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THEORIES OF CHANGE FOR EVALUATING TRANSFORMATION-ORIENTED R&I PROGRAMMES: THE CASE OF THE 7TH ENERGY RESEARCH PROGRAMME IN GERMANY

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ABSTRACT

This article investigates how Theories of Change for transformation-oriented R&I programmes can be designed to better grasp system transformation processes and thereby set the basis for a deeper understanding of transformative impact mechanisms and programme learning.

The analysis is based within the realm of the energy system, which is an area of specific concern for socio-technical transformation. It focuses on the "7th Energy Research Programme" (EFP) of the German Federal Ministry of Economic Affairs and Climate Action, which is the key R&I policy instrument contributing to the transformation of the energy system in Germany.

The article shows how a programme theory approach can be combined with multi-level perspective innovation system thinking and the concept of transformative outcomes to increase the evaluability of complex, transformation-oriented R&I programmes.

BACKGROUND

Within the realm of transformation-oriented policies, the energy system is an area of specific concern for a sustainability transformation of our society. The energy sector produces at least two-thirds of total greenhouse-gas (GHG) emissions (cf. Ritchie and Moser 2020). To contribute to the achievement of the goals set in the landmark Paris Agreement of the United Nations Framework Convention on Climate Change in 2015, European Union (EU) efforts and efforts of EU Member States set clear targets for realising the Energy Transition ("Energiewende").

The EU aims to be climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions is at the heart of the European Green Deal and in line with the EU's commitment to global climate action under the Paris Agreement. For reaching this goal, primary energy consumption should be halved by 2050 compared with 2008 and a renewables ratio of 60% to gross final energy consumption should be achieved. As an intermediate step, the EU has set a common goal for the European energy transition: sun, wind, water and biomass are to cover 40 percent of the EU's electricity demand by 2030.

To contribute to this European end, the German government adopted the Climate Protection Plan 2050 to become largely greenhouse gas neutral by 2050. This goal was legally anchored in the Federal Climate Protection Act in 2019 (KSG 2019) and underpinned with measures in the Climate Protection Programme 2030. At the same time, it was decided to phase out coal by 2038 at the latest. In 2021, the federal government brought forward the long-term target from 2050 to 2045, aiming at an even faster energy transition.

R&I policy efforts at EU and EU Member States levels tackle the grand policy objectives for the Energy transition outlined above. At the European level, the Strategic Energy Technology (SET) Plan is a key endeavour for gearing R&I policies towards a sustainability transformation,[1] addressing the whole innovation system, and tackling both financing and the regulatory framework. Germany's "7th Energy Research Programme – Innovations for the Energy Transition" (EFP), is an outstanding example of governmental R&I programmes for a sustainability energy transition at the national level. The 7th EFP is assigned a key role in the German energy system transition by establishing a link between the long-term goals of the Federal Government and the time horizons of business technology research.

With the 7th EFP the federal government of Germany promotes research and development in the field of forward-looking energy technologies. It supports companies and research institutions to develop new technologies for energy supply, energy efficiency in sectors of

1 European Commission (2007), Strategic Energy Technology Plan. Retrieved March18, 2022, from https://ec.europa.eu/energy/topics/technology-and-innovation/strategic-energy-technology-plan_en#key-action-areas

consumption such as industry or housing, and system integration. Key new elements of the 7th EFP in comparison with its predecessors are:[2] 1) a stronger focus on technology and knowledge transfer including the introduction of a new instrument called "Living Labs for the Energy Transition" as a new programme pillar; 2) a broadening of the research spectrum that previously centred on individual technologies to encompass systemic and inter-systemic issues; and 3) a stronger focus on networking with international and European research.

The emphasis on the systemic character of transformation processes, an increased focus on cross-technology issues, system integration, and sector coupling play a central role in the programme. Furthermore, the embedding of individual technologies in overall societal trends and in the various sectors of energy generation and consumption are put focus on. In this way, government support for technology development and innovation is set to make a significant contribution to accelerate the transformation of the energy system, strengthening the industrial competitiveness and provide risk prevention for society as a whole.

RESEARCH QUESTION AND APPROACH

During early 2021, the four-year accompanying evaluation of the R&I funding measures and the accompanying measures of 7th Energy Research Programme have been initiated. The evaluation focuses on the non-nuclear research activities. The evaluation aims at developing analyses, reflections and recommendations as a basis for steering and continuous improvement of the programme ("programme learning") on the one hand, while also contributing to an assessment of programme effectiveness and impact on the other hand.

The evaluation commenced its work against the increasing need to frame the R&I programme evaluation in the energy system transformation context, and the key research questions of this article are:

- How can theories of change set the basis for an understanding of transformative impact mechanisms and programme learning?
- How can concepts of transitions in socio-technical systems extend theories of change to better capture transformation processes?

Our research is embedded in the ongoing planning process of the accompanying evaluation for the EFP. For establishing a theory of change of the programme, we investigate and test how a programme-theory based evaluation approach (Funnell and Rogers 2011; Rogers 2014) can be combined with 1) a multi-level perspective of system innovation (Geels et al. 2017), and 2) the concept of transformative outcomes (Ghosh et al. 2020, 2021).

