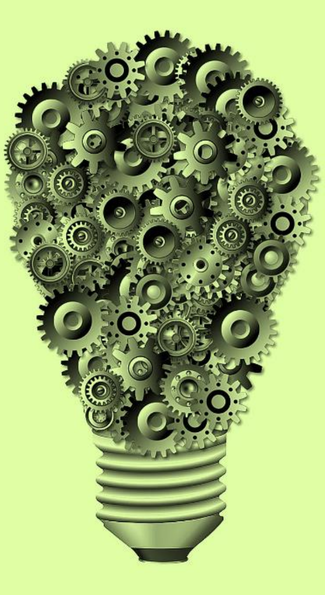
TRANSrisk

TRANSITION PATHWAYS AND RISK ANALYSIS
FOR CLIMATE CHANGE POLICIES

Policy Briefs



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Innovation Dynamics in Transition Pathways

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1 INTRODUCTION

As the IPCC report on 1.5. degrees of global warming has made abundantly clear, time is running out to meet even the 2 degrees target stipulated in the landmark Paris Agreement (IPCC 2018). In order to still have a chance to limit global warming to those temperatures, all sectors of our economy would need to radically reduce their emission through 'deep-decarbonisation' to be achieved by 2050 in most 1.5 scenarios. Given the fact that current efforts fall about 13 to 15 Gt of CO2e short of even a 2 degrees goal (United Nations Environment Programme, 2018), the urgency and the extent of the task at hand becomes clear: reductions equivalent of the totality of China's greenhouse gas emissions in 2016 would be necessary (Climate Action Tracker 2018).

This enormous feat is unlikely to be achieved by simply rendering conventional technologies and processes more efficient and 'greener'. A fundamental shift and tremendous innovation has to happen in the way societies produce, distribute and consume goods and services. For instance, if decarbonisation targets consistent with 1.5C scenarios are to be achieved in the transport sector, shares of low-carbon biofuels would have to increase to between 35% and 65% by 2050, a huge increase compared to the current 3% share (IPCC 2018). A multi-pronged approach will be needed to not only invest in transport technology but also fundamentally rethink the way we travel, including by favouring communal over individual means of transport and by city planning that strongly discourages automobile use.

However, innovation comes in many forms, and transitions from a carbon-intensive to a low-carbon system can take many pathways. For instance, decarbonisation in the transport sector can be driven by increasing the sector's biofuels uptake or by electrifying the vehicle fleet using renewable energies. Both options are likely to look different when it comes to costs, infrastructure needs and risks along the implementation pathway. In the same vein, one innovation system might need quite different support systems compared to another. It was such questions about the 'what' and 'how' of low-carbon transition scenarios and the risks and benefits associated with them which were at the heart of the policy-oriented research in TRANSrisk.

The research programme in TRANSrisk included national, regional and global studies across different sectors and applications, ranging from small-scale renewables to large-scale industrial applications. The cases focused especially on the electric power sector but there were also cases in sectors such as transport, household, agriculture and industry. Besides investigating risks along transition pathways, TRANSrisk paid particular attention to how innovation in certain technologies and practices could help overcome those risks.

This brief gives an overview of some of the research findings and provides some recommendations as to how transition pathways and the innovation systems they need can be supported. Not all case studies are reviewed here, but rather selected results from selected case studies are used to provide a broader perspective. Thus this brief synthesises relevant policy recommendations in relation to innovation dynamics and transition pathways by using the results of case studies in combination with the overall national, regional and global framework in TRANSrisk. For more detailed information on a given case study or in relation to methodological issues or studies carried out at regional and global levels, the underlying reports are available on the TRANSrisk website.

2 Approach to innovation systems and transition pathways

TRANSrisk featured two overall approaches in the analysis of innovation systems in transition pathways, which were refined and nuanced along the way. The first consisted of a thorough stakeholder engagement process that adopts a socio-technical view on key actors and stakeholders in the innovation system. Using a variety of tools, methods and formats, the main objective was to co-create sustainability pathways together with a large variety of stakeholders and to elaborate research questions associated with those pathways. Some of those pathways were elaborated in specific case studies and country contexts such as the development of geothermal energy in Kenya, while other pathways were mapped using a broader societal perspective at regional or global level. For instance, one pathway envisioned a change in dietary habits of European citizens, towards vegetarian diets and less meat.

