

Energy autarky: A conceptual framework for sustainable regional development

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ABSTRACT

Energy autarky is presented as a conceptual framework for implementing sustainable regional development based on the transformation of the energy subsystem. It is conceptualized as a situation in which the energy services used for sustaining local consumption, local production and the export of goods and services are derived from locally renewable energy resources. Technically, the implementation of higher degrees of energy autarky rests on increasing energy efficiency, realizing the potential of renewable energy resources and relying on a decentralized energy system. Practically, a transition towards regional energy autarky requires administrations and civil society actors to initialize and develop projects at the local level, ensure their acceptance and support by the regional population and implement the project in collaboration with relevant actors. Besides the description of the concept and the benefits its implementation brings, this article provides a process for implementation, and some examples from Austria, Germany and Switzerland.

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1. Introduction

The abundance of energy is one of the basic foundations of modern civilizations (Afgan et al., 1998; Haas et al. 2008; Hammond, 2004), and we have every interest in ensuring that energy services continue to be available in the future. Currently, however, the energy subsystem threatens the natural capital upon which present and future generations rely for material and immaterial needs. In order to have an energy system that is compatible with the interests of future generations, it needs to be transformed and made sustainable.

The sustainability of energy systems is a substantially debated topic (see Omer, 2008; Afgan et al., 1998; Dincer and Rosen, 1998). In order to call an energy system sustainable, it must be capable of providing the energy services demanded by the current population, whilst ensuring that future generations find the economic, social and ecological resources they require (WCED, 1987). In its current configuration, the energy subsystem of most developed or

developing countries is far from such a state. Among other things, it substantially contributes to problematic climate change, negatively impacts on human health, threatens biodiversity, contributes to pollution and poses a whole series of risks (WBGU, 2003; BAFU and BFS, 2009; IPCC, 2007).

In response to this societal problem situation, substantial policy efforts, ranging from the international down to the local level, have long been implemented. Efforts have increased further as the problematic nature of anthropogenic climate change has become increasingly evident. Technical concepts and ideas play a major role in developing policy measures in the fields of energy and climate policy. However, technical approaches are not stand-alone, disjoint from human life worlds. It is particularly insufficient to see the human dimension as an “end-of-pipe” issue, which needs to be dealt with during the implementation or diffusion stage (Hendricks, 2009). Instead, we propose viewing the transformation of the energy system as one process within larger societal transformations, which can either promote or constrain the transformation process of the energy subsystem according to rationales external to the energy subsystem. To account for this perspective, we refer to the energy subsystem rather than to the energy system. Hence, concepts are required, which explicitly account for societal interests and provide ways to “piggy-back” the transformation of the energy subsystem to change efforts that further the broader population’s material and immaterial interests (Jefferson, 2008). Regional development based on an autarkic energy system is an example of such a change effort. Energy autarky as we present it in this article is a

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framework for local action towards the development of a region's viability, based on the transformation of the energy subsystem.

Successful concepts will not only profit from lower policy resistance; they should also unlock material and immaterial resources towards the change effort, which would hardly be accessible through top-down, delocalized or command-and-control approaches. Therefore, we need concepts that not only entail acceptance of technologies and innovations, but go beyond this and enable local actors to actively participate in the transformation of the energy subsystem, while simultaneously pursuing their interests and contributing to the greater good of their society.

We define a region to be energy autarkic when it relies on its own energy resources for generating the useful energy required to sustain the society within that region. To qualify as sustainable, additional criteria – such as the decarbonization of the energy subsystem – must be met. The concept of sustainable development upon which this article is founded goes back to the Brundtland Report (WCED, 1987), which defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. In 1992, this idea gained broad legitimacy as the United Nations adopted it as the leading idea for the 21st century at the conference in Rio de Janeiro. The conference resulted in the establishment of the local agenda 21 (LA21), the main goal of which is to involve the local societal actors in decision-making regarding sustainability issues, by way of collaborative target-setting and assessments (Owen and Videras, 2008). We draw on the LA21 as a framework within which energy autarky can be situated, and the importance we attach to collaboration is particularly in line with the LA21 framework.

By transforming the energy system, resources are mobilized, which strengthen the social, economic and ecological foundations of regions and promote their further development. The added value from the concept lies in its ability to integrate insights from the literature and provide a framework within which societal action on the local level can be conducted. Moreover, energy autarky might be a new goal for aspiring regions that have already achieved substantial success in reducing the negative impact of their energy subsystem.