Our research process includes the following key steps: First, we delineate the strategic and operational objectives of the programme including its design principles. Based upon this initial analysis of design characteristics and instrumental setting, we then show how the 7th EFP can be positioned in a multi-level perspective that grasps the manifold objectives and instruments of the programme and puts them in the context of the energy system transformation.

In our analysis, we then proceed to elaborate a theory of change for each instrument and identify main impact pathways that are intended to transform the energy system.

Based upon this analysis, we finally investigate whether and how the categories of transformative outcomes (see Ghosh et al. 2021) can be used to better understand the impact mechanisms of the programme and hence to increase its evaluability. Ghosh et al. show how transformation-oriented innovation programmes can shape ongoing transformation dynamics. Studying what types of Experimental Policy Engagements are most suitable for enabling transformation, the authors define three general spatially-bounded macro processes and sub-processes referred to as "transformative outcomes"[3] that policy actors can have some control over.

By assessing to what extent these processes can be observed in practice, they can be considered and reflexively addressed on an ongoing basis, e.g. in a formative evaluation, as a basis to continuously improve their policy engagements. Therefore, we research the correspondence of transformative outcomes and impact pathways within the overall programme theory.

OBJECTIVES AND INSTRUMENTS OF THE 7TH EFP

The 7th EFP has the ambition to contribute to the overarching energy and climate targets of the German federal government, aiming to be climate neutral by 2045, reduce carbon emissions by 88% in 2040 and by 65% in 2030 compared with 1990 (see KSG 2019).

The analysis of the programme documents and its regulations show that the programme is characterised by the following funding principles: 1) technology neutrality; 2) extension of project funding to include system integration & cross-system topics; 3) a focus on technology and innovation transfer & innovation-friendly framework conditions; and 4) strengthening international / European cooperation.

The programme and its instruments pursue the following strategic and operational objectives that are related to the energy transition challenges. The strategic objectives are:

- advancing the energy transition (develop holistic, innovative solutions & launching them quickly on the market; create environmentally-friendly, safe, and economic energy supply; activate innovation dynamics),
- strengthen the industrial competitiveness through modernisation, maintenance and development of competences, and creation of export opportunities of competitive technologies, and
- prevention of societal risks through a diversity of technological options.

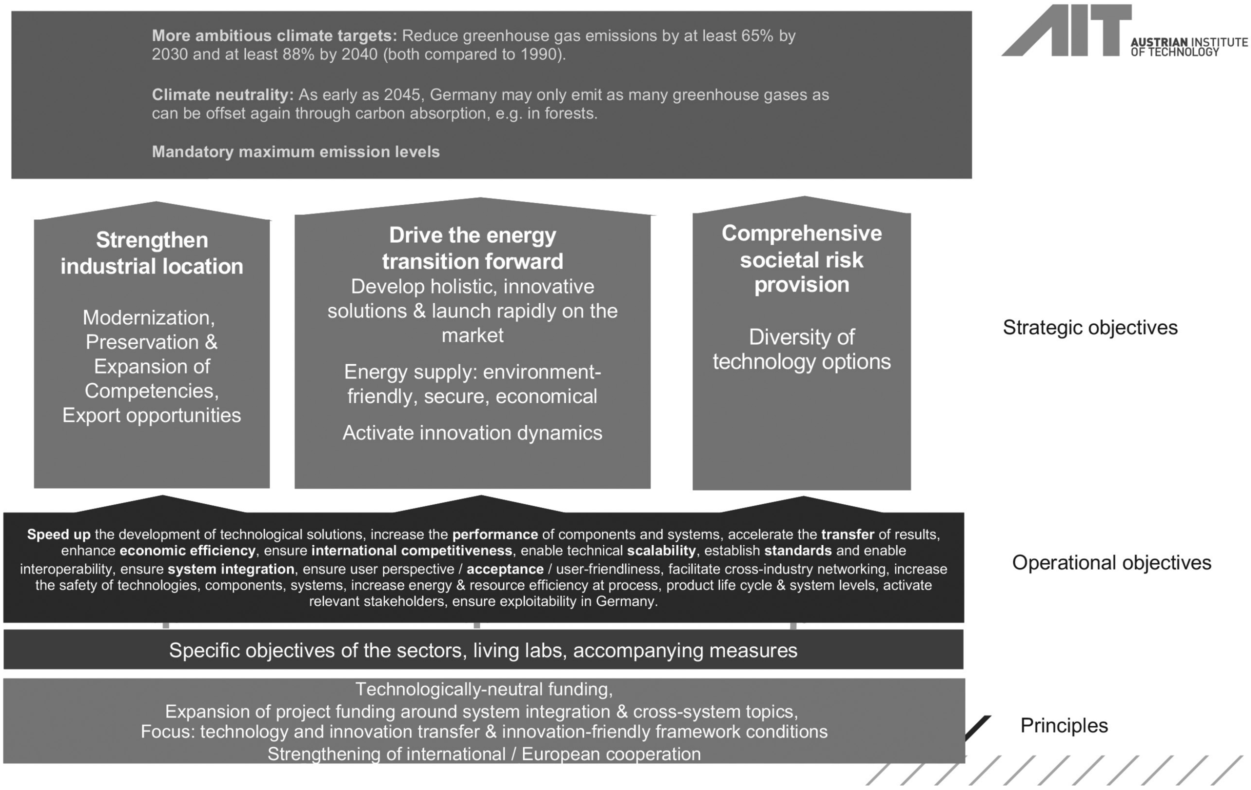
The operational targets are: 1) to develop technological solutions faster; 2) to increase performance of components and systems; 3) to