A second complementary approach included the analysis of those scenarios and pathways in the context of the technological innovation systems (TIS) perspective. Technological developments, institutions and organisational practices supporting those systems along different pathways were investigated in detail, using a panoply of qualitative and quantitative research methods to look at costs, benefits and particularly risks and uncertainties. The case studies often employed a detailed perspective quite specific to local contexts, while the broader pathways analyses compared those cases to link them to regional and global developments. In carrying out these approaches, a variety of tools and methods were used. Table 1 provides an overview of key tools and methods and the case study countries where they were applied.

Table 1: Selection of tools and methods used in case studies

Tools and Methods	Purpose and/or application or sector	Applied in
Social Sciences Tools		
Stakeholder Attribute Matrix (SAM)	Identify stakeholders attitude and power to transition pathways	Indonesia, Netherlands
Q-method exercise	Identify and assess peoples‘ world-views’ about a certain topic	Indonesia
H-form exercise	Assess people's opinions about specific questions	Indonesia, Netherlands
Social Network Analysis (SNA)	Visualises relationships between actors by displaying them as networks	Indonesia
Micro-Models		
WEGDYN	Investigate macro-economic implications for investments in decarbonising the steel sector	Austria
Global Climate Assessment Model (GCAM)	Integrated assessment for energy, land and emissions at global and national levels in relation to changes in energy demand, land use, water and other resources, across multiple agro-ecological zones.	UK, East Africa
Times Integrated Assessment Model (TIAM-ECN)	Optimisation across different costs, prices and availability, applied at global and national levels, focusing on energy demand and supply shifts and interactions across multiple end-uses, sectors and trade configurations, focusing on the effects of.	Kenya, other regional and global analyses
E3ME model	Evaluate the economy-wide implications for major technological and sectoral shifts in energy markets in terms of GHG emissions	Indonesia, Netherlands, UK
Micro-Models		
Agent-based modelling (ABM)	Investigate the agency of technology users and simulate different types of possible changes in existing markets to stimulate efficiency and innovation.	Kenya
TEEM-BSAM	Energy model, simulates operation of electricity markets	Greece
TEEM-DREEM	Energy model, supports assessment of demand flexibility	Greece

3 Risks and uncertainties on transition pathways

Characterising risks and uncertainties along transition pathways was a key feature within the TRANSrisk research effort. To facilitate collaboration between partners and to develop a shared vocabulary when investigating different pathways, several boundaries were drawn. Risks were divided between consequential and implementation risk, to differentiate between barriers to transition pathways and the negative consequences which could arise once these pathways and/or practices have been implemented (consequential risks). Then, risks were grouped according to six categories, namely economic, regulatory, political, social, environmental and technological risks. Table 2 gives an overview with one illustrative example each, found in case studies. Full details for the case studies can be found on the TRANSrisk website.

Table 2: overview of risk categorisation with some examples from case studies

Risk typology	Implementation Risk	Consequential Risk
Economic	Prevalence of fossil fuel subsidies (Indonesia)	Increasing prices (UK)
Regulatory/Institutional	Lack of sector-specific targets and/or policy framework (Sweden, Austria)	Industry/business collapse after retro-active policy changes (Greece)
Political	Unclear division of responsibilities between national and sub-national level (UK, Indonesia, Switzerland)	Fall-out after Brexit (UK)
Social	Public Opposition to renewables (Switzerland)	Costs & benefits not shared equally amongst communities (Kenya)
Environmental	Concerns of changes in soil quality when implementing transition (Netherlands)	Well contamination (Kenya)
Technological	Technology not adapted to user needs (Indonesia)	Faulty technology releases methane (Indonesia)

However, this systematic classification of risks is not to suggest that risks are uniform and independent from local context. On the contrary, risks and uncertainties on transition pathways, hindering the market diffusion of low carbon technologies and practices, are highly context specific. Therefore, we can observe increasing solar PV uptake in Greece, for example, does pose different challenges than reducing livestock farming in the Netherlands. Similarly, strategies to mitigate those risks and address uncertainties are unlikely to be the same for both pathways. Nevertheless, some general cross-case study observations are possible.

