*Kopernikus Project*
*Energy Transition Navigation System | ENavi*
*Status Report 2018*

# ENERGY TRANSITION CALLS FOR DIALOGUE WITH SOCIETY

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KOPERNIKUS PROJEKTE
ENavi
Die Zukunft unserer Energie

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# CONTENTS

The four Kopernikus Projects for the Energy Transition are funded by the Federal Ministry of Education and Research (BMBF) and started at the end of 2016. At the centre of the Kopernikus Project **ENavi**, described here, is the Roadsmap for a systemically linked navigation towards the energy transition. This status report describes the main findings. In particular, the collages for the three main topics – put together from several mosaic stones of the 13 work packages – provide insights into sustainable structures and requirements for electricity systems, heat supply and mobility.

# 1. ENAVI: NAVIGATING TOWARDS A SUCCESSFUL ENERGY TRANSITION

**A successful energy transition depends on society**

The transformation of the energy system, which is currently dominated by fossil fuels, into a system based on renewable energies, largely free of $CO_2$, is a profound process of change. The energy transition encompasses technical, economic, organisational, legal, political, social and systems-scientific challenges – throughout all sectors (electricity, heating, mobility) and all areas of application (household, industry, trade, transport).

According to the study on the social sustainability of the energy transition, with the participation of ENavi, almost 90 percent of the German population still support the new energy transition. However, more than half of the respondents consider its implementation to be expensive and unfair. Many have lost confidence in energy policy.

Citizens are affected in the same way as stakeholders in the economy, science, civil society and politics. There is a lack of reliable orientation for all. Who will carry the costs of this conversion to a largely fossil-free energy supply? What will the environmental costs be if the energy transition is not implemented on time? But particularly: How can the effects and side effects of interventions in complex policy areas be assessed? What consequences are to be expected if, for example, the state prescribes an exit from coal usage at a specific point in time? Uncertainty prevails across all stakeholder groups.

*Wherever there is a particularly high degree of complexity on the road to the energy transition, we are here to offer orientation,*

explains **Prof. Dr Ortwin Renn** of the Institute for Advanced Sustainibility Studies (IASS), spokesman for the Kopernikus Project ENavi

- **59 associated partners** (24 research institutes, 18 university institutes, three non-governmental organisations, nine companies, three local authorities, two regional authorities) are working in **13 thematic work packages.**
- In addition, **26 competence partners** are contributing their practical experience to the topics of infrastructure, heating and mobility.

The Kopernikus Project Energy Transition Navigation System | ENavi unites a wide range of technical expertise (see Table 1) aided by a decidedly systemic approach. The key words here are **integration and networking:** the aim is an inter-/ transdisciplinary approach to integrate political instances and work across sectors. The work packages (WP) contribute their respective research results as individual elements of a common mosaic – a consistent and knowledge-based development path for a sustainable energy transition. Depending on topic, the respective mosaic consists, on a flexible basis, of several interacting building blocks, for example scenarios, technology profiles, and action narratives (also simply referred to as narratives).

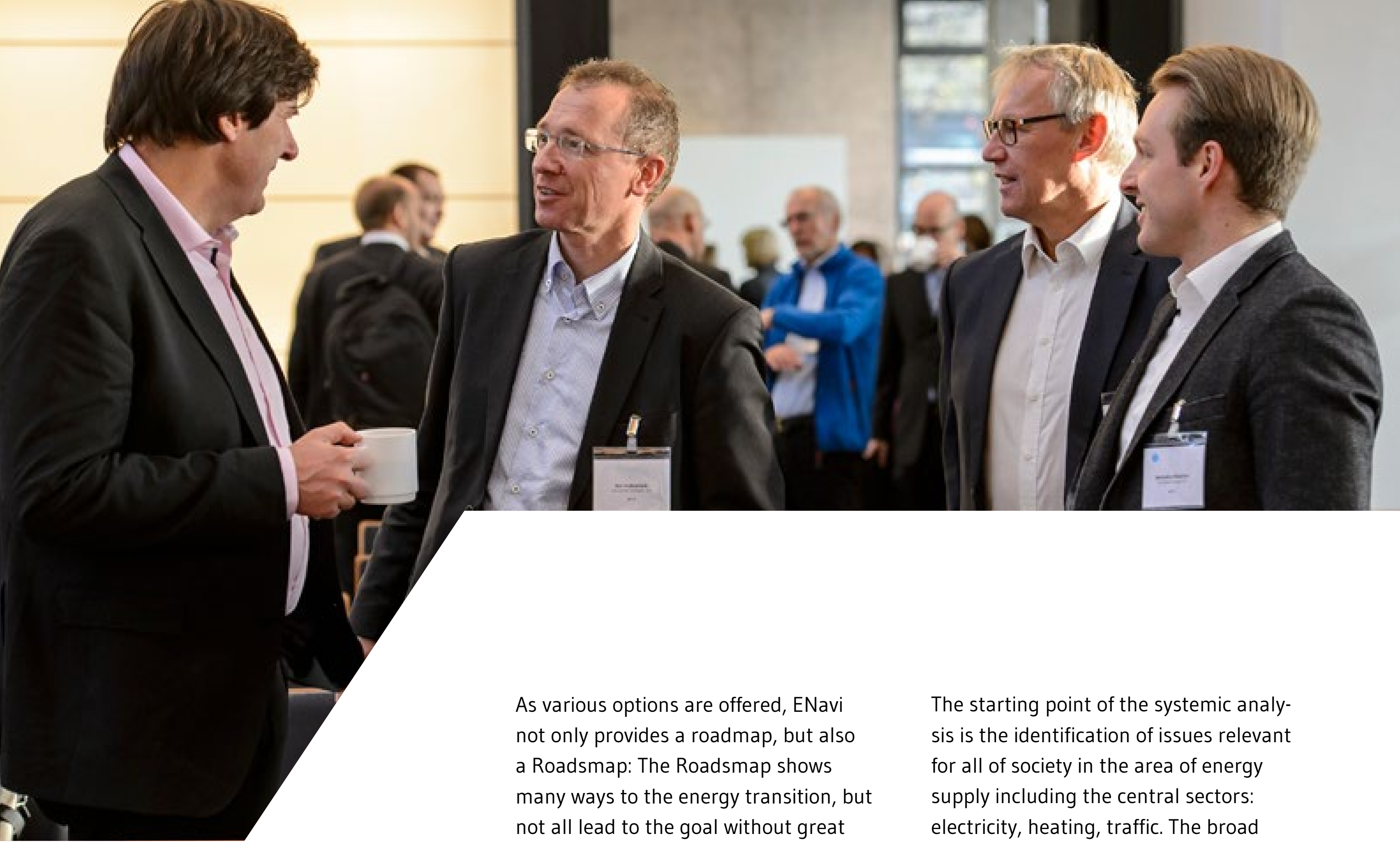
For a long time, the energy transition was viewed as something that could be achieved through linear – consecutive implementation. First of all, energy systems were techno-economically simulated. Ecological aspects were then integrated. Finally, social acceptance was examined. This approach failed to reach its target. This is clearly visible in the lack of investment in energy-efficient renovation of buildings and the sluggish demand for electric cars. Profound, innovation-driven transformation will not occur without the acceptance and early support of citizens.