2 Bundesministerium für Wirtschaft und Energie (2018), 7th Energy Research Programme of the Federal Government. Retrieved March18, 2022, from https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/7th-energy-research-programme-of-the-federal-government.pdf?__blob=publicationFile&v=5

3 From an evaluation perspective it seems confusing to refer to processes to enable change as outcomes, because outcomes are generally understood as changes in the status quo that result from an intervention. One may therefore consider "transformative outcomes" as introduced by Gosh et al. rather as "transformative mechanisms" inducing transformative change.

accelerate transfer of results; 4) to increase economic efficiency; 5) to ensure international competitiveness; 6) to enable technical scalability; 7) to establish standards and enable interoperability; 8) to ensure system integration; 9) to ensure user perspective / acceptance / user-friendliness; 10) to enable cross-sector networking; 11) to increase the safety of technologies, components and systems; 12) to increase energy & resource efficiency at the process, product life cycle and system levels; 13) to activate relevant actors; and 14) to ensure exploitability in Germany.

Figure 1: Objectives of the 7th Energy Research programme
Source: Own illustration



The 7th EFP tackles the energy system transformation through three different types of instruments: 1) R&I projects; 2) Living Labs, and 3) Accompanying Measures. The three instruments are collectively geared towards the supply of new technologies (technology push), the speeding up of new knowledge and technology transfer (demand pulls), and system development efforts. They target practices within:

1) the renewable energy supply system (solar energy, geothermal energy, wind energy, biomass from plants, and hydropower) and their system integration
2) the energy consumption sectors (e.g. industry, transport, buildings and neighbourhoods), and
3) the development of green substitutes for carbon-based technologies, e.g. fuel cell technologies.

THE 7TH EFP FROM A MULTI-LEVEL PERSPECTIVE

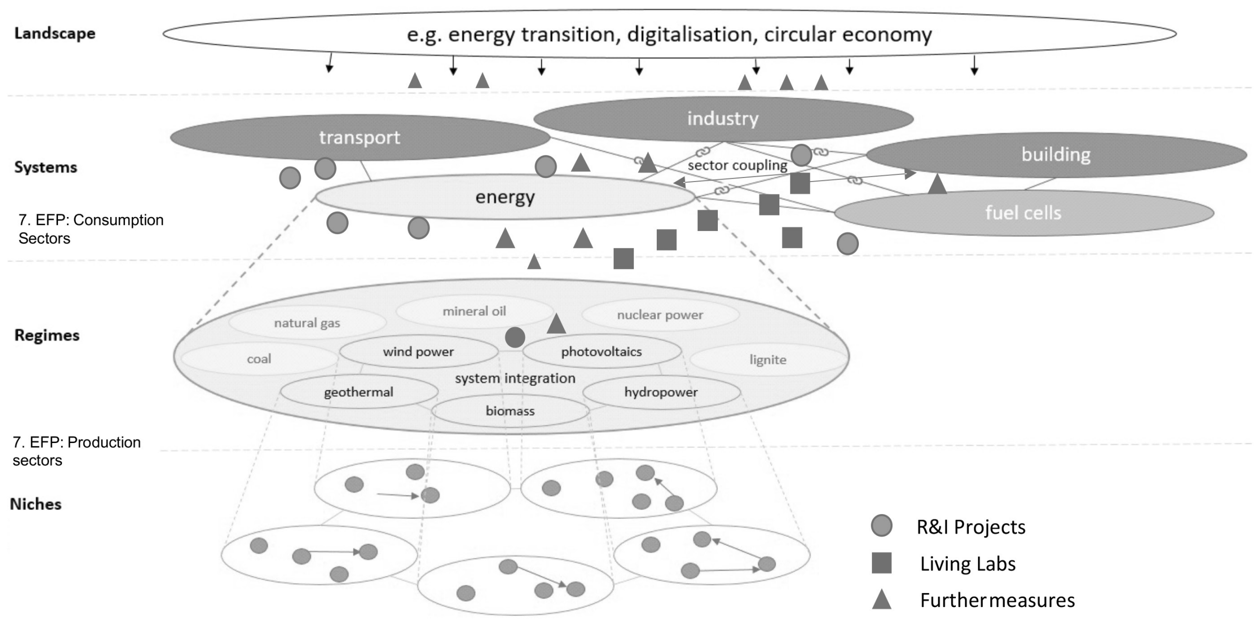
For the analysis of the 7th EFP we make use of the multi-level perspective of system innovation. The multi-level perspective was designed as a broad heuristic to capture transitions in different socio-technical systems such as mobility or food (EEA 2018; Geels et al. 2017). The basic idea is that due to existing path dependencies, dominant regimes (e.g. energy production from fossil fuels) can only be changed through profound technological and social measures that simultaneously destabilise the regimes and generate spaces for radically different solutions. In its standard form, the multi-level perspective differentiates between three levels (Geels 2006):

- The macro level is the socio-technical landscape, i.e. the wider exogenous environment that affects socio-technical development (e.g. globalisation, environmental challenges, policy framework etc.);
- The meso-level is formed by socio-technical regimes providing the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures (Rip and Kemp 1998);
- The micro level is formed by technological niches that emerge in "protected spaces", which act as "incubation rooms" for radical novelties (Schot 1998, Kemp et al. 1998), to shield them from mainstream market selection.

