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Consortium name	Transition to a resource efficient and climate neutral electricity system (EL-TRAN)
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1. Rationale

This consortium will help to resolve policy problems involved in a transition to a resource efficient, climate neutral electricity system. The initial phase of such a transition is currently underway in Finland. It is a response to global megatrends including climate change, increasing competition for fossil fuels among Asia's emerging economies, and the EU's visions like the 2050 Roadmap to a Resource Efficient Europe and the low-carbon objectives of the Energy Roadmap 2050 (Commission 2011a, b). Several reports by the Government of Finland, the energy industry and non-governmental organisations (NOGs) alike agree that Finland's energy transition will eventually include a switch to a higher share of renewable resources and a diminishing share of fossil fuels in primary energy production and will lead to a higher share of electricity in the final consumption of energy. These reports also foresee a need for new electricity networks, technology and other infrastructure. The predominantly centralised Finnish electricity system of today is to become more automated or 'smarter' and decentralised. Some energy consumers including citizens can become energy producers (e.g. Energiateollisuus 2010; Pöyry 2015; Salo 2015; TEM 2013, 2014).

We welcome this initial vision. However, we suggest that Finland lacks a full comprehension of what resource efficiency entails in the context of this transition, what complex policy problems such a society-wide energy transition will involve and generate, and how to respond to them:

1. The key energy actors usually decide on a case-to-case basis on new power plants and other energy projects, which are primarily driven by business interests in profitability. Yet the effects of these decisions on the whole electricity system and on other stakeholders including citizen consumers remain unclear.
2. A higher share of domestically produced renewable energy and hence greater self-sufficiency of the electricity system can result in inefficiencies in terms of resource use, infrastructure development and costs. This is so if high volumes of affordably priced, renewably produced electricity is available from neighbouring countries, assuming that network interconnections of electricity systems are enhanced as targeted by the EU.
3. While many Finnish reports treat biomass resources as a promising solution, the problem of how they will fit into the development of the whole electricity system remains unsolved.
4. Citizen consumers can improve resource efficiency for example by becoming small-scale producers of renewable energy and feeding it into networks, by installing automated

heating systems and following the forthcoming near zero energy discharge building codes. However, complex problems emerge on how to develop, connect and manage the different parts of the de-centralising electricity network.

5. The resource efficiency gains of more flexible use of energy create the problem of whether industrial or citizen consumers are to be flexible and when.
6. The electrification of transport, including vehicle-to-grid (V2G) technologies, automation and new electrical appliances, and increased use of renewables contribute to the society's electrification. This makes uninterrupted power supply an even more critical infrastructure. For example, the new energy market act in practice requires high-cost cabling of rural distribution networks to guarantee power supply after natural disasters. More resource efficient solutions could rely on de-centralised production, or 'island use' on the local level.
7. Renewable energy generates problems on how to optimise power balance in the energy system owing to the intermittent nature or varying output of renewable energy solutions.
8. Further policy problems emerge regarding which parts of the existing infrastructure to replace, which to use more efficiently, and which new solutions to promote, where, and when and with what requirements.

The consortium will confront these and further problems by means of a powerful interdisciplinary methodology informed by social theory and continuous interaction with stakeholders. First, we scrutinise critically the expressed interests in resource efficiency and climate neutrality vis-à-vis other competing interests held by key Finnish actors and stakeholders. For this end, we consult the energy industry, investors, the public sector and citizen-consumers. Because many policy problems ensuing from the initiated energy transition centre on electricity, we concentrate on Finland's electricity system including producers, networks and consumers. We also situate the Finnish case into the wider context of interests and trends on the global and EU levels and in Finland's neighbourhood on which the efficient use of resources in Finland depends. This is because Finland's energy system relies on developments on these levels with regard to capacity issues, interconnections, pricing, competition and regulation. Second, we analyse how individual energy solutions can support greater resource efficiency and climate neutrality against the structure of constraints and opportunities along four dimensions: a) resource development, infrastructure and technology; b) costs, finance, business models and markets; c) institutions; and d) ecology, climate and air quality. On this basis, we form a model of how to optimise individual solutions vis-à-vis each other and the interests driving and shaping Finland's energy transition. Third, we generate requirements for Finnish energy policy actors and stakeholders to realise the energy transition and a roadmap for the public sector to support the process.

2. Societal significance and impact

We issue a roadmap for the Finnish public sector to support the key actors and stakeholders in the initiated energy transition. This roadmap will include tasks for each public sector actor to attain an optimal balance between costs and benefits. It will include suggestions for institutional change and regulation. We create new information interfaces by means of our stakeholder interaction plan (see section 7). The consortium supports the development of business models based on renewable energy and new types of electricity systems and hence helps to generate new tracks of employment. The consortium's work for realising the interests in resource efficient and climate neutral society will help to improve air quality and contribute to public health. While these interests drive public policies in Finland and the EU, we will seek to accommodate these with the diverse interests of energy companies, and industrial and domestic consumers. We explore options for Pareto optimality in the optimisation of the electricity system whereby the transition would leave no actor worse off than initially. This supports the whole society's involvement and contributes to education, training and competence building in this area. We advise on the extent to which Finland's energy transition can build on domestic capacities and how much it depends on external networks, markets and regulation.

3. Objectives

WP1: Stakeholder interaction (UTA [lead], TTU, VTT, UTU, UEF, TAMK; see section 7).

WP2: Comparative analysis of actors, interests and frames driving energy policies (UTA [lead], UEF). The objective of WP2 is to compare the interests among Finnish stakeholders and the wider cognitive policy frames by which they rank these interests and combine them in the formulation of energy policies. We contrast the interests in resource efficiency and climate neutrality to the further interests held by various public sector, energy business and NGO actors. These include for example competence growth, energy business, profits and export capacity, security of supply, reliability, quality and resilience. Our analysis covers the interests of citizen-consumers. It extends to their framings and acceptance of energy solutions. We study the grounds by which they make decisions on energy consumption and production on the household level. We compare these results to the wider context of interests driving energy policies on the global level – including the USA and China – and the EU level including the regulatory, competition and further interests. This analysis also delves into the interests in Finland's neighbouring countries, which most directly shape the future of Finland's electricity system. Research questions:

1. How can we ensure that decisions on individual energy projects take into account the system perspective including the interests of key stakeholders?
2. What policy problems may ensue from citizens' frames of energy policy and their new roles in energy production and consumption?
3. Are the Finnish interests compatible with those in the countries on which Finland's energy system depends?

WP3: Electricity system development solutions (TUT [lead], VTT, UTA, UEF, TAMK). The objective of WP3 is to examine individual solutions vis-à-vis resource efficiency and climate neutrality. First, we examine the development of renewable resources decisive for Finland's energy transition. We hypothesise that the potential of solar power is underestimated and expect wind power to grow depending on choices between in-land and offshore solutions and public acceptance. For biomass solutions we cover replacement of coal and natural gas with biofuels in large-scale combined heat and power (CHP) plants; bio-refineries combining the production of power, heat and energy carriers (pellets, liquid fuels and other bio-products); and hybrid systems combining solar and bio-power. The requirements of increased nuclear power use on the balance management of the power system are included. Second, we consider the problems of security of supply, reliability, back-up capacity and storage ensuing from the large-scale supply of highly intermittent renewably produced electricity into the network and related infrastructures. Third, we weigh the realisability of near zero discharge building codes and the automation of energy use in buildings from the point of view of the construction industry and citizens. Fourth, we scrutinise the resource efficiency benefits of energy use flexibility by industrial and domestic consumers, of 'smart' operation of electricity networks and V2G technologies, of energy islands and local or nearby micro-grids, heat pumps and local CHP solutions avoiding costly cabling solutions; and distance heating and cold. Research questions:

1. How does the variable output of renewable energy production affect the future electricity system?
2. How to maintain power balance on the system level and quality on the micro grid level?
3. What type of demand response features and electric power storages are needed?
4. Which constraints exist on the part of the construction industry and consumers for the actual realisation of zero discharge buildings and the flexible use of energy in buildings through automation?
5. Can smart networks, energy islands and other local solutions improve resource efficiency?
6. How structural constraints and opportunities shape each individual solution (see Figure 1)?

WP4: Optimisation solutions for the electricity system (TUT [lead], VTT, UEF, UTA). The first objective of WP4 is to model the individual solutions analysed in WP3. Second, we combine these models to assess their mutual dependencies in the context of the whole system. In this way, we build an overall model of what type of an electricity system Finland's energy transition requires and of how to operate it. The overall model will accommodate the diverse interests of the actors and stakeholders in the energy system as outlined in WP2 and cover resilience regarding natural disasters and cyber-attacks. We describe the dominant dynamic characteristics of the system's components. The model accounts for how the system evolves when actors change their behaviour in response to the management of the supply-demand balance. WP4 also draws upon the first and second iterations of the work on scenarios and trends in WP5. In this way, the overall model will seek to optimise the electricity system to take into account our analysis of the prospects of key actors and stakeholders to realise their interests given the structure of constraints and opportunities each individual solution encounters. Research questions:

1. How to model the system components to account for essential dynamics from one minute to several years?
2. How to operate the system and by what algorithms to develop optimal solutions?
3. How to (re)design the system in future scenarios (2020, 2040, etc.) given the diverse interests of key stakeholders and the structure of constraints and opportunities shaping their choices (see Figure 1)?

WP5: Trends and scenarios (UTU [lead], TUT, UTA). The objective of WP5 is to help the consortium to be proactive in relation to future societal trends. In the first iteration, we proceed from the results of WP2 on the interests of different actors and stakeholders from the global level to the Finnish context to assess trends on these levels. We focus on trends vis-à-vis energy demand, trade, interconnections, planned power sector reforms and overall integration of neighbouring energy systems affecting Finland. The first iteration incorporates input on the existing problems in renewable resource development, and technological and infrastructural problems from the early work in WP3-4. In the second iteration, we use the compiled information on interests, trends and problems to organise futures workshops with key actors and stakeholders including citizens to develop scenarios for Finland's energy transition (see section 10). The workshops function as forums for back-casting scenario building in order to discern development paths to resource efficiency and climate neutrality. In the final iteration, we summarise the scenario work. Research questions:

1. What effects external energy trends have on Finland's prospects of energy transition?
2. Which structural constraints hamper Finland's energy transition (see Figure 1)?
3. What constraints and opportunities for Finland's energy transition stakeholders incl. citizens identify?

WP6: Requirements for Finnish energy policy actors and stakeholders (UTA [lead], TTU, VTT, UTU, UEF, TAMK). The objective in the first iteration is to examine current regulatory and other requirements including taxation shaping the choices of actors. In the second iteration, we outline who should do what regarding each solution, taking into account the structure of constraints and opportunities set by the dimensions of structure. This will include energy policy and legal recommendations, energy market and electricity network governance, supervision and incentive structure, etc. Research questions:

1. To what extent are current requirements for actors conducive for the energy transition?
2. What new requirements for Finland's energy transition can be generated for various energy actors taking into account our work on the constraints, solutions, optimisation and scenarios?

WP7: Roadmap for Finland's transition to a resource efficient and climate neutral energy system (UTA [lead], TTU, VTT, UTU, UEF, TAMK). The objective of WP7 is to establish a roadmap for Finnish public sector actors to support the energy transition optimally. It will include indicators to determine how the requirements are converted into tangible solutions and policies; and milestones to assess the progress vis-à-vis the revised set of interests driving the transition.

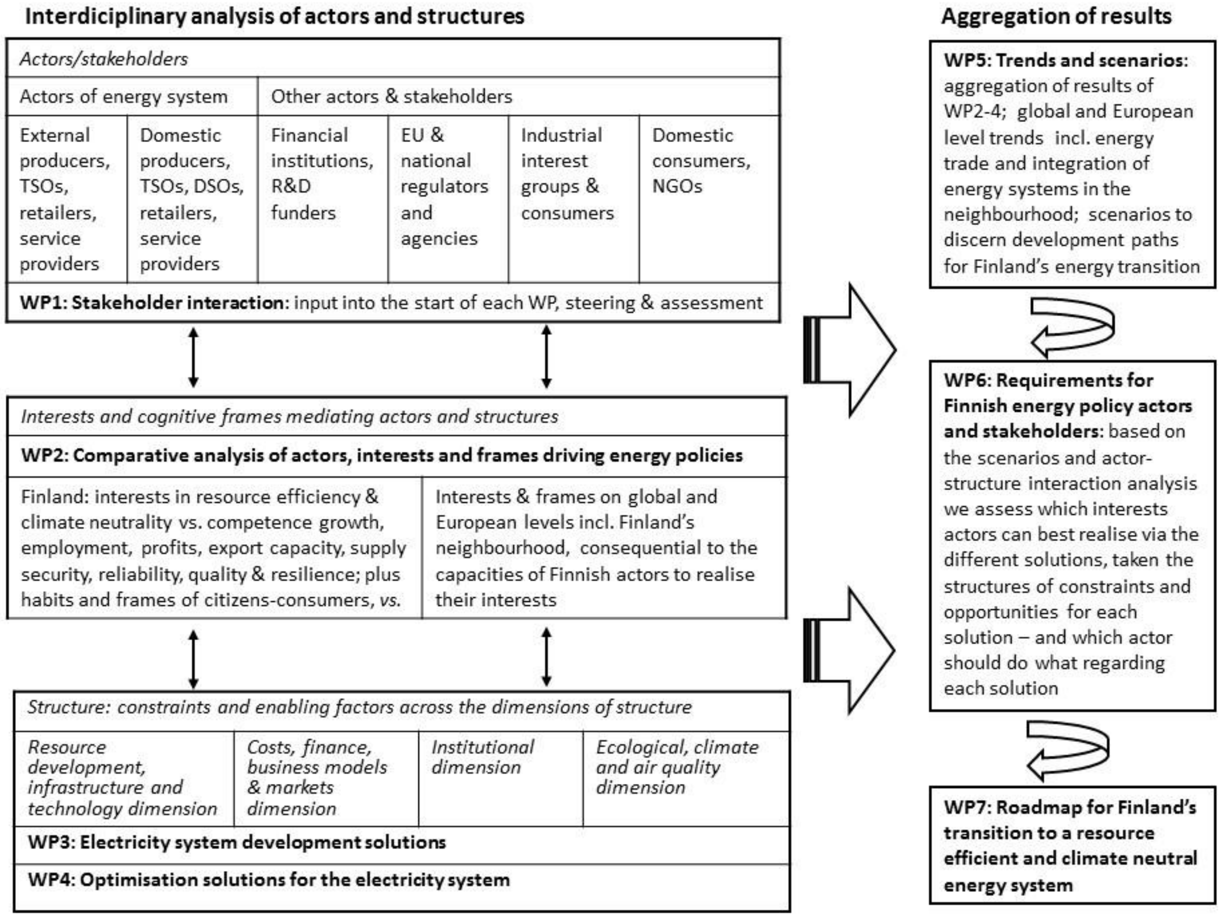
4. Research methods

Our interdisciplinary methodology builds on several methods. First, stakeholder interaction (WP1) takes place throughout the consortium's work (see sections 6, 7).

Second, actor-structure analysis drawing some insight from the sociological structuration theory of Giddens (1984) functions as the underlying method of all work. It builds upon UTA's work on the actors, structures and their mutual structuration processes in energy policy formation (e.g. Aalto et al. 2014). Through WP1, we interact with the key actors and stakeholders of Finnish energy policy. In WP2, we analyse actors, their interests, and the wider cognitive frames they use in energy policy formulation as well as the habits and acceptance of citizen-consumers. WP3-4 turn the focus on how individual and system level solutions can help to realise the actors' interests. We examine these prospects against the structure of constraints and opportunities within which actors need to make choices. We discern four dimensions of structure shaping each individual solution and the optimisation on the system level: resource development, infrastructure and technology; costs, finance, business models and markets; institutions; and ecology, climate and air quality. In WP5, we deepen our actor analysis and stakeholder interaction by means of conducting participatory futures workshops and drawing scenarios on that basis.

Third, in WP6-7 we aggregate the results of the actor-structure analysis and articulate them in a policy relevant format. We develop clear and concise requirements for all actors given what we know of the structures shaping their choices. Finally, we produce a roadmap for Finnish public sector actors to facilitate the energy transition in the practical sense (Figure 1).

Figure 1: Interdisciplinary methodology



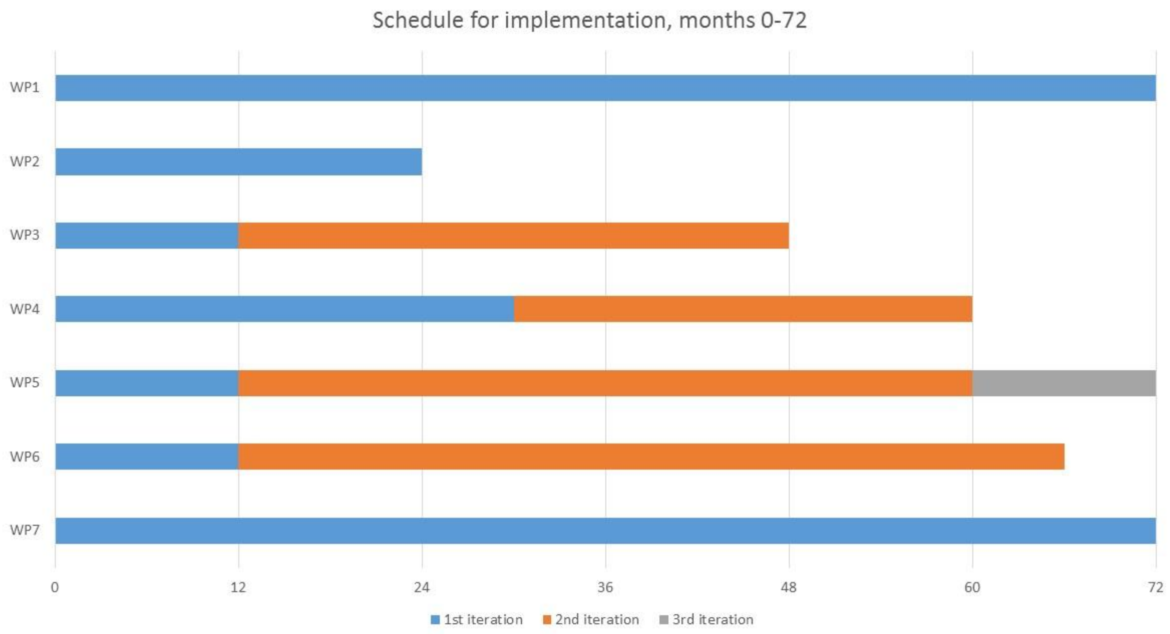
In WP2-4, we begin the work by an interdisciplinary meta-analysis of existing literature among all relevant partners. In WP2 we compare the similarities and differences of interests among Finnish actors in relation to those on the global, European and northern European levels. Our Q methodological experiments with carefully selected expert respondents in Finland and the neighbouring countries involve them into face-to-face or web-based sessions where they rank a set of statements on interests and views on the future electricity system. The factor analysis of the individual rankings offers systematic knowledge on shared interests and policy frames best enabling policy coordination and of the potential conflicts. Our opinion survey among Finnish energy consumers elucidates acceptance of and informal constraints for energy transition.

In WP3, we use qualitative and quantitative case study methods to evaluate the potential of each individual resource development, technological and infrastructural solution. In WP4, we combine mathematically based models of individual solutions into a qualitative multi-objective modelling of the whole electricity system to optimise it vis-à-vis resource efficiency and climate neutrality, taking into account our analysis of actors and interests (see WP2). The participatory futures workshops of WP5 combine futures wheel, futures tables and cross impact analysis.

5. Ethical issues

We will follow the ethical guidelines of the Finnish Advisory Board on Research Integrity. We apply these guidelines to conclude agreements regulating confidentiality and data use with all actors and stakeholders recruited for the Q methodological experiments and surveys. We will use well-trained interviewers aware of these standards. We will ask prior consent from end customers when planning demand response mechanisms, including information exchange between different parts of the energy system. Therefore, we will hold the measurement information from the real customers confidential and anonymous.

6. Implementation schedule



Selected bibliography

Aalto, P. (2011) 'Organizing Interdisciplinary International Studies: from Puzzlement to Research Programmes', in P. Aalto, V. Harle and S. Moisio (eds) *International Studies: Interdisciplinary Approaches*, pp. 66-91. Palgrave.

Aalto, P. (2014) 'Institutions in European and Asian Energy Markets: A Methodological Overview', *Energy Policy* 74: 4-15 (DOI: 10.1016/j.enpol.2014.08.022).

Aalto, P. (2012, with D. Korkmaz Temel) 'Towards a Wider European Energy Security Society: from Vulnerability and Viability to Sustainability', in P. Aalto, V. Harle and S. Moisio (eds) *Global and Regional Problems: towards Interdisciplinary Study*, pp. 79-104. Farnham: Ashgate.

Aalto, P. (2014, with D. Dusseault, M.D. Kennedy and M. Kivinen) 'Russia's Energy Relations in the East and West: Towards a Social Structurationist Approach to Energy Policy Formation', *Journal of International Relations and Development* 17(1): 1-29 (DOI:10.1057/jird.2012.29).