# 2. WHAT ENAVI WANTS TO ACHIEVE: EVIDENCE-BASED, PRACTICAL RECOMMEN-DATIONS FOR ACTION

**Navigation as an Interdisciplinary and Transdisciplinary Process**

In order to achieve the German government's energy transition and the climate targets for 2050, the energy system must be understood as a whole. This includes systemic analyses of the associated technical, economic, ecological, legal and social challenges. The Energy Transition Navigation System | ENavi informs economic and political decision-makers of concrete options for action that are both scientifically evidence-based and tested in practice.

The inter- and transdisciplinary approach associated with this is expressed in the image of navigation. The navigation system is intended to help policymakers and economic actors to make upcoming decisions on the shaping of the energy transition by showing the respective consequences, path dependencies and trade-offs for various options (transformation paths). Depending on the political programme or vision of the future, decision-makers can then determine for themselves which of these paths are particularly appropriate, politically opportune or practicable.



As various options are offered, ENavi not only provides a roadmap, but also a Roadsmap: The Roadsmap shows many ways to the energy transition, but not all lead to the goal without great burdens or side effects. A central task of ENavi is to develop proposals to mitigate negative effects as well as accompanying measures for unavoidable side effects and at the same time to identify opportunities for positive side effects. Above all, it is important to map the effects of political and economic interventions in the energy system in all their facets and with all trade-offs. To this end simulations, scenarios and models, but also expert surveys (group Delphi) and interactive stakeholder dialogues are used, and practical experience (living labs, model regions) is systematically collected in order to obtain as complete a picture as possible.

The starting point of the systemic analysis is the identification of issues relevant for all of society in the area of energy supply including the central sectors: electricity, heating, traffic. The broad research team works on the tasks in an interdisciplinary manner throughout all areas of engineering, natural sciences, economics, law, social and behavioural sciences, ecology, and systems analysis.

The essential characteristic of ENavi is the interaction of **system knowledge** (what causes what?), **orientational knowledge** (where to go?) and **transformation knowledge** (how best to get there?). This is done in the above-mentioned 13 work packages and additionally in six working groups (for acceptance, modelling and scenarios, law, technology, transdisciplinary discourse, doctoral students) that extend across all of the work packages in order to provide points of contact or opportunities for exchange with the other Kopernikus Projects.

*Page 9: The 13 thematic ENavi Work Packages*

| | |
|---|---|
| **Roadsmap and navigation**<br>Prof. Dr Armin Grunwald | We are developing the navigation instrument as a "toolbox" that combines the results of the other work packages and reveals pathways to a sustainable energy system. |
| **Technological transformation**<br>Prof. Dr Frithjof Staiß | We show the advantages and disadvantages of different technologies and look for new technological solutions by developing "technology profiles". We also explore how innovations can assert themselves on the market. |
| **Economic instrument check**<br>Prof. Dr Ottmar Edenhofer (until 05 / 2018),<br>Dr Michael Pahle (from 05 / 2018),<br>Prof. Dr Kai Hufendiek | With the aid of energy-economic models, we examine how German and European policy instruments can navigate the sustainable transformation of the energy system. This is supplemented by the microeconomic perspective, including competitive pricing in markets with high shares of renewable energies. |
| **A legally sound success**<br>Prof. Dr Michael Rodi | We identify and provide answers to the most important legal questions on the success of the turn of energy policies with regard to market, regulatory, and institutional design, multi-level distribution of responsibility in matters of law and regulation, legality and legitimacy. |
| **Policy coordination and participation**<br>Prof. Dr Michèle Knodt | We analyse energy governance in Germany, Austria, Poland and the EU as well as the participation of citizens and civil society in the energy transition. |
| **Behaviour in the context of changing values and lifestyles**<br>Dr Birgit Mack,<br>Prof. Dr Ellen Matthies | We look at how private households and companies are adapting to the energy transition, paying particular attention to their willingness to invest in this process and change their behaviour. |
| **Compatibility of the SDGs**<br>Prof. Dr Ottmar Edenhofer,<br>Dr Gunnar Luderer | We investigate the benefits and unintended side effects of the energy transition on the environment (for example on air pollution or resource consumption) with a view to harmonising the different sustainable development goals. |
| **Merging systems**<br>Prof. Dr Hans-Martin Henning | We develop methods for the analysis of measures for coupling sectors and describe cross-sector transformation paths. In the process, we will provide a clear overview of how different sectors interact in the energy transition. |
| **Digitalisation and ICT**<br>Prof. Dr Clemens Hoffmann,<br>Prof. Dr Carlo Jaeger | We point to options for greater flexibilisation on both the supply and demand sides, with a particular focus on the flexibilisation of electricity demand; the smart-heating breakthrough thanks to digitalisation; and changes in traffic behaviour. |
| **International perspective**<br>Prof. Dr Ottmar Edenhofer,<br>Dr Michael Pahle | We prepare country studies on climate and energy policy, for example in Poland, and organise international workshops, for example in China – on the basis that the energy transition can only succeed if it is embedded as an international principle. |
| **Multi-criteria assessment**<br>Prof. Dr Ortwin Renn | We derive policy packages and scenarios from the complex insights of the ENavi partners, which we also assess based on ethical, legal, economic, ecological, and social criteria. |
| **Science-practice dialogue**<br>Dr Marion Dreyer,<br>Dr Steffi Ober, Dr Piet Sellke | We foster the collaboration between science and society in the research process, integrate communities of practice and insights from the field into scientific discourse, and lay the foundations for a continuous dialogue. |
| **Testing of the navigation tool in practice**<br>Prof. Dr Michael Rodi,<br>Prof. Dr-Ing. Manfred Fischedick | The living labs (among others, public utility companies/GEODE) subject the scientific results to practical trials and feed the findings into scientific discourse. In addition, we identify which experiences of real transformation processes in model regions (for example the Ruhr region) should be considered in the design of future processes. |