Economic risks have been identified and analysed prominently in TRANSrisk and constitute a formidable barrier to transition pathways. Overall, this is due to the fact that most clean technologies still come at a price premium compared to conventional ones. While this is due to the nature of innovation – usually, new technologies and practices have not yet had the necessary learning curve to bring costs down sufficiently – several factors have been identified in case studies where conventional, polluting practices have clear advantages. In Indonesia, prevailing fossil fuel subsidies made conventional energy sources such as liquified petroleum gas (LPG) attractive for farmers, therefore disincentivising investment in biodigesters. Similarly, in Austria, conventional steel and iron making plants benefit from free allocation of EU-ETS emission allowances. Conversely, model results have shown that an increase in the diffusion of innovative technologies and practices might drive up prices as observed in the modelling efforts carried out for the UK case study which might lead to a 18% increase in electricity prices if renewables are preferred over nuclear energy. Interestingly, recent auctions tendering offshore wind capacity yielded a significantly lower price for electricity compared to the government guaranteed strike price for nuclear power (£92.50).

However, conventional technologies and practices don't only benefit from direct support but also from a supporting regime which developed over decades and which has stabilised around norms, behaviours and institutions. Insights from the UK case study on nuclear power showed, how intricate and complex one innovation system such as nuclear power is, with private and public actors catering to its maintenance. The UK expects to spend more than £460 million in the local nuclear innovation system compared to £177 million in the local renewable innovation system. Moreover, regulation might be in place which still caters to the specific needs of the conventional regime, thus hindering increasing uptake of certain renewable technologies like solar PV. Those regulatory and institutional risks have been observed, for instance in Greece, where current policies such as net-metering could be optimised or where the frequent changes to the regulatory framework (including retroactive changes) had significant negative impact on solar PV developments and the Greek solar industry.

Similarly, political risks arose in many case studies. One of the most prevailing was the unclear division of competencies between national and sub-national governance levels. This has been identified as a barrier in the UK, Kenya, Austria and Switzerland. The Swiss case study also observed a diverging interest between national policies that seemed to favour reducing electricity consumption while local (canton) stakeholders favoured increasing local electricity production. Moreover, the lack of political frameworks and/or sector specific transition targets were found detrimental to supporting innovative technologies such as the electrification of road freight (Sweden) or hydrogen-based steel and iron making (Austria). Other political barriers observed were related to cumbersome bureaucratic procedures, for instance in Indonesia (Bali), where farmers willing to adopt biodigesters in their backyard had to submit applications twice to two different entities for a government-led programme.

Social risks were often manifest in public opposition to renewable developments. Those opposition might have diverging reasons. In the Swiss case study, some stakeholders were concerned about the negative impact renewable installations might have on the picturesque alpine scenery. In Kenya, however, opposition to large scale geothermal developments were more motivated by equity concerns where marginalised local communities feared they would shoulder the burden of the development on their lands while the benefits (cheaper electricity prices) would accrue far away in urban communities.

Often those social risks arose from concerns about environmental risks of innovation systems and transition pathways. Geothermal developments in Kenya were one example where well contamination was noted as an environmental risk. In the UK nuclear pathway, the potential of nuclear accidents like the Fukushima catastrophe of 2011 was identified as a significant environmental risk. Interestingly, Dutch stakeholders in the farming community were concerned that even overall beneficial measures to increase manure management might negatively impact the soil quality, thus impacting their business model, showing how closely related environmental and social risks are.

