



# Flex4RES

Flexible Nordic Energy Systems

## Flex4RES publications

2015 - 2019



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## Flex4RES project summary

The Flex4RES project investigated how an intensified interaction between coupled energy markets supported by coherent regulatory frameworks can facilitate the integration of high shares of variable renewable energy (VRE) into Nordic-Baltic energy systems ensuring stability, sustainability, and cost-efficiency.

Through a holistic system approach based on coupled energy markets, the potential costs and benefits of achieving flexibility in the Nordic-Baltic electricity market from the heat, gas and transport sectors, as well as through electricity transmission and generation were identified. Flex4RES developed and applied a multidisciplinary research strategy that combined the technical analysis of flexibility needs and potentials; the economic analysis of markets and regulatory frameworks; and the modelling of energy systems, which quantifies impacts.

Flex4RES identified transition pathways to sustainable Nordic energy systems through the development of coherent regulatory frameworks and market designs that facilitate market interactions which are optimal for the Nordic-Baltic conditions in an EU context. Flex4RES will comprehensively discuss and disseminate the recommended pathways and market designs for achieving a future sustainable Nordic-Baltic energy solution with a variety of stakeholders from government, industry and civil society.

**WHY:** To ensure that a future decarbonised energy system is possible, in line with climate concerns, national decarbonisation targets, and the UN SDGs.

**HOW:** By increasing flexibility to accommodate the needs of a decarbonised system with high shares of variable renewable energy.

**WHAT:** Identifying and assessing regulatory and technical pathways towards coherent Nordic energy systems.

More information regarding the Flex4Res project can be found at [www.Flex4RES.org](http://www.Flex4RES.org) or by contacting project manager Klaus Skytte at [klsk@dtu.dk](mailto:klsk@dtu.dk)

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**Flex4RES**  
Flexible Nordic Energy Systems

Flex4RES publication report, August 2019

**Flexible Nordic Energy Systems**

## Flex4RES publications

Within Flex4RES the following papers/documentations are available:

- 33** published journal articles and book chapters,
- 22** peer reviewed, published conference papers,
- 11** reports,
- 15** forthcoming journal articles under review

on subjects related to the transition to flexible, decarbonised energy systems based increasingly on variable renewables. If you do not have direct access to the articles, please do not hesitate to contact the authors that would be pleased to send you a copy.

### Reports

- K. Skytte, C. Bergaentzlé, F. Fausto, P.A. Gunkel, **Flexible Nordic Energy Systems. Summary Report**, 2019. 120 p. Nordic Energy Research, <https://www.nordicenergy.org/article/act-fast-and-nordic-while-paving-the-way-for-carbon-neutrality/> ISBN: 978-87-93458-65-9
- C. Bergaentzlé, L. R. Boscán Flores, K. Skytte, E. R. Soysal, and O. J. Olsen, **Framework conditions for flexibility in the electricity sector in the Nordic and Baltic Countries**. 2016. ISBN: 978-87-93458-46-8
- E. Blom, and L. Söder. **Including Hydropower in Large Scale Power System Models**. Available from <http://kth.diva-portal.org/smash/record.jsf?pid=diva2%3A1320598&dswid=-4766>
- L. R. Boscán Flores et al., **Framework conditions for flexibility in the Gas–Electricity interface of Nordic and Baltic countries: A focus on Power-to-Gas (P2G)**. 2017. ISBN: 978-87-93458-50-5
- A. Crosara, E. Tomasson, and L. Söder, **Generation Adequacy in the Nordic and Baltic Region: Case Studies from 2020 to 2050**. KTH, 2019. Available from <http://kth.diva-portal.org/smash/record.jsf?pid=diva2%3A1336561&dswid=-9620>
- F. Karimi, P. D. Lund, K. Skytte, and C. Bergaentzlé, **Better Policies Accelerate Clean Energy Transition. Policy brief - Focus on energy system flexibility**. 2018. Available: <https://www.nordicenergy.org/article/better-policies-accelerate-clean-energy-transition/> ISBN: 978-87-93458-56-7.
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- D. Møller Sneum, E. Sandberg, E. R. Soysal, K. Skytte, and O. J. Olsen, **Framework conditions for flexibility in the district heating-electricity interface**. 2016. ISBN: 978-87-93458-42-0
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- L. Sønderberg Petersen, R. B. Berg, C. Bergaentzlé, S. Bolwig, and K. Skytte, Eds., **Smart grid Transitions: System solutions and consumer behaviour**. Department of Management Engineering, Technical University of Denmark, 2017. ISBN: 978-87-93458-51-2

## Published journal articles & books

- V. Arabzadeh, S. Pilpola, and P. D. Lund, **Coupling Variable Renewable Electricity Production to the Heating Sector through Curtailment and Power-to-heat Strategies for Accelerated Emission Reduction**, *Futur. Cities Environ.*, vol. 5, no. 1, Jan. 2019. DOI:10.5334/fce.58
- C. Bergaentzlé, I. Græsted Jensen, K. Skytte, and O. J. Olsen, **Electricity grid tariffs as a tool for flexible energy systems: A Danish case study**, *Energy Policy*, pp. 12–21, Mar. 2019. DOI:10.1016/j.enpol.2018.11.021
- D. Blumberga, E. Vigants, F. Romagnoli, A. Blumberga, S. N. Kalnins, and I. Veidenbergs, **Hybrid System with Biomethanation for Wind Energy Accumulation in the Baltic Countries**, *Energy Procedia*, vol. 75, pp. 754–759, Aug. 2015. Available: <https://www.sciencedirect.com/science/article/pii/S1876610215012758> DOI:10.1016/J.EGYPRO.2015.07.507
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- R. Bramstoft and K. Skytte, **Decarbonizing Sweden’s energy and transportation system by 2050**, *International Journal of Sustainable Energy Planning and Management*, vol. 14, p. 3-20, 2017. DOI:10.5278/ijsepm.2017.14.2
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### Forthcoming peer-reviewed articles

- G. Bazbauers, **Power sector flexibility through power-to-heat and power-to-gas application**, *Submitted for publication.*
- C. Bergaentzlé, K. Skytte, and P. A. Gunkel, **Comparative analysis of cross-border and cross-sector approaches for flexibility in the Nordic countries**, *Submitted for publication.*
- S. Bolwig *et al.*, **Transition pathways to a flexible and carbon-neutral energy system in the Nordic-Baltic region: Coupling techno-economic modelling and socio-technical analyses**, *Submitted for publication.*
- Y.-K. Chen, H. Koduvere, P.A. Gunkel, J.G. Kirkerud, K. Skytte, H. Ravn, T.F. Bolkesjø **The role of cross-border power transmission in a renewable-rich power system – a model analysis for Northwestern Europe**, *Submitted for publication.*
- Y.-K. Chen, A. Hexeberg, K.E. Rosendahl, T.F. Bolkesjø, **Review on long-term trends of North-West European power market.** *Submitted for publication.*
- F. Fausto and K. Skytte, **Power Purchase Agreements and the Energy Only Market: A Hybrid Design for Future Decarbonized Power Markets**, *Submitted for publication.*
- I. Graested Jensen, F. Wiese, R. Bramstoft, and M. Münster, **Potential role of renewable gas in the transition of electricity and district heating systems**, *Submitted for publication.*
- P. A. Gunkel, H. Ravn, S. Petrovic, F. Fausto, H. Koduvere, and J. G. Kirkerud, **Modelling transmission systems in energy system analysis: a comparative study**, *Submitted for publication.*
- J. Jasiūnas, J. Mikkola, P.D. Lund, **Review on energy system resilience.** *Submitted for publication.*
- J. G. Kirkerud, N. O. Nagel, and T. F. Bolkesjø, **The role of demand response in the future renewable Northern European energy system**, *Submitted for publication.*
- H. Koduvere, S. Buchholz, and H. Ravn, **Constructing aggregated time series data for energy system model analyses**, *Submitted for publication.*
- P. D. Lund, V. Arabzadeh, J. Mikkola, and J. Jasiūnas, **Deep decarbonization of urban energy systems through renewable energy and sector-coupling flexibility strategies**, *Submitted for publication.*
- P. D. Lund *et al.*, **Pathway analysis of a zero-emission transition in the Nordic-Baltic region**, *Submitted for publication.*
- K. Skytte, C. Bergaentzlé, and O. J. Olsen, **Grid tariffs that facilitate flexible use of power-to-heat.**, *Submitted for publication.*
- P. Sorknæs, H. Lund, I.R. Skov, S. Djørup, K. Skytte, P.E. Morthorst, **Smart Energy Markets - future electricity, gas and heating markets.** *Submitted for publication.*



## Published conference articles

- C. Bergaentzlé, K. Skytte, J-G. Kirkerud, and O-J. Olsen, **Electrification and Interconnections for Flexibility: A Comparative Analysis**, in *2019 16th International Conference on the European Energy Market (EEM)*. IEEE Xplore
- C. Bergaentzlé, K. Skytte, E. R. Soysal, L. R. Boscán Flores, and O. J. Olsen, **Regulatory barriers for activating flexibility in the Nordic-Baltic electricity market**, in *2017 14th International Conference on the European Energy Market (EEM)*, 2017, pp. 1–6. DOI:10.1109/EEM.2017.7981948 ISBN: 978-1-5090-5499-2
- T. F. Bolkesjø, J. G. Kirkerud, and E. Trømborg, **Power market impacts of increased use of electricity in the heating sector**, in *2017 14th International Conference on the European Energy Market (EEM)*, 2017, pp. 1–6. DOI:10.1109/EEM.2017.7981955 ISBN: 978-1-5090-5499-2
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- A. Crosara, E. Tómasson and L. Söder, **Generation Adequacy in the Nordic and Baltic Area: The Potential of Flexible Residential Electric Heating**, 2019 IEEE PES Innovative Smart Grid Technologies Europe (ISGT-Europe)
- F. J. Fausto, P. A. Gunkel, K. Skytte, C. Bergaentzlé, and R. McKenna, **Designing Taxes and Tariffs for Electricity Systems with Complex Flexible Actors**, in *2019 16th International Conference on the European Energy Market (EEM)*, 2019
- J. Gea-Bermúdez, L. Pade, A. Papakonstantinou, M Koivisto, **North Sea Offshore grid - effects of integration towards 2050**, in *2018 15th International Conference on the European Energy Market (EEM)*, 10.1109/EEM.2018.8469945
- P.A. Gunkel, F.J. Fausto, K. Skytte, C. Bergaentzlé, **The Impact of EV Charging Schemes on the Nordic Energy System**, in the *2019 16th International Conference on the European Energy Market (EEM)*. IEEE Xplore.
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- E. R. Soysal, O. J. Olsen, K. Skytte, and J. K. Sekamane, **Intraday market asymmetries — A Nordic example**, in *2017 14th International Conference on the European Energy Market (EEM)*, 2017, pp. 1–6. DOI:10.1109/EEM.2017.7981920 ISBN: 978-1-5090-5499-2
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### Podcasts (<https://www.nordicenergy.org/flagship/flex4res/flex4res-podcasts/>)

Energy Polycast, Flex4RES results disseminated in a straightforward (and geeky) way. With host D. M. Sneum. Available: <https://energypolycast.podbean.com/> or <https://www.nordicenergy.org/flagship/flex4res/flex4res-podcasts/>

Available episodes:

- F. Fausto, D.M. Sneum, **Power Purchase Agreements - Good for the energy system – and for old ladies.**
- P. Lund, D.M. Sneum, **Policies for flexibility: A Flex4RES perspective. What have violins to do with flexibility and sector coupling?**
- K. Skytte, D.M. Sneum, **The future Nordic energy system. Water as storage and flexibility provider - flushing batteries away.**



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in addition to the above list we have made videos, PhD courses, and a lot of conference presentations. Please do not hesitate to contact the authors to get a copy of the papers or other material.

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