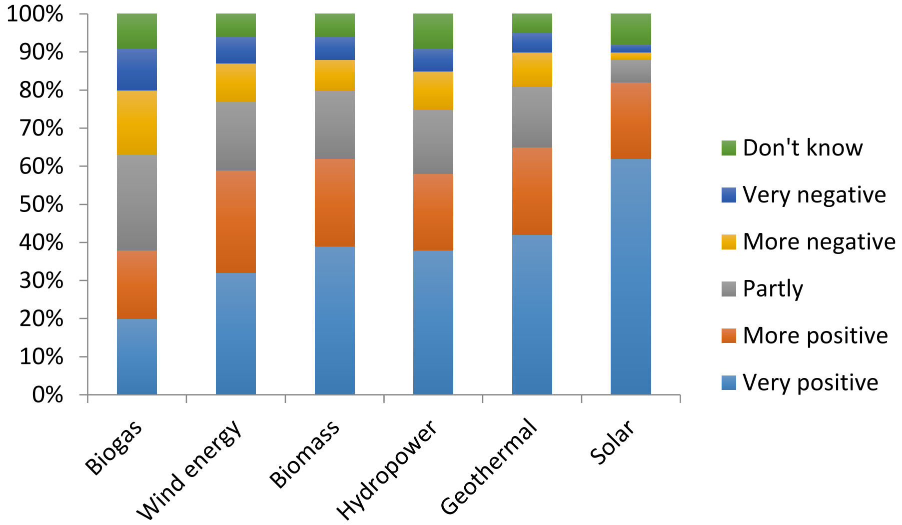

Figure A1: Support for renewable energy sources in Freistadt

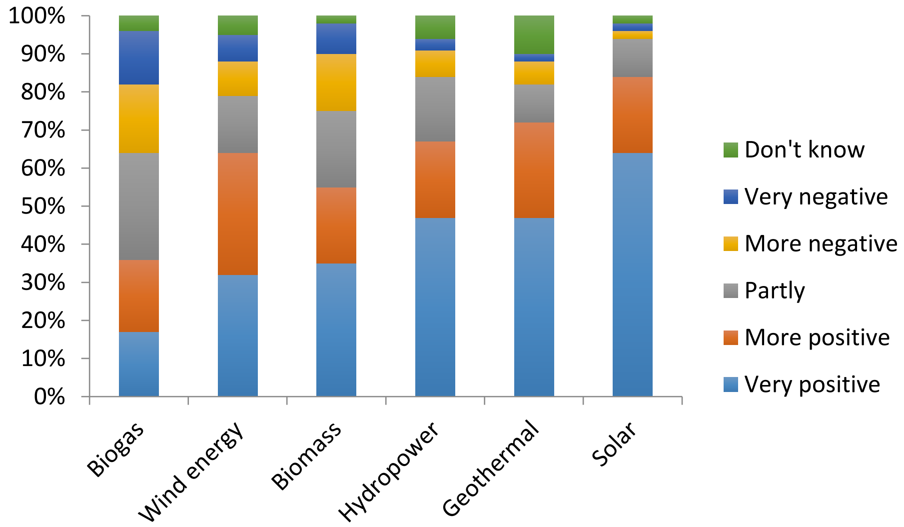

Figure A2: Support for renewable energy sources in Amstetten

The second most popular source of energy in both regions is geothermal, followed by biomass and wind energy. Biogas is the least popular source of energy, with less than 20% of inhabitants in Freistadt and Amstetten having a very positive attitude towards it. The share of inhabitants having a very negative attitude towards biogas is more than 14% in Amstetten and more than 10% in Freistadt. At the same time only 4% in both regions have a very negative attitude towards solar energy. When respondents were asked to explain their negative attitude towards certain types of renewable energy sources they mentioned visibility impacts, noise, smell, and health and safety issues. Also according to these variables biogas had the lowest level of support.

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