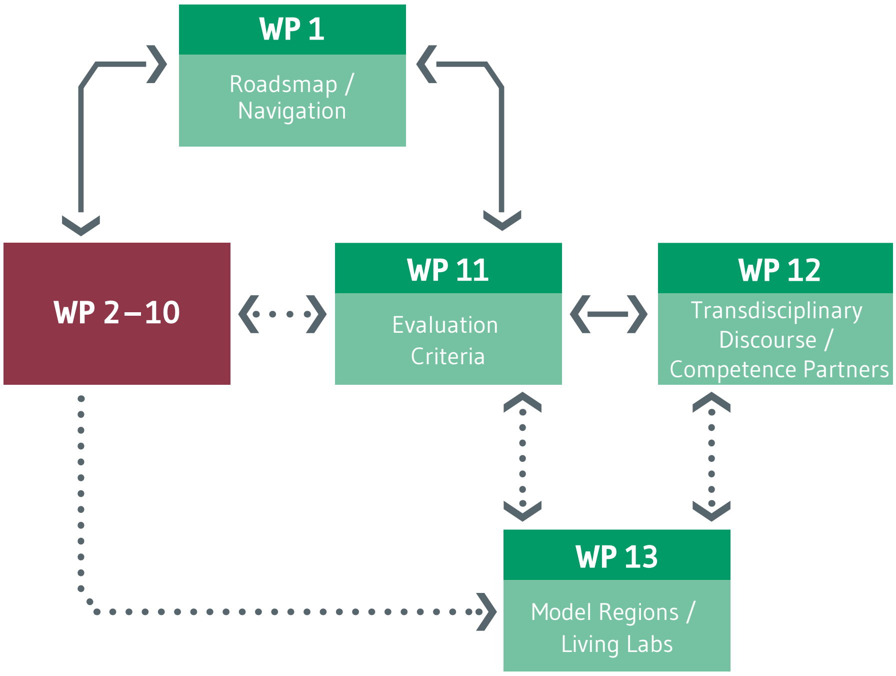



*Figure 1: ENavi interplay for creating a Roadsmap*

That about explains the scientific analysis with its inter-/transdisciplinary claim. However, this is not enough to translate the results into policy and action-relevant orientations. ENavi translates the interdisciplinary research results into concrete policy packages via institutionalised dialogue with involved social parties, such as companies, associations and non-governmental organisations, evaluates them on the basis of central criteria such as effectiveness, efficiency, acceptability, as well as fairness, and tests them – in part in model regions and living labs. The joint development and reflection of these policy packages, within the scope of the interplay of science and practice, represent the essential characteristics of the transdisciplinary approach pursued by the Project. Figure 1 shows the interplay of the work packages (WP) for the creation, evaluation and trial of policy packages and (coupled) scenarios (roads for the Roadsmap(s)) to achieve the desired objectives.

In a *first step*, the research teams in the work packages WP2–10 produce and collect action-relevant research results and develop proposals for transformation paths and possible policy interventions (policy packages) that are suitable for achieving the objectives associated with the energy transition. Further expertise comes from the competence partners (practitioners, works councils) and the living labs.

In a *second step*, an interdependence analysis is used to identify side effects, synergies and instances of incompatibility for each of the policy packages and quantify these as far as possible (WP1). This creates impact profiles for options for measures in all of the fields of impact that are necessary for the subsequent evaluation of the measures. Parallel to this, scenarios are created (roads for the Roadsmap) in which the policy packages are integrated as drivers of the desired and respectively set targets.

In the *third step* the agenda consists of the evaluation of the policy packages and, later, also of the Roadsmap. The researchers carry out a comprehensive evaluation of the policy packages and Roadsmaps, including their likely side effects. They also identify trade-offs and uncertainties associated with the implementation. The interdisciplinary team of WP11 has developed a comprehensive catalogue of criteria for this purpose. Methodologically, a dynamic multi-criteria assessment is used predominantly for this purpose.

In the *fourth step* the researchers of WP12 feed the policy packages with their evaluated impact profiles, into the dialogue with practitioners (the "competence partners" and the "works council platform") and the decision-makers from politics, civil society and the economic sector.

Using the methodical approach of the living labs, the scientific results are tested in practice and the findings are fed back into the scientific discourse. Knowledge from transformation processes that have already taken place in model regions will also be processed and fed into the discussion.

In the *fifth and last step* the results of the discursive dialogue and the practical tests are integrated as elements into a larger Roadsmap.

This ENavi process can be seen in the sequence shown in Figure 2. In the first project phase, until 2019, the concrete procedure will be demonstrated in the test runs for **three main topics:**

1. **Transformation of the electricity system** including coupling with heat
2. **Move to sustainable heating** through sector coupling, user integration and flexible, smart control
3. **Decarbonisation of transport** with a focus on multimodality, intermodality and alternative engines

These three topics of the first phase are at different stages of implementation. The overview of the turn of electricity policies, composed of many individual mosaic pieces, mainly comprises model scenarios that are currently being further developed into complex options for measures in transdisciplinary dialogue with stakeholders. The systemic overview of the move to sustainable heating includes the modelling of innovative forms of coupling heat and power, as well as new developments for the production of green fuels and improved efficiency through digitalisation. Possible solutions are tested in living labs, such as public utility companies (GEODE), for their practical suitability. The synopsis of the turn in traffic policies concentrates on the development of optimised policy packages to promote sustainable mobility. To this end, literature analysis and expert knowledge (group Delphi approach) were combined with the knowledge from the competence partners and a comprehensive impact analysis was carried out. The analyses of the three main topics developed so far are described in detail in the following chapters.

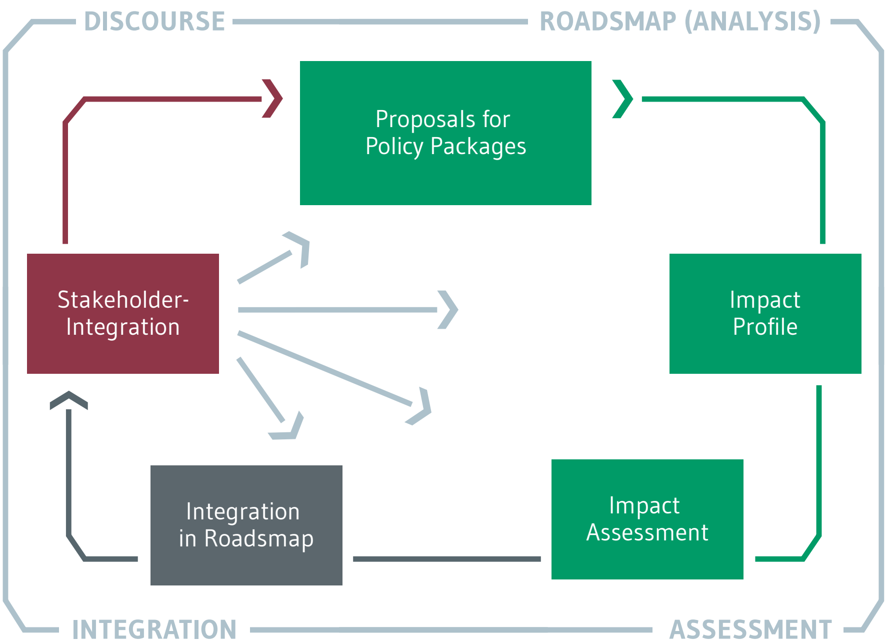



*Figure 2: Methodological procedure*

> *Through dialogue with parties from the field and with society, the necessary technological transformation of the energy transition is made considerably more feasible.*
> **Prof. Dr Frithjof Staiß,** ZSW Zentrum für Sonnenenergie- und Wasserstoff-Forschung

# 3. THE TRANSFORMATION OF THE ELECTRICITY SYSTEM: A TEST RUN FOR THE NAVIGATION SYSTEM

## The transformation of the electricity system as first mosaic

The "mosaic" of the transformation of the electricity system is the first and most developed main topic for the concrete implementation of the navigation approach. It analyses possible transformation paths in the electricity sector against the background of the current political debate: the failure to meet the 2020 climate targets and the establishment of a commission to draw up proposals for phasing out coal.

The results are intended to inform decision-makers about measures to phase out coal and the effects of corresponding paths. The added value compared to other studies is mostly to be found in the resolute inclusion of social parties, a multitude of scientific disciplines, and the European perspective. The results are fed purposefully into political-social discourse and summarised in **a synthesis report,** which is available as a first draft. Scientists are already involved in intensive exchange with members of the "Coal Commission" and other decision-making bodies.