Lastly, technological risks can seriously affect transition pathways. Technical risks can either stem from technologies that are ill adapted to user needs and/or the conditions they are employed in. This was the case in Indonesia (Bali), where biodigesters laid idle after users complained about the insufficient size of the biodigesters and building materials could not withstand the alternating dry and wet climate. Moreover, technical risks can arise if two innovation systems interact in a suboptimal way such as observed in the Swedish case study where reduction of road freight emissions could be achieved by increasing the use of biofuels which in turn could hinder electrification efforts, another pathway possible.

4 Perspectives on Innovation

Innovation in TRANSrisk was understood comprehensively in that it encompassed not only new technologies but also innovative means of management and deployment, as well as social and institutional innovation that could spur behavioural changes. On the one hand, TRANSrisk looked at the specific technologies needed for several specific transition pathways. Those innovations ranged from quite well-established climate mitigation technologies such as geothermal or solar PV to less experimented ones such as hydrogen-based steel making. On the other hand, TRANSrisk went beyond a technological focus, and looked at the technological innovation system (TIS) as a whole by including in the analysis the actors, networks and institutions who contribute to the development, diffusion and utilisation of new products and processes (Bergek et al. 2008).

Beyond the technologies themselves that are necessary for transition pathways, surrounding factors have also been investigated. For instance, new and innovative technologies often require new institutions (including rules and norms) in order to reach their full potential. Here, TRANSrisk used the multi-level perspective (MLP) theory which describes the competition between stable, old and/or dominant socio-technical regimes based on decades of support and common practice and innovative, less stable and less codified niche technologies (Geels and Schot 2007). One example is the UK case study where the two investigated transition pathways (centralised, large-scale nuclear power vs. small-scale, decentralised renewable power) need quite different set of rules and network design. In the same vein, the case study in Greece showed how increasing solar PV penetration might entail some behavioural change as well, from consumers of electricity to 'prosumers' who actively take part in the power markets by the use of smart meters. Innovation (in this case as well as more generally) is not only about the technology (solar PV and smart meters) but is also related to behavioural change and management practices that might go hand in hand with new technology.

Understanding innovation more broadly in relation to the social embeddedness of technology also reveals mechanisms for social and institutional innovation that might help to overcome the aforementioned barriers (Geels, 2002). Indeed, barriers such as unclear division of responsibilities between public and private sector entities or between the national and sub-national level can't be fixed by technology. Institutional innovation and social innovation has to be fostered in order to do away with such barriers in order to strengthen the transition pathway. What makes this change in practice and behaviour innovative is creating the willingness and capacity to do things differently while also having the potential to reap wider sustainability benefits (Bakker and Konings, 2018).

5 Co-benefits and opportunities of pathways and Innovation Systems

Many innovation systems have the potential of delivering significant co-benefits, i.e. benefits which go beyond the primary objective of the technology and/or practice. In the case of transition pathways to low carbon futures, it means that technologies, measures and systems will achieve societal benefits beyond reductions in emissions or improved climate resilience. Co-benefits were investigated in a number of case studies. These included, among others: the Indonesian case study in which social, health and economic benefits from biogas production were observed for farming households; the solar PV case study in Greece in which impacts on employment and GDP were estimated; and comparative co-benefits for nuclear and renewables in the UK in terms of improved health and energy security.

Table 3: selected co-benefits in some case studies

Case Study	Type of co-benefit	Description
Biogas from household digesters in Indonesia (Bali)	Household Economic	Savings on fuel; additional revenues from bio-fertiliser by-products
	Health	Reduced indoor air pollution
	Social, Gender	More spare time for women
	Economy-wide	Small, but positive on economy and employment
Solar PV increase and support policies in Greece	Economic	Positive impact on employment and GDP (+1.8% by 2040 compared to BAU) if solar PV increases
Nuclear and renewables in the UK	Health	Reduced air pollution from increase of low-carbon electricity sources
	Economic, Security	Reduced energy import dependency

In some cases, by-products of the innovation system lead to additional co-benefits, such as additional revenues for Indonesian farmers who were able to sell bio-fertiliser, a by-product of the biodigester process. Moreover, adopting biodigesters on the household level has the potential to improve the wellbeing of women, particularly if the household used traditional biomass such as firewood to satisfy its energy needs before adopting biodigesters. Foraging for firewood is a labour-intensive job, taking up to two hours per day and is mostly done by women. By using biogas, those two hours could be used for social, cultural or economic activities.