Originally developed for the analysis of individual regimes, the multi-level perspective has since been extended to make interactions of different regimes and systems tangible (see Rosenbloom 2020). Such a broader perspective makes it possible to reflect and systematise the various technical levels of analysis ("fachliche Betrachtungsebenen") that informed the design of the 7th EFP: consumption sectors, energy production, system integration, cross-system research topics, and the accompanying measures (i.e. establishment and support of sector networks, accompanying studies, public relations, research communication at programme level).

Figure 2 illustrates how the instrumental setting of the 7th EFP and its structural composition can be analysed and portrayed following the heuristic of the multi-level perspective. The figure shows that the different intervention mechanisms of the programme tackle to varying degrees: 1) different levels of the socio-technical system; and 2) different sub-regimes (energy production sectors) and systems (energy consumption sectors). Therein, the impact creation process of the programme can be understood as a process of mutual alignment of developments at different levels.

Figure 2: Technical Levels of Analysis, Sectors, and instruments of the 7th EFP in a Multi-Level Perspective
Source: Own illustration



For the operationalisation of the evaluation, the following lessons can be drawn from the positioning of the programme in a multi-level perspective:

First, we acknowledge that the application of the multi-level perspective allows to facilitate a close correspondence between the programme theory (objectives and intervention mechanisms) and the perspectives of programme managers. As such, it is an important attribute that improves the evaluation's transparency and facilitates the generation of a shared understanding of the programme.

Second, we see that the multi-level perspective allows integrating considerations of production and consumption sectors. The programme addresses a number of specific consumption and production sectors are. Each sector has specific targets which are to be achieved next to achieving the overarching operative programme objectives. For example, the analysis of objectives of the specific sectors of production and consumption shows that sector-specific targets encompass: 1) specific goals for existing technologies (e.g. new processes, products, applications); 2) energy and cost efficiency-related goals; 3) goals related to the substitution of specific materials or technologies; and 4) goals related to the system integration of new technologies.

Third, we see that the sector-specific targets of the R&I programme reflect challenges at the regime and system level, which the R&I instruments of the programme shall address. For the operationalisation of the empirical evaluation, they allow to define sector-specific hypotheses concerning the relevance and coherence of objectives, the appropriateness of challenges addressed by R&I portfolios, and the required characteristics of actors involved in the process.

Finally, stemming from the multi-level perspective, a decisive factor, and a challenge for the accompanying evaluation of the 7th EFP, is to analyse to what extent the measures of the 7th EFP correspond to the developments at the regime and landscape level. The multi-level perspective is a heuristic indicating that the 7th EFP does not exist in isolation but is embedded in a socio-technical system that is not only shaped by R&I initiatives alone but also demand-side policies, regulatory policies, socio-economic trends and market structures at the regime level, that shape the conditions for knowledge diffusion, societal acceptance of transition process, speed and uptake of new solutions.

However, the multi-level perspective does not specify which landscape and regime dynamics need to be taken into account. We therefore suggest performing a STEEP analysis in evaluations to create a structured overview of the factors that may spur or impede the progress of technology uptake, the types of topics and research challenges that should be addressed, and the stakeholders that should be considered in future activities.

The multi-level perspective also draws attention to the fact that R&I funding is only one measure within the toolbox of innovation policy geared at enabling transformational change. Compared to other innovation-oriented instruments like regulatory reform or financial incentives for the uptake of new technologies, R&I funding is confronted with the challenge of (a) high uncertainty about success, (b) long time-spans before results have a tangible effect, and (c) small budgets compared to other instruments using public spending, and (d) dependencies of other related policies such as regulatory reforms and sector specific policies.

Figure 3: STEEP analysis – System trends exerting impact on the EFP
Source: Own compilation

Social	Technological	Economic	Environmental	Political & Legal
• Societal acceptance of the energy transition • Social disparities • Poverty risk • Housing/Living standards • Public health disparities • Discourse about distributive justice • Civil society movements • Energy consumption patterns • Position towards nuclear energy	• Low-carbon hydrogen and hydrogen-based fuels • Carbon capture technologies • Innovation speed & upscaling • Cross-cutting technology development • Digitisation • Sector-Coupling • Decentralisation and flexibility of the electricity infrastructure • Energy efficiency technologies for high-carbon industries • International cooperation • Costs for alternative energy technologies	• Clean electricity roll-out • Diversity in energy suppliers • Energy technology start-ups & supply market development • Energy market integration: international, national • Energy costs • Energy imports • Turnover of renewables, and energy related technologies	• Climate change: global warming • Extreme weather events: constant rain, snowfall, thunderstorm, hail drought, strong winds and storms, floods, heat waves	• Active design of structural change: Economic stimulus /recovery package • German Development and Resilience Plan (DARP) • Regulation: End Coal-Fired Power Generation • Climate-friendly mobility act • Hydrogen Strategy • Offshore Wind Energy Act • Emission trading and CO2 prices • International conflicts & availability of raw materials • Energy taxes • Energy market regulation • Sustainability Investments Regulations (EU-Taxonomy, Corporate Sustainability Directive)

PATHWAYS TO IMPACT

Departing from the investigation of the instrumental setting of the programme from this multi-level perspective, we can further dive into the investigation how the programme seeks to achieve its objectives and eventually contribute to system transformation.