Bergh, J.C.J.M van den and Bruinsma, F.R. (2008, ed.) *Managing the Transition to Renewable Energy: Theory and Practice from Local, Regional and Macro Perspectives*. Edward Elgar.

Bressand, A. (2013), 'The role of markets and investment in global energy', in Andreas Goldthau (ed), *The Handbook of global energy policy*, Oxford: Wiley-Blackwell, pp. 15-29.

Brown, M.A. and Sovacool, B.K. (2011) *Climate Change and Global Energy Security: Technology and Policy Options*. MIT Press.

Giddens, A. (1984) *The Constitution of Society: Outline of the Theory of Structuration*, Cambridge: Polity Press.

Hippel, D.F. von et al. (2011) 'Evaluating the Energy Security Impacts of Energy Policies', in B.K. Sovacool (ed.) *The Routledge Handbook of Energy Security*, pp. 74-95. Routledge.

Kivimaa, M. and Mickwitz, P. (2011) 'Public policy as a part of transforming energy systems: framing bioenergy in Finnish energy policy', *Journal of Cleaner Production* 19: 1812–21.

Lund, P. D. (2007) 'The link between political decision-making and energy options: assessing future role of renewable energy and energy efficiency in Finland', *Energy*, *32*(12): 2271-81.

Salo, M. (2015) *Energiakäänne: Saksan ja Suomen energiapoliittiset valinnat*. Vihreä Sivistysliitto ry.

7. Interaction plan (WP1: stakeholder interaction)
The objective is to ensure strong and systematic input from the key actors and stakeholders into the start, steering and assessment of the results of WP2-7.

The consortium supports a society-wide energy transition in Finland, in particular regarding the electricity system. This makes external and domestic energy producers, transmission system operators (TSOs), distribution system operators (DSOs), energy retailers and service providers the key actors for the consortium. These actors operate within what we termed the dimension of resource development, technology and infrastructure in our model of the structures shaping the formation of energy policies (see Figure 1 above). Four groups of stakeholders have direct interests in the work of the key actors of the electricity energy system. Each actor and stakeholder will obtain directly applicable benefits from the participation into the consortium's work.

Key actors	Example of application of research results
Energy producers	Support for more resource efficient and climate neutral solutions for the development of energy resources, technology and infrastructure; systematic knowledge of the interests, frames and trends as well as acceptability of solutions on the part of stakeholders
Transmission system operators (TSOs)	Optimised solutions for tackling the system-level disruptive effects of the energy transition in the development of the electricity network, realising the diverse interests of key actors and stakeholders
Distribution system operators (DSOs)	Optimised solutions for tackling the system-level disruptive effects of the energy transition in the distribution of electricity to consumers; better awareness of the interests, frames and habits of industrial and domestic consumers
Energy retailers	Knowledge of interests, frames and habits of consumers; support for the development of new business models and acceptability by the consumers
Service providers	Support for capacity building of new solutions and knowledge of the constraints on the part of customers
Financial institutions, R&D funders	Systematic knowledge supporting funding and R&D decisions for the often highly capital intensive, long-term and complex energy projects defined by uncertainty
EU & national regulators and agencies	Critical review of existing legislation, licencing and permits; identification of resource inefficient policies; requirements for reforms; advice on the compatibility of the various interests vis-à-vis Finland's energy transition and its dependence on neighbouring countries; support for the practical realisation of the initial energy transition vision
Industrial consumers	Information of how to prepare for temporary supply disruptions in a more flexible electrical energy system
Domestic consumers and NGOs	Information of how to prepare for temporary supply disruptions in a more flexible electricity system and how to mobilise in terms of small-scale production and storage

Stakeholder interaction will be materialised in two formats. First, we organise twice a year a workshop where the consortium invites representatives of the actors and stakeholders committed to the project (see Table above). Second, WP5 organises an annual series of participatory futures workshops with further stakeholders to support our scenario work. The participatory futures workshops involve the wider groups of stakeholders. After the funding period, all partners will have developed strong ties and experience of working with actors and stakeholders outside their core competence area. This ensures that the thus consolidated research cluster continues to generate joint work and accumulate knowledge also after the end of the funding period. The active role of the partners in education, development and training further supports the long-term transfer of knowledge into skills affecting the society in the long-term.