6 Recommendations: how can innovation systems and transition pathways be supported?

In order for transition pathways to reach low-carbon objectives, it is fundamental to mitigate risks (and overcome barriers), to strengthen the innovation system(s) necessary for each pathway and to provide opportunities to reap co-benefits of transition pathways. Although recommendations on how to accomplish such aims are often highly context specific, some recommendations can be made as to how innovation can be strengthened or stimulated and risks mitigated.

A stakeholder-centred dialogue to build a common vision

Research in TRANSrisk showed the value in bringing a large variety of stakeholders together to discuss common visions and pathways. Often, different stakeholder groups don't sufficiently "talk" to each other; there is a tendency to avoid opposing views such that diverging opinions are either filtered out or not tolerated. This tunnel vision hinders the emergence of a broad coalition based on a shared understanding on how a transition would be best achieved in a given context. Moreover, including voices in the dialogue which are normally not heard very loudly (e.g. small farmers in Bali, Indonesia), can uncover blind spots and provide fresh new propositions on how to overcome barriers and strengthen the innovation system. It is therefore of great importance to facilitate the emergence of multi-stakeholder dialogues for a shared vision of the future.

A long term but flexible policy framework with sector specific targets

Having a common vision is rarely enough. This vision has to be translated into practice which places policy makers at the heart of every transition pathway and innovation system. TRANSrisk research identified risks from a lacking or subpar policy framework in all the case studies. Yet, having a clear policy signal and supportive regulation is of utmost importance for business stakeholders and civil society to move forward. Therefore, only a long-term policy framework which sets out the medium and long term objectives, ideally buttressed with sectoral targets, will facilitate the advancement on transition pathways. However, policy frameworks should be flexible enough to respond to market developments in order to minimise price increases or harness the advantages of falling costs of renewable technologies. Also, a clear division of responsibilities and obligations between the national and the sub-national level will boost low-carbon transitions, either by providing opportunities for sub-national governments to be even more ambitious (observed in Indonesian case) or by avoiding double-standards in regulations (Canadian case) or a lack of ownership for the objectives and targets (Kenyan case).

Strengthening the innovation system itself

The innovation system is at the heart of a given transition pathway and requires a clear policy framework. From a technological perspective, it is useful to understand diffusion of innovations as a journey in stages which necessitates tailor-made support depending on the stage of the journey/innovation. For instance, targeted and generous R&D funding in the beginning will help less mature technologies to ripen and to ensure that technologies are adapted appropriately to user needs. Once technologies are mature, environmental standard setting policies are important in order to facilitate new markets by lowering the cost for clean technologies and raising the cost for conventional ones and polluting practices. Both "pull" and "push" factors are needed to improve the performance of the innovation system.

From a business perspective, promoting opportunities in growing markets for clean technologies to benefit from first-mover advantage will further strengthen the innovation system, particularly since conventional business strategies based on fossil fuels may become unprofitable as the liability of climate change becomes better incorporated into markets. Furthermore, public-private research collaboration have been fruitful to strengthen innovation systems, as exemplified in the Swedish case study on electrification of road freight.

It is important to understand innovation in a broad societal sense. Diffusion of each new technology has to go hand in hand with a change (innovation) in the way society uses and interacts with this technology as well. If norms, rules and behaviours don't evolve together with specific technologies, barriers on transition pathways will arise, even if the technology is mature and ready to contribute towards the Paris Agreement's objective. Figure 1 provides an overview of the different connections and necessary improvements involved in building a comprehensive innovation system.

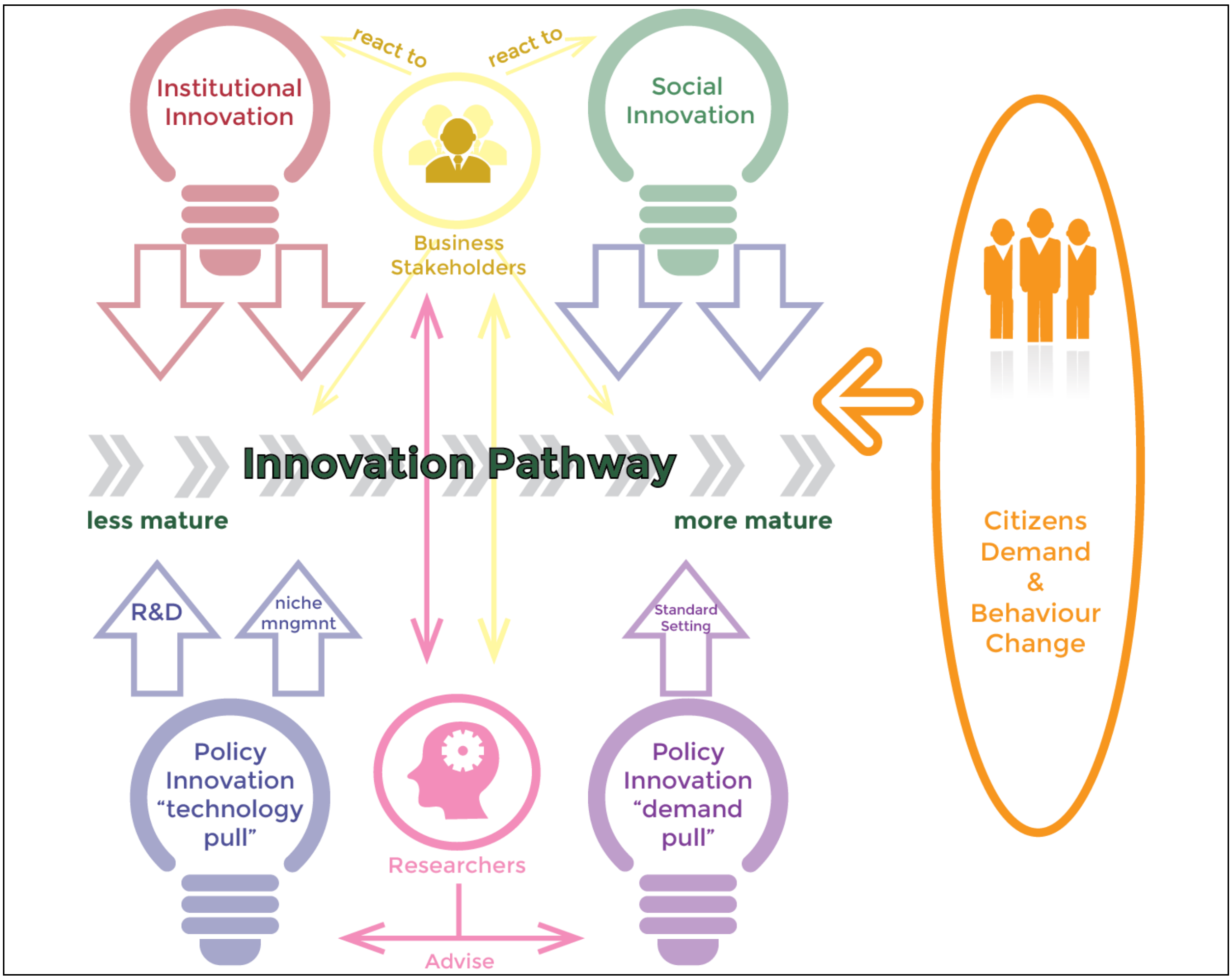


Figure 1: components and relations in a well-working innovation system (adapted from Grubb et al. 2017)

A level playing field

Carbon intensive technologies do not only have an advantage because pollution is inadequately priced-in and because years of experimentation make them less expensive than their cleaner competition. It is also because decades of support and practices built around them have generated rather robust norms and behaviours. In Indonesia, subsidised liquified petroleum gas is seen as cheaper and convenient alternative to biodigesters while new, innovative technologies such as hydrogen-based steel making come with a significant premium price tag. Therefore, doing away with fossil fuel subsidies or starting to put an appropriate price on carbon might not be enough to really level the playing field. Targeted support to clean technologies might still be warranted in order to support them to compete with old habits, and transition pathways also need to tackle the question of how to shift practices, norms and behaviour in order to accommodate low-carbon technologies.

Engaged citizens

Indeed, pressure from the bottom up is needed if transition pathways are to succeed. Citizens as either vehicles of this pressure and/or in their role as consumers have a key role to play. TRANSrisk modelling showed how, for instance, dietary choices of EU citizens could lower emissions in the EU. Of course, mechanisms to exercise pressure to demand cleaner technologies depend strongly on the country context and whether local political conditions allow for citizens to make their voices heard. But if conditions allow for it, consumers and citizens have to do their share in inducing necessary behavioural change to support the levelling of the playing field from the bottom up.

Thorough monitoring, evaluation and transparency provisions

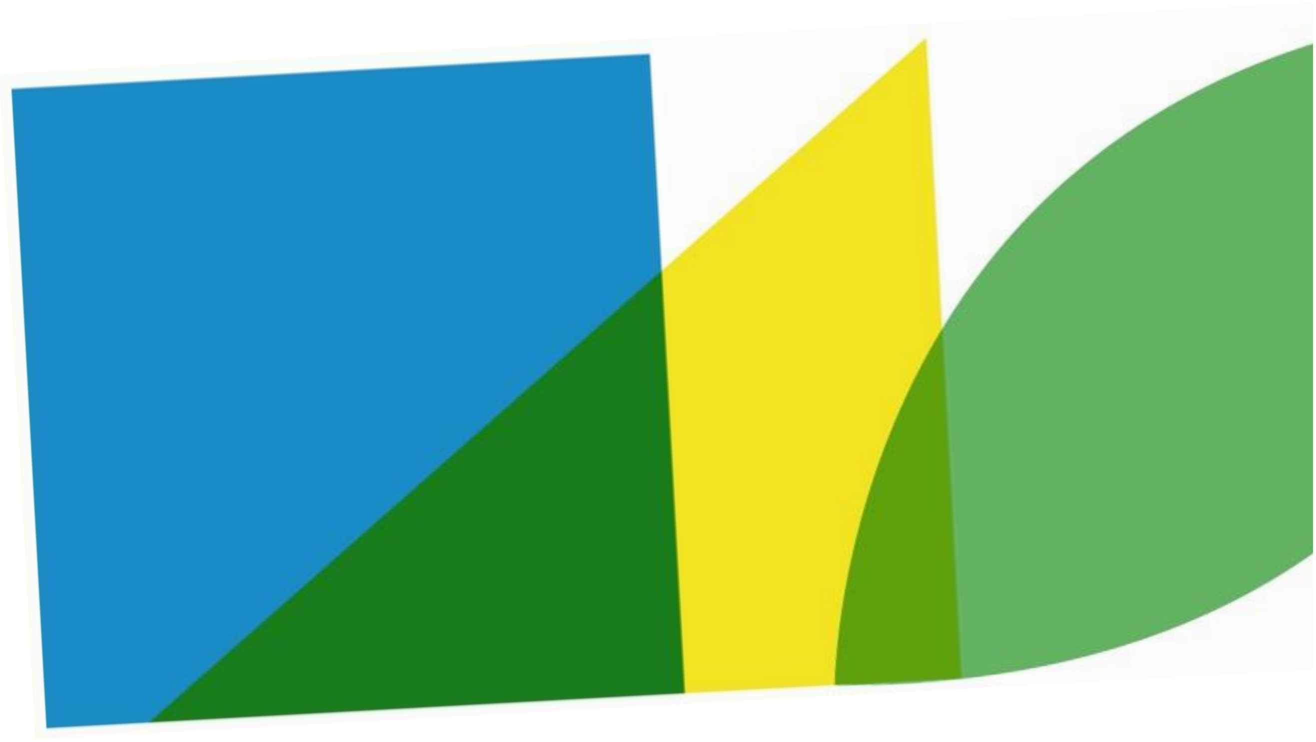
All options detailed above crucially depend on whether they are adequately monitored and evaluated and on whether the impacts of those measures are investigated and conveyed in a transparent manner. Without monitoring and evaluation, there is no way of knowing whether technologies correspond to user needs and whether policies have had the intended effect. Moreover, making those evaluations available to a large group of stakeholders would help them to do their share on transition pathways. Here, researchers have a key role to play in providing for robust, science-based evidence of how transition pathways are progressing and identifying key impacts of particular technologies or practices.

Limiting consequences, spreading the benefits

Monitoring and evaluation activities are particularly important, since it is clear that not all stakeholders will benefit equally on transition pathways with some not benefitting at all. For instance, while TRANSrisk modelling results suggest that jobs lost in the fossil fuel sector in the EU are more than compensated by jobs in the renewable energy sector, some scenarios can lead to negative impacts in some countries and/or regions. It is therefore of utmost importance to develop strategies to soften these negative consequences for affected stakeholders and to share the benefits in the widest possible manner which in turn would avoid backlash against transition pathways as observed quite recently in France but also in case study countries like the UK.

Better communication

Lastly, a better communication effort to avoid silos where groups become isolated, might be able to broaden the coalition necessary to accelerate transition pathways. Often, climate policies are insufficiently communicated and decisions are taking in a rather top-down manner. Clear and continuous communication efforts are therefore key measures in facilitating the inclusive dialogue discussed above.



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REFERENCES AND NOTES

This brief is based on the TRANSrisk Deliverable 6.5 (Innovation Dynamics in Transition Pathways). Readers interested in more details can find the deliverable as well as relevant case studies and other reports on the TRANSrisk website. The following are the additional references:

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About TRANSrisk

TRANSrisk is studying the **risks and uncertainties** within **low carbon transition pathways**, and how transitions can be implemented in ways that are **technically, economically** and **sociably** feasible. The project's objective is to produce a new assessment framework, and an accompanying **toolbox, for policy makers.**

TRANSrisk's unique approach sees us combining **economic computer models** with **input from people working in the area of study ("stakeholders").** Models provide a useful means of predicting the future impacts of decisions we take now, but **factors such as political opinion and public acceptability** are very difficult to predict via a purely numerical approach. TRANSrisk is using **stakeholder input** to feed our models, and is presenting the results **back to stakeholders** to see how this affects their views.

14 country case studies lie at the core of TRANSrisk's work. To fully understand the range of transition pathways our **case studies encompass the globe**, as presented in the adjoining map. In alphabetical order they are: **Austria, Canada, Chile, China, Greece, India, Indonesia, Kenya, the Netherlands, Poland, Spain, Sweden, Switzerland and the United Kingdom.**

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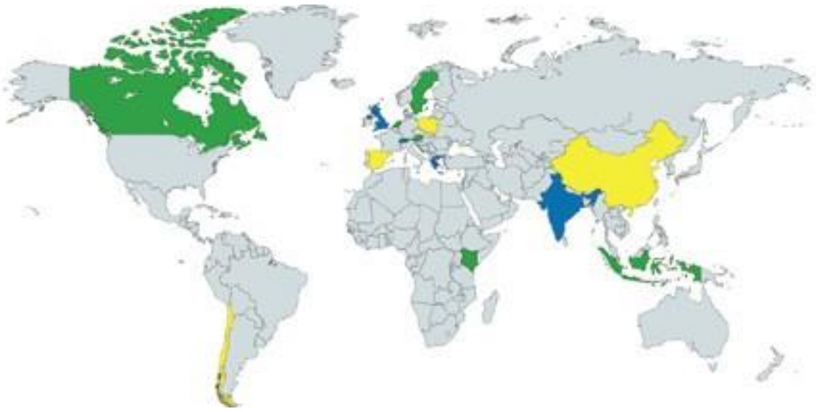

The team behind TRANSrisk is a knit partnership of 12 leading universities / research institutions, based in the EU, Switzerland, and Chile.