The programme theory approach (see Rogers 2014) connects the underlying rationales of a programme (a specific challenge to be addressed), with an overall roadmap on how specific activities are expected to produce immediate outputs connected to outcomes/intermediate impacts and eventually the realisation of the objectives.

As the 7th EFP tackles the energy system transformation through three different types of instruments (R&I Projects, Living Labs for the Energy Transition, Accompanying Measures), we developed instrument-specific theories of change based on an analysis of 1) programme documentations and interviews with representatives from 1) the responsible federal ministry, 2) the managing agency, and 3) R&I actors engaged in the programme.

While sharing this overall orientation, each instrument pursues a set of different activities and rests upon specific pathways to impact, which aim to mutually reinforce each other. (Figure 5 – full theory of change for R&I projects):

- The **R&I-projects** addressing single technologies follow impact pathways through the generation of new knowledge, qualification, technological innovation, and transfer of pilot demonstrations into business practices. Transdisciplinary research projects focus on system development through focusing on cross-systemic issues of the energy transition.
- The **Living Labs** projects follow pathways of developing complete system solutions for the whole energy sector. Testing and piloting of solutions in real world environments, networking of main energy system actors for collectively avoiding CO2 emissions are key impact pathways.
- The **Accompanying Measures** are collectively geared towards accelerating the creation of impact at the regime level through synthesising knowledge, increasing circulation and transfer in research networks, enabling new partnerships, enhancing qualification and increasing transparency.

Figure 4: Instrument-specific Activities and Impact Pathways
Source: Own compilation

R&I Projects, Pilots & Demonstrators		Living Labs		Accompanying Measures	
Activities	**Pathways**	**Activities**	**Pathways**	**Activities**	**Pathways**
Individual R&I projects on single technologies Collaborative R&I projects on single technologies Pilot Projects & Demonstration projects Transdisciplinary research projects on systemic and cross-systemic issues of the energy transition	Knowledge creation & capacity development Networking Economic valorisation Transfer System development	Collaborative R&I in Living Lab contexts related to: • Digitalisation, ICT development • Reflection of experimentation clauses • Developing and building industrial plants • Test / pilot operation / demonstration • Supplementary R&D on individual issues Living Lab Coordination	Innovation Upscaling Avoiding CO2 emissions Diffusion	Establishment and support for Energy Transition Research & Innovation Platform and Research Networks Accompanying research and studies Research Communication Public Relations at programme level	Synthesizing knowledge Knowledge circulation & and transfer Enabling cooperation Increasing qualification Increasing transparency

Figure 6 illustrates the complete theory of change including the main impact pathways of 1) knowledge generation, 2) network creation, 3) innovation, 4) transfer, and 5) system development. The theory of change following impact pathways (see Douthwaite et al., 2003) is a model describing how the programme and activities therein seek to achieve impact and allows for a better attribution of programme activities to impacts achieved. The theory of change has been elaborated in an iterative process of documentary analysis of programme instruments, interviews of project participants, and reflections with programme authorities (ministries and programme management).

The theory of change is a model that is capable of explicitly illustrating causal hypothesis of programme interventions and aspired impacts of new programmes (Balthasar and Fässler, 2017). Taking an intervention-based perspective with a focus on programme actors, it illustrates a sequence of conditions that must be achieved for a problem to be solved (see Clark and Anderson, 2004). The theory of change is necessarily a reduction of complexity and therefore has tendencies to omit context consideration.

In our analysis of the 7th EFP, the multi-level perspective provides means to better understand the specific intervention mechanisms of the programme and allows to pose a number of evaluative questions for the collection of empirical data, relating to key impact pathways and the socio-technical innovation system. We will answer the "classic" evaluation questions about effectiveness, efficiency, relevance, coherence etc. in the evaluation, but the MULTI-LEVEL PERSPECTIVE leads to some additional questions and specific perspectives that we want to address. Examples of questions relating to key impact pathways in the context of the multi-level perspective are:

