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Tampere University	VTT	SYKE Finnish Environment Institute	FIIA FINNISH INSTITUTE OF INTERNATIONAL AFFAIRS	UNIVERSITY OF EASTERN FINLAND

Infrastructure/institutions match for resilient & just green electrification (2IMATCH)

The 2IMATCH consortium examines **how green electrification can deliver a more resilient energy system and society in an uncertain world** disrupted by several human-made disasters and seemingly persistent global confrontation. With green electrification, we refer to the ongoing transition to a climate neutral and effective system where electricity, based largely on renewable sources, becomes the main energy carrier in all consumption sectors and where electricity-based fuels such as hydrogen, ammonia and methanol become commonplace.

Achieving a resilient system and society via green electrification requires interdisciplinary research. On the one hand, this emerging system offers considerable **resilience benefits** since it uses domestically available renewable resources and will have a networked structure combining effective large-scale infrastructures with small-scale decentralized ones. On the other hand, this networked structure occasions **new vulnerabilities** vis-a-vis (i) the predominant energy carrier, as the power, transport, heating and industry sectors become interconnected by electricity; (ii) cross-border electricity interconnectors, as increasing variable output electricity generation from wind and solar is more efficiently balanced using assets across a larger area; (iii) cyberattacks, as the system becomes highly data and IT reliant; and (iv) new energy geopolitics, where competition for critical and strategic minerals and metals, access to technologies and markets, and over international order in general co-exist with business opportunities.

We propose that reaping the benefits whilst restraining the new vulnerabilities requires new and refurbished energy infrastructure; and **institutional adaptation and innovation** (Fig 1). The main challenge here is how to match infrastructure development with corresponding institutional development. An **optimal infrastructure/ institutions match** can: (i) deliver the resilience benefits and avert vulnerabilities; (ii) control the associated costs; (iii) protect energy justice and further socio-economic interests; (iv) prevent excessive securitization of critical infrastructure development, noting how security considerations today pervade societal debates, while energy geopolitics shapes investment, trade and international interaction (Fig 2).

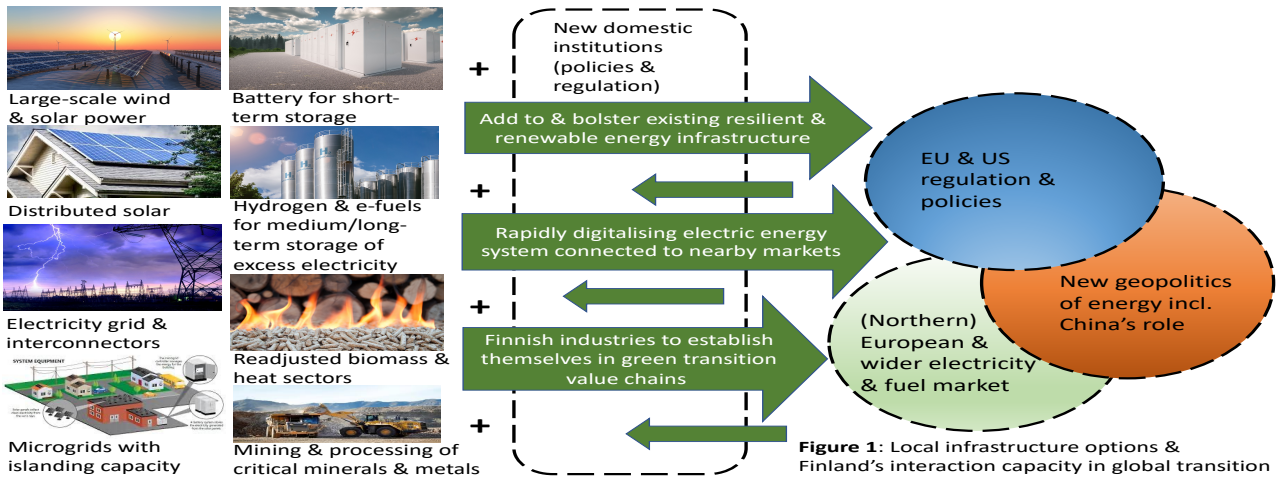

Figure 1: Local infrastructure options & Finland's interaction capacity in global transition

The 2IMATCH consortium focuses on **Finland** as a **local case of global energy transition** owing to the **high interaction capacity of Finnish actors**. Finland can add to and must bolster its existing renewable and resilient energy infrastructure. The country has a rapidly digitalizing electric energy system with a strong national transmission grid and interconnections to European markets. Finnish industries have capacities for establishing themselves in the markets for green electrification technologies and related data and security solutions. We will consider the country's choices for infrastructure and institutions in the context of **electricity and fuels trade** in northern Europe and beyond; we will also analyze **EU regulation and policies,** for example, on standards for renewables deployment and green hydrogen, and ongoing reform of the EU electricity market design. Moreover, we scrutinize the Finnish choices in the context of **new geopolitics of energy wherein energy justice is also in question** (Fig 2).

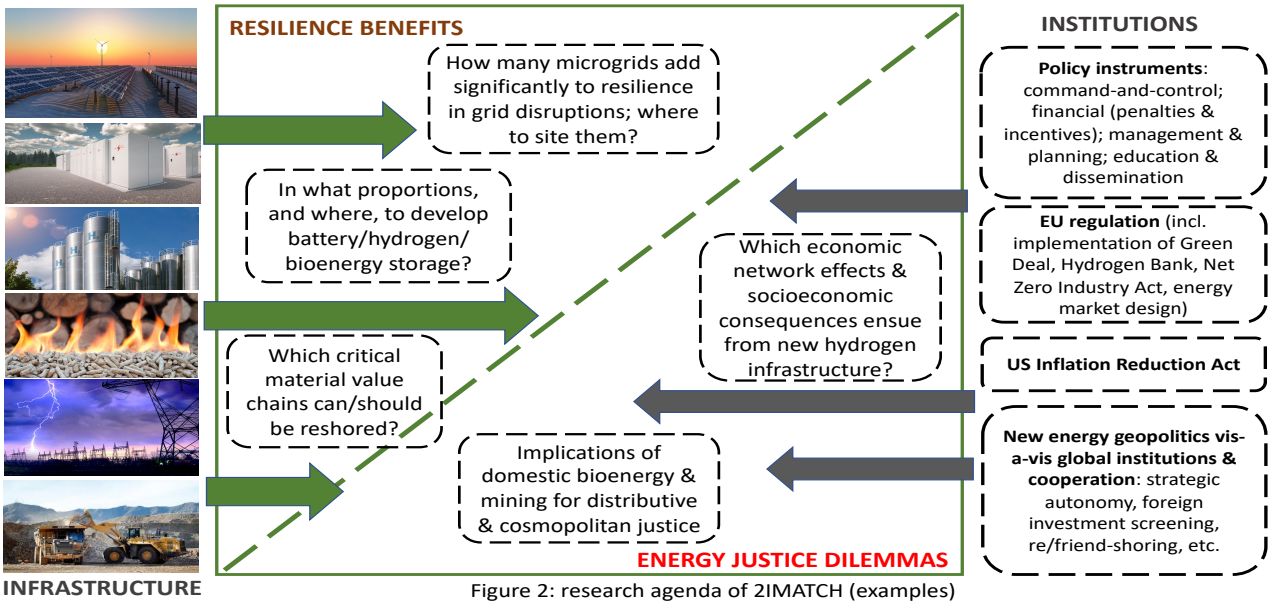

Figure 2: research agenda of 2IMATCH (examples)

The **scientific contributions** are: (i) solution proposals regarding the dilemmas that emerge between resilience and justice in new infrastructure development, informed by interdisciplinary research ranging from environmental science and engineering to law and politics; (ii) analyses on how new regulations and policies in the USA and the EU shape new energy geopolitics and in turn, Finnish choices; (iii) optimization solutions for considering various combinations of large and small, centralized and decentralized infrastructures, enabled by a methodologically advanced, open access & open data modelling tool; (iv) a new conceptual framework for a more comprehensive study of resilience, informed by recent advances in interdisciplinary security studies; and (v) comparative knowledge on the resilience and justice implications of energy infrastructure and institutional reforms, by means of case studies on the respective choices in Estonia, Norway, Germany, Israel, USA and Japan; and on the role of China in this transition.

The consortium has strong expertise in energy engineering and environmental science, international security and energy transitions, as well as experience in stakeholder research and interaction. We will use methods such as modelling, case studies, the law-in-context approach, Q methodology, qualitative comparative analysis (QCA), co-creation and observation methods.

Stakeholder benefits: authorities and critical infrastructure owners will obtain systematic information on the consequences of more resilient infrastructure choices, regarding costs, emissions, local environmental impacts, the 'do no significant harm' principle, network externalities for adjacent industries, the various aspects of energy justice, and geopolitical risk.

For municipal utilities and SMEs, we will produce an open-source asset planning framework with open access datasets and easy-to-use interface based on state-of-the-art energy system modelling tools. The decisions these stakeholders need to make (e.g. expanding district heating, investing in wind power, batteries or deep geothermal energy, dismantling existing power plants, developing new energy technologies, etc.) are complex, affected by larger energy systems. Smaller energy companies lack access to such decision-making support tools, yet they remain responsible for many investments needed for the energy transition. Our legal, policy and comparative case study analyses will equip energy and security authorities to assess how critical infrastructure investments are affected by larger trends, including energy geopolitics. Stakeholders are involved in co-creation workshops and simulation games. The project will also improve our capability to provide ad-hoc advice for authorities on short notice. The **interaction methods** comprise (i) expert panel; (ii) biannual co-creation workshops; (iii) simulation games; (iii) seminars, roundtables and meetings; (iv) policy briefs, blogs, podcasts; (v) digital platform; (vi) stakeholder interviews.

Consortium PI researchers

PI Name	**Roles** (key competence)	**Affiliation during project**
Prof. Pami Aalto	Lead PI (energy system & policy, international security, political economy, stakeholder research, interdisciplinarity)	Politics Unit, Faculty of Management and Business & research platform on Climate Neutral Energy Systems and Society (CNESS), Tampere university (TAU)
Dr. Eneken Tikk	*WP4: Resilience and security orders* (strategic stability, cybersecurity governance, digitalization normative leadership)	Tampere Centre for Security, Risk & Resilience (TASERR) & Politics Unit, MAB Faculty, TAU
Dr. Ulla Saari, Docent, Senior Researcher	*WP6: Interaction* (business management, industrial management and engineering, social sciences, stakeholder & environmental research)	Center for Innovation & Technology Research (CITER), Unit of Industrial Engineering & Management, Faculty of Management and Business, Tampere university
Dr. Juha Kiviluoma, Principal Scientist	*WP3: Open data modelling framework* (energy system modelling for decision-making)	VTT Technical Research Finland Ltd.
Dr. Sampo Soimakallio, Docent, Leading Researcher, Group Manager	*WP1: Interdisciplinary analysis of infrastructural challenges* (environmental research and energy engineering; biomass & land use in life-cycle analysis)	Finnish Environment Institute (SYKE)
Dr. Sirja-Leena Penttinen, Senior Lecturer	*WP2: Institutional challenges* (international & European energy law; implications of sustainable energy transition to markets and investments)	Law School, University of Eastern Finland
Dr. Marco Siddi, Docent, Senior Researcher	*WP5: Case studies* (European security; EU energy & climate frameworks)	Finnish Institute of International Affairs

International collaborators: The consortium will conduct field visits to all case study countries (Estonia, Germany, Norway; Israel, Japan, USA; and China); and has partners in Denmark;

Estonia; Japan; Germany; Hong Kong/China; Norway; Sweden; and the USA. The modelling team will work with the Spine tools development community, including KU Leuven, University College Dublin, KTH Royal Institute of Technology in Sweden, DTU Technical University of Denmark, TNO in the Netherlands, Electric Power Research Institute in Dublin, Ireland and the National Renewable Energy Laboratory in the USA.

The work programme of 2IMATCH is divided into seven WPs:

	Project months											
WP	**1-6**	**7-12**	**13-18**	**19-24**	**25-30**	**31-36**	**37-42**	**43-48**	**49-54**	**55-60**	**61-66**	**67-72**
1		**M1.1**		**M1.2**				**M1.3**				
2			**M2.1**		**M2.2**					**M2.3**		
3						**M3.1**						**M3.2**
4				**M4.1**						**M4.2**		
5						**M5.1**						**M5.2**
6	Kick-off	Event	**M6.1**	Event	Event	Event	Event	Event	**M6.2**	Event	Event	Final event
7						**M7.1**						**M7.2**

M1.1 Resilience taxonomy
M1.2 Energy justice implications considered
M1.3 Local choices in global value chains
M2.1 Policy instruments for infrastructure renewal and refurbishment
M2.2 Effects of EU and US policies & subsidies reviewed
M2.3 Validation of policy instruments
M3.1 Tool available & cost-optimal and resilient energy infrastructures modelled
M3.2 Support for the infrastructure decision-making of local level stakeholders provided
M4.1 New conceptual understanding reached of resilience in energy infrastructure development
M4.2 Q methodological analysis completed on views of energy system stakeholders
M5.1 Case studies Estonia, Norway, Germany completed
M5.2 Case studies Israel, Japan, USA completed
M6.1 Simulation game 1 completed
M6.2 Simulation game 2 completed
M7.1 First phase report