This contribution is of a mostly theoretical and conceptual nature. We do, however, provide some empirical grounding by addressing a small number of transformation projects, which we deem compatible with the concept of energy autarky. A limitation of this article is that it does not examine the arguments in favor of trade in energy resources between regions. Regarding the general applicability of this contribution, we must note that we are primarily addressing the situation in Austria, Germany and Switzerland. For now, it remains uncertain as to what extent our contribution could apply to other industrialized countries.

The remainder of this article is structured as follows. In the next section, we review the literature (Section 2). Then, we present our model (Section 3) and discuss the process for its implementation (Section 4). We then discuss regions where concepts similar to energy autarky have been implemented (Section 5), before closing with conclusions (Section 6).

2. Literature review

Energy autarky, as we describe it, is not an entirely new idea. There are several overlapping streams of research in the scientific literature, which address the issue of energy subsystem change towards sustainability and related topics. We briefly introduce selected streams of research upon which energy autarky can be grounded.

One stream of literature deals with community ownership as a means of promoting local energy systems based on renewable, endogenous potentials. According to Walker (2008), community renewable energy has long been advocated as an approach to implementing renewable energy technologies, with an emphasis on engagement and empowerment, self-sufficiency and local determination (also see Dunn, 1978; Hoffman and High-Pippert, 2005 and Lovins, 1977; quoted in Walker, 2008). Toke et al. (2008) investigated institutional variables related to wind energy deployment outcomes across six European countries. They found that local ownership contributes to overcoming negative attitudes towards wind farms because with local ownership, “significant local networks supporting wind farm developments” (p. 1144) can be activated.

We find that community ownership should be an important aspect of energy autarky as we conceptualize it. However, it has to address challenges such as the difficulty of defining the appropriate community and conflict within communities (see Aitken, 2010a). Nevertheless, energy autarky emphasizes the interdependencies between energy and the social, economic and ecological subsystems of a region, and it in principle reaches further, with the transformation of the whole region's energy system as a goal. Similar to this stream, Zoellner et al. (2008) discuss *energy sustainable communities* and point out the importance of considering social aspects. Because individuals are both initiators of change and consumers of energy, community awareness of the energy subsystem is important.

Scheer (2007) argues that the successful introduction of renewable energies can be attributed to two types of strategies: either autonomously initiated political strategies, or strategies that create a platform upon which investors can act autonomously. Pioneering renewable energy technologies were initially found in particular cities rather than national governments. Such pioneering local governments ultimately gave rise to the industrial foundation upon which subsequent government programs were based (Scheer, 2007: 237p.).

Some contributions address the issue of autarky or autonomy on a subregional level. El Bassam (2001) presents the integrated renewable energy farm (IREF)—a “farming system model with an optimal energetic autonomy, which includes food production and if possible, energy exports” (p. 402). And in El Bassam and Maegaard (2004), an extensive analysis of planning guidelines, technologies and applications for integrated renewable energy for rural communities is presented, again with a strong focus on the farm. This is a very valuable contribution, although it does not detail how the transformation of a whole region could be achieved.

Moreover, there is a stream of literature on decentralized energy systems, which is an important source of inspiration for energy autarky. For example, Alanne and Saari (2006: 539) find that distributed energy systems can be an “efficient, reliable and environmentally friendly alternative to the traditional energy system”. Wolfe (2008) argues that while most of the technologies for a decentralized energy system exist, substantial policy and regulatory reform is needed to optimize the potential on-site generation and two-way interchanges with the grid.

Mårtensson and Westerberg (2007), in a study of three different strategy models for transforming local energy systems towards bio-energy, conclude that “what is fundamental for transformation processes within the energy system is how the problem(s) and its solution(s) are understood and related to one another, how resources and actors are mobilized, and how the process of change is organized and communicated” (p. 6103). Energy autarky is a promising framework within which such a transformation process can be initialized and implemented.

Finally, we wish to mention the European Energy Award, which “supports communities that want to contribute to a

sustainable energy policy and urban development through the rational use of energy, and an increased use of renewable energies" (EEA, undated). It provides instruction for the guidance and control of communal energy policy, allows cities to exchange experiences, and makes successes visible by giving awards. We believe that energy autarky could be a vision for the further development of the European Energy Award (CIPRA, 2010). In addition to contributions in the scientific literature, practitioners report on pioneering projects (see Section 5).

3. Sustainable energy autarky: the model

According to the New Oxford American dictionary, the term *autarky* is derived from the Greek word *autarkes* and means "economic independence or self-sufficiency". In contrast, the term *autonomy* refers to "freedom from external control or influence" and self-government. We think that the term *autarky* better reflects the meaning of our concept, because the concept of "relying on internal resources", embodied in the term *autarky*, is somewhat more in line with our model than the concept of "independence/self-government", embodied in the term *autonomy*.

Specifically, we define energy autarky as a situation in which a region does not import substantial amounts of energy resources from other regions, but rather relies on its own resources to satisfy its need for energy services. This strong definition of energy autarky is unlikely to be fully achieved, because exchanges with other regions probably always lead to a certain amount of importing energy. After all, regions are open systems that exchange information, persons, materials and also energy with one another, with mutual benefit. Because regions are open systems, energy autarky should be understood as a vision to move towards, rather than a call for regional isolation. At the core of energy autarky is the insight that by generating energy locally, economic values are created, which contribute to the viability of the whole region (see Section 3.4).

A limitation of this definition of energy autarky is that it potentially allows for the exploitation of fossil energy resources such as oil, gas, coal or peat found within the region. However, in its application for sustainable regional development, we insist that energy resources and technologies, which qualify as sustainable, are used.⁴ Hence, in the following, we restrict our discussion to sustainable energy autarky and omit cases of energy autarky based on the depletion of fossil energy resources such as historically very important coal or peat schemes. Energy autarky as we conceptualize it here differs from such coal or peat schemes through its explicit aim to contribute to sustainable development—not just economic growth. And it strongly relies on the involvement of local actors, who are seen as a force contributing to the transformation of the energy subsystem into more sustainable patterns.

The achievement of a sustainable energy subsystem by way of energy autarky rests on three closely related principles:

- Use of endogenous potentials for renewable energy resources rather than energy imports.
- Decentralization of the energy system.
- Increases in the energy efficiency of the supply and the demand side.

By relying on endogenous potentials for renewable energy, the energy system is de-carbonized, as energy imports are currently mostly from fossil, carbon-based sources. The notable exception is the import of electricity. Here, the carbon footprint depends on how it was generated.

The decentralization of the energy system is important for several reasons: First, short distances for the transport of energy resources lead to minimal losses and enhanced efficiency of the energy supply. Second, several energy technologies such as solar panels, micro-generation, wood-based heating systems and heat pump, are suitable for decentralized, small-scale operations. Decentralization increases producers' and consumers' freedom regarding their technological choice and opens up opportunities for local innovations.⁵ However, decentralization relies on energy subsystems, which can deal with non-synchronized behavior of supply and demand.

Increasing the energy efficiency on the supply and the demand side is of central importance: By increasing the efficiency, the amount of primary energy used to provide a given level of energy services to the population can be reduced. However, efficiency gains might become reduced to some degree by the rebound effect (Herring and Roy, 2007; De Haan, 2009). Therefore, increasing the sufficiency (e.g., using fewer resources by reducing consumption) is a fourth strategy that might gain importance should the pressures from the energy and climate crisis enable strong public policy interventions. Currently, however, sufficiency strategies are not a cornerstone of Western policy approaches, as governments prefer technical fixes to curbing consumption (Herring, 2006).

3.1. Conceptualizing the region as an open system

In order to characterize and eventually operationalize the fundamental relations between the region and its environment, a systems perspective and the principles of thermodynamics (Sonntag et al., 2002) need to be referred to. The principles of thermodynamics enable the analysis of energy flows, as will be shown below.

The notion of the system refers to a whole composed of parts (subsystems) and a boundary delimiting the system and its environment (Mingers and White, 2010). By employing a systems perspective, a boundary is drawn between what is in the system and what is outside. Generally, the boundaries of the system follow administrative borders, such as communal borders. In practice, however, any typology that differentiates space into distinct regions can be applied, although boundaries that follow political divisions seem best.

The internal structure of the region's society is conceptualized as consisting of different subsystems. In addition to the energy subsystem, we conceptualize the region to consist of a social, economic and ecological subsystem. All these subsystems are open to their environment. For example, individuals in the system interact with individuals outside of the system, and information, energy, goods and services are exchanged across the system's boundaries. These flows can be generally characterized as energy flows, material flows and information flows and they sustain the society within the system. In practice, however, these three kinds of flows are often mingled. For example, trade in goods is mostly a material flow, but the import of equipment that embodies new technology has a strong information component. The import of heating oil is mostly an energy flow, but the energy is embodied

⁴ Discussing the sustainability of energy resources and technologies is beyond the scope of this article. However, we assume that energy resources, which qualify as "sustainable", are renewable, lead to low emissions of greenhouse gases and generally contribute to the viability of the ecological, economic and social dimensions of society.

⁵ See *Alanne and Saari (2006)* for further definitions regarding the decentralization of the energy subsystem.

must rely on a localized technology mix, which considers natural potentials as well as a broad variety of aspects ranging from population density and the structure of settlements to the larger socio-technical landscape (Geels and Schott, 2007).

3.3. Analysis of regions

In the following, we analyze two (hypothetical) regions, one with a conventional energy subsystem and one that implements energy autarky.

3.3.1. Regions with conventional energy subsystems

The conventional energy subsystem is characterized by high shares of imports of primary energy, fossil resources and inefficient conversion. Fig. 1 shows the energy-flow diagram of a conventional energy subsystem (upper tier) and outlines its interactions with the economic (middle tier) and social subsystems (lower tier). In order to keep Figs. 1 (and 2) simple, the ecological subsystem is not explicitly included.

- The primary energy input (P, in the upper tier of Fig. 1) is mostly from imported fossil energy resources. In industrial nations, the majority of primary energy is from such resources (IEA, 2008). Hence, such energy subsystems are frequently referred to as carbon-based energy subsystems. The secondary energy (S) too is often imported, although some might be generated from imported primary energy resources or from local resources (e.g. hydro power). Final energy (F) provides the consumer with fuel, heat and electricity. To derive useful energy (U) from final energy, typical energy converters such as heating systems, motors, lamps, etc. are employed. The efficiency of energy converters substantially varies within and across technologies, with the light bulb as probably the most inefficient technology.

Over all steps of the conversion process, a lot of exergy is lost and entropy generated. In addition, exergy needs to be expended to transport primary energy carriers into the region, thus diminishing the efficiency of the whole energy subsystem. The non-energetic output of the energy subsystem consists of wastes and emissions, which contribute to dangerous climate change and endanger the health of the population. The emissions are predominantly from central power plants based on coal or gas power, combustion engines and oil-based heating systems.

In the economic subsystem, the import of energy is accompanied by a substantial outflow of capital. This means that income generated within the region flows out and no longer contributes to the regional economy. This, in turn, negatively affects the social subsystem, as the resources to sustain societal infrastructures are scarce.

3.3.2. Regions with autarkic energy subsystems

Fig. 2 shows a system diagram of regions with autarkic energy subsystems. As in Fig. 1, the energy subsystem in Fig. 2 also converts energy resources from primary energy to secondary, final and ultimately useful energy. However, in energy autarkic regions, the input of primary energy (P) and secondary energy (S) from outside the region are minimized. This means that the region now predominantly relies on regional energy resources, which – as we argued above – should not contain problematic resources such as fossil fuels or nuclear fission material. In addition, increased energy efficiency reduces the amount of exergy that needs to be replaced. (Hence, in Fig. 2 the boxes for fossil energy resources, electricity, heat, electricity and fuel are smaller, whereas the box for regional resources is bigger.)

An autarkic energy subsystem leads to a larger volume of production and employment in the region due to the required construction, operation and maintenance of heat and power

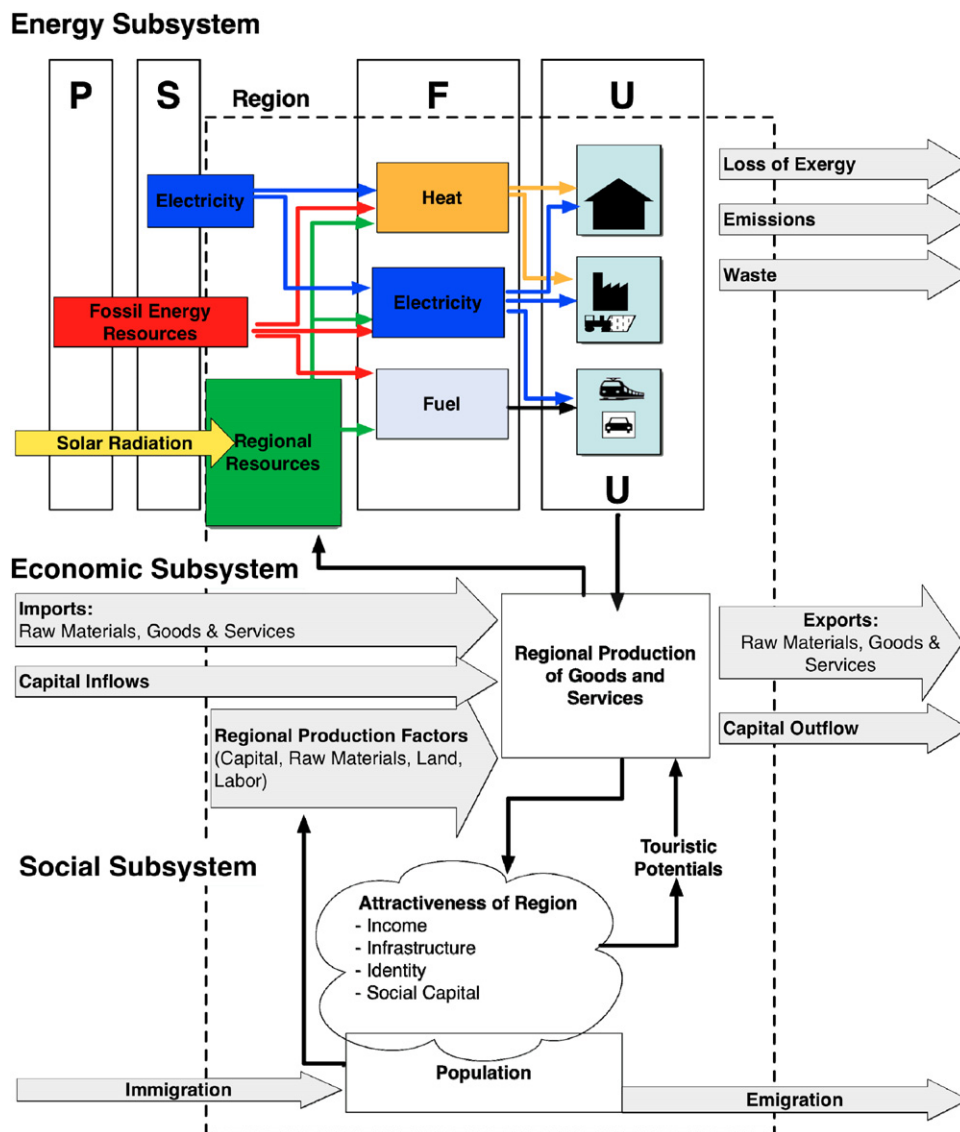


Fig. 2. System diagram of regions with autarkic energy subsystems.

the mitigation of dangerous climate change if the emissions of greenhouse gases are reduced. The city of Güssing (see Section 5.1), for example, achieved a 35% reduction of yearly CO₂ emissions between 1990 and 2005 (Brunner et al., 2006: 94). As rapid climate change is threatening habitats and biodiversity, the ecological effects of energy autarky can include such secondary effects too. On a local level, energy autarky can contribute to reducing waste, as organic materials (wood, food rests, garden waste, etc.) can be used to generate gas or biodiesel. An increased demand for agricultural products for energy generation may contribute to maintaining cultural landscapes. A reduction of fossil fuel use can contribute to a reduction of health hazards, by way of cleaner air. And as energy autarky contributes to the mitigation of climate change, a whole series of health benefits may emerge (see IAMP, 2010).

3.4.2. Economic effects

Above, we briefly touched upon the effects of energy autarky on the economic subsystem. In particular, we emphasized the importance of value creation within the region that comes from substituting imported fossil resources with locally available energy resources. Funds that previously left the region in

exchange for energy imports⁶ are now available in the local economy and can help to extend and close value creation chains within the region. In consequence, capital remains within the region, thus contributing to its economic viability.

By basing the provision of energy services on local resources and investing in energy efficiency, the demand for local goods and services is increased. For example, farming and forestry might be able to provide biomass to energy generation facilities and hence generate more income. And as the local generation of energy increases the demand for labor, jobs are created in the local energy sector, which previously might have been in centralized, extra-regional plants. Consequently, the added value created within the region rises. In return, tax revenues can be expected to rise, thereby increasing the ability of a region to provide services and infrastructure to its population and businesses. A further economic effect of energy autarky is that it provides insurance against high prices of fossil-based energy. The construction sector and the

⁶ In 2009, end-users in Switzerland paid 15.43 billion (15.43×10^9) Swiss francs for oil products, of which 3.25 billion Francs were expended for heating oil and 12.18 billion francs were expended for propulsion fuels (BFE 2010: 50).

machine industry in particular can be expected to gain from bigger markets. Yet, tourism can also gain if energy autarky is actively used to increase tourists' awareness of the region and promote tourism in general and eco-tourism in particular.

However, this discussion remains conceptual, because due to the large diversity among regions, it is not reasonable to claim that energy autarky is beneficial for all or even the majority of regions. For example, CIPRA (2010: 11) warns that they found only little robust insight in the literature regarding the potential for value creation of energy regions. Moreover, they found that the employment and value creation effects may be presented in a simplified and overly optimistic manner. Therefore, the approach needs to be evaluated during the implementation process (see Section 4), and may, after taking into consideration all benefits and costs of the specific case, turn out to be economically unattractive.

3.4.3. Social effects

The implementation of energy autarky in a region has the potential to increase the attractiveness of the region in several different ways, including, but going beyond, the economic contributions discussed above. Peripheral regions, whose viability is often threatened by depopulation processes, can particularly profit from the increased opportunities and regional attractiveness brought about by energy autarky. Increasing a region's attractiveness might retain young people. Reversing the trend from emigration to immigration generally leads to lower per capita costs of infrastructure. Consequently, infrastructures such as public transport, schooling, health care, etc. can be provided at cheaper per capita costs, thus potentially reducing the burden of taxation and setting income free. This, in turn, further increases the region's attractiveness, potentially triggering a reinforcing feedback process.

Several factors contribute to increasing attractiveness, such as the quality of the environment, a strong regional identity, the amount and quality of relationships residents have with one another and the image the region has with people on the outside. Regional identity means the local population's identification with the region's characteristics. Technical artifacts – such as wind-mills – contribute to a region's uniqueness, and could contribute to the marketing of the region's products, at least insofar as they are innovations. By interacting with one another during the process of implementing energy autarky, interpersonal relationships are created and reshaped. This can contribute to integration among the local population and can increase the social capital of its residents.⁷ However, there is also the possibility of differences regarding interests or preferences leading to conflict. Achieving a project of such significance can increase the roots the population has in the region. Pioneering innovative concepts in response to the pressing climate and energy problems can also increase the region's prestige. And finally, communities can renew their ability to act if participation “learned” in the context of the implementation of energy autarky can be transferred to other domains. Consequently, dependencies on external actors are reduced and communities and regions are empowered to develop or sustain their economic, social and ecological viability.

4. Energy autarky: the process

In the following, we propose an ideal-typical process for implementing sustainable development of a region by way of an autarkic energy subsystem. The process is a theoretically enriched

synthesis of several contributions from practitioners (CIPRA, 2010; FNR, 2008; Tischer et al., 2006).

Energy autarky relies on the involvement of local actors. Actors of the energy subsystem are particularly relevant, but involvement of the general public is an additional asset. According to Rayner (2010: 2623), “the process of how we choose an energy future is (...) as important to a socially, politically, economically and environmentally sustainable outcome as any technological option on the table.”

Local participation is seen as a way of increasing the legitimacy of decision processes. Increasing legitimacy can increase the social acceptance of renewable energy innovations, which according to Wüstenhagen et al. (2007), is increasingly recognized as a constraining factor in the expansion of the share of renewable energy. Zoellner et al. (2008) conclude that a further expansion of renewable energies requires more support on the local level. And Walker (2008: 4402), based on several contributions in the literature (Loring, 2007; Toke, 2005; Walker et al., 2007; CSE et al., 2007), finds some evidence and a widespread acceptance that projects, which are fully or partially owned by the community in which they are located, are more acceptable and that such projects have lesser problems obtaining permits than others. Besides fostering the acceptance of the project, participation of a broad variety of local actors encourages the inclusion of local knowledge and hence increases the quality of the project (Mårtensson and Westerberg, 2007). However, Aitken (2010b), in an analysis of wind power, cautions against the conclusion that “engendering trust and facilitating participation in planning and development processes will lead to greater rates of planning approval” (p. 1838). She stresses the importance of consultation and participation processes with an open outcome and contrasts them with participation processes that developers use to overcome local resistance without properly understanding local objections.

For local actors, energy autarky in their region will most likely be an innovation. Rogers (2003: 12) defines innovations as “an ideal practice, or object that is perceived as new by an individual or other unit of adoption”. In order to effectively implement energy autarky, the diffusion of this idea across the relevant local actors must occur. Behind the diffusion of an innovation is a decision-making process, which leads either to the adoption or the rejection of an innovation by a decision-maker. In the following, we propose a process for implementing energy autarky, which is theoretically guided by the innovation–decision model according to Rogers (2003: ch. 4).

In order to implement energy autarky, the process needs to be initialized and preliminary preparations need to take place. This corresponds to the knowledge stage, where potential adopters gain knowledge of the innovation's existence and its functions. Second, a series of analyses needs to be carried out in order to provide the basis for the adoption or rejection decision. This corresponds to the persuasion stage, where a favorable or unfavorable attitude towards the innovation is formed. Third, strategic decisions, concerning the general configuration of the energy subsystem, need to be made. This corresponds to the decision stage, where activities leading to adoption or rejection of an innovation are carried out. Fourth, operative planning and subsequent implementation occurs (implementation stage). In a fifth step, evaluation and monitoring activities are conducted, which roughly correspond to the confirmation stage. Each step is discussed below.

4.1. Initialization and preparation

Basically, any individual, group or organization can initialize the process towards regional energy autarky. Such a change effort, however, relies on the increasing involvement of others. In the early stages, the identification of possible leaders is of major

⁷ By social capital, we mean the “ability to secure benefits through membership in networks and social structures” (Portes, 1998: 8).

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Table 1
Examples of regional initiatives we deem compatible with the notion of energy autarky.

Region (Country)	Description, further information
Bio-energy villages (Bioenergiedörfer)	In bio-energy villages (Bioenergiedörfer), local biomass is used as the resource in order to supply heat and electricity. This concept addresses villages with about 500–1000 inhabitants. It gives a lot of weight to societal dimensions, because the state of technology is seen as adequate. The municipality “Jühnde” in Lower Saxony was the first to implement the concept in 2006. Fuels are still based on fossil resources. Although the village is not completely autarkic, it generates double the electricity it uses (FNR, 2008). As of June 2010, more than 25 villages have implemented the concept (see FNR, undated).
Energietal Toggenburg (CH)	The association “Energietal Toggenburg” aims to make the Swiss Toggenburg region energy autarkic by about the year 2035 and wants to achieve the 2000-watt society by 2060. The project is seen as an opportunity to develop the region, unite it behind a common vision and improve its image (Energietal Toggenburg, undated).
Energy autarkic model regions in Saxony (Germany)	In the German state of Saxony there are currently four energy autarkic model regions. The first – and best documented – is the region around Annaberg, a peripheral region that has lost over 12% of its population since German reunification. In 2007, the Saxony state government commissioned the development of a concept for energy autarky. The result provides a rigorous approach to the analysis of efficiency potentials (see Mixdorf and Zschau, 2007). Recently, the regions Bautzener Oberland, Vogtlandkreis and Westlausitz have also become energy autarkic models (ERN, undated; Mixdorf and Zschau, 2007).
Energievision Murau (A)	The district Murau in Austria has a population of over 32,000 living in 35 communities in an area of 1385 square kilometers. The region aims to be energy autarkic in heat and electricity by the year 2015 (Energieagentur Obersteiermark, undated).
Energierregion Goms (CH)	In 2007, the idea was formulated to make the Swiss Goms region the first energy region in the Alps. The aim is to use local resources to reduce negative externalities and increase income in and touristic attractiveness of the region (unternehmenGoms and Basler+Partner AG, 2009).
Kötschach-Mauthen (A)	The Austrian community Kötschach-Mauthen aspires to achieve energy autarky by the year 2020. Currently, 74.6% of the local demand for energy is supplied from local resources (Verein “energie:autark Kötschach-Mauthen”, undated).
Oil of Emmental (CH)	The project “Oil of Emmental” was initiated by societal actors in this Swiss valley. The project aims to move from a situation where 90% of energy is imported, to a situation where most of the energy is locally generated (Oil of Emmental, undated).

implementation can be achieved. This phase also entails the actual construction work itself, whether it is done by public or private actors.

4.5. Monitoring and evaluation

Monitoring and evaluation should occur both during the process of organizing and implementing energy autarky, and in the post-implementation phase. During the project, monitoring and periodic evaluation of the current status helps to prevent the project from stalling or derailing. After the construction phase, monitoring and evaluation helps to ensure optimal operation of energy plants and may provide foresight for future energy needs.

5. Review: experiences with energy autarky on a regional level

Several projects and initiatives exist that pioneer the idea of regional energy autarky as a form of sustainable regional development, although names, labels and details may differ. In the following, we summarize the results of desktop research aiming to identify pioneers in Austria, Germany and Switzerland. We expect that initiatives similar to those reported here could be found in further countries.

5.1. Energy autarky in the city of Güssing (Austria)

The city of Güssing is located in the south east of Austria in the Burgenland state and has about 3800 inhabitants. It has a surface area of 49.31 square kilometers, of which about 46% is forest and about 40% is used for agriculture. Until the 1990s, Güssing was an economically peripheral region, which suffered from strong structural change. It had relatively poor transport connections, strong emigration of particularly the skilled workers and companies almost never relocated to the city.

Before 1990, the city had spent about 1.5 million euro per year on fossil fuels. In 1990, the municipal authorities set the goal of basing the whole energy supply on renewables, particularly wood. The reason for such a goal was that the city wanted to break the vicious

circle of economic decline, which was threatening the viability of the whole region (Brunner et al., 2006; EEE, 2010; Koch et al., 2006). According to Horak et al. (2007: 17), the population was initially rather skeptical towards the idea. In order to demonstrate the technical viability to the population, the first installations of the district heating system were made in public buildings.

In 1996, the first biomass power plant and the first district heating system were built in Güssing. Based on the region's wood supply, the demand for heat and electricity by the city's households and industry could be met. Further technical installations followed. With the foundation of the European Centre for Renewable Energy⁹ in Güssing, a platform for future innovations and a strong promoting agency was established, dedicated to the promotion of the “Güssing model”. Eco-energy tourism and a network of sport and culture organization were initiated. In consequence, the attractiveness of the city increased and tourism picked up, with about 400 persons per week now visiting Güssing (EEE, 2010). According to Koch et al. (2006), about 1000 new jobs and about 50 new companies were created in the whole district in which Güssing is located, as a direct or indirect consequence of energy autarky. As a consequence of the success of energy autarky in the city of Güssing, plans are underway to expand energy autarky to the whole district.

According to Horak et al. (2007: 15), the finance was organized by the municipal administration of the city. Additionally, the state Burgenland subsidizes alternative energy technologies in housing. Brunner et al. (2006: 96) find that although the local price of wood is rather high, installations can be run economically, because Austria has supported green electricity since 2003 (Ökostromverordnung).

5.2. Further examples

Several further examples can be found. Table 1 lists the projects we deem compatible with the notion of energy autarky for sustainable regional development (see CIPRA (2010) for further examples).

⁹ See <http://www.eee-info.net/cms/EN> for further information on the center, its services and the model it promotes.

5.3. Discussion

Comparing these cases, we find that the individuals pioneering energy autarky come from a large variety of backgrounds, spanning from scientific institutions researching bio-energy villages to idealists from the population (Goms, Oil of Emmental). We further find that the motives of the initiators are diverse. Mostly, energy autarky is seen as a means towards strengthening the local economy (Goms, Toggenburg). Nevertheless, considerations regarding the environment and the promotion of societal goals are also relevant.

6. Conclusions

As a conclusion to our research, we find that energy autarky should be conceptualized as a programmatic vision with practical potential rather than as a technical term. Our conceptualization may motivate and enable administrations and civil society actors to respond to the problematic aspects of industrialized countries' energy subsystems and strengthen their regions' economic, social and ecological viability. In such an endeavor, the broad, yet dispersed, literature developed by practitioners must be considered.

We believe that our research makes the following contributions: First, sustainable regional development through energy autarky may provide an overriding vision or framework, within which renewable energy innovation can be positioned, and hence social acceptance of renewable energy innovations may be increased (see Wüstenhagen et al., 2007). Second, sustainable energy autarky has the potential to inspire the further development of the European Energy Award (see CIPRA, 2010). It could inspire communities that are advanced within the European Energy Award to take their energy policy to the next level. Third, while we believe that energy autarky also has potential in cities, it may require different technologies, since space-intensive technologies (e.g. wind power, biomass) are limited in cities. Furthermore, the implementation process may have to be adapted. Fourth, we believe that the concept has great potential in equatorial countries, where strong solar radiation and large biomass potentials might make energy autarky economically very attractive.

An important gap in the literature concerns the lack of comparative empirical research. Further research should look at the success factors behind successful regions. Moreover, it should compare successful cases with cases where implementation failed or was rejected by the population. A historical reconstruction of decision processes might prove useful in this regard. Further research should also compare sustainable energy autarky with past approaches, where hydro or coal projects were used to strengthen the viability of peripheral regions. Furthermore, it should investigate whether – and if so how – the concept is useful in developing and transitioning economies.

Statement of author contributions

Ursula Dold and Adrian Stämpfli conceived the research underlying this article at Oekozentrum Langenbruck with support from the other authors. Adrian Stämpfli conducted the underlying research with support from the other authors. Matthias Müller conceived and wrote most of the article, with feedback from Adrian Stämpfli and Thomas Hammer.

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