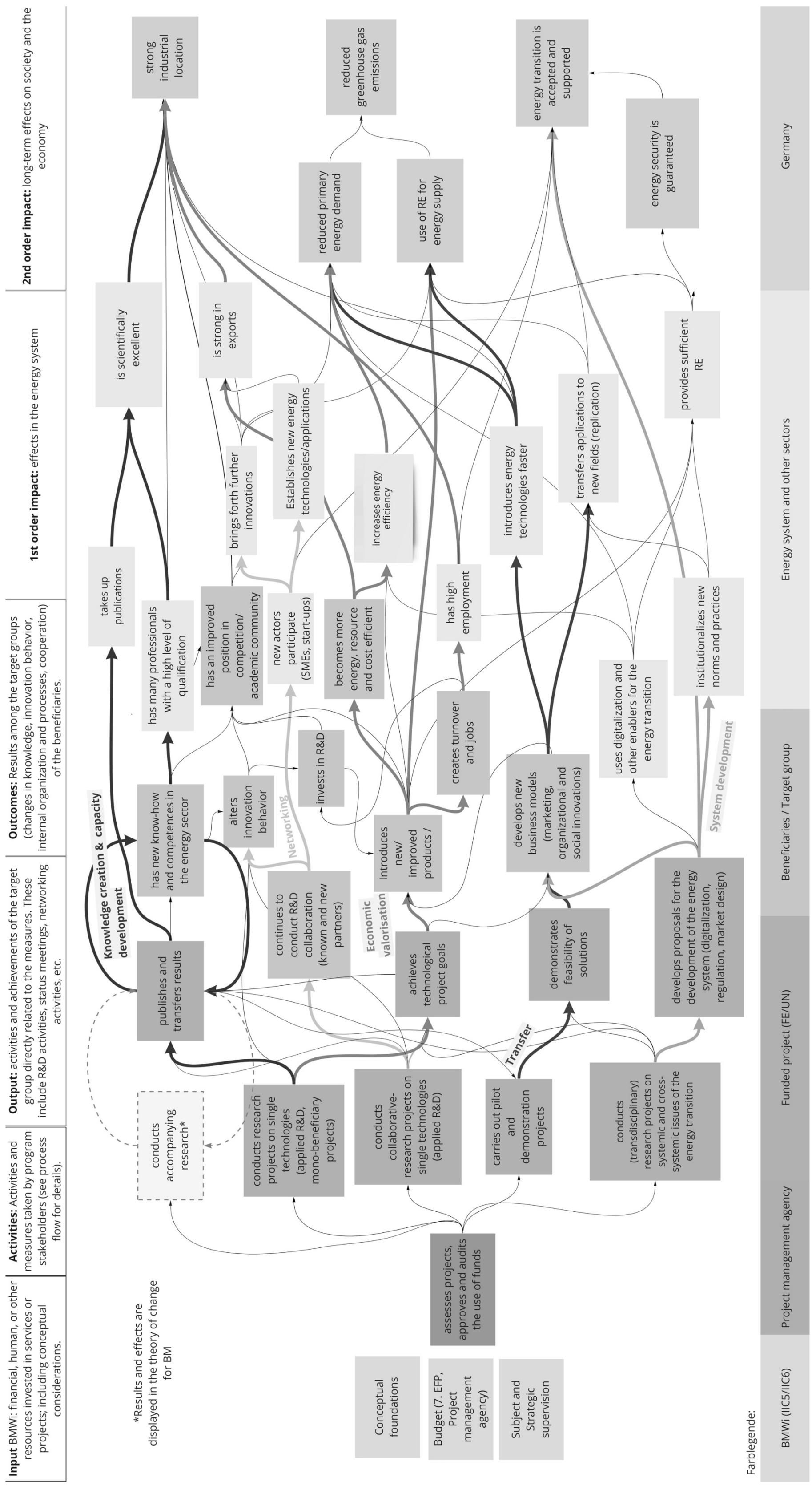
PATHWAY 1: THE KNOWLEDGE CREATION AND CAPACITY BUILDING PROCESS

- Which actors are performing the research and development work in the programme? How are they anchored in the socio-technical innovation system?
- To which extent is there an active communication and dissemination of learnings and outcomes of innovative practices of research results?
- Is the knowledge being primarily generated for the right stakeholders? Those who could bring it to application??
- Does capacity building encompass only existent regimes or does it prepare for niches and their training and qualification needs?
- Are skills and procedures, ways of working, rules and regulations objects of research? How is this knowledge being transferred?

PATHWAY 2: NETWORK CREATION

- Which actors are actively involved in the knowledge generation process of the projects? What is their role in the socio-technical innovation system?
- Which activities are being performed that enable knowledge exchange between owners, producers, and researchers on a regular basis?
- To which extent is there collaboration across organisational boundaries for certain focus areas/topics in the projects?

Figure 5: Theory of Change "R&I Projects"
Source: Own compilation



- Are actors involved or being addressed that are of particular importance for the transformation of the energy sector? (E.g. energy communities, the again increasing number of municipal energy providers/utilities, IT companies, start-ups).
- How are new actors involved in the process of knowledge generation and diffusion that can promote a transformation of the energy system?
- How do incumbent regime actors position themselves vis-à-vis transformation processes in the socio-technical innovation system? What role do incumbent regime actors play in knowledge diffusion and transfer of the programme?

PATHWAY 3: INNOVATION

- Do the research topics addressed contribute to the creation of energy technologies that are new to the market? Do they potentially open up new niches for the sustainable transformation of the energy system (e.g. technologies for better coping with the decentralisation of energy supply)?
- What contribution does the research make to increasing the market penetration of niche technologies (for example regarding cost reduction of renewable energies/applications)?
- What are the economic application potentials of the new technologies?
- Which measures within the programme/the project are being taken to increase chances of market introduction or market penetration?
- What are the characteristics of the markets targeted by the new technologies? What is the positioning of incumbent regime actors? Are there new market entrants?
- What is the level of entrepreneurial activities in the specific socio-technical innovation system?
- Which elements of the socio-technical innovation system increase or decrease possibilities for market introduction and sustainable market penetration of newly developed technologies?

PATHWAY 4: TRANSFER

- What is the technological maturity of the research and development subjects? Can their application be demonstrated successfully?
- Which activities are being performed for developing new business models that reach new users in different market, and/or shorten supply chains, making the innovation accessible to a broader audience?
- To what extent are there shared goals that facilitate successful interaction and learning?
- Which activities are being performed that enable cross-sectoral exchange between different type of actors?
- Are there any complementary actions in addition to R&D subsidies within the programme/outside the programme that support speeding up market formation and market penetration?
- Which regulatory aspects need to be considered/changed for the introduction/increased market penetration of new technologies?
- Are the research activities leading to good practices and to the creation of guidelines so that innovative practices can be implemented in a different context, such as a different location?

PATHWAY 5: SYSTEM DEVELOPMENT

- What is the extent of transdisciplinary research dealing with socio-technical system development cross-cutting research topics?
- Are research results providing evidence for high-level policy making?
- Is there a promotion for the formalisation of ideas and new practices by incumbent actors (local policy bodies, industry associations, etc.)?
- Do the research results have an impact on changes in standards / norms / other regulatory aspects (e.g. providing guidance in the development of new regulations and norms that support an innovation)?
- To which extent are suggestions for market development and regulatory frameworks being taken up in the policy discourse?

IMPACT PATHWAYS AND TRANSFORMATIVE OUTCOMES OF THE 7TH EFP

For positioning the impact creation process in the energy transition policy context, we analyse to what extent the programme and its instruments target the energy transition. Raven et al (2016) accentuate that this needs to be realised through strategic niche support. Furthermore, this also requires deconstructing and working against harmful regimes (Turnheim and Geels 2012; Kiviima and Kern 2016). The above introduced concept of “transformative outcomes” identifies three general spatially-bounded macro processes that actors can have control over: (1) building or nurturing niches; (2) expanding and mainstreaming niches, and (3) opening up and unlocking regimes. In each of these three macro-processes, four sub-processes were identified that actors (e.g. programme owners/managers and project leaders) can have control over. The transformative outcomes are not in any particular order and can “co-evolve through time and space”. They provide more granular categories which specify important leverage points for niche development and regime destabilisation.

While the transformative outcomes are described in detail in Ghosh et al. (2021) we focus here on the question to which extent the instruments and identified impact pathways of the programme correspond with the transformative outcomes outlined therein.

Figure 6: Impact Pathways and Transformative outcomes of the 7th EFP
Source: Own compilation elaborating on Gosh et al. (2020)

R&I Projects	Living Labs	Accompanying Measures	Transformative Outcomes
Impact Pathways			
Building and Nurturing Niches			
Knowledge Generation	Innovation		**Shielding**: protecting new and more sustainable practices from external influences and helping them grow
		Knowledge Circulation & Transfer	**Learning**: providing regular opportunities for discussing experiences, obstacles and needs related to a new practice as well as challenging related values and assumptions that people might have
Network Creation		Enabling cooperation	**Networking**: protecting and progressing new practices by gaining interest of more people and creating connections between them
System development		Synthesising Knowledge	**Navigating expectations**: navigating and converging expectations of different actors the legitimacy of new practices is developed and their potential explored
Expanding and mainstreaming niches			
Economic valorisation	Upscaling		**Upscaling**: conducting deliberate action to get more users involved into new and more sustainable practices
Transfer	Diffusion	Increasing qualification	**Replicating**: transferring the new and more sustainable practices to another location
		Enabling cooperation	**Circulating**: exchange of knowledge, ideas and resources between multiple related alternative practices
	Diffusion		**Institutionalising**: turning new and more sustainable practices into more permanent and more widely available ones
Opening up and unlocking regimes			
			De-aligning and destabilising regimes: disrupting and weakening dominant practices. This can be done by changing one of the dominant dimensions for example through the introduction of new policies
System development	Avoiding CO2 emissions	Transparency	**Unlearning and deep learning of regime actors**: dominant actors question their assumptions and change their view on the potential of new and more sustainable practices and the ability of the dominant practice to respond to threats and opportunities, such as climate change and digitalisation
Network creation		Enabling cooperation	**Strengthening regime-niche interactions**: Frequency and quality of interactions between empowered actors from the niche and the regime on a non-competitive basis
		Synthesising knowledge	**Changing perceptions of landscape pressures**: dominant actors to reach the point of view that immediate action is warranted, and new emerging more sustainable narratives need to be promoted

In the context of the 7th EFP we can assume that shielding of R&D activities is a key function being provided through direct R&D funding in the R&I projects and Living Labs that address all innovations necessary for system innovation (e.g. technology, organisational, business models, etc.). The R&D funding of the programme provides a protected space for developing new ideas that aim to spur the technological advancement of the energy system. The living labs also provide research infrastructures and a targeted R&I portfolio that support experimentation with niche technologies and niche actors.

Network creation through R&I projects and specific instruments of the "Accompanying Measures" of the 7th EFP are supposed to gather research, user and policy communities and facilitate collective **learning** and **networking**. While the collaborative R&I projects build networks starting from the project level, nine "Energy Research Networks"[4] represent the broad research landscape on the topics of bioenergy, buildings and neighbourhoods, renewable energies, flexible energy conversion, industry and commerce, electricity grids, start-ups, system analysis and hydrogen. The networks are supposed to be dialogue-oriented forums for exchange between research, politics and industry and offer space for a self-organised process of their members. In terms of transformative outcomes illustrated by Ghosh et al. (2021), they provide room for synthesizing knowledge, discussion of alternative ideas, reflection and learning.

It can also be expected that **navigating expectations** is a deliberate result of the Accompanying Measures and the R&I projects of the 7th EFP. Within the instrument of R&I projects, system development is being promoted through support of R&I focussing on cross-system topics and system integration. As a result, contributions to the development of standards, norms and other regulatory aspects, as well as high-level policy making should arise. Within the Accompanying Measures, the "Energy Transition Platform for Research & Innovation", which acts as an advisory body for the Federal Ministry for Economic Affairs and Climate Action has the function to facilitate dialogue on the strategic direction of energy research policy with national stakeholders from politics, business, science and society. A main task of the Energy Transition Platform for R&I is to synthesize the collective knowledge gathered in the research networks.

Expanding and mainstreaming niches can mostly be related to the R&I activities of the "Living Labs". The process of upscaling in the living labs aims to increase the reference capability of novel technological solutions, which should turn into novel standard operations at the regime level and contribute to cost-reductions of these novel technologies. Diffusion is linked to the process of introducing system solutions, building and applying blue-prints and the diffusions of new processes/standard practices at the level of the energy system and other sectors. While these outcomes are also included somewhat in the R&I projects, they are more explicitly formulated and aspired in the Living Lab concept of the programme.

In the context of expanding and mainstreaming niches, the accompanying measures may have an amplifying function, as they aim to provide means for collective exchange of knowledge, ideas and resources between multiple related alternative practices in a self-organised manner.

When it comes to **opening-up and unlocking regimes** one should primarily be aware that R&I policies and instruments might not be the most powerful tool to rely upon. An introduction and implementation of new regulatory policies, changes in fiscal policies (prices/taxation) may challenge and trigger the search for new solutions much more effectively than technologically open R&I programmes.

Nevertheless, for the 7th EFP the pathways of Network Creation (R&I projects) and Enabling Cooperation (Accompanying Measures) are presumably also functions of the EFP networks for **strengthening regime-niche interactions**, whereas Living Labs seek to deeply change the path of existing regimes through CO2 avoidance and sectoral diffusion of new solutions. Furthermore, the pathway of **synthesising knowledge** may contribute to alter perceptions of main regime actors concerning landscape pressures and start to pursue new pathways.

Just from this exercise of describing the relationship between instruments and pathways of the 7th EFP and the concept of "transformative outcomes", it becomes clear that the programme has not only a transformative ambition but might be able to contribute to change existent socio-technical innovation systems. For advancing the operationalisation of the evaluation, the exercise shows that the bottom-up created Theory of Change of EFP instruments including their pathways of impacts can be related to transformative outcomes, which allows to better tailor the empirical evaluation design towards the relevance, coherence and effectiveness of the programme in terms of its contribution to the energy transition.

REFLECTIONS

Through establishing an integrated programme theory for the 7th EFP, we show how predominantly linear theories of change can be enhanced by integrating a multi-level perspective and transformative outcomes. The emerging programme theory reflects the need to develop formative and embedded monitoring and evaluation of transformation-oriented R&I programmes, embedded in a multi-level perspective.

Putting the evaluation of the 7th Energy Research Programme in the multi-level perspective facilitates 1) taking a more dynamic perspective on the intervention mechanisms of the evaluation object and 2) better integrating external factors at the regime and landscape level that exert influence on the effectiveness of the programme. Positioning the programme in the multi-level-perspective shows that building and nurturing niches, with the ambition to replicate and upscale technological system innovations at the regime levels of energy production and consumption is the main impact mechanism of the instruments R&I projects and Living Labs, while certain parts of these instruments also cover developments at the landscape level (i.e. through transdisciplinary research projects and system analysis of the energy transition process), and the interaction between different consumption and production sectors. The various accompanying measures of the programme aim to contribute to synthesizing collective knowledge, niche-regime interactions beyond the project level and navigating expectations.

While the theory of change can be created in a bottom-up manner, based on programme documentation, views and perspectives of programme management and project participants, the multi-level perspective is a heuristic that allows to frame hypotheses and questions concerning the impact creation process, and facilitate programme learning. For instance, for considering the contribution of the EFP to opening-up and unlocking regimes, the frequency and quality of interactions in the socio-technical innovation systems needs to be explored by the evaluation as well as the changing perceptions and actions of actors in the socio-technical system. In the case of regime-niche interactions, the evaluation will also have to consider path-dependencies and rigidities of incumbent regimes causing a lock-in in existing trajectories. For example, as regards the energy transition Ghosh et al. (2021) warn that even when alternatives are proposed by regime actors, they tend to reaffirm the architecture of the system as it is.

4 See: Projektträger Jülich (n.d.), Forschungsnetzwerke Energie, retrieved March 18, 2022, from https://www.forschungsnetzwerke-energie.de/forschungsnetzwerke-energie

While the combination of the multi-level perspective with an input-output-outcome-impact model at an aggregate level increases accountability, it remains a key challenge to define indicators that reflect the complexity of transformation processes on the one hand, while specifically detailing the contribution of a programme towards these processes on the other. As the programme theory delineates the main pathways to impact of the programme and considers external influential factors as well, it should not only allow for deep learning loops for programme owners and actors in the programme but also contribute to an enhanced evaluability of transformation-oriented R&I programmes. In this regard, our analysis has shown that the inductively generated impact pathways from the theory of change can be looked at through the lens of transformative outcomes. An additional advantage of using a perspective which has been derived from the literature is better comparability with other transformative RTI programmes.

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