PATHWAYS project

Exploring transition pathways to sustainable, low carbon societies

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Deliverable D4.1

Tools and procedures for linking three approaches to transition pathways

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Contents

1 Introduction

1.1 Purpose and structure

The purpose of this document is to report on activities developed through Task 4.1 in Work Package 4 of the PATHWAYS project ('Exploring transition pathways to sustainable, low carbon societies'). The overall aim of WP4 ('Integration and governance') is to develop the means for connecting and linking three perspectives on sustainability transitions, develop ways of characterising the state of transition pathways, assess the role of policy and governance in transitions, and draw scientific conclusions about the nature and dynamics of transitions (and transition types) and their governability. WP4 also provides a structure for iterative collaboration and participation across the entire PATHWAYS project team. WP4 aims to contribute to a conceptual framework that provides a uniform understanding and terminology of policy and governance across the WPs and highlights the areas in which each of the three research approaches contributes to the analysis of the role of policy and governance in the context of transitions.

Specifically, Task 4.1 is concerned with developing tools and procedures for linking the three main analytical approaches. This implies identifying key linking elements between and across approaches (e.g. key economic, technological, institutional or policy indicators, and elements such as actors, institutions, networks, and regimes). Another related task is to facilitate interaction in practice. This deliverable contributes to this task by providing an interim report ('draft') on progress mid-way into the project.

We first provide an overview of the integration strategy pursued in PATHWAYS. We then present the main principles in detail including common problems and objectives, shared concepts, empirical integration, and data and metrics, specified how these elements can be mobilised across the three approaches in practice. We also specify the procedures that will structure such collaborative work. We conclude with an outlook on the evaluation of transitions pathways via the establishment of such an interdisciplinary chain of analysis. A number of supporting notes are presented as annexes.

1.2 PATHWAYS approach

The PATHWAYS concept aims to better understand transition pathways to sustainable, low carbon and resource-efficient societies and the related challenges. The PATHWAYS approach is to link three different analytical perspectives between which there has been relatively little interaction, quantitative systems modelling, and initiative-based learning. In PATHWAYS, we use the approaches to look at two fundamentally different categories of transition pathways in five key domains where transitions are expected.

The three approaches considered provide contrasted views on transition pathways. They share problem-driven objectives, but each provides their specific scientific outlook and adopts a different attitude toward governance:

Quantitative Systems Modelling combine information on global environmental problems, their main causes and possible response options and their costs and benefits, in order to provide a comprehensive quantitative forward-looking macro picture of transition pathways towards sustainability targets. Integrated Assessment Models (IAMs) can link future goals to the concrete implementation of technologies and the related policies over time. However, IAMS have typically little to say about the interests or motivations of actors and social groups involved in these transitions (van Vuuren and Kok 2012, van Vuuren et al 2011).

Socio-technical transition analysis works at the meso-level, focusing on different social groups (industry, policy-makers, civil society, consumers, etc.) and the degree of alignment or tension in their beliefs, motivations, problem agendas and strategies. The multi-level perspective (MLP) has been accepted as a key tool to focus at structural factors, innovation opportunities, and the role of key actors (Geels and Schot 2007, Foxon et al 2013). While transition studies introduce more complexity in the description of social systems than techno-economic models, it sacrifices the macro-level and future-oriented analysis of IAMs.

Initiative-based learning engages with concrete sustainability projects. In these projects, actors with different views and motivations need to align technological opportunities, consumer preferences, infrastructure requirements, and policy frameworks into working configurations. Initiative-based analyses reveal the complexity and uncertainty of transitions in the making. Case study approaches, such as participatory action research, however often lack a broader analytical framework of how experiments and niches influence and change regimes or the broader context (as provided by other approaches).

1.3 Integration objectives and expectations

Within WP4, we explore and mobilise opportunities for greater integration between three approaches to transitions. The PATHWAYS approach seeks to link the analysis of the three perspectives to overcome some of their weaknesses. We do this by coupling of methods and tools from each approach, in order to create an integrated, multi-scale and interdisciplinary chain of analysis. This is an iterative process, on-going throughout the project's lifetime, with regular opportunities for evaluation and improvement.

At project level (within WP4), integration activities rest on three specific integrative threads examining specific aspects of integration, supported by dedicated task forces:

(i) tools and procedures,
(ii) visualisation and representation, and
(iii) governance and policy

These integrative task forces make up the 'enabling architecture' that guide the search for integration opportunities.

<u>Procedure</u>: The task forces have their own work programme based on a *contrast, compare, combine* approach. Progress is regularly fed back to and from other project activities, through workshops, and planned activity reports (T4.1, T4.2, T4.3).

Task 4.1 is formulated as one of three 'integrative threads' that run throughout the project. This means that successive activities and deliverables engage with challenges of tools and procedures at their own level, enabling and enabled by an on-going 'meta' reflection on these topics at project level. These processes are both complementary and cumulative.

At WP4 level, a dedicated task force that runs throughout the project lifetime leads the reflection on tools and procedures for linking and integration. It is tasked with delivering D4.1 ('Draft report on tools and procedures for linking approaches to transition pathways'), facilitate research interaction across work packages, and evaluate integration strategies in regular workshops.

In this report, we are concerned with presenting tools and procedures for linking different approaches to sustainability transition pathways. To meet these objectives, we seek to address the following questions:

- What are the main assumptions and mechanisms implicit to each approach?
- What are the main weaknesses of each approach and how could integration with other approaches compensate for these?
- What are the main methodological obstacles and opportunities for integration?
- What are the core methodological elements that can enable linking across approaches? (tools)
- What is the appropriate strategy for the operationalization of linkages? (procedures)
- How can we evaluate the benefits of integration?

2 Integration strategy

2.1 Integration objectives

In PATHWAYS, we aim to achieve a more robust evaluation of the state and dynamics of sustainability transitions (past, current and future). Current approaches to sustainability transitions offer fragmented insights and evaluation of sustainability transitions, with each approach characterised by its specific strengths and weaknesses.

We propose to overcome these weaknesses by pursuing greater integration of three analytical approaches, with two objectives – that is, integration is not an end in itself, but pursued for specific ends (see also Figure 1, representing integration as an open question, the modalities of which are determined by the objectives pursued):

- Analytical: Generate findings that are relevant for advancing scientific understanding of sustainability transitions
- