TRANSPORT ASPECTS OF LOCAL AND REGIONAL ENERGY AUTONOMY FINDINGS FROM A MODELLING STUDY OF LIECHTENSTEIN

Hans-Martin Neumann[1], Dieter Genske[2], Peter Droege[3]
[1,2,3]*University of Liechtenstein, Institute of Architecture and Planning, Fürst-Franz-Josef-Strasse 9490, Vaduz, Liechtenstein*

Received 18 July 2011; accepted 2 September 2011

Abstract: A growing number of regional and local communities in Europe aim towards "energy autonomy". These communities try to cover their energy demand for electricity, heating and cooling to 100 % by renewable energies from local and regional sources. Is this approach also useful and viable for transport? Should the European institutions support such strategies? In this paper we will present and discuss modelling results for Liechtenstein as well as provide an overview of ongoing research project focusing on the cross-border region around Lake Constance.

Keyword: energy autonomy, renewable energies, sustainable transport, Liechtenstein, BAER.

1. Introduction

The socio-political, economic and environmental stability of the European Union is at great risk, due to its reliance on highly polluting, low-resilience and non-renewable energy sources and distribution networks. Regional strategies for rebuilding renewable supply systems are essential in eliminating this nexus of threats (Droege, 2011). As long as oil was abundant and cheap, the dependence on fossil fuels was no problem. However, today there is little doubt among energy experts that "the day of cheap and easy oil is over." (Birol, 2009). Recent studies strongly suggest that the world oil production capacity is either close to its peak or has already passed it (International Energy Agency, 2009).

The dependence on fossil fuels is particularly high in the field of transport. In Europe, 96.5 % of energy demand related to transport is covered by fossil fuels (Gilbert and Perl, 2010). As the global climate is rapidly changing and oil production is peaking, many ideas for post-fossil transport systems that rely on renewable energy have been developed recently (Canzler and Knie, 2009; Schindler and Zittel, 2008; Brake, 2009; WWF-Deutschland, 2009a). These proposals can be seen as part of a larger movement in favour of renewable energy. Many experts call for energy supply systems that are based by 100 % on renewable energy (World Wildlife Fund for Nature, 2011; Scheer, 2005). It is hotly debated, where this energy should come from: Large-scale efforts like the proposed photovoltaic plants in the deserts of Africa, or the extensive fields of energy crops that can be found in many southern countries, are also associated with big risks in terms of ecological impacts and project funding (Scheer, 2010; Droege, 2009). Projects that provide renewable energy at the local and

[1] Corresponding author: hans-martin.neumann@uni.li

regional level seem to be more successful. Thus, a whole European movement of local and regional communities aiming at energy autonomy has evolved. Many of these communities are very successful in terms of electricity and heat generation, and efficiency gains in the building stock, but only few focus on transport energy (Radzi, 2009; Energie Klima Plan GmbH and Universität Liechtenstein, 2011).

2. Method

Can the concept of regional energy autonomy also be applied in the field of transport? Is it technically possible to cover a region`s transport energy demand by renewable regional sources alone? To answer these questions this paper presents the results of a regional study for Liechtenstein that analysed renewable energy generation potential as well as the energy demand (Fig. 1). The study was carried out by the University of Liechtenstein, the Nordhausen University of Applied Science and the Energie-Klima-Plan GmbH with financial support from the government of Liechtenstein (Energie Klima Plan GmbH and Universität Liechtenstein, 2011).

The study analyses renewable energy potentials by using the Space Type Energy Model (STEM). This model allows for a quantitative assessment of a region's potential to cover its own energy demand. Based on a region-specific typology of built-up and open spaces, STEM calculates the energy demand and production capacity for renewable energy in a region (Genske, 2009).

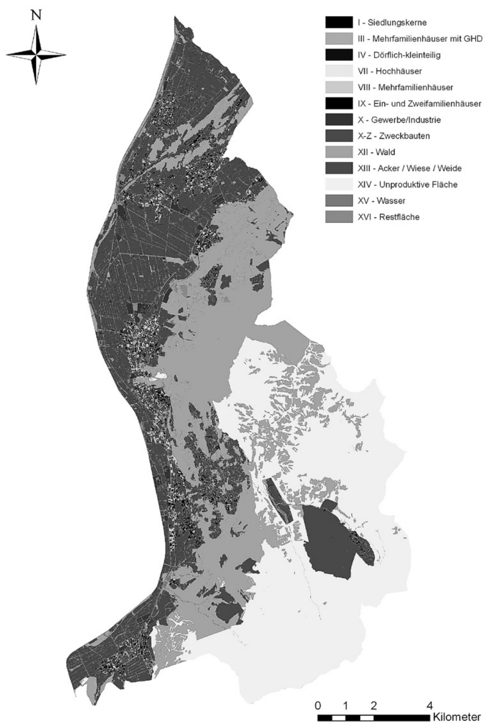

Fig. 1.
Energetic Space Types for Liechtenstein

Current transport energy demand has been calculated based on data from national energy statistics reflecting fuel sales was used. In order to estimate the future energy demand of Liechtenstein, scenarios that were originally developed in Germany (WWF-Deutschland, 2009b), were tailored to the context of Liechtenstein. Based on the transport energy demand per capita of 2010, the curve progression for previous German scenarios was used to extrapolate the future fuel and electricity demand per capita. In a next step, the demand per capita was multiplied by the number of inhabitants for 2050, as forecast by the national office of statistics.

Thus, two scenarios for the year 2050 have been developed: A) A **reference scenario** that takes into account likely future improvements to energy efficiency as well as the continued expansion of renewable energy along the lines of current trends. B) An **innovation scenario** that aims at an energy-autonomous Liechtenstein until 2050 and explores technical options for the optimal exploitation of renewable energy sources and improved energy efficiency.

3. Results

With a surface of 160 m^2 and 36000 inhabitants, Liechtenstein is the 4th smallest country in Europe. Liechtenstein is highly industrialized and has about as many workplaces as inhabitants. Two thirds of persons working in Liechtenstein are commuters that live in neighbouring Austria and Switzerland. In 2010, the primary energy demand of Liechtenstein amounted to 2.589 GWh. Transport accounts for a 400 GWh or about one quarter of the annual final energy demand, which is almost exclusively covered by petroleum, diesel, kerosene and natural gas, i.e. fossil fuels. The future energy demand of Liechtenstein is strongly influenced by demographics. According to a prognosis carried out by the national office of statistics, it is likely that the country's population will have risen to 44000 by the year 2050. This will significantly influence the energy demand.

3.1. Liechtenstein's Future Transport Energy Demand

As far as the transport energy demand is concerned, the **reference scenario** (Table 1 and Fig. 2) is based on the assumption that passenger transport volume remains stable until 2030 and then recedes slightly due to demographic effects. Freight transport, however, is predicted to grow by more than 80 %. With regard to the car fleet, it is assumed that the share of hybrids will be 23 % and the share of electric vehicles will reach 13 % in 2050. The car fleet of the year 2050 will only need about half of the energy that was needed by the car fleet in 2005. However, 80 % of the energy demand of the car fleet will still be covered by fossil fuels. The truck fleet of 2050 will run almost exclusively by (slightly more efficient) diesel trucks. Overall, the final energy demand in transport will be lowered by one third until the year 2050 in the reference scenario. Rail passenger transport is set to diminish by 4 %, whilst rail freight transport increases by 116 %. Both passenger and freight trains will be more energy efficient in the future. Although air transport is predicted to grow significantly, its energy consumption will remain almost stable, due to increased energy efficiency. In the reference scenario, the total energy demand of transport will be 27 % lower in 2050 than in 2005. This is mostly a consequence of more efficient vehicles.

Table 1
Reference Scenario: Final Energy Demand

Year	Reference Scenario		
	Total Energy Demand	Transport Energy Demand	Share of Transport
2010	1527	413	27.0 %
2050	1216	264	21.8 %

Table 2
Innovation Scenario: Final Energy Demand

Year	Innovation Scenario		
	Total Energy Demand	Transport Energy Demand	Share of Transport
2010	1527	413	27.0 %
2050	859	203	23.6 %

In the **innovation scenario** (Table 2 and Fig. 2), the volume of passenger transport will peak in 2030 and drop slightly thereafter. This trend can be explained by a shift away from car use, in favour of bike trips and walking. Nevertheless, the proportion of trips covered by private motorcars is almost as big as in the reference scenario due to demographic influences. In freight transport, the proportion of rail and water transport is higher and the average shipping distance is shorter than in the reference scenario. Petroleum-powered vehicles will be phased out between 2030 and 2050. The introduction of Diesel-powered cars is assumed to peak in 2018. In 2050, two thirds of vehicles will be hybrids and one fifth will be powered exclusively by electricity. The total energy demand of road transport will decline by 47 % until 2050. All liquid fossil fuels will be replaced by liquid biofuels until the end of that period. Thus, the total transport energy demand per capita decreases to 203 kWh and the overall transport energy demand will decrease to 5,590 GWh.

3.2. Liechtenstein's Potential for the Generation of Renewable Transport Energy

Generally speaking, renewable transport energy comes in two forms: Biofuels and Electricity. Theoretically, STEM allows an

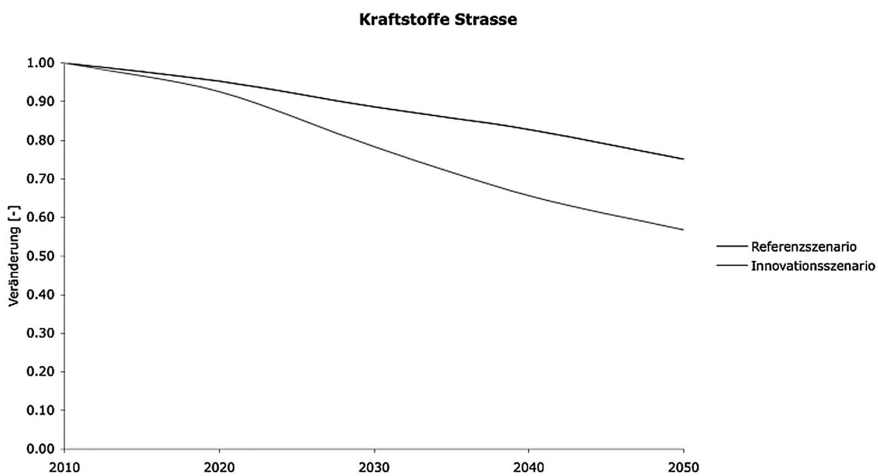

Fig. 2.
Reduction Paths of Transport Energy Demand for Liechtenstein

assessment of Liechtenstein`s potential for both forms of renewable transport energy. The generation potential for biofuels is usually diffuse, i.e. not bound to a specific installation or site. It is possible to assess its magnitude based on the typology of open spaces that is used for STEM. Energy crops can be grown on most of the open spaces. Thus, each open space type yields a specific amount of biofuels per year. If the total area covered by each open space type is known, the country's potential for renewable transport energy could be determined. For the study of Liechtenstein, however, it was decided not to take into account biofuels. Due to the country's small size, mountainous terrain and high population density, arable land is very limited. In light of these limitations and the fact that the cultivation of energy crops at a large scale would compete with food production, biofuels were not deemed to be an appropriate option for an energy autonomous Liechtenstein.

In the case of electricity generation, one has to differentiate between two types of potentials: On the one hand, there are installations that are bound to a specific site (e.g. a water power station at a river). This first type falls into the category of "concrete potentials". On the other hand, some generation potentials are not as dependent on specific geographic features, such as a river, but rather on the space type they are situated in. The solar yield of a specific photovoltaic element, for example, might be influenced by nearby objects casting shadows, such as buildings and trees. As Everding and Kloos (2007) have observed, these variations are related to the urban form (i.e. the space type) of the area installation site. This second type of potential "diffuse potential". In 2010, Liechtenstein produced 68 GWh of electricity domestically, using solar and water power. This amounts to only about 4.5 % of the final energy demand. The electricity demand of transport was 15.88 GWh.

The more conservative "reference scenario" is based on the Kyoto targets for Liechtenstein and the goals of current government programs such as the "energy concept 2013" and the "energy vision 2020". It is very possible that these targets and goals can be reached by the installation of photovoltaic panels on roofs and facades along with other measures that require limited investments. These measures may be taken by house owners and other petty private investors with some financial support from the government. No new power plants or other large scale installations will be built, i.e. no additional concrete potentials will be exploited. Rising from 68 GWh in 2010 to 174 GWh in 2050, the renewable electricity generation will almost triple. On the demand side, moderate efficiency gains are assumed, which lead to a decrease in the final energy demand from 1.527 GWh in 2010 to 1.216 GWh in 2050, even though the population is going to increase by roughly 25 % in this period of time. The energy demand will lessen from 413 GWh in 2010 to 264 GWh in 2050, which is due to more energy efficient vehicles and the increasing proportion of electric vehicles and semi-electrical hybrids. Both require less energy than conventional cars propelled by internal combustion engines. The electricity demand of transport will rise only slightly from 15.88 GWh in 2010 to 21.16 GWh in 2050 (Table 3). The contribution of electricity to the coverage of the transport energy demand will be quite small in the reference scenario. It will rise from 3.8 % in 2010 to 6,6 % in 2050. The remaining 93.4 % of transport energy demand will continue to be covered by fossil fuels in 2050.

Table 3
Electricity and Fuel Demand of Transport

	Electricity (GWh)	Fuel (GWh)
Reference Scenario		
2010	15.88	400.10
2050	21.16	300.80
Innovation Scenario		
2010	15.88	400.10
2050	25.13	222.01

The more progressive innovation scenario aims at the continuous reduction of energy demand as well as a broad shift away from fossil and nuclear energies, towards renewable sources. This includes not only the application of small scale pv installations on rooftops, but also windpower, and the decentralized use of water power and of geothermal energy. In this way, the technical potential of Liechtenstein for the generation of renewable energy can be largely exploited. The only restrictions taken into account in these scenarios refer to the conservation of valuable buildings and landscapes. It assumed that buildings and landscapes that are protected for reasons of conservation have no potential for the generation of renewable energy, as neither photovoltaic elements nor wind or water turbines can be installed here. In the innovation scenario, the introduction of renewable energy installations at a broad scale will lead to a large increase in the generation of renewable energy. The domestic production of renewable electricity will rise almost by the factor 4 from 68 GWh to 211 GWh. It is also assumed that advanced efficiency measures are implemented at a large scale. Thus, final energy consumption will drop by 44 %, from 1,527 GWh in 2010 to 859 GWh in 2050.

Simultaneously, transport energy demand goes down by more than 50 % from 413 GWh to 203 GWh. The electricity demand of transport will rise from 15.88 GWh in 2010 to 25.13 GWh in 2050. This means that 10.2 % of the final energy demand of transport will be covered by renewable electricity that can be generated inside the country. The electricity needed for transport purposes makes up only about 12 % of the electricity that will be generated in Liechtenstein. So at the first glance, it seems very possible to cover the energy demand of transport completely by renewable sources in the innovation scenario.

4. Discussion and Questions for Further Research

Two problems remain, however. The first is that there will be more than enough electricity to cover the demand of transport, but not enough to cover the overall electricity demand of Liechtenstein in 2050. This means that transport would compete with the private households, industry and with small business, retail and services for the scarce resource of regional renewable electricity. Apparently, this is a problem of timing. If we extrapolate the underlying trends for energy demand and the introduction of renewable energy technologies for the time after 2050, it seems that energy demand and renewable energy demand could match in the mid 2070´s even under the difficult spatial conditions that are found in Liechtenstein. Of course, one can speculate that enhanced technology may shorten the timeline so that electricity demand and renewable electricity supply would meet earlier, i.e. in the mid 21st century. The second problem is that even under the optimistic assumptions taken in the innovation scenario, renewable electricity will cover only 10.2 % of the transport energy demand. According to the innovation scenario for Germany that was used as a reference, it will be technically possible to replace all liquid fossil fuels by biofuels until 2050. These are, of course, also renewable, and they might even be CO2-neutral, if no fossil fuels and other oil derivatives are used for the cultivation of the energy crop. However, as has been stated already, there are not enough land resources in Liechtenstein to grow energy crops. This means that by 2050 Liechtenstein may have a transport system that relies to 100 % on renewable energy. However, due to the big proportion of biofuels and Liechtenstein`s limited land resources, it will be very difficult, if not impossible, to achieve energy autonomy in the field of transport.

As Wackernagel and Reese (1996) have pointed out, land is a scarce resource, not only in the context of Liechtenstein, but also at global scale. Biofuels, as climate-friendly as they might be, have frequently been criticized for the huge areas of cultivatable land that are required. Growing energy crops may compete with food production for land resources, reduce biodiversity and consume a lot of water. Thus it is legitimate to ask if a transport system that relies to 90 % on biofuels should be a permanent solution. Many of the problems associated with biofuels could be avoided, if electric vehicles propelled by photovoltaic solar energy were to play a more prominent

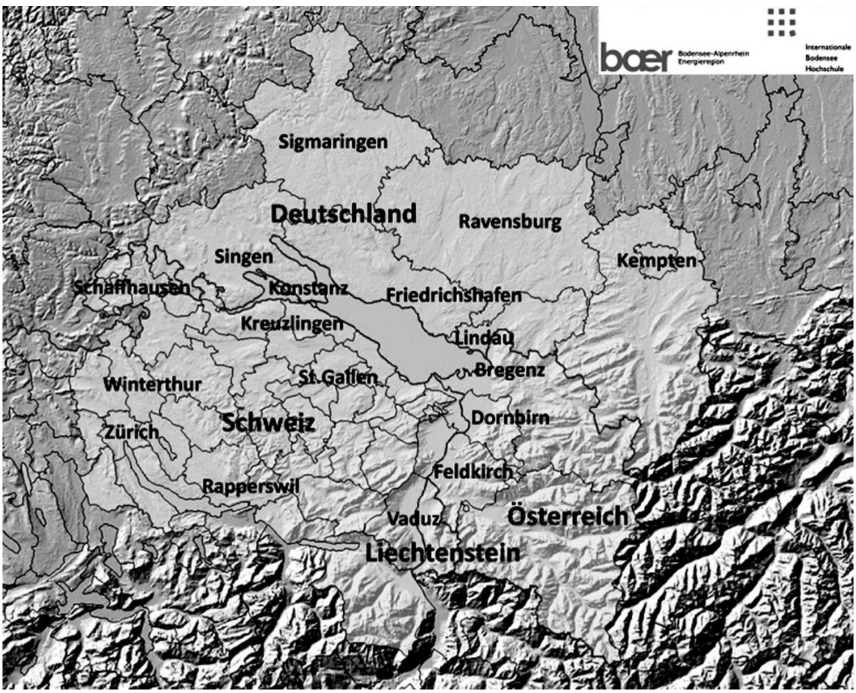

Fig. 3.
Area of the Research Project BAER – Lake Constance Alpine Rhine Energy Region
Source: www.baernet.org

part: The energetic yield of one square meter of a photovoltaic element is about thirty-five times bigger than the yield of one square meter of farm land on which energy crops are grown. Also, the energy demand of a vehicle that is propelled by internal combustion engines is about two to three times bigger than the energy demand of an electric vehicle. In the innovation scenario for Germany, a rather slow introduction rate for electric vehicles is assumed. It would be interesting to clearly identify the factors that drive or impede the introduction of electric vehicles and the phasing-out of vehicles propelled by liquid (fossil) fuels.

The generation of renewable energy always requires space. As we have seen, it is rather difficult to cover the energy demand of Liechtenstein by renewable sources, as it is mountainous and quite suburbanized and thus densely populated. This is the case for electricity, and even more for biofuels. Similar or even more severe problems may arise if energy autonomy was to be achieved for communities that are even more densely populated, such as cities and their metropolitan areas. On the other hand, a substantial number of rural communities throughout the world have achieved energy autonomy already. This raises questions regarding the optimal scale at which one may achieve regional energy autonomy.

These two questions will (among others related to the broad field of regional energy autonomy) be addressed in the research project BAER (Fig. 3) which is currently being carried out as part of the BAER project, funded by Interreg IV. BAER looks at the cross-border region around Lake Constance, including parts of Switzerland, Austria, Southern Germany and, of course, Liechtenstein.

References

Birol, F. 2009. Warning: Oil supplies are running out fast, in *The Independent* [online]. Available from internet: < http://www.independent.co.uk/news/science/warning-oil-supplies-are-running-out-fast-1766585.html>.

Brake, M. 2009. *Mobilität im regenerativen Zeitalter-Was bewegt uns nach dem Öl? [Mobility in the renewable era. What drives us to the oil?].* 1. Aufl. Hannover: Heise (Telepolis). 146 p.

Canzler, W.; Knie, A. 2009. Grüne Wege aus der Autokrise-Vom Autobauer zum Mobilitätsdienstleister [Green ways out of the car from the car manufactures to crisis in mobility services] [online]. Available from internet: < http://www.boell.de/downloads/E-Digest2009-03Autokrise.pdf>.

Droege, P. 2009. *100 % Renewable. Energy autonomy in action*. London: Earthscan. 368 p.

Droege, P. 2011. President's Policy Release. Bonn: Eurosolar e.V.

Energie Klima Plan GmbH and Universität Liechtenstein. 2011. *Erneuerbares Liechtenstein. Entwurf Endbericht [Renewable Liechtenstein. Draft Final Report].* Vaduz and Nordhausen: in print.

Everding, D.; Kloos, M. 2007. *Solarer Städtebau. Vom Pilotprojekt zum planerischen Leitbild [Solar Urban Planning. From a pilot project to the planning model]*. Stuttgart: Kohlhammer. 253 p.

Genske, D. D. 2009. *Nutzung städtischer Freiflächen für erneuerbare Energien*. Ein Projekt des Forschungsprogramms „Experimenteller Wohnungs- und Städtebau» (ExWoSt) des Bundesministeriums für Verkehr, Bau und Stadtentwicklung (BMVBS) und des Bundesamtes für Bauwesen und Raumordnung (BBR). Bonn: Bundesamt für Bauwesen und Raumordnung [*Use of urban open spaces for renewable energies.* A project of the research program „Experimental Housing and Urban Development" (ExWoSt) of the Federal Ministry of Transport, Building and Urban Development (BMVBS) and the Federal Office for Building and Regional Planning (BBR). Bonn: Federal Office for Building and Regional Planning]. 150 p.

Gilbert, R.; Perl, A. 2010. *Transport revolutions, Moving people and freight without oil. 2., rev. ed.* London: Earthscan. 434 p.

International Energy Agency. 2009. *Energy Balances of OECD-Countries 2009*. Paris: OECD/IEA. 354 p.

Radzi, A. 2009. *100 % Renewable Champions. International Case Studies. in 100 % renewable. Energy autonomy in action*. London: Earthscan, 93-165.

Scheer, H. 2005. *Energieautonomie: Eine neue Politik für erneuerbare Energien. [Energy Autonomy: A New Policy for Renewable Energy].* München: Kunstmann. 315 p.

Scheer, H. 2010. *Der energethische Imperativ: 100 Prozent jetzt: wie der vollständige Wechsel zu erneuerbaren Energien zu realisieren ist [The imperative of energeticist: get the 100 percent like the whole change is to implement renewable energy].* München: Verlag Antje Kunstmann. 321 p.

Schindler, J.; Zittel, W. 2008. Zukunft der weltweiten Erdölversorgung [Future of the world>s oil supply] [online]. Available from internet: <http://www.lbst.de/ressources/docs2008/2008-05-21_EWG_Erdoelstudie_D.pdf>.

Wackernagel, M.; Rees, W. 1996. *Our Ecological Footprint. Reducing Human Impact on the Earth*. Gabriola Island (BC): New Society Publishers. 160 p.

World Wildlife Fund for Nature. 2011. The Energy Report. 100 % Renewable Energy by 2050 [online]. Available from internet: < assets.panda.org/downloads/101223_energy_report_final_print_2.pdf>.

WWF-Deutschland. 2009a. Modell Deutschland. Klimaschutz bis 2050 [Germany Model. Climate Change in 2050] [online]. Available from internet: <http://www.oeko.de/oekodoc/948/2009-054-de.pdf>.

WWF-Deutschland. 2009b. Modell Deutschland. Klimaschutz bis 2050: Vom Ziel her denken [Germany Model. Climate Change 2050: The target of forth thinking] [online]. Available from internet: < http://www.wwf.de/fileadmin/fm-wwf/pdf_neu/WWF_Modell_Deutschland_Teil1.pdf>.

MODELIRANJE ODRŽIVOSTI LOKALNIH I REGIONALNIH AUTONOMNIH IZVORA ENERGIJE U TRANSPORTU – PRIMER LIHTENŠTAJNA

Hans-Martin Neumann, Dieter Genske, Peter Droege

Sažetak: Sve veći broj regionalnih i lokalnih zajednica u Evropi stremi ka korišćenju „autonomnih izvora energije“. Ove zajednice u potpunosti teže zadovoljenju sopstvene energetske potražnje u pogledu struje, grejanja i hlađenja koristeći obnovljivu energiju lokalnih i regionalnih izvora. Da li je ovakav pristup koristan i održiv u oblasti transporta? Da li bi evropske institucije trebalo da podrže ovakve strategije? U ovom radu su prikazani i analizirani rezultati modeliranja zasnovani na primeru Lihtenštajna i dat je detaljan pregled aktuelnog istraživačkog projekta koji se odnosi na međugranični region oko Bodenskog jezera.

Ključne reči: autonomni izvori energije, obnovljivi izvori energije, održivi transport, Lihtenštajn, BAER.