Research Notes Letter

Research & Innovation for a sustainable Baltic Sea Region

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Recent research from BUP Member Universities

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Introduction

The main part of this issue of the Research Notes Letter **builds on published research articles submitted to us** by researchers at the BUP Member Universities. Thank you for your cooperation and to give us the possibility to convey your research findings to a larger audience.

To have your publication presented both on the BUP web site and in a forthcoming issue of this newsletter please fill in the Research Notes Letter Form. Articles focusing on sustainable development in a wide sense or Education for Sustainable Development in the Baltic Sea Region are preferred.

On the BUP web site we have added some Researcher Presentations according to the BUP Themes. You will find all the presentations under the heading Researchers. There is room for many more, so take this opportunity to join the BUP researcher network by filling out the Researcher Presentation Form. A photo of yourself is required, preferably in the jpg-format.

Next issue of the Research Notes Letter will be published in the early autumn. Welcome with your contribution!

Have a nice summer!

Christian Andersson Ulrika Klintberg

Content

Analysis Acoustic Impact of Ukrainian Carpathians Wind Power Parks on the Adjacent Residential Area

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Type of publication: Article peer review

Abstract

The article analyzes the acoustic loading of wind farms in order to determine their environmental impact to ensure environmental safety. The influence of the wind power installations of the projected wind power station within the boundaries of the Polonyna Borzhava in the Eastern Carpathians on the acoustic and vibrations regime surrounding area was evaluated. Acoustic calculations were carried out in the Ecoblik company program «Acoustics» and comparatively obtained results with acceptable levels of acoustic load according to the current normative documents. As a result, the calculated values of the levels of acoustic pollution at the boundary of the sanitary protection zone meet the current standards.

Citation

Paslavskyi, M. M., Ruda, M. V. and Bojko, T. Gh. 2020. Analysis Acoustic Impact of Ukrainian Carpathians Wind Power Parks on the Adjacent Residential Area. *ΛΌΓΟΣ. The Art of Scientific Mind* 10: 48-60.
DOI: 10.36074/2617-7064.10.010

Employment in the financial sector of economy: features and trends

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Type of publication: Article peer review

Abstract

The significant transformation of employment in terms of its quantitative and qualitative characteristics is a hallmark of the current labor market. Some labor market segments differ in the market condition, growth rates, and the mechanisms of adaptation to change. This article aims at analyzing employment trends in the Ukrainian financial sector in the context of global labor market trends. The research is based on methodological approaches to the employment study of the International Labor Organization and the information of the State Statistics Service of Ukraine.

The study found out that in the pre-crisis period, employment in financial activities increased at a faster rate than other types of economic activity. However, after 2008, the trend has reversed. The concentration ratio of employees of the financial and insurance activities in the capital and in economically developed regions is moderate and steadily increasing. A decrease in the intensity of vocational training and advanced training is the negative aspect of the crisis processes in the Ukrainian financial sector.

Citation

Paska, I. Satyr, L., Zadorozhna, R., Stadnik, L. and Shevchenko, A. 2019. Employment in the financial sector of economy: features and trends. *Nowadays and Future Jobs*, 2(1), 4-14. DOI 10.21511/nfj.2.2020.02

Urban Acupuncture in Historic Environment: Research of Analogues

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Type of publication: Article peer review

Abstract

Today's cities face a variety of development, rehabilitation and preservation challenges. Historical built environment deserves particular attention in this regard. Urban regeneration projects are particularly complex here because of the dense urban fabric and the risk of damage to the heritage values. In order to understand how to overcome these challenges, we explore the concept of urban acupuncture in this research. The urban acupuncture focuses on small, precisely targeted, rapid and usually low-cost changes that positively affect social, ecological, and even economical and physical dimensions of the surrounding environment. The aim of this research was to identify the recent interventions in historic urban environment of Kaunas city (Lithuania) that can be seen as the analogues of urban acupuncture and to evaluate them using the designed set of criteria integrating the characteristics of urban acupuncture, the patterns of socially and ecologically responsible biophilic design and the requirements for preservation and development of historic built environment.

Citation

Daugėlaitė, A. and Gražulevičiūtė - Vileniškė, I. 2018. Urban Acupuncture in Historic Environment: Research of Analogues. *Journal of Sustainable Architecture and Civil Engineering*, 23(2): 5-15.
DOI 10.5755/j01.sace.23.2.21434

Riding without a ticket: geography of free fare public transport policy in Poland

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Type of publication: Article peer review

Abstract

A policy instrument promoting a free fare public transport policy (FFPT) has recently been put into practice in 66 municipalities across Poland. By contributing to the academic debate on the concept of FFPT (e.g. Kębłowski 2019), the main goal of this paper is to create a typology of the schemes where FFPT is in operation in Poland based on analyses of a geographical mapping of these projects. This study analyses how different municipalities are implementing the concept in order to define a typology of FFTP projects and to understand how the development landscape of the urban transport system is changing in the light of free fare transport policies, topics which are not fully covered in the academic literature. The findings confirm that there is a new dynamic in the development of urban transport systems and permit the identification of key characteristics of this trend. Besides the typology of implementation of FFPT, the study also presents an up-to-date inventory of FFPT projects with the key characteristic features of each system. Although the study does not provide specific recommendations regarding the introduction of a FFPT policy, it represents a good starting point for future and more detailed studies. Such studies are necessary in order to understand the role of FFPT not only in the context of the development of a given transport system, its impact on modal split, and travel behavior, but also to uncover the different politics which lie behind them.

Citation

Štraub, D. 2019. Riding without a ticket: geography of free fare public transport policy in Poland. *Urban Development Issues*, Volume 64, Issue 1, Pages 17–27, eISSN 2544-6258
DOI: 10.2478/udi-2019-0020

Validation and Comparison of Water Quality Products in Baltic Lakes Using Sentinel-2 MSI and Sentinel-3 OLCI Data

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Type of publication: Article peer review

Abstract

Inland waters, including lakes, are one of the key points of the carbon cycle. Using remote sensing data in lake monitoring has advantages in both temporal and spatial coverage over traditional in-situ methods that are time consuming and expensive. In this study, we compared two sensors on different Copernicus satellites: Multispectral Instrument (MSI) on Sentinel-2 and Ocean and Land Color Instrument (OLCI) on Sentinel-3 to validate several processors and methods to derive water quality products with best performing atmospheric correction processor applied. For validation we used in-situ data from 49 sampling points across four different lakes, collected during 2018. Level-2 optical water quality products, such as chlorophyll-a and the total suspended matter concentrations, water transparency, and the absorption coefficient of the colored dissolved organic matter were compared against in-situ data. Along with the water quality products, the optical water types were obtained, because in lakes one-method-to-all approach is not working well due to the optical complexity of the inland waters. The dynamics of the optical water types of the two sensors were generally in agreement. In most cases, the band ratio algorithms for both sensors with optical water type guidance gave the best results. The best algorithms to obtain the Level-2 water quality products were different for MSI and OLCI. MSI always outperformed OLCI, with R2 0.84–0.97 for different water quality products. Deriving the water quality parameters with optical water type classification should be the first step in estimating the ecological status of the lakes with remote sensing.

Citation

Soomets, T., Uudeberg, K., Jakovels, D., Brauns, A., Zagars, M. and Kutser, T. 2020. Validation and Comparison of Water Quality Products in Baltic Lakes Using Sentinel-2 MSI and Sentinel-3 OLCI Data. *Sensors 2020*, 20, 742.
DOI 10.3390/s20030742

Towards a relational paradigm in sustainability research, practice, and education

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Type of publication: Article peer review

Abstract

Relational thinking has recently gained increasing prominence across academic disciplines in an attempt to understand complex phenomena in terms of constitutive processes and relations. Interdisciplinary fields of study, such as science and technology studies (STS), the environmental humanities, and the posthumanities, for example, have started to reformulate academic understanding of nature-cultures based on relational thinking. Although the sustainability crisis serves as a contemporary backdrop and in fact calls for such innovative forms of interdisciplinary scholarship, the field of sustainability research has not yet tapped into the rich possibilities offered by relational thinking. Against this background, the purpose of this paper is to identify relational approaches to ontology, epistemology, and ethics which are relevant to sustainability research. More specifically, we analyze how relational approaches have been understood and conceptualized across a broad range of disciplines and contexts relevant to sustainability to identify and harness connections and contributions for future sustainability-related work. Our results highlight common themes and patterns across relational approaches, helping to identify and characterize a relational paradigm within sustainability research. On this basis, we conclude with a call to action for sustainability researchers to co-develop a research agenda for advancing this relational paradigm within sustainability research, practice, and education.

Citation

Walsh, Z., Böhme, J. and Wamsler, C. 2020. Towards a relational paradigm in sustainability research, practice, and education. *Ambio* (2020).
DOI 10.1007/s13280-020-01322-y

Spatial Diversification of the Level of Development and the Financial Situation of Rural Communes in the Świętokrzyskie Voivodship

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Type of publication: Article peer review

Abstract

The aim of the article is to evaluate the spatial disproportions in the development of rural municipalities in relation to their financial situation with the use of a non-standard synthetic measure. The analysis in the area of finance and development of communes concerned the years 2011, 2014 and 2017. The study covered 70 rural communes in the Świętokrzyskie Voivodeship. Data exploration was possible due to the use of data from the Local Data Bank of the Central Statistical Office and the Regional Audit Chamber. The method used in the work is a synthetic measure of development and the financial situation. Local self-government can fulfil its tasks when it is equipped with stable and efficient sources of income and an appropriate level of endogenous resources. The economic potential, infrastructure, financial resources are an important development factor. The group of communes with the best situation in terms of development was created, among others, by Sitkówka-Nowiny, Morawica and Strawczyn Communes, which are located in the Kielce district and are characterized by a good financial situation and economic potential. The research showed disproportions between rural communes characterized by an industrial function and units with a traditional agricultural function.

Citation

Prus P., and Dziekański P. 2019. Spatial Diversification of the Level of Development and the Financial Situation of Rural Communes in the Świętokrzyskie Voivodship. *Annals of the Polish Association of Agricultural and Agribusiness Economists*, Vol. XXI, No. (1), 74-82
DOI: 10.5604/01.3001.0013.0854

Rural landscape status, functions and human factors in the transboundary Nemunas delta region

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Type of publication: Article peer review

Abstract

The geography of border regions is not only determined by geopolitical issues, but also by physical factors, cultural traditions, economic activities and demographic change. Twenty-five years ago, the rural landscapes in the Šilutė (Lithuania) and Slavsk (Russia) administrative districts, which are located in the Nemunas river delta area, were dominated by agriculture, based on polder systems. Subsequently, agriculture has shrunk, and some agricultural land has been abandoned. As a result of migration, the total and rural populations in Slavsk district have remained the same as 25 years ago. In Šilutė district, the total and rural populations have been decreasing each year since 1990–1991. Traditional agriculture in Šilutė district is supplemented by organic farms and, in parallel with commercial fisheries, recreational fishing has increased. Rural tourism, water and nature tourism and other recreational activities have also increased, particularly in Rusnė Island and Nemunas Delta Regional Park territory (Lithuania's part of the delta). Protected areas have increased four-fold since 1991–1992, while there has been a negligible increase in built-up areas in the whole delta region. Though recreation and tourism are less developed in Slavsk district, and small and medium enterprises are fewer than in Šilutė district, the rural landscape is evidently changing in the whole region. It is transforming from a traditional agricultural–fishery region to a multifunctional region that is focused on increasing conservation and recreational activities.

Citation:

Verkulevičiūtė-Kriukienė, D, Bučienė, A and Beteika, L. 2018. Rural landscape status, functions and human factors in the transboundary Nemunas delta region. *Area*. 2018; 50: 353– 363.
DOI: 10.1111/area.12383

Airborne survey of trace gases and aerosols over the Southern Baltic Sea: from clean marine boundary layer to shipping corridor effect

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Type of publication: Article peer review

Abstract

The influence of shipping on air quality over the Southern Baltic Sea was investigated by characterizing the horizontal and vertical distribution of aerosols and trace gases using airborne measurements in the summer of 2015. Generally, continental and anthropogenic emissions affected the vertical distribution of atmospheric pollutants, leading to pronounced stratification in and above the marine boundary layer and controlling the aerosol extinction. Marine traffic along the shipping corridor "Kadet Fairway" in the Arkona Basin is shown to influence the presence and properties of both trace gases and aerosol particles in the lowest atmospheric layer. Total particle number concentration and NOy mixing ratio increased in the corridor plumes, relative to background, by a factor 1.55 and 3.45, respectively. Titration, triggered by the enhanced presence of nitrogen compounds, led to a median ozone depletion of 19% in the corridor plumes. The enforcement of the Sulphur Emission Control Area (SECA) might be responsible for the minor sulphur dioxide increase (20%) in the corridor plumes. Ship traffic caused a minor enhancement of black carbon mass concentration, estimated to be around 10%. The study of individual ship plumes indicated that ship emitted aerosol was substantially different from background aerosol: fresh ship exhaust was preferentially enriched in aerosol particles with diameters below 100 nm and in black carbon particles with core diameters above 300-400 nm. With the present work the impact of marine traffic on the concentration and properties of atmospheric components within the marine boundary layer over the open water of the Southern Baltic Sea is assessed with airborne observations for the first time. Due to the high uncertainty affecting the estimations of ship

emissions, this dataset represents a valuable reference for the assessment of ship emission inventories and related environmental-climatic impacts on the Southern Baltic Sea.

Citation

Zanatta, M., Bozem, H. Köllner, F. et al. 2020. Airborne survey of trace gases and aerosols over the Southern Baltic Sea: from clean marine boundary layer to shipping corridor effect. *Tellus B: Chemical and Physical Meteorology*, 72:1, 1-24.
DOI: 10.1080/16000889.2019.1695349

Blue Growth Potential in South Baltic Sea Region

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Type of publication: Article peer review

Abstract

The Baltic Sea Region (BSR) stands for a flagship maritime region in Europe with dominating SME sector. Nevertheless, compared with other European regions, the cooperation and promotion activities of companies that belong to the Blue Economy in South Baltic Sea Region (SBSR) are not sufficient. As a response to this, the EU-project INTERMARE South Baltic aims to support the maritime economy in the SBSR by the creation of a network of companies and stakeholders.

In line with the project, this study aims to analyse the future potential of the maritime economy and to identify trends that impact the sustainable development of the blue sector in SBSR. Based on primary data from a SBSR wide survey, descriptive statistical analysis is applied and Compound Annual Growth Rate is used as an indicator. The findings reveal need for actions regarding the sub-sectors Transport, Offshore oil & gas, Aquaculture, Fishery, Mineral resources and Biotechnology.

Citation

Philipp, R., Prause, G. and Meyer, C. 2020. Blue Growth Potential in South Baltic Sea Region. *Transport and Telecommunication*, 21 (1): 69–83.
DOI: 10.2478/ttj-2020-0006

The meagre future of benthic fauna in a coastal sea - Benthic responses to recovery from eutrophication in a changing climate

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Affiliation: 1) University of Helsinki, Hanko, Finland 2) Stockholm University, Stockholm, Sweden

Type of publication: Article peer review

Abstract

Nutrient loading and climate change affect coastal ecosystems worldwide. Unravelling the combined effects of these pressures on benthic macrofauna is essential for understanding the future functioning of coastal ecosystems, as it is an important component linking the benthic and pelagic realms. In this study, we extended an existing model of benthic macrofauna coupled with a physical–biogeochemical model of the Baltic Sea to study the combined effects of changing nutrient loads and climate on biomass and metabolism of benthic macrofauna historically and in scenarios for the future. Based on a statistical comparison with a large validation dataset of measured biomasses, the model showed good or reasonable performance across the different basins and depth strata in the model area. In scenarios with decreasing nutrient loads according to the Baltic Sea Action Plan but also with continued recent loads (mean loads 2012–2014), overall macrofaunal biomass and carbon processing were projected to decrease significantly by the end of the century despite improved oxygen conditions at the seafloor. Climate change led to intensified pelagic recycling of primary production and reduced export of particulate organic carbon to the seafloor with negative effects on macrofaunal biomass. In the high nutrient load scenario, representing the highest recorded historical loads, climate change counteracted the effects of increased productivity leading to a hyperbolic response: biomass and carbon processing increased up to mid□21st century but then decreased, giving almost no net change by the end of the 21st century compared to present. The study shows that benthic responses to environmental change are nonlinear and partly decoupled from pelagic responses and indicates that benthic–pelagic coupling might be weaker in a warmer and less eutrophic sea.

Citation

Ehrnsten, E., Norkko, A., Müller□Karulis, B., Gustafsson, E. and Gustafsson, B. G. 2020. The meagre future of benthic fauna in a coastal sea - Benthic responses to recovery from

eutrophication in a changing climate. *Global Change Biology*, 26 (4): 2235-2250. DOI 10.1111/gcb.15014

Basin-wide variations in trends in water level maxima in the Baltic Sea

Authors: Katri Pindsoo[1] and Tarmo Soomere[1,2]
Affiliation: 1) Tallinn University of Technology, Estonia 2) Estonian Academy of Sciences, Tallinn, Estonia
Type of publication: Article peer review

Abstract

Extreme water levels in the Baltic Sea have increased much faster than the global sea level rise. We employ long-term simulations with the Rossby Centre Ocean (RCO) circulation model in 1961–2005 for the quantification of (i) spatial variability of the increase rate of water level maxima in this water body and (ii) the contribution from different water level components to this increase. The increase rates of water level maxima vary from about 1.5 to 10 mm/yr. These values do not involve the vertical crust movements. The fastest increase in water level maxima occurred in the eastern Gulf of Finland (8–10 mm/yr), Gulf of Riga (6–9 mm/yr), near Klaipėda (6–8 mm/yr) and in the south-western Baltic Sea (5–7 mm/yr). Most of the increase in these locations stems from stronger local storm surges. The upsurge of the water level maxima on the shores of Sweden and in the eastern Gulf of Bothnia is typically 3–4 mm/yr and is almost fully governed by the joint impact of global sea level rise and increase in the maximum water volume of the entire sea.

Citation

Pindsoo, K. and Soomere, T. 2020. Basin-wide variations in trends in water level maxima in the Baltic Sea. *Continental Shelf Research*, Volume 193, 104029.
DOI 10.1016/j.csr.2019.104029

Transition towards a circular economy at a regional level: A case study on closing biological loops

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Affiliation: 1) LUT University, Lappeenranta, Finland 2) LAB University of Applied Sciences, Lahti, Finland
Type of publication: Article peer review

Abstract

The transition towards a circular economy requires a systemic change, where regions play a vital role. In Finland's Päijät-Häme region, European and national targets for a circular economy were implemented on a regional level. The regional development programme and strategy of the area emphasizes a circular economy as a key feature. In practice, a circular economy strategy was set up through a road map process involving stakeholders from local government, industry and academia. The strategy aims to strengthen circular economy implementation in real-world systems through five identified goals. The goals focus on closing both technical and biological loops, as well as promoting sustainable energy technologies, new consumption models and demonstration sites. This paper illustrates how a move towards a circular economy is supported through regional strategy implementation. Furthermore, opportunities and challenges related to the transition towards the circular economy are presented via a case analysis of a local bio-based industrial symbiosis where biogas and fertilizer are produced from biowaste streams and sewage sludge. New technologies such as these create more business opportunities at the interface of material and energy cycles even where their implementation faces financing challenges. Regulations need to support the implementation of effective symbioses emerging from new solutions but are also needed to safeguard the environment and human health when closing biological loops. The regional circular economy strategy described, and the case of bio-based industrial symbiosis are both recognized as transferable good practices at the European level. A stakeholder-based approach is shown to be crucial to continuous development towards a circular economy society.

Citation

Vanhamäki, S., Virtanen, M., Luste, S. and Manskinen, K. 2020. Transition towards a circular economy at a regional level: A case study on closing biological loops. *Resources, Conservation and Recycling*. Vol.156.
DOI 10.1016/j.resconrec.2020.104716

Policy dialogue on a bioeconomy for sustainable development in the Baltic Sea region

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Affiliation: 1) Stockholm Environmental Institute, Stockholm, Sweden
Type of publication: SEI Workshop report

Abstract

Advances in the bioeconomy could help achieve the United Nations Sustainable Development Goals (SDGs) in high-income, emerging and low-income economies alike (Johnson and Silveira 2014; Johnson and Altman 2014) by alleviating dependency on fossil fuels and improving overall levels of well-being and productivity. However, the transition pathways to a bioeconomy will differ widely with different starting points for the use of bio-based resources. Low-income countries still rely significantly on bio-based resources, albeit at low efficiency (sometimes referred to as "the natural economy") while high-income countries rely heavily on a fossil-based economy. The Policy Dialogues are being implemented as part of the SEI Initiative on Governing Bioeconomy Pathways. A series of dialogues, or stakeholder engagement workshops, are conducted in different countries to identify and discuss various potential pathways to achieving a sustainable and inclusive bioeconomy. The dialogues have national and regional scope and connect to local concerns and global markets by convening and engaging with a diverse group of stakeholders. This workshop brief presents the results of the first in the series, the Policy Dialogue on a Bioeconomy for Sustainable Development in the Baltic Sea Region, which was held in Tallinn, Estonia on 27 February 2019. This workshop served as a pilot of the stakeholder engagement methodology developed for the project. This brief provides some background on the bioeconomy in the Baltic region and a summary of the stakeholder engagement methodology developed for the project. It also summarizes the group discussions during the workshop and reflects on the methodology and its future evolution.

Citation

Gladkykh, G., Bessonova, E., Fielding, M., Johnsson, F. X., and Petersson, K. 2020. Policy dialogue on a bioeconomy for sustainable development in the Baltic Sea region. *SEI Workshop report January 2020.*

A strategic approach to sustainable transport system development - Part 2: the case of a vision for electric vehicle systems in Southeast Sweden

Authors: Sven Borén[1], Lisiana Nurhadi[1], Henrik Ny[1], Karl-Henrik Robèrt[1], Göran Broman[1] and Louise Trygg (Ödlund)[2]
Affiliation: 1) Blekinge Institute of Technology, Karlskrona, Sweden 2) Linköping University, Sweden
Type of publication: Article peer review

Abstract

Electric vehicles seem to offer a great potential for sustainable transport development. The Swedish pioneer project GreenCharge Southeast is designed as a cooperative action research approach that aims to explore a roadmap for a fossil-free transport system by 2030 with a focus on electric vehicles. In the first paper of this tandem publication, the authors propose a new generic process model embedding the Framework of Strategic Sustainable Development. The purpose of applying it in an action-research mode as described in this paper was twofold: (i) to develop a vision for sustainable regional transport and a coarse roadmap towards that vision, and, while doing so, (ii) get additional empirical experiences to inform the development of the new generic process model. Experts from many sectors and organizations involved in the GreenCharge project provided vital information and reviewed all planning perspectives presented in Paper 1 in two sequential multi-stakeholder seminars. The results include a sustainable vision for electric vehicle systems in southeast Sweden within a sustainable regional transport system within a sustainable global society, as well as an initial development plan towards such a vision for the transport sector. The vision is framed by the universal sustainability principles, and the development plan is informed by the strategic guidelines, of the above-mentioned framework. Among other things, the vision and plan imply a shift to renewable energy and a more optimized use of areas and thus a new type of spatial planning. For example, the vision and plan imply a lower built-in demand for transport, more integrated traffic modes, and more multi-functional use of areas for energy and transport infrastructures, for example. Some inherent benefits of electric vehicles are highlighted in the vision and plan, including near-zero local emissions and flexibility as regards primary energy sources. The vision and plan also imply improved governance for more effective cross-sector collaboration to ensure coordinated development within the transport sector and between the transportation sector and other relevant sectors. Meanwhile, the new generic process model was refined and is ready to be applied and further tested in the GreenCharge project and in other projects within the transport sector as well as other sectors.

The study confirmed that the new generic process model suggested in support of sustainable transport system and community development is helpful for giving diverse stakeholders, with various specialties and perspectives, a way of working that is goal-oriented and builds on effective, iterative learning loops and co-creation.

Citation

Borén, S. Nurhadi, L., Ny, H., Robèrt, K.-H., Broman, G., Trygg (Ödlund), L. 2017. A strategic approach to sustainable transport system development - Part 2: the case of a vision for electric vehicle systems in Southeast Sweden. *Journal of Cleaner Production*, 140(1): 62-71.
DOI 10.1016/j.jclepro.2016.02.055

Deep decarbonization of urban energy systems through renewable energy and sector-coupling flexibility strategies

Authors: Vahid Arabzadeh[1], Jani Mikkola[1], Justinas Jasiūnas[1] and Peter D. Lund[1]
Affiliation: 1) Aalto University, Aalto, Espoo, Finland
Type of publication: Article peer review

Abstract

This paper presents deep decarbonization strategies for city-level energy systems. Helsinki city is used as a case in the analysis. The strategies are mainly based on extensive electrification employing renewable electricity, storage, and sector-coupling strategies. We perform energy, economic, and resilience analyses for the different cases. An energy balance model with 1-h resolution is used to optimize the energy system on macro-scale, while a MILP-algorithm is used for micro-level optimization of operation of individual plants against different criteria. The results indicate that a zero-carbon energy system is feasible by 2050, but it would also require coupling to the exogenous energy system (national electricity market) to balance mismatches. Power-to-heat coupling, or storage alone would not be adequate. As an example of system dynamics limitations, with a wind power capacity of 1.5 GW corresponding to 56% of the annual electricity demand in Helsinki, 90% of the wind electricity can be used locally in the different sectors, but the rest needs coupling to the exogenous market due to mismatch and plant limitations. The decarbonization strategies with increasing variable renewable energy production generally improve the resilience of the energy system, but with some concerns to adequacy of peak production and electricity dependency of heating.

Citation

Arabzadeh, V., Mikkola, J., Jasiūnas, J. and Lund, P. D. 2020. Deep decarbonization of urban energy systems through renewable energy and sector-coupling flexibility strategies. *Journal of Environmental Management*, 260: 110090.
DOI 10.1016/j.jenvman.2020.110090