## Methodological approach and current status of work

The methodological approach is based on the ENavi process (see Figure 2) for which individual steps have been methodically formulated to apply it to the priority topics. The corresponding loop has currently been run through a total of one and a half times. At the beginning, a number of scenarios were developed around possible measures and the corresponding paths were roughly explored in order to gain initial insights. These were the basis of discussion for the subsequent exchange with stakeholders. Based on feedback from stakeholders, the selection and definition of scenarios and measures were revised and alternative or accompanying measures included. To this end, more in-depth qualitative analyses were carried out on legal feasibility as well as qualitative impact assessments along several dimensions. The following is an example description of the first key results of these analyses, including stakeholder feedback.

## Key results and findings of the scenarios and model-based preliminary studies

› The model-based analyses, which also include all other sectors (sector integration), show that achieving the climate targets requires an almost complete phase-out of coal by 2050 (below 50 TWh). Only for Carbon Capture and Storage (CCS) is this not the case; however, this is viewed as unrealistic by a broad majority of stakeholders and is therefore not being further pursued.

› For the year 2030, however, there is still considerable leeway: coal-fired power generation varies between 44 and 150 TWh among the scenarios. Two factors have a reducing effect on the climate gas: (a) Embedding the energy transition into a more ambitious European policy and (b) cost-efficient distribution of the climate protection requirements among the various sectors, in contrast to the existing sectoral targets. The latter would mean an even more ambitious 2030 target for the energy sector, equivalent to a faster exit from coal usage (see Figure 3).

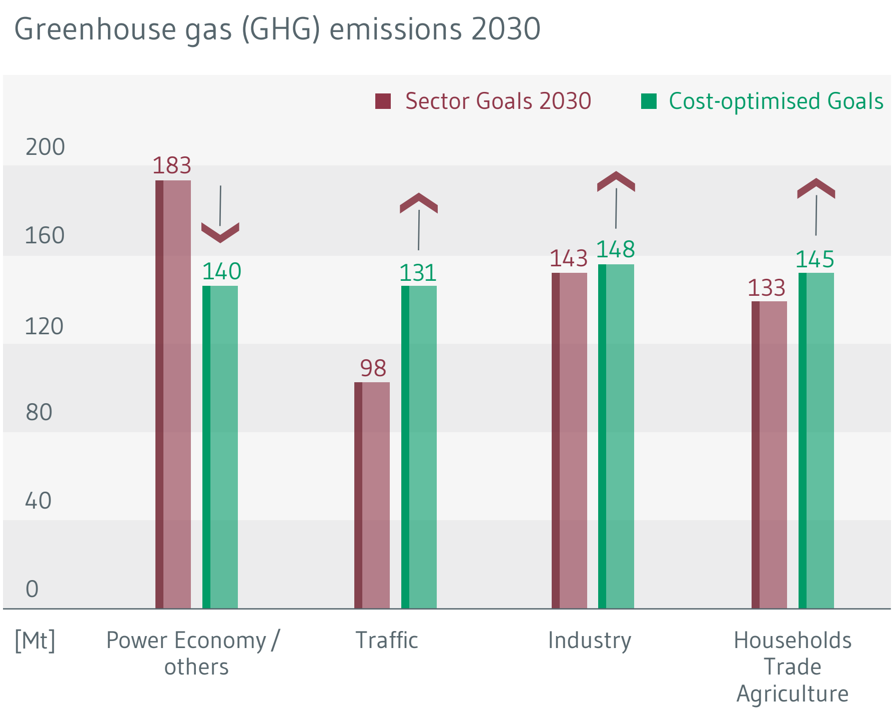



*Figure 3: Greenhouse gas (GHG) emissions by sector if the sector targets for 2030 are reached and the target is achieved at optimum cost*

› The preliminary studies continue to show the clear advantages of expanding the exit from coal usage to a European level. The national measures envisaged in Germany should therefore be coordinated – also in the face of current discussions on cooperation with France – with the measures of other European countries (pioneering alliance on climate policy) and the EU.

## Key results and findings for measures and paths

› Legal analyses show that a regulatory implementation through shutdown times for power plants is constitutionally permissible, but possibly entails obligations to pay compensation. Other options (for example emission budgets) do not have a comparable signalling effect or are subject to considerable legal uncertainty under EU law. Alternative decommissioning through European industrial plant law was generally viewed critically by stakeholders and was, therefore, not considered further. A direct $CO_2$ tax on $CO_2$ emissions is permitted under Union law, but requires a two-thirds majority amendment of the Constitution. Indirectly, pricing mechanisms through adjustment of energy taxes on the $CO_2$ intensity of the respective energy sources could be implemented by reforming the harmonised energy tax law throughout Europe, without having to change the Constitution.

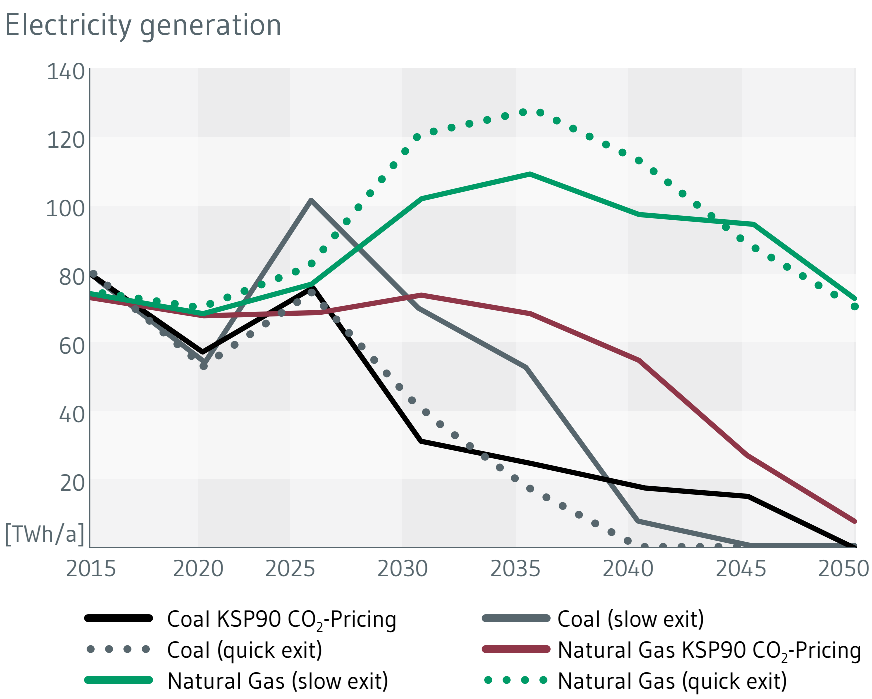



*Figure 4: Rebound effects (higher coal and gas power generation) in the case of a regulatory exit from coal usage*

› If coal were to be phased out according to regulatory law order to achieve the sector targets in 2030, around 18–22 GW of coal-fired power plants would still be active on the market (43 GW at the end of 2017), generating approximately 110–136 TWh of coal-fired electricity. The differences result from the various boundaries with regard to district heating and gas generation, which are currently still being consolidated among the models. However, on its own, a regulatory phase-out is not sufficient to achieve the long-term climate goals, since the loss in generated electricity is compensated by existing coal-fired power plants, additional gas-fired power plants, or higher imports (rebound effects, see Figure 4). Additional measures are therefore necessary, such as a minimum $CO_2$ price or increased support for the expansion of domestic renewable energies.

› A $CO_2$ minimum price would also have the advantages of reducing the above-mentioned rebound effects and – if the right choice is made – being more cost-efficient. The latter is important because an accompanying survey of 11,000 households has shown that although the acceptance of the energy transition is still quite high, the willingness to pay for the corresponding measures has decreased. Higher electricity imports, which would be relevant in terms of securing supply, can be reduced by further increasing the domestic expansion of renewable energy at all levels (large-scale plants or intelligent decentralised systems).

› All forms of national measures are also associated with a waterbed effect within European emissions trading: Emissions reductions in Germany lead to increased emissions in other countries in the short to long term. This could be prevented by decommissioning 1 to 2 billion certificates (Osorio et al.). A coordinated approach within the scope of a pioneering alliance in favour of a $CO_2$ price could also mitigate this effect.

› Discussions with stakeholders have also shown that the macroeconomic and distribution effects of measures – who are the winners and losers? – play an important role. The focus is on accompanying measures for the regions that are directly affected. Therefore, experience has been gathered within the scope of the model regions in order to find out how a necessary structural change could be shaped in association with the reduction of coal-fired power generation. This is tested in practice in the Ensdorf living lab.

## Main results and findings of the impact assessment

› The cumulative additional costs (not including discounts) in electricity generation to enable a rapid regulatory phase-out, compared to the sectoral target scenario (achievement of the sectoral climate protection plan goals, see Figure 3), amount to 37 billion euros (4 percent increase); within the overall energy system, the amount is 106 billion euros. This corresponds to annual costs (over 30 years) of approximately 31 or 90 euros per household. However, induced electricity price effects on the markets and other cost components, such as compensation payments or additional subsidies for the further expansion of domestic renewable energies, have not yet been taken into account.

› With regard to the macroeconomic effects, the results diverge greatly, especially with regard to the ambitious climate goals for the year 2050. The reason for this is that various model approaches are used, the corresponding strengths and weaknesses of which are currently being investigated by a group of experts in order to ultimately obtain robust results.

› Achieving the climate protection targets has a clear additional benefit: by reducing air pollution, around 3,000 (Europe) and 1,800 (Germany) premature deaths per year will be avoided in 2030, and water use will be reduced by 50 to 70 percent. However, the expected land use, especially for bioenergy crops, could double by 2050.

## Outlook

A renewed exchange with stakeholders is planned by the end of the first phase of the Project, which should lead to a further consolidation of the results and an improvement in the robustness of the options for action. Within this framework, the measures developed will continue to be systematically evaluated. Topics arising from this exchange should then be included in the subsequent application for the second project phase in the sense of a co-design. The fundamental approach is to be continued and the involvement of stakeholders implemented even more resolutely. The guiding idea in terms of content shall be the (almost) zero emissions society, which requires a transformation of all sectors and a correspondingly integrated approach (sector integration). In this respect, more intensive integration with the other Kopernikus Projects will also be sought, for example through the development of common scenarios, which could build on the experience and results of this priority topic.

*The transformation of the electricity system is a key milestone in achieving Germany's climate protection targets. However, a corresponding strategy must be embedded in Europe in order to be successful in the long term.*

**Prof. Dr Ottmar Edenhofer,** Potsdam-Institut für Klimafolgenforschung (PIK)

# 4. THE TRANSFORMATION OF THE HEAT SECTOR: SECTOR COUPLING, EFFICIENCY AND DIGITALISATION

A further mosaic on the way to a successful energy transition concerns the heat sector. Heat supply in industry, commerce, trade, services, public buildings, and households accounts for more than half of the total end-user energy consumption. In contrast to the electricity supply, renewable energy sources have played only a minor role here so far. The main focus in the heating sector is currently on improving energy efficiency, both in the thermal insulation of buildings and in the conversion of primary energy into the required energy services. The digitalisation of heating services offers particular potential for improving efficiency. The traditional instruments and incentives have so far failed to achieve the increases in efficiency that policymakers have targeted. Digital control systems conceptualised by the ENavi team, which are due to be tested in the future, can achieve significant improvements in efficiency.

There has also been little progress in the expansion of the district heating infrastructure, because economic and regulatory framework conditions often make expansion unattractive. At the same time, there are too few efforts to tackle the decarbonisation of the heating sector in a similar systematic fashion to the electricity sector. There is a lack of effective parties who could advance innovation in the heating sector across all user groups. The opportunities offered by innovative decentralised approaches are also often associated with heating applications, but require appropriate investment decisions by a large number of small players.

## Modelling the transition to sustainable heating

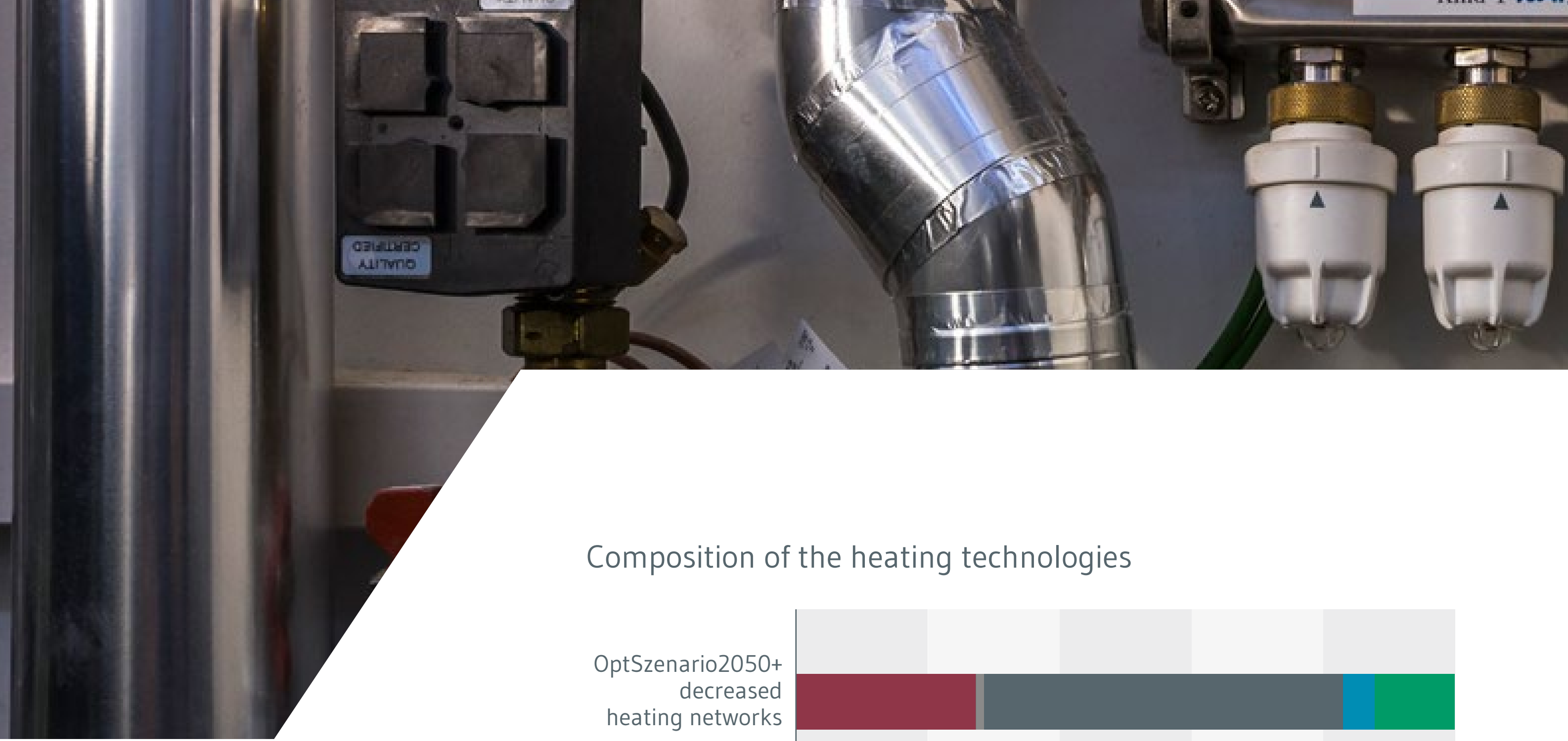
The ENavi consortium has therefore chosen heat supply as one of its three main topics. Practical experience from the living labs and case study clusters are integrated into the modelling of the local and national energy system. Using the evaluation criteria developed by ENavi, it will then be examined which instruments are best suited to increase the dissemination of renewable heating technologies, including smart decentralised electricity/heat generation and storage systems, and to improve efficiency.

A central element in the mosaic of the transition sustainable heating is the analysis of the sector-coupled energy system, in particular an investigation of the role of combined heat and power (CHP), heating pump systems, bidirectional heat networks and the use of solar thermal energy. The focus is on system and user integration as well as operational optimisation and market integration (for example P2P marketing) of the plants.

Another element of the systemic analysis is the inclusion of the individual costs and benefits of decentralised heat applications as well as the use of storage tanks and their integration into the overall system. Above all, relevant decentralised electricity and heating systems (heat pumps, own use of PV-systems, battery storage, mini CHP systems), including the new opportunities and possibilities offered by digitalisation, will be compared at the level of overall system and individual parties.

An important issue concerns investment decisions: Which (monetary and non-monetary) factors influence investment decisions on the heating market? Incentive systems have so far focused on (mainly self-using) homeowners, property communities, whereas tenants are insufficiently taken into account. There is also a lack of integration of suitable multipliers (for example tradespeople and enterprises). ENavi checks current market mechanisms and existing instruments for their effectiveness with regard to investment decisions by parties at various levels. Analyses of the heating market for buildings in comparison with developments in the industrial sector (process heat and efficiency measures) are also of particular significance. ENavi's partners have already analysed the currently available technologies on the heating market, including intelligent control systems, with regard to their technological and economic maturity and have characterised their ways of functioning and their effects.

Soft factors, such as social scientific and legal aspects, are also important inhibiting factors in the heat sector. These now flow into the model-based energy system analyses for the first time and allow a deeper analysis of inhibiting factors, including derivation of solution strategies.



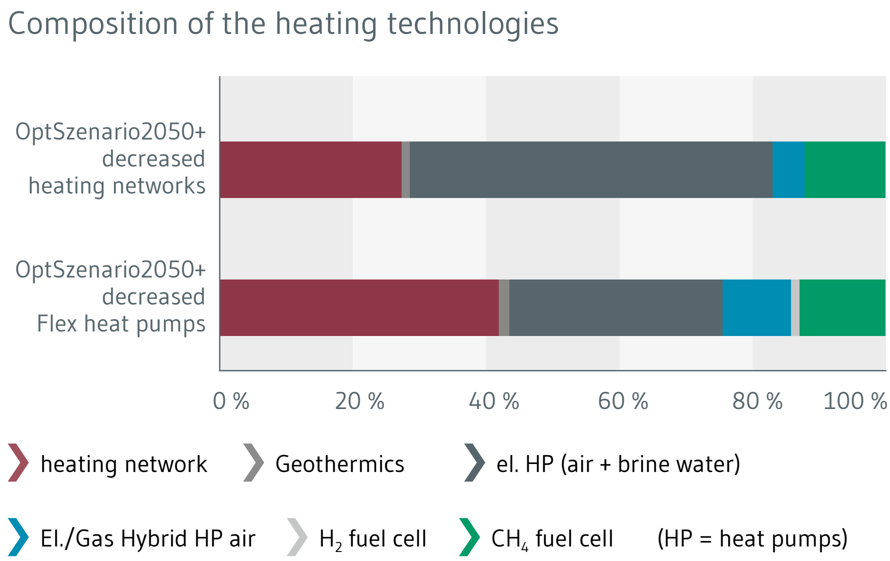



*Figure 5: Impact of reduced flexibility of heat pumps and heating networks on the optimised composition of heat supply technologies in 2050*

The modelling results show that the implementation of the energy transition in the heat sector cannot be achieved without much stronger interlacing with electricity generation. The Project partners concentrate on two important topics: 1.) the analysis of flexible operation of heating technologies adapted by targeted intelligent control (for example heat pumps and heating networks, see Figure 5) and user integration, and 2.) the comparison of various power-to-X applications in the heating sector, such as the potential of "green" gas, fed in from renewable energy sources, for example hydrogen electrolysis and subsequent methane synthesisation.

## Institutional design: legal framework and regulation

The analysis of the existing legal framework and proposals for its further development are topics of the ENavi studies from a legal perspective. The focus is on, among other things, improving the competitiveness of electricity in the heat sector and unifying the regulatory framework to facilitate investments in efficiency and heat generation through sectoral coupling and renewable energy sources. This includes detailed analyses of institutional economics, including effectiveness and efficiency as well as distributional effects and acceptance aspects, especially with regard to digitalisation. The legal analyses are accompanied by psychological and sociological studies on the perceived barriers and inhibiting factors to investment decisions in the field of heat supply.

## Practical knowledge from the living labs

The technical, legal and social scientific knowledge flows into the practical implementation and/or operational trials of the proposals in actual fields of application.

Stadtwerke Bietigheim-Bissingen, for example, is developing an integrated neighbourhood concept for the $CO_2$-free supply of the historic old town with energy from the region, taking into account the requirements for protection of monuments. In the Mecklenburg case study cluster, the energy value chain, including heat supply, is being optimised; possible regional decarbonisation paths are determined with the aid of models. In particular, this involves the development of suitable business models and effective incentive systems.

Stadtwerke Rosenheim is working with the niche technology of wood gasification in combination with a combined heat and power (CHP) plant that can contribute to system stability through flexible power and heat generation.

The "SekOptima"-Tool, developed by our practice partners enables intelligent market- and system-oriented, cross-sector control of heat production based on heat demand forecasts and is being tested in a district in Heidelberg.

In the living lab in Berlin, heat supply concepts are being developed with close involvement of the electricity sector. This includes energy-efficient redevelopment and modernisation as well as digitalisation in the residential area.

As of the 2018/19 heating season, ENavi plans to investigate, in a total of two to three heating periods, how digital control instruments in conjunction with economic subsidies can reduce heat consumption in homes.

Approximately 300 households in the Anhalt region are to be equipped with intelligent room heating control systems for this purpose. The focus is on the question: Which behavioural incentives and which social regulation instruments motivate consumers?

*The energy efficiency of buildings is a central starting point for reduction of emissions. Regulation is challenging because of the large number of involved parties with heterogeneous interests. Nevertheless, in view of the long-term nature of investment decisions, a rapid adaptation of the legal framework is necessary, on the basis of well-founded interdisciplinary recommendations for action.*

**Prof. Dr. Michael Rodi,** Institut für Klimaschutz, Energie und Mobilität (IKEM)

# 5. THE TRANSFORMATION OF THE TRANSPORT SECTOR: THE INTER- AND TRANS-DISCIPLINARY APPROACH

The third mosaic deals with the decarbonisation of transport as part of the transformation of the overall energy system towards climate neutrality and sustainability. So far, it has not been possible to reduce greenhouse gas emissions from transport to below the level of 1990. On the contrary, $CO_2$ emissions have been rising significantly for some years now, and other emissions such as nitrogen oxides have also recently come to the fore. In order to counteract this, it is necessary to abandon the use of fossil fuels in transport and to radically change our mobility behaviour. Changes in the urban structure and the networking of rural areas will have to complement this in the long term.

### The inter- and transdisciplinary approach to the design of policy packages

An inter- and transdisciplinary bundle of measures that takes up this challenge is central to the priority topic of transport.

*What are the essential characteristics here?*

› Problems and solution approaches differ significantly from one transport sector to another. Cross-sector solutions for diverse areas of traffic, such as urban passenger traffic, freight traffic or air traffic are only of limited use. Urban passenger transport in core cities and densely populated surrounding areas will be examined first of all. Further traffic areas in ENavi Phase II are to be investigated.

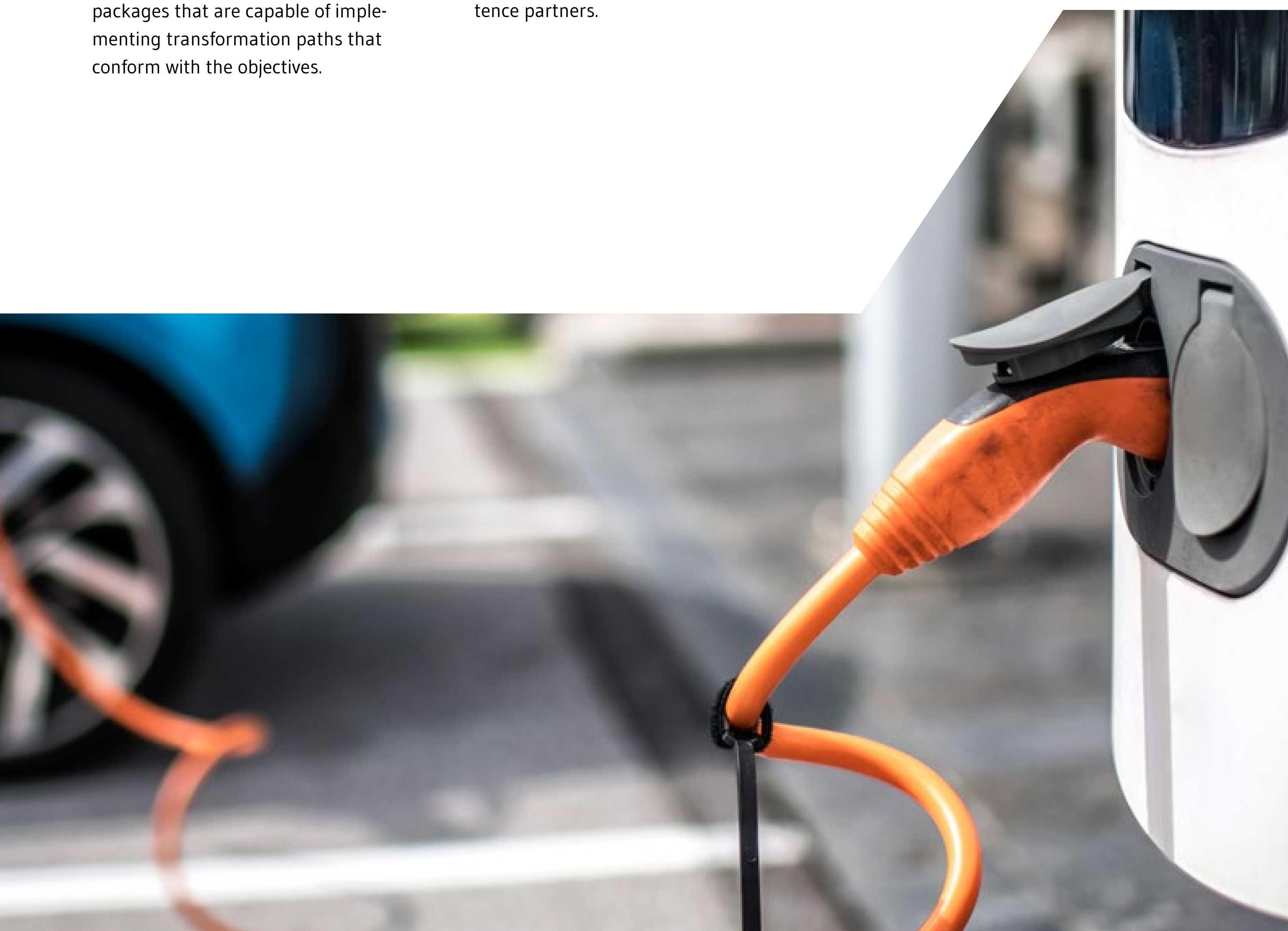
› The approach aims to target promising transformation paths towards a climate-friendly and sustainable energy system and the policy interventions and measures associated with this. In urban passenger transport, the transformation paths "Multi- and Intermodality" and "Alternative Engines" are regarded as promising for a change in transport policies – they are currently the focus of research work.

› The perspective of systemically structured policy packages stands for the idea that there is a need for combined interventions and measures that aim to mitigate mutually unintended effects and enhance benefits. This is the only way to realise promising transformation paths towards a climate-friendly future. It is therefore a question of tailor-made policy packages that are capable of implementing transformation paths that conform with the objectives.

› For the transformation paths "Multi- and Intermodality" and "Alternative Engines", a policy package consisting of core and accompanying measures will be developed using various methods: literature evaluation, internal ENavi group Delphi, legal-economic modelling, input from living labs and further inclusion of practical experience.

It is particularly important for this complex of priority topics that the practical and experiential knowledge of economic and social parties is integrated into the development of the policy package at an early stage and in several iterations. A first literature-based draft of the policy package was modified and extended on the basis of a group Delphi workshop with ENavi internal experts. This was followed by moderated science-practice dialogues with all three ENavi competence partners.

In addition, there are studies on electromobility on the basis of institutional economics and legal foundations (for example setting up the charging infrastructure, controlled charging, quota regulation for alternative engines, diesel ban). A further central feedback loop will be discourse on the evaluation profiles of the policy packages with the practice partners and other stakeholders with regard to trade-offs and suitability for practice. The inter- and transdisciplinary approach builds bridges between the ENavi disciplines and between science and practice in the development of transformation paths towards sustainable mobility.



## Key results: The two policy packages for Multi- and Intermodality and Alternative Engines

The policy package "Strengthening Multi- and Intermodality" (Figure 6) aims to effect a change in mobility behaviour. It consists of two core measures: Core measure I "Promoting public transport" includes increasing the share of public transport in the modal split (among other things, through expansion of public transport networks, and, also among other things, factors related to clocking, route network, additional lines), while Core measure II "Integrated land management" aims at a reduction of motorised individual traffic (MIT) in urban areas through target-oriented land (re)use and urban planning. In order to strengthen the impact of the core measures and at the same time mitigate unintended consequences, these are flanked by further regulatory, promotional and information measures.

The introduction of access restrictions in inner-city areas, for example in the form of a socially acceptable city toll or in the form of speed 30 zones, increases the effect of calming traffic in these areas. As further accompanying measures, the simplification of intermodal offers (expansion of digitalisation and sharing concepts, integrated ticketing via one-stop-shop solution, etc.) will be included in the analysis. Various measures can also serve as a source of cross-financing for other measures, provided the legal requirements are met. A participatory information campaign accompanies all measures to communicate municipal offers clearly and positively and to reveal compensatory alternatives to any restrictions that are experienced.

The policy package "Increasing alternative engines" aims to use technological means to achieve a climate-neutral transport sector in 2050. The focus is on the use of alternative engines in the motorised traffic area. The measures are an integration of various instruments and are applied at various regulatory levels. The Core measure I "$CO_2$ fleet limit value of 60 g/km by 2030" is a regulatory lead instrument. The $CO_2$ limit values for new cars are considered to have a particularly far-reaching effect compared with other measures, despite all criticism of the calculation methods, as they address all fleets of new cars and almost all manufacturers (with the exception of very small fleets).

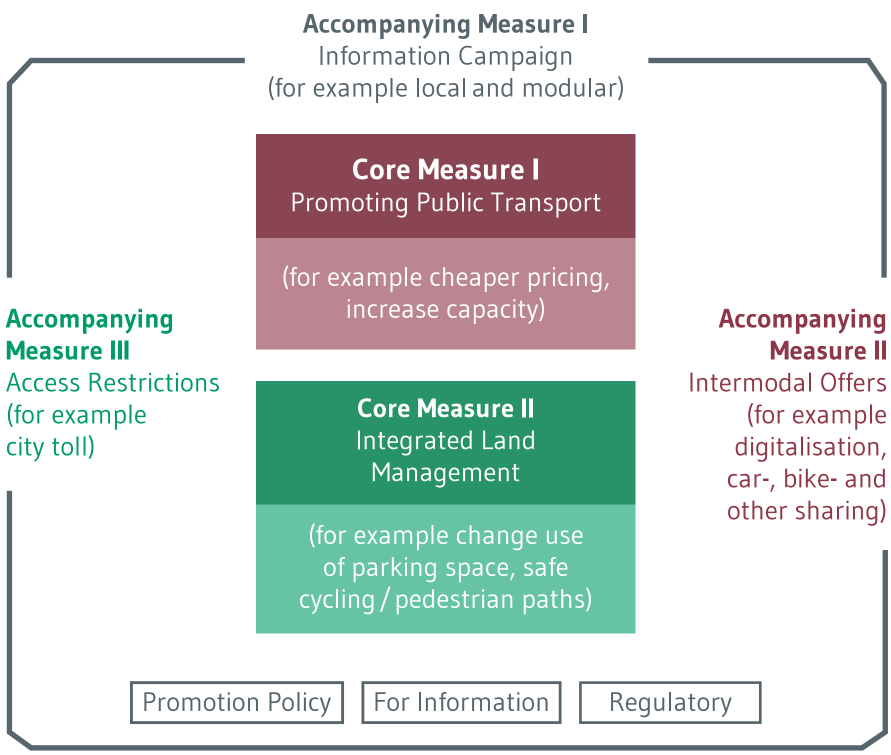



*Figure 6: The policy package "Strengthening Multi- and Intermodality in urban areas through (low-cost) public transport and integrated land management"*

*Merging the various specialist cultures, schools of thought and methods into a common product is the greatest challenge for ENavi – and its greatest strength at the same time.*

**Prof. Dr Michèle Knodt,** Technische Universität Darmstadt

This push measure forces manufacturers to advance technology developments and offer them on the market. Core measure II "Introduction of a $CO_2$ component for fossil fuels", on the other hand, is an economic pull measure aimed primarily at increasing user costs for motorised individual traffic with conventional engines and fossil fuels. The aim is to privilege alternative engines over conventional engines. This is directly supported by various accompanying measures, such as a reform of the vehicle tax in favour of climate-friendly, fuel-efficient, light vehicles and a $CO_2$-dependent parking fee structure.

Both measures should increase the attractiveness of alternative engines with additional economic advantages and encourage users to consider them when buying. Two further accompanying measures in the area of infrastructure (building charging infrastructure and technological development "intelligent charging pillar") and communication (user-specific information campaigns on electromobility) complement the core push and pull measures.

## Outlook

In order to gain a comprehensive overview of the potential implications of the policy packages, a systematic impact assessment of the (intended and unintended) effects and interactions of the two central policy packages will be carried out in the second half of 2018 in accordance with the ENavi process (Figure 2), taking the expertise from all ENavi work packages into account.

This collection, systematisation and interpretation of quantitative and qualitative data serves as a basis for the creation of evaluation profiles, which are then fed into the evaluation process and the discursive process of consultation. Both steps form the basis for a possible redesign of the policy packages.

# 6. ENAVI'S VISIBLE CONTRIBUTIONS TO THE ENERGY TRANSITION

### Practical insights with long-term effect

The results which are already available and those which are foreseeable for the duration of the first phase provide reliable and practice based contributions to the implementation of the energy transition that exceed the conventional policy advice of experts: ENavi's special architecture ensures a cross-disciplinary and transdisciplinary approach within the scope of a transparent and accessible sequence of knowledge acquisition, integration from evidence-based knowledge (mosaic stones) to consistent and dynamically oriented overviews, evaluation of the policy packages and development paths (Roadsmap) on this basis, discourse with decision-makers and practice partners, trials in living labs and modification of the results for implementation in practical policies. The focus is on scientifically founded, systemically networked strategies and interventions for the gradual implementation of the energy transition that have been tried and tested in discourse and can, at the same time, be implemented in practice. The ENavi team is in an optimum position for these tasks, above all to create and evaluate solutions and recommendations for action within the context of a democratically constituted and pluralistically active society.

The results to date have been documented in numerous publications and revealed in presentations and at ENavi events. Many research results have already been successfully introduced into political discourse.

The inter- and transdisciplinary cooperation beyond and above the work packages resulted during the first Project phase in the **three main topics**. These are representative of specific issues in decarbonisation in the electricity, heat and transport sectors. Political decisions will already be necessary in the mid-term, which the ENavi results provide effective and scientific support to.

In the second phase, these main topics will be further elaborated and discussed and further main topics will be added. In particular, sector coupling and digitalisation processes will play a central role here.

Across the Kopernikus Projects, first plans have emerged for concrete cooperation between the Kopernikus Projects SynErgie and ENavi in order to obtain an assessment of the economic flexibility potential of sector coupling in industry. Using its instruments within the context of a new topic of focus, ENavi could derive important information for SynErgie. On this basis, the SynErgie consortium could simulate instances of economic flexibility and their resulting costs. The results would then flow back into ENavi's scenarios. This could lead to an iterative process.

All in all, the related topics of social compatibility, justice, and fairness already play a central role. Within the ENavi consortium, but also in cooperation with the three other Kopernikus Projects, the interactions between technical development, organisational implementation, regulatory framework conditions, and individual and social behaviour will increasingly be systematically analysed in the future and, building on this, policy packages and targeted Roadsmaps will be developed, which will be evaluated and modified together with the practice partners and the decision-makers. In this way, ENavi not only makes an important contribution to academic research, but also to the practical implementation of the energy transition.