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Measuring Regional Economic Value-Added of Renewable Energy: The Case of Germany

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Abstract

Continued high investment into renewable energy sources are changing the global energy industry, leading to a rapidly growing global share of renewable energy in regard to installed capacity for energy generation, energy production and consumption. While climate protection and safety are important goals, promoters of renewable energy also aim for the decentralization of the energy system and for positive economic effects in respect to regional development. Yet, the measurement, assessment and projection of possible economic effects by renewable energy for regional development face various empirical and methodological obstacles. This paper introduces the methodology for regional economic value-added modeling by three German research institutions which apply value chain analysis to the renewable energy industry. A comprehensive, comparative analysis highlights a high level of consistency and validity of their results for the German economy and illustrates how municipalities, local planners and politicians can apply regional value-added analysis to device strategies for regional economic development. It concludes by highlighting the importance of the local value chain structure and local ownership for regional economic development based on renewable energy.

Keywords

Renewable Energy, Value Chain Analysis, Value-Added Modeling, Regional Development, German Energy Transition

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1. Introduction

Since the beginning of the 21st century, renewable energy sources such as solar power, wind power, hydro power, geo-thermal power or biomass have grown into a major force that is changing the global energy industry. Since 2004, annual global investment into renewable energy sources expanded from $40 billion to more than $200 billion in 2010-2012, far exceeding the net investment into traditional energy sources such as fossil fuels or nuclear power (REN21 Status Report, 2013, pp. 56-63). This trend is expected to continue with annual investment reaching $400-500 billion between 2020 and 2025 (REN21 Future Report, 2013). Renewable energy (including hydro power) already accounts for 19% of total global energy consumption for electricity, heating/cooling and transportation; this share is expected to rise to 30-45% in 2050 (REN21 Future Report, 2013).

Among the highly industrialized countries, Germany is considered to be the pioneer and leader of the energy transition towards renewable energy. In 2013, renewable energy accounted for an estimated 12.3% of Germany's total energy consumption (electricity, heating and transportation) as compared to less than 3% in 1995 (BMWi, 2014). And in terms of Germany's gross electricity consumption, the share of renewable energy sources rose from about 5% in 1998 to 25.4% in 2013, 8.9% contributed by wind, 8% by biomass (incl. waste), 5% by solar energy and 3.5% by water power. With a total of 152.6 billion KWh produced in 2013, renewable energy has become Germany's second most important source of electricity after lignite and coal, contributing a significantly higher share than nuclear power (16% / 99.5 billion KWh) (AEE, 2014). Since 2000, the installed capacity for electricity generation by renewable energy has increased by more than six times from 12.3 Gigawatt to 77.1 Gigawatt in 2012 (BMWi, 2014). Between 2004 and 2011, a total amount of €109 billion have been invested into electricity generation by renewable energy sources, almost twice as much as the total investment by the conventional electric power industry which invested a mere €56 billion during the same period (AEE, 2014; BDEW, 2013). As a result, within a decade renewable energy sources have become an indispensable pillar of the energy system of the world's fourth largest economy.

Interestingly, the key forces behind the impressive growth of renewable energy in Germany are individual citizens, farmers and local municipalities, who are driving the fundamental change of Germany's energy landscape. According to Germany's Agency for Renewable Energies (AEE), almost half of the installed capacity for electricity generation by renewable energy sources in 2012 is owned by private individuals (35% by private households, 11% by farmers); private business unrelated to the energy industry accounts for another 14% and smaller utility firms (including those owned by municipalities, so-called "Stadtwerke") own 7% of the installed capacity, while only 5% has been invested by the top 4 large power utilities (AEE, 2014). Developers, contracting firms and financial institutions (banks, funds) hold a (growing) 25%-share of ownership. Further analysis reveals that about 1.5 million individual citizens and farmers, as well a growing number of municipality-controlled utility firms have been the key driving forces behind the rapid expansion of a largely decentralized system of renewable energy production (AEE, 2014).

Also local municipalities are actively investing into renewable energy. Since the deregulation and liberalization of the European energy market from 1998 onwards, municipality-owned utilities have steadily increased their share in energy production and distribution, and now account for about 10% of Germany's net electricity generation capacity (BDEW, 2013; VKU, 2014; Wuppertal Institut für Klima, Umwelt, und Energie, 2013, p. 4-7). As municipal-controlled utilities are setting aggressive goals for the expansion of renewable energy, this trend towards municipality-owned utilities is likely to further accelerate the energy transition in Germany.[1]

Above facts support the conclusion that ordinary citizens, farmers and municipalities are the driving forces behind Germany's energy transition. These actors also constitute a growing, solid and broad foundation for an emerging decentralized system of smaller-scale, regionally distributed power generation and distribution based on renewable energy technologies that increasingly undermines the economic foundations of the prevailing, highly concentrated system of large-scale power plants based on nuclear and fossil fuels.[2] Therefore, Germany's energy transition is likely to also have profound, long-term socio-economic impacts, leading to a shift in regard to the flow of capital, employment and the structure of the energy industry. In fact, these socio-economic characteristics of a decentralized energy system and the notion of "energy democracy" as a force for regional economic development have been a key political argument by longstanding promoters of renewable energy sources like the German politician Herman Scheer (Scheer, 2004). Increasingly, politicians and policymakers who promote renewable energy on regional and municipality level not only point to their benefits in regard to meeting climate protection goals, but argue that renewable energy contributes to strengthening and developing the local economy as well as regional social infrastructure, because energy-related resources stay within the community and are employed to generate new employment, local business creation, and local economic value (Hoppenbrook/Albrecht, 2009, pp. 11-19).

However, while the conceptual ideas to foster sustainable, regional economic development by the promotion of a decentralized energy system based on renewable energy sources may sound convincing, fundamental questions remain about the exact definition, measurement, and assessment of possible economic effects of renewable energy sources for the local economy. What are meaningful and measurable criteria? What are the essential premises and key parameters for modeling these effects? What are the required type, quality and sources of data? And how should a robust as well as practical model be constructed in order to be applied for the formulation of meaningful policy targets, effective policies and specific measures? The following section discusses three approaches by three German research institutions to measure and assess the regional economic effects of renewable energy sources.

2. The value chain approach: Measuring regional value-added by renewable energy

2.1. Value-added of renewable energy: Overview on three models from Germany

Political, economic and regional study science have established various methods and tools to define, measure and assess the economic impact of a given policy or project on the development of regional economies, such as economic base models, input-output analysis, social accounting matrix, integrated econometric/input-output or computable general equilibrium models (Loveridge, 2004; Breitschopf/Nathani/Resch, 2011). However, empirical studies on the effects of renewable energies for regional economic development are rather limited in scope, such as regional project studies or case studies of selected renewable energy technologies (Allen/McGregor/Swales, 2011; Klagge/Brocke, 2011).

In three different models German researchers from the fields of economics, material management and environmental policy are proposing a new approach that builds on value-chain analysis, and attempts to comprehensively measure and evaluate the economic value-added generated by renewable energies in a given region (Hirschl et al., 2010; Kosfeld/Gückelhorn, 2012; BMVBS, 2011; IfaS, 2013). The three models discussed in this paper have been developed by the Institute for Ecological Economy Research (IÖW), The Institute of Economics at the University of Kassel, and the Institute for Applied Material Flow Management (IfaS) at Trier University.

Value-added is a well established concept in economic theory that refers to the transformation of materials, goods or services as inputs into goods and services with higher monetary value. It, therefore, captures the monetary value of an economic activity as the difference between the value of the produced output and the value of the external factor inputs required to conduct this activity (Samuelson/Nordhaus, 2010). National accounts of an economy measure the value-added either from the perspective of value generation (= output value minus cost of input factors), or from the perspective of income distribution; the later approach refers to how the value-added is distributed as income to the individual providers of factor inputs ("stakeholders") such as labor, capital, land, or public services.

Value chain analysis, rooted in industrial organization theory and first conceptualized by Michael Porter, interprets a firm as a flow of economic activities that transform inputs and information into higher-value output (Porter, 1985). In doing so, it disaggregates a company into various interlocked activities that are the source of a firm's competitive advantage and together form a value creating system which creates customer benefits. The design of a firm's value chain reflects fundamental strategic choices in terms of the horizontal depth and vertical scope of its economic activities. As a whole, it determines the firm's positioning within an industry's comprehensive value system. While differing in various details, the three models apply two common "building blocks":

① the construction of detailed value chains for individual renewable energy technologies based on technology-specific cost structures

② the calculation of technology-specific, regional value-added based on the projection of personal income generation, business profit and regional tax income

In the following, each building block of the models is explained in detail and further illustrated by describing the model by the Institute for Ecological Economy Research (IÖW).

2.2. Value chain design for renewable energy: Technology-specific cost structures

The structure of the value system in the renewable energy industry expands along several dimensions (Hoppenbrook/Albrecht, 2009, pp. 21-22): Horizontally, the value-creating process related to the generation, transmission and distribution of renewable energy includes activities such as land and site management, plant operation, energy storage and transmission, sales and marketing, as well as various services related to energy consumption and customer support; vertically, the operation of a renewable energy plant across its life cycle involves value-creating activities such as installation, maintenance as well as repowering or decommissioning. Both, horizontal- as well as vertical-oriented value-creating processes may be tightly linked and often require further supporting activities such as projecting, planning, financing, tax and legal advice, or other professional services. Furthermore, the diverse activities related to the production of plant equipment, parts, materials and software themselves constitute a comprehensive value-creating system.

The structure of the value-creation system in each of three models differs in terms of scope and level of detail, but in general they distinguish four aggregated stages in the value-system of renewable energy: ① direct investment (e.g. production of plant equipment including trading), ② investment-related support (e.g. project planning, installation and assembly), ③ plant operation (e.g. land and site management, maintenance, utilities, support services such as financing, insurance, tax and legal advice, administration, repowering and decommissioning), and ④ commercial management (e.g. management services by the plant owners). The activities related to the investment stage have one-time effects of value creation, while activities related to the plant operation and commercial management generate continuous value over the life-time of a plant. The IÖW study covers 16 different renewable energy technologies, the IfaS study 20, and the study by Kassel University 9. While Kassel University only refers to technologies for electricity generation, IÖW and IfaS also include heat generation and transportation.

The base for value-added calculation is a comprehensive analysis of the cost structures of each individual step in the overall value chain of a specific renewable energy technology (e.g. 350kW small-scale water power plant) to which specific cost values are attached. The specific cost values for each value step have been estimated and validated based on extensive screening of technology-specific research studies, the analysis of investment prospects of renewable energy funds, the analysis of technology-specific reference cases, as well as expert interviews. Data sources for all three studies usually range between the years 2007 and 2010. In order to compare value-added structures of different technologies, these cost values are standardized as Euro per unit of output (kW) (Hirschl et al., 2010, pp. 27-38; BMVBS, 2011, pp. 27-37; IfaS, 2013, pp. 20-52)

Despite the fact that the three studies refer to different types of technologies and apply various different data sources for their estimation of technology-specific cost structures, a comparative analysis of the derived values as well as the applied calculation schemes reveals a remarkable consistency of the resulting values for technology-specific investment, operating cost, revenue and profit levels (Table 1). The high level of consistency of the derived values despite the differing methodological approaches in the underlying models indicates that the models are robust and provide a robust and valid data structure

Table 1 Comparative Analysis of Technology-specific Cost and Revenue Structures by IÖW, Kassel University and IfaS

Renewable Energy Technology		IÖW				Kassel				IfaS	
	Solar	invest (€/kW)	operating cost (as % of invest)	revenue (€/kW)	profit b. tax (€/kW)	invest (€/kW)	operating cost (as % of invest)	revenue (€/kW)	profit b. tax (€/kW)	invest (€/kW)	operating cost (as % of invest)
electric power generation	roof <10kW					3,484	2.3%	374-402	57-84	3,000	1.5%
	roof 10-30kW	3,277	1.5%	344	133						
	roof 30-100kW										
	roof 100-1000KW	3,008	1.5%	287	105	3,508	2.0%	361-387	41-67		
	land (>1000kW)	2,869	1.5%	336	66	3,195	2.0%	296-317			
	Wind (onshore)										
	<500KW					1,040	3.7%	134-165	22-51		
	2000KW	1,246	4.8% - 6.6%	181	37	1,300	4.2%	165-201	26-53	1,309	4.8% - 6%
	Water										
	10-30KW					4,200	5.1%	584	174	9,000	3.1%
	300KW	5,500	2.3%	634	88	3,068	5.7%	584	267	5,570	3.1%
	>2000KW									4,140	1.9%
	Biogas (co-generation)										
	50 - 150kWel					3,750	391	1,859	548	4,000	
	350-500kWel	3,099	13%	1,494	226	3,150	431	1,560	230	2,763	11%
	1000kWel	2,174	7%	1,244	196						
heat generation	**Biomass**										
	15KW (wood)	1,051	1.7%							950	3.1%
	60kW (wood)									550	12
	5000 - 20000kW (co-generation)	3,948	12%	1,009	105					2,000-3,000	10%
	Solar thermal										
	<20sqm	794 €/sqm	1.5%							1,000 €/sqm	1%
	>20sqm	545 €/sqm	1.5%								

Source: Own calculation and analysis based on data of Hirschl et al. (2010), pp. 39-180 (IÖW study), IfaS (2013), pp. 31-42, and BMVBS (2011), pp. 62-160; operating cost exclude depreciation and interest payments, as well as cost for substrates in case of biomass

for the projection and assessment of regional value-added of the different renewable energy sources.

2.3. Projection of the regional value-added of renewable energy

The three models estimate the value-added generated by a specific renewable energy technology from the perspective of value distribution to its stakeholders. However, the three models differ in regard to the exact definition and measurement of regional value-added as well as the scope of their value-added model. While the IÖW and IfaS cover all four stages of the industry value chain including production of equipment and components, the Kassel University model refers just to the operation and management stage. IÖW and IfaS define and measure regional value-added as the total sum of net personnel incomes for employees along all value-creation steps, after-tax profits for the plant owners and other business partners involved throughout the value creation process, as well as regional tax income. Kassel University refers to the value-added for the facility owner and operator as *direct* value-added and considers financial institutions that provide loans to the operator as a stakeholder; therefore, the interest payments for loans are fully included as a part of direct value-added, while the IÖW and IfaS only count the personal income and profits of financing activities as value-added. Furthermore, in contrast to the IÖW and IfaS models the Kassel University model considers the value creating effects from activities such as service and maintenance, utilities, tax and accounting services that support the facility operation as *indirect* value-added (BMVBS, 2011, pp. 27-38).[3] Due to their broader scope of the value chain, the IÖW and IfaS models also cover these indirect value-added effects, but apply a different scheme of calculation.

In order to derive technology-specific, regional value-added figures, the personal net income of employees, the after-tax profits of the plant owner and other business partners, as well as the regional tax income have to be estimated for each step along the value chain. However, in most cases the availability of robust project-specific data along all steps of the value chain for a selected renewable energy technology is limited. Therefore the models apply industry-specific statistical measures such as labor cost ratios or profit rates. For instance, the IÖW model provides an estimate for the personnel cost ratio, average personnel income per head, and the average profitability for each individual step in the value chain based on industry-specific, statistical data from the German Central Bank. The underlying assumption is that the planning, production and operation of renewable energy plants involves typical industries such as mechanical engineering, electric engineering, construction, insurance, banking, consulting and the like, who would not engage in services for renewable energy unless at least average returns can be achieved. Therefore, it is justified that industrial statistics on average, industry-specific employment, salaries, or profitability are applied at each step of the value chain as an estimate of employee income and industry profits. Again, the data are standardized as euro per unit of output (€/kW)

Based on the estimate of before-tax profits and gross personal incomes, the net personal income, after-tax firm profits as well as regional tax income can be derived by taking into account the characteristics of the national social security system, personal and corporate tax system, as well as the national system of government finance which determines the distribution of national, regional and local taxes.

To obtain the overall regional direct value-added for a unit of energy output (kW) of a specific renewable energy technology, the value-added data for each step in the technology-specific value chain are then aggregated across all stages of the respective value chain. Thereby, the annual as well as long-term potential for regional economic value generation

Table 2 Regional Value-Added by Type of Renewable Energy Technology (€/kW)

Type of Technology	IÖW	Kassel University
solar power (150kW roof)	120	113
solar power (>1MW free land)	86	74
wind power (2MW)	55	65

Source: own calculation based on data from Hirschl et al. (2010), pp. 49/80 (IÖW model) and BMVBS (2011), pp. 103/125 (Kassel University model), excluding regional value-added at investment stage and induced, multiplier effects

on investment and operating stage, its distribution in terms of net personnel income, net business profits as well as local tax income can be assessed and evaluated. For example, the IÖW results for the regional value-added of a small-scale water power plant (350kW) for the year 2009 imply a potential to generate a regional value-added of about €1.5 million over a period of 20 years, of which €100,000 are regional taxes. The data reveal that even without having the actual production of the plant equipment and components located in the region, the potential for regional added value amounts to €1.2 million, if the plant is built and operated by companies located in the region (Hirschl et al., 2010, p. 114).

Each of the three models is based on standardized values for regional value-added of a specific renewable energy technology. However, only the IÖW study has made detailed data for technology-specific value-added publicly available, thereby making a direct comparison of results for the three models and an assessment of their validity difficult.[4] Only in case of two reference technologies of solar power (150kW roof installation; 1MW field installation) and for a 2MW reference wind power installation the studies of IÖW and Kassel University provide a comparable data set which allows for a general comparison. The similarity of their results, summarized in Table 2, gives some indication that the models are robust, and generate valid and practically applicable data (Hirschl et al, 2010; BMVBS, 2011).[5] This, however, should not come as a surprise, because the underlying database of technology-specific cost and revenue structures has been shown to be very solid and robust.

The following section analyzes the creation of regional value-added in local economies by means of renewable energy technologies from various angles by referring to the respective results of the three studies.

3. Creation of regional economic value-added by renewable energy

3.1. Regional value-added of renewable energy in Germany: The IÖW study

The IÖW study analyzes the economic potential of renewable energy for the whole of Germany based on average data of the regional value-added for 16 specific renewable energy sources based on the year 2009. In a first step, it compares the average regional value-added by type of technology.

Comparison of regional value-added by type of technology

The comparison of the (average) regional value-added for different types of renewable energy technology reveals the potential for value creation by taking into account the actual amount of energy generated over time. For this purpose, the data for value-added that have been standardized by unit of installed capacity (€/kW) are computed into standardized values that show the average amount of generated energy over a certain period of time (€/kWh) in order to reflect the differences in the utilization rates between the different types of technology. For example, in Germany, for each kW of installed capacity, water power generates more energy over time (kWh) than solar, because of its higher utilization rate. For computation, estimates for the average hours of load (= average hours of operating time per year) of a given technology are provided. The IÖW study leads to interesting results for Germany in regard to the technology-specific potential for the

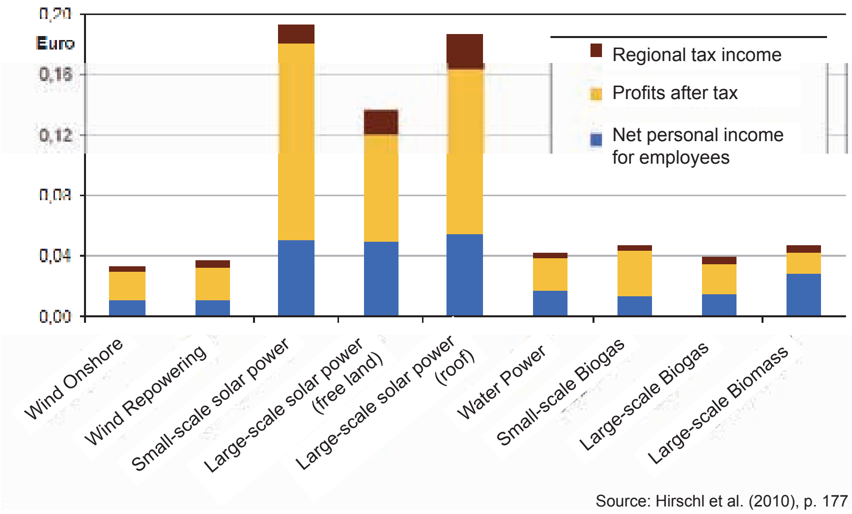

Chart 1: Comparing Regional Value Added by Type of Income based on generated power (€/kWh)

creation of regional value-added (Hirschl et al., 2010, p. 175 -180):

First, solar energy is the most expensive renewable energy technology due its comparatively high investment cost and comparatively low utilization rate (Chart 1). However, it creates substantially higher value-added for a community (14-19 ct/kWh) than, for instance, onshore wind power or biomass. Furthermore, across all technologies, profits for the owner of the installation account for the highest share of value-added, followed by personal income, while the share of local tax income is comparatively small.

Interestingly, across all technologies the value-added generated at the stage of equipment production accounts for only 10-20% of the overall value-added, while the highest value-added, mainly in form of profits, is generated by the commercial management of the facilities (Chart 2). This implies that although the equipment is not manufactured within the region, a substantial share of value-added stays in the region, as long as the facility is planned, installed, operated and owned by businesses and people from the region.

In terms of absolute values, solar power generates a comparatively high value-added also at the stage of planning/installation as well as the stage of technical operation. However, in terms of relative share, the stage of technical operation contributes to a comparatively high share of regional value-added for biomass, biogas, water power and wind power. This reflects the comparatively higher service intensity of these technologies.

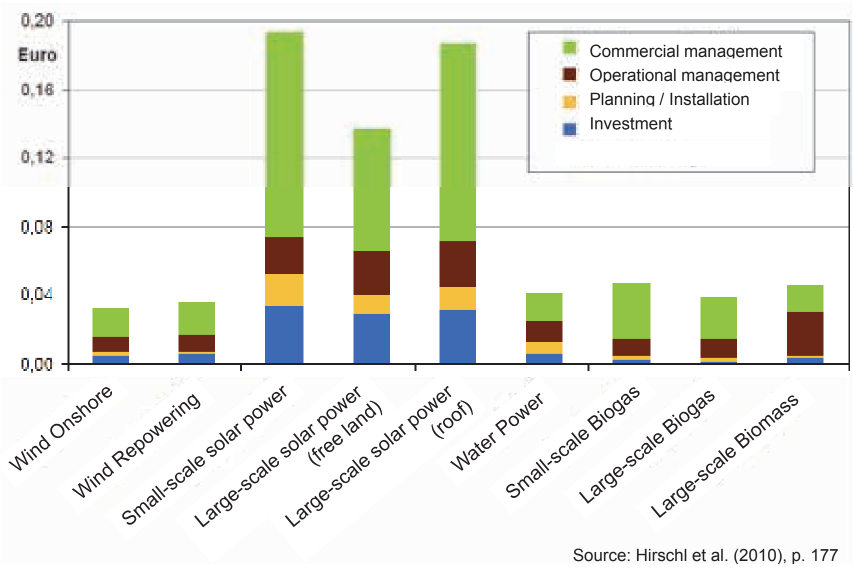

Chart 2 Comparing Regional Value Added by Type Value Adding Stage based on generated power (€/kWh)

Estimating present and future value-added by renewable energies for Germany

Furthermore, the IÖW study provides an estimate for the value-added of renewable energies and the creation of net employment for the whole of Germany in 2009, updated also for 2010 and 2011 (Hirschl et al., 2010, pp. 201-210; Hirschl/Aretz/Böther, 2010, pp. 9-11). The results are summarized in Table 3:

- The amount of regional value-added generated by renewable energies for the whole of Germany amounts to about €6.8 Billion in 2009, €10.5 Billion in 2010, and about €9 Billion in 2011.
- Solar and wind power account for about 70% of the overall regional value-added, while biomass and biogas as well as renewable energy sources for heat generation are less significant.
- About 50% of the regional value-added takes the form of personal income for employees working on the different stages of the value chains. The IÖW estimates that renewable energy directly provided full-time employment for about 116,000 people (Hirschl et al., 2010, p. 204).
- About 40% of the regional value-added is contributed by profits, indicating the

Table 3 Regional Value-Added for Germany (2009 ~ 2011)

Mil. €	2009		2010		2011	
Total Regional Value Added	6,785	100%	10,534	100%	8,948	100%
Stages						
investment	1,880	28%	3,506	33%	2,279	25%
planning/installation	1,214	18%	2,666	25%	1,553	17%
technical operation	1,399	21%	1,758	17%	1,996	22%
commercial management	2,248	33%	2,555	24%	3,072	34%
trade	44	1%	49	0%	48	1%
Distribution						
personal income	3,283	48%	5,887	56%	4,311	48%
profits	2,878	42%	3,743	36%	3,796	42%
regional tax income	624	9%	904	9%	841	9%
Energy Source						
solar	2,445	36%	5,764	55%	3,882	43%
wind	2,050	30%	2,241	21%	2,246	25%
biomass (electricity)	456	7%	501	5%	583	7%
biogas	557	8%	584	6%	673	8%
water	30	0%	129	1%	76	1%
heat pumps	253	4%	282	3%	305	3%
solar thermal	354	5%	224	2%	347	4%
biomass (heat)	81	1%	62	1%	91	1%
bio fuels	557	8%	747	7%	745	8%

Source: Hirschl et al. (2010) / Hirschl/Aretz./Böther (2010)

Table 4 Share of Regional Value Added by Renewable Energy in relation to Feed-In Tariff Payments and Total Investment

Operation stage (only electricity generation)	2009	2010	2011
Feed-in Tariff Payments (Mil. €)	10,780	13,182	16,735
Regional Value-added by technical operation & commercial management (Mil. €)	3,051	3,532	4,018
Regional share of direct value added on operating stage	***28%***	***27%***	***24%***
Investment stage (only electricity generation)	**2009**	**2010**	**2011**
Investment into renewable energies (Mil. €)	20,400	26,600	23,200
Regional Value-added at investment, planning & installation stage (Mil. €)	2,484	5,686	3,193
Regional share of direct value added on investment stage	***12%***	***21%***	***14%***

Source: own calculation based on data from BDEW (2014), pp. 40/41, AEE (website), Hirschl et al. (2010) / Hirschl/Aretz/Böther (2010)

importance of the structure and location of ownership. On the other hand, value-added in form of regional tax income is comparatively small, indicating that renewable energies contribution to regional government finances are rather limited, at least within the context of Germany's regional tax system.

In order to judge their significance, the results need to be related to the overall value-added potential that can be generated by renewable energies. For electricity generation, data can be obtained from Germany's feed-in tariff system and are summarized in Table 4:

For example, on the investment stage, between 12-21% of the total amount invested into renewable energies between 2009 and 2011 has remained in regional economies as value-added in form of personal income, profits and regional taxes. And 24-28% of the total feed-in tariff payments between 2009 and 2011 ended up as regional value-added generated by the technical operation and commercial management of renewable energy facilities.

While the value-added generated on investment and planning/installation stage naturally fluctuates, the value-added generated through the technical operation and commercial management has grown steadily. The share of regional value-added on the investment (=production) stage is less than one third of the total value-added, indicating the rather limited role of manufacturing for regional development.

The IÖW also provides a forecast for the regional value-added by renewable energy for Germany in 2020, based on two different scenarios for the projected installed capacity in 2020 (Hirschl et al., 2010, pp. 211-218, 223-239). Both scenarios, one more conservative by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) (Nitsch, 2007, p. 14-30) and the other more progressive by the German Renewable Energy Federation (BEE, 2009, p. 8-17) are based on specific targets for the expansion of renewable

Table 5 Economic Effects of Renewable Energy for Germany in 2020

		Base 2009	Scenario 2020	
Share of renewables			**BMU**	**BEE**
	electricity consumption	16.3%	34.7%	46.8%
	heat consumption	8.8%	17.2%	25.1%
	transport fuel consumption	5.5%	11.5%	21.4%
Impact				
	regional value added (Bil. €)	6.8	7.2	13.2
	net employment (persons)	116,013	101,877	212,422
	reduction of CO_2 emissions (Mil tons)	77	125	202
	reduction in imported fossil fuels (Bil. €)	3.7	11.5	34.8

Source: Nitsch (2007), BEE (2009)

energies and project the regional value-added for Germany in 2020, the level of net employment in the renewable energy industry, as well the ecological impact on the reduction of CO_2 emission and the import of fossil fuels. The results are summarized in Table 5.

In both scenarios the regional value-added continues to grow and helps to significantly reduce CO_2 emissions as well as the import of fossil fuels, although the projections by the BMU are substantially lower than those of the BEE. In regard to employment, the BMU scenario projects a decline in net employment, mainly due to the gradual decline in new investments as well as the continued fall in prices for renewable energy equipment.

3.2. Analysis of regional differences in value-added of renewable energy

The IÖW study provides comprehensive evidence on the overall potential of renewable energy for the creation of regional value-added, regional employment and the substitution of fossil fuel imports. It also highlights the comparatively high contribution of profits from facility operations to regional value-added, thereby indicating the general importance of regional ownership of renewable energy facilities. On the other hand, only limited evidence is given in regard to the impact that regional characteristics and region-specific differences such as climate conditions or local industry structure may have on the potential of renewable energy for regional development and the creation of regional value-added. In this respect, the studies from Kassel University and IfaS allow further insights due to their focus on specific regions (IfaS, 2013, pp. 74-371; BMVBS, 2011, pp. 40-160). Table 6 summarizes the results of the regional value-added in terms of € per kilowatt for the 15 municipalities, community districts and regions analyzed in the studies by Kassel

Table 6 Regional Value Added (€/kW), Energy Mix and Share of Business Profit

	Region	Regional Value-Added (€/kW)	Renewable Energy Technology Mix				Profit as % of Regional Value-Added
			Solar	Wind	Biomass/-gas	Water	
above average	Nettersheim	€141	52%	11%	38%	0%	82%
	Zschadrass	€124	16%	32%	52%	0%	96%
	Nordschwarzwald	€109	40%	19%	33%	8%	83%
	Münster	€91	55%	11%	34%	0%	59%
	Friesland	€85	7%	84%	9%	0%	65%
	Augsburg	€76	48%	0%	36%	16%	80%
	Fürth	€76	62%	0%	32%	6%	69%
	Wildpoldsried	€75	24%	47%	29%	0%	87%
	Strälen	€72	47%	35%	18%	0%	80%
below average	Hannover	€62	8%	**84%**	8%	1%	**52%**
	Mainz	€55	55%	26%	19%	0%	70%
	Trier	€54	13%	**63%**	10%	14%	**51%**
	Kaiserslautern	€49	37%	0%	63%	0%	71%
	Karlsruhe	€42	57%	10%	33%	0%	65%
	Morbach	€31	13%	**76%**	11%	0%	**71%**
weighted average*		**€66**					

Source: Own calculation based on data from IfaS (IfaS, 2013, pp. 74-371) and Kassel University (BMVBS, 2011, pp. 40-160); the analysis refers to value-added generated on operation stage, excluding one-time effects during the investment stage; the average is weighted by installed capacity in the respective regions.

University and IfaS.

The data reveal significant differences in regional value-added by renewable energy. While it seems plausible that the value-added of renewable energies for a specific region is influenced by local conditions in the respective region, the question remains what are specific causes for these differences? One possible explanation could be the differing energy mix in the respective regions, because the different renewable energy technologies have revealed significant differences in respect to their potential for regional value-added. The IÖW study results suggest that the solar power generates a significantly higher overall regional value-added than wind power, biomass / biogas or hydro power. Our analysis of the data for the 15 regions generally supports these findings:

- The regional value-added in regions with a dominant share of wind power is mostly substantially lower than that of regions with a high share of solar power. In Morbach, where wind power accounts for 76% of the installed capacity for renewable energy, the regional value-added amounts to just €31 per kilowatt. The values in other regions with a high share of wind power such as Hannover (84%) or Trier (63%) are also below average.
- On the other hand, regions with a dominant share of solar power such as Fürth (62%),

Münster (55%), Nettersheim (52%), Augsburg (48%) or Strälen (47%) achieve above-average regional value-added.

- Interestingly, the highest regional value-added is generated in regions with a high combined share of solar power and biomass/biogas such as Nettersheim (52% solar/ 38% biomass), Nordschwarzwald (40% / 33%), Münster (55%/34%) or Zschadrass (16%/52%).

On the other hand, our analysis also reveals significant differences in regard to regional value-added between regions with a similar energy mix. For example, in the cities of Karlsruhe or Mainz, where solar power accounts for 57% and 55% respectively, the regional value-added is significantly lower than in regions with a similar dominance of solar power such as Münster (55%) or Nettersheim (52%). The same is true for wind power. For example, in Nordfriesland and Hannover, both regions located in wind-rich Northern Germany, wind power accounts for 84% of installed capacity, but the regional value-added differs significantly (€85/kW in Nordfriesland versus €62/kW in Hannover). Similarly, there are significant differences between regions dominated by biomass/biogas. The city of Kaiserslautern with a 63%-share of biomass/biogas records a far-below average regional value-added of merely €49/kW as compared to the region around Zschadrass (52% biomass share) which shows one of the highest regional value-added (€124/kW) in the sample.

Therefore, the predominant regional mix of renewable energies alone cannot sufficiently explain the significant differences in regional value-added in the sampled regions. In theory, differences in climate conditions and the resulting differences in load or utilization rates could be another explanation, because the revenue per installed kilowatt of capacity highly depends on the rate of capacity utilization. Unfortunately the studies do not disclose details on differences in climate conditions. However, in our view, climate conditions should not necessarily be an important factor for explaining the noted regional differences in value-added, because investors are unlikely to invest in projects with technologies that do not fit to the regional climate conditions and do not generate at least average returns.

Next to technology, a further plausible explanation for regional differences in value-added may be differences in the underlying ownership structures. As the IÖW study has revealed, business profits from the ownership and management of the installed facilities, rather than employee income or regional taxes, account for the highest share of regional value-added across all types of renewable energy technology. Therefore, regional value-added is likely to vary depending on the registered location of the facility owner. If the facility owner is located within the region, business profits are likely to increase the value-added of this region and to claim a proportionately higher share of the regional value-added than personal income or regional taxes. Our analysis of the sampled regions generally supports this conclusion:

- Regions, in which business profits account for 80% or more of the regional value-added, also record an above-average regional value-added, while renewable energy in regions with a business profit share of less than 70% often generate only below-average regional value-added.
- Those regions like Zschadrass, Wildpoldsried, Nordschwarzwald or Nettersheim with a comparatively high absolute regional value-added and a high share of business profits also have a high share of biomass facilities which are usually owned by local farmers. On the other hand, wind-dominated regions like Hannover or Trier, record a below-average absolute amount of regional value-added and have a low share of business profits; this may be explained by the tendency that wind farms are often owned and operated by external investors from outside the region.[6]

Yet another factor that may influence the value-added of renewable energy for a specific region is the local availability and structure of the value chain in the region. The overall amount of personal income and business profit generated in a region depends largely on whether the various activities along the value chain such as service and maintenance, financing, or tax and legal consulting can be performed within the region and by firms located within the region. In case certain value chain activities are not located in the specific region, no value-added is created for the region, but needs to be imported from outside the region. And even if a particular value chain activity is physically located in the region, it depends on the location of the owners of the related firms to what extent value-added remains in the particular region. Unfortunately the studies by Kassel University and IfaS do not provide any information on the local availability and structures of the relevant value chains in the sampled regions.

In this respect, the IÖW study provides some supporting evidence. The IÖW applied their model to three municipalities differing in terms of population size (from 5,000 to 100,000) and the mix of installed renewable energy capacity (solar power, biogas, biomass as predominant renewable energy source) and, based on these cases, constructed five model communities for reference (Hirschl et al., 2010, pp. 182-199). The analysis of the regional value-added for each community and reference model reveals significant differences in regard to the structure and scope of the local value chain. For example, in case of a small community with only 5,000 inhabitants, solar power has been the main source of regional value-added, a large part of which was generated as income by the operational management of these installations, because the equipment was operated and maintained by local business and citizens. However, the value-added share of profits from wind power has been comparatively low, as the installations were mostly owned by external investors and serviced by firms from outside the region. In the case of wind power, this ownership structure resulted in a comparatively high regional value-added share for the land lease.

In conclusion our analysis of the three models of regional value-added has highlighted various aspects of regional value-added creation by renewable energy technologies:

- The potential for the creation of regional value-added differs by type of technology.
- Business profits generated by the operation and management of renewable energy facilities account for the highest share of regional value-added across all types of technologies.
- The predominant mix of renewable energy sources determines the overall potential for value creation in a given region.
- Local ownership of the operating facility is thought to have an important influence on the share of value-added that remains in the region.
- The degree of local availability and ownership of firms that provide various services for the installation and operation of renewable energy facilities determine the locally generated personal income and business profit and, as a consequence, the regional tax income.

4. Applying economic value-added modeling for regional energy policy – The case of Rhein-Hunsrück-District

The three value-added models that have been discussed have produced a robust and reliable database for the measuring and assessment of the economic effects of renewable energies on a regional level. Value-added modeling offers powerful tools to support planners, politicians and policy makers in regions and municipalities to device policies for the promotion of renewable energies with the objective of regional economic development. In particular, it provides quantitative and transparent data as a base for fact-based judgment and decision-making.

The following case study on the Rhein-Hunsrück District illustrates how value-added analysis can be integrated into a regional climate protection and energy policy concept and how municipalities can evaluate and project the economic effects of renewable energy for their region.

Located in the heart of the State of Rhineland-Palatinate in the Central-Western part of Germany, the Rhein-Hunsrück District governs 134 municipalities with about 100,000 residents, 45,000 households and a land size of about 96,000 hectares (Rhein-Hunsrück-Kreis, 2014). 75% of the municipalities are small villages with less than 500 residents. 46% of the land area is covered by forests, 42% by farm land and only 12% by settlements and roads, making the Rhein-Hunsrück District a rather thinly populated, predominantly rural area. Rhein-Hunsrück District is host of the Hahn airport, operated mainly for low-cost airlines, yet medium-sized firms, smaller-scale craft shops and local services, as well as tourism, winemaking and farming form the backbone of the local economy.

The Rhein-Hunsrück District is considered to be a model case for becoming a 100% renewable energy region that has transformed itself from a net energy importer to a net energy exporter within half a decade (IfaS, 2011). The district council started to promote climate protection in the late 1990's, triggered by the "Agenda 21" process and supported by the climate initiative of the German government. Already in 1999, the district council established an energy controlling system for public buildings and implemented measures to monitor and increase the energy efficiency of public buildings. In 2006, the district council adopted the first integrated energy concept which laid out measures to promote energy conservation, energy efficiency, as well as the development of a decentralized energy system based on renewable energy. In 2011, an Integrated Climate Protection Concept laid out specific targets, policies and measures to become a fully zero-emission region by 2020 in respect to electricity, heating, waste management as well as transportation. The concept, worked out by the Institute for Applied Material Flow Management (IfaS), specifies key policy goals that go far beyond those of the German federal government:

- Reduction of energy consumption by 40% in 2050 (e.g. reduction of 210 million liters of heating oil)
- Increase of energy efficiency in buildings by 50% in 2050
- Reduction of energy imports by €258 million (from €293 million in 2009 to €35 million) in 2050, thereby keeping the economic value within the region
- Reduction of CO_2 emissions of presently 573,000 tons to achieve a surplus of 32,000 tons in 2050
- Generation of an accumulated regional value-added of €14.6 billion by 2050 through

the implementation of the concept

The first part of the concept contains a detailed analysis of the prevailing status quo, as well as an assessment of the technically and economically feasible potential for energy savings, for the increase in energy efficiency and for the expansion of renewable energy (mainly solar power, solar thermal, wind power, biomass, water power and geo-thermal power). The analysis encompasses electricity, heating, transportation as well as waste management.

The second part of the concept spells out a comprehensive strategy and operational roadmap. Particular attention is given to the role of the district government in the area of information, communication, monitoring and controlling, and network building among the various stakeholder groups in the community such as farmers, local business, educational institutions, citizens, public welfare institutions and public administration. The operational roadmap was developed through a series of 9 workshops with active participation of more than 300 citizens who submitted more than 200 specific proposals. The roadmap specifies a set of 92 measures classified into 7 categories (building management, transportation, electricity generation, heating and cooling, land management and urban planning, public procurement, communication and public relations). A professional climate manager, who has been hired at the beginning of 2012 and is partially financed (65%) by the German federal government, oversees the program, facilitates the networking process, and coordinates communication and support activities by the district government.

A central management tool is the “Energy Chart” (“Energie-Steckbrief”) that takes stock of the installed and planned capacity of renewable energy sources, monitors the generated amount of energy, and assesses their economic and ecological effects. Key data for the area of electricity are summarized in Table 7 for the years 2009, 2011, 2012 and 2015 (projection).

The table shows the rapid growth in the number of installed facilities and capacity for electricity generation, in particular by wind power. In 2007, renewable energy covered 57% of the electricity consumption; within 5 years this share rose to 149% in 2012, thereby making the district a net exporter of electricity (AEE, 2010). Based on the present expansion scenario, this share will rise to 507% in 2020, and to 828% in 2050, which would transform the district into a major energy supplier to the densely populated areas of the nearby city of Mainz (202,000 residents) and Trier (106,000 residents) (IfaS, 2011, pp. 110-111).

Table 7 Renewable Energy in Rhein-Hunsrück-District and their Significance for Regional Income

		No. of installed facilities	installed capacity (MW)	generated electricity (MWh)	% of electricity consumption	regional income (M€)	
						from operation	from invest
2009	solar	1,268	20	n.a.	n.a.	n.a.	n.a.
	wind	85	136				
	biomass	12	2				
	total	**1,365**	**158**	**271,314**	**53.7%**		
2011	solar	2,404	44	42,647	9%	15.7	23.8
	wind	149	287	443,139	94%	3.9	29.8
	biomass	14	3	8,806	2%	3.2	1.3
	total	**2,567**	**334**	**494,592**	**105%**	**22.8**	**54.9**
2012	solar	3,092	65	57,271	12%	18.2	30.9
	wind	169	400	620,223	131%	6	34.8
	biomass	16	5	29,212	6%	8.3	2.3
	total	**3,277**	**469**	**706,706**	**149%**	**32.5**	**68.0**
2015	solar	3,092	65	57,271	12%	18.2	30.9
	wind	308	782	1,269,810	268%	10.9	99.4
	biomass	16	5	29,212	6%	8.3	2.3
	total	**3,416**	**851**	**1,356,293**	**286%**	**37.4**	**132.55**

Source: Rhein-Hunsrück-Kreis Energiesteckbrief (2011); Rhein-Hunsrück-Kreis (2011), interview with Mr. Frank-Michael Uhle, Climate Manager, on August 7th, 2013 in Simmern/Germany; only expansion of wind power considered for 2015

The analysis by IfaS revealed that about 50% of the district's energy consumption is attributed to heating (1.2 million MWh per year), in particular by private households using oil, while electricity consumption accounts for only 19%. Therefore, the district's energy and climate policy emphasizes measures to reduce the energy consumption for heating. The local government is taking the lead in raising the energy efficiency of public buildings, for instance by continuously applying the most rigid building standards and investing into latest heat insulation technologies. On the other hand, it encourages the investment of households into modern technologies for heating systems, such as heat pumps or co-generation facilities to replace traditional fossil fuel heating systems. As a result, for example, 54% of all new buildings in 2012 are equipped with emission-neutral heat pumps for heating. The district is also investing heavily into local heating grids that integrate the heating systems of several public buildings and are fed with heat generated by biomass (Rhein-Hunsrück-Kreis, 2013). Between September 2009 and April 2012, the district government and its municipal waste management company RHE have invested €7.5 million to build 3 local heating grids that supply heat to a total of 33 public buildings (21 school buildings, 8 sport gyms, 2 swimming pools and one library). The system has drawn nation-wide attention in Germany, because it uses gardening waste of private households such as branches from trees, bushes and shrubs as biomass substrates. The gardening waste is collected by the local waste management company from 120 disposal points and transported to the central waste disposal site, where it is dried, shredded and sieved. 30-50% of the collected gardening waste can be used as substrates to fire the three wood burning boilers, while 50-70% is sold as high quality compost and organic fertilizers. The system to feed the local heating grid poses substantial technical and logistical challenges, but is commercially viable, because it can rely on a stable, low cost supply of wooden substrates from gardening waste and is independent from the dynamics in the market of biomass substrates. The partners have also agreed on a long-term, yet competitive price of 10.3¢ per kWh.[7]

As a result of high energy efficiency standards and investment into local heating grids feeding on gardening waste, the consumption of heating oil has been reduced by more than 610,000 liters annually, replacing imports of fossil fuels worth €11 million over 20 years and avoiding 770 tons of annual CO_2 emissions. The local grid heating concept also created 5 new full-time jobs. Backed by success and ample, free supply of gardening waste, the district is planning local heating grids in another 2 municipalities (Rhein-Hunsrück-Kreis, 2013, p. 8).

The rapid expansion of renewable energy has generated substantial income for the district, either in form of payments from feed-in-tariffs, from services such as maintenance, and from the lease of land. Since 2009, the district government systematically estimates what is referred to as “value-added” generated by renewable energy sources. For 2012, the accumulated regional gross income that has been generated through continued investment is estimated at €68 million to rise to €133 million by 2015, in particular through locally available services such as planning, construction and installation. The annual gross income generated by the operation and commercial management of these facilities is estimated at €32.5 million in 2012, rising to €37.4 million per year in 2015 (Rhein-Hunsrück-Kreis, 2011). Except for wind power, where most facilities are owned by external investors, the revenue from feed-in tariffs mostly stays within the region. Also, many of the value adding activities along the value chain for solar power, wind power and biomass (including local supply of substrates) are located within the region leading to additional personal income from employment. Some farmers as well as municipalities also enjoy economic benefits from leasing their land to windfarm owners.[8]

In 2009, the IÖW analyzed the value-added generated by renewable energy in the Rhein-Hunsrück-District, applying its model of regional value chain analysis. The results underline the positive impact of renewable energy for regional economic development (AEE, 2010):

- In 2009, renewable energy generated regional economic value-added in form of personal income, local profits and local tax income of €9.4million, including about €1.1 million income from land lease.
- Generation of electricity from renewable energy sources accounted for €7.5million (€3.7million from wind power, €3.1 million from solar power, €0.7 million from biogas), while heat generation contributed €0.5million and bio-fuels for transportation €0.3million.
- Profits amounted to €4.3 million, mainly from wind power (€1.9. million) and from solar power (€1.2 million), while personal income amounted to €3.3 million, and local tax income to €0.7 million.
- As there are no production facilities for renewable energy equipment located in the region, the value-added is generated only at the stages of installation / planning, facility operation and maintenance, as well as in some cases also at the stage of commercial management depending on the technology. In the case of solar power, the commercial owners are mostly local citizens, therefore the income from the commercial management and ownership stays within the region. However, in case of wind power most owners are external investors, so a large share of the value-added from the commercial management (about €2.2 million) leaves the region and is not included in the regional value-added.
- Renewable energy provided jobs for 86 full-time employees in 2009, mostly for local craft shops offering services for installation, planning, operation and maintenance of the solar and wind power facilities. The figure, however, does not include jobs for the planting and supply of substrates for bio fuels and local biogas plants.
- For 2009, renewable energy caused a reduction of CO_2 emissions by 269,103 tons and of imports for fossil fuels by €12.3 million

For a local economy with an estimated gross domestic product of €2,648 million (2008), additional value-added of €8.3 million or merely 0.3% may not sound impressive. Yet, when considering the fast rate of expansion in the installation of renewable energy facilities that has led to a tripling of installed capacity and generated energy between 2009 and 2012, this share has increased to 1% in 2012 and will further rise to 1.5 ~ 2% by 2015 based on our calculation. Therefore, it can be concluded, that renewable energy is a dynamic force for regional economic development in the Rhein-Hunsrück-District, securing employment and creating substantial income for the residents and district government. For a structurally rather weak region like the Rhein-Hunsrück-District, renewable energy has become a major factor for economic stability and security.

First-hand impressions by local planners and officials confirm this conclusion. Frank-Michael Uhle, the District's Climate Manager, says: *"These are not just airy numbers. I know that these economic benefits are real, because I meet with the local residents every day and they tell me that they are busy. I notice that local craft shops are hiring people like electrical engineers, because they struggle to keep up with installations and maintaining the local solar plants. And the German wind power company Enercon has established a local service station for their wind mills creating 4 new, well paying full-time jobs."*[9] And Mr. Anton Christ, the mayor of the small village of Mastershausen and the pioneer of wind parks in the district adds: "*My community has benefitted a lot from the 14 wind mills that were build here since 2007. We have reinvested the receipts from the lease of community land into the building of an elderly care center, creating 10 full-time and 4 part-time jobs. We would not have been able to do this without the wind mills, but now we can offer high quality service to our elderly people in the community who would have otherwise left the region. We have also become a tourist attraction and created the Masterhausen hiking course to demonstrate our efforts in renewable energy. Our next project will be the development of a local heating grid based on straw. And all this has really created a strong and healthy community spirit among our residents.*"[10]

5. Conclusions

This paper introduced three models developed by German academics for measuring and assessing the regional value-added of renewable energy by applying value chain analysis to the renewable energy industry. Value chain analysis delivers detailed insight into the cost structures and revenue streams of renewable energy sources along the various stages of production, planning and installation, technical operation and commercial management of renewable energy facilities. A comparative analysis of the underlying data structures as well as the obtained results revealed a remarkable degree of consistency of the three models despite various differences in regard to model scope and methodology. The modeling of regional value-added of renewable energy based on the analysis of the industry's value chain provides a valid and robust database for policy making and strategy planning in a given region or municipality.

The evaluation of regional value-added for Germany reveals the significant economic effects that renewable energy can have for regional development, creating regional income streams and new employment opportunities. It provides region-specific insights into the potential sources and stages of value creation as well as about the distribution of value-added along the region-specific value chain. Regional value-added analysis lays the foundation for a comprehensive assessment of the status quo or future economic potential of renewable energies in a given region. It, therefore, offers a powerful tool to regions and local municipalities supporting their efforts to formulate strategies and policies for regional development, energy and climate protection. The example of the Rhein-Hunsrück-District illustrated how the concept of regional value-added can become an integral part of a region's comprehensive climate protection and energy policy. It can be applied to compare the economic and ecological effectiveness of different renewable energy technologies in a specific region, in order to decide on the most suitable energy mix, to formulate feasible, realistic policy targets and to evaluate possible policy options. It allows the development of future scenarios and forecasts of the potential economic effects that can be expected from the expansion of renewable energy sources in a given region. And finally, by highlighting the economic effects, regional value-added analysis helps to strengthen the acceptance of renewable energies in a community and serves as an instrument for communication and network building with regional stakeholders.

The results of regional value-added analysis for Germany have highlighted that the generation of regional value-added depends largely on the scope and structure of the regional value chain. Value-added analysis provides insights into the region-specific structure and characteristics of regional value chain in renewable energy. Thereby, it gives indications about the economic potential of renewable energy in a given region and about how a region can mobilize, leverage and upgrade regional resources such as local firms, skills, know-how as well as assets. Taking comprehensive stock of locally available resources and capabilities is an important first step when developing regional strategies for renewable energy that capitalize on a region's potential and play to the specific regional strengths and characteristics.

However, the generation of regional value is significantly influenced by the underlying ownership structures, as profits from the commercial management usually account for the largest share in the value-added of renewable energy. Value-added analysis provides insight into the technology-specific structure of revenue streams and, thereby, helps to promote local ownership and local acceptance for renewable energy. Municipalities have a strong influence on establishing rules, requirements and frameworks for investment into renewable energy and can encourage local investment and ownership through public policy.

Finally, regional value-added analysis can serve as an effective tool for the communication of policies and for the mobilizing of active participation by regional stakeholders in the policy process, thereby establishing trust, acceptance and consensus among the various stakeholders in a community. As many examples have shown, open communication by the municipality, local initiative and active participation by citizens, as well as strong networks among key stakeholders are essential for the success of renewable energy projects and for fostering local capacity building (Aretz et al., 2013, pp. 22-26). Regional value-added analysis supports the process of building local consensus and fosters cooperation among the various stakeholders with diverging interests in a community or region.

Yet, while it has been demonstrated that the model of regional value-added by renewable energy based on the analysis of the industry's value chain delivers generally consistent, robust and valid results, it remains to be seen, whether the results that have been obtained for Germany are applicable to other regions or countries. The construction of the model itself relies on the availability of and access to a solid and comprehensive set of fundamental data such as cost structures and revenue streams for individual renewable energy technologies along all stages of the industry's value chain across various regional locations. This requires a sufficiently large and regionally representative installation base of renewable energy facilities, as well as insight into technology-specific cost drivers and their local economics. While the cost of power generation by renewable energies are continuing to decline sharply due to a falling investment cost, there remain remarkable international differences in respect to equipment cost, and to an even higher degree in respect to other investment cost, often referred to as "balance-of-system cost" (IRENA, 2013; JREF 2013; Seel/Barbose/Wiser, 2013). Regional and country-related differences in costs for activities such as site assessment, construction, installation or maintenance are likely to have a significant influence on the economic viability of individual projects and technologies, thereby determining the overall potential for the generation of regional value-added. The same can be assumed for differences in respect to the regulatory framework that influence the revenue streams from renewable energy sources, for instance the existence and specific design of feed-in tariff schemes or national tax schemes.

As the analysis for Germany has shown, regional value-added from renewable technologies largely depends on local ownership and the existence of local value chains. In Germany, local ownership of renewable energy facilities by citizens, energy cooperatives, local business and municipalities is widely spread, thereby increasing the likelihood that a significant portion of the revenues from renewable energy stays within the region. The factors that have contributed to such a high ratio of local ownership, however, remain unclear. It needs to be evaluated to what extend national differences in various areas such as finance, investment incentives, taxes, environmental awareness, or citizens' initiative encourage or impede the spread of local ownership. Similarly, the existence of local value chains and the availability of local capacities, skills and qualifications may well be influenced by country-specific, structural factors. For example, the strong federal system of Germany has laid the foundations for vibrant regional economies with qualified local craft industries (so-called "Handwerk"), supporting professional services, and clusters of regional universities and think tanks (Porter, 1998, pp. 335-382). The federal, decentralized structure of Germany may well have supported the creation of a favorable environment in which local supporting industries and services for renewable energy could flourish.

Despite these limitations regional value-added models of renewable energy based on the industry's value chain analysis provide a systematic approach to evaluate the potential for regional development by promoting renewable energy.

Notes

1 This trend is exemplified by the so-called "100%"- Renewable Energy Regions" ("100ee region"), a network of regions and municipalities that pursues the long-term vision of a complete transition of their energy systems to renewable energy. Presently, the network connects 138 cities, municipalities and regional districts covering about 20 million people or about a fourth of Germany's population. (100ee regions, 2013)

2 The rapid growth of renewable energy is considered to be an important cause of the declining profitability of Europe's established power utilities (2013, October 12, *The Economist*).

3 The model of Kassel University further takes into consideration that the directly and indirectly generated value-added is (partially) spent for consumption in the region, thereby inducing additional value creation. Specifically, the model applies region-specific marginal consumption rates and income multipliers to measure and calculate these induced effects.

4 This is also due to a different focus of each study: While the IÖW describes in detail the methodology and calculation schemes for deriving technology-specific potentials for regional value-added, the studies of Kassel University and IfaS emphasize the application of the models to specific regions. The IfaS study provides data for 11 community districts and municipalities in Germany, while Kassel University applies its model to 4 larger regions.

5 Own calculation based on data from IÖW (excluding investment stage) and Kassel University (excluding induced, multiplier effects). The data from Kassel University refer to the average of four regions (Kassel, Friesland, Trier, Nordschwarzwald) to which their model was applied, while the data from IÖW were build on averages for all of Germany.

6 Again, our analysis of the sampled regions also reveal apparently contradicting results such as for Münster with a comparatively high absolute regional value-added, but a comparatively low share of business profit, or for Kaiserslautern and Morbach with the opposite structures.

7 Interview with Mr. Klaus-Peter Hildenbrand, Technical Director of Rhein-Hunsrück Entsorgung (RHE) waste management company on August 7th, 2013 in Simmern/Germany

8 It has to be noted that the applied methodology differs significantly from the value-added concept of the IÖW, and rather measures the gross income obtained from renewable energy sources; this leads to double counting, because the income of one party (for example from maintenance services) is paid for by the facility owner from the income they have obtained from feed-in tariff payments. Nevertheless, the gross income and its rapid growth indicate the dynamic expansion of regional economic activity.

9 Interview with Mr. Frank-Michael Uhle on 7.8.2013 in Simmern/Germany

10 Interview with Mr. Anton Christ on 7.8.2013 in Mastershausen/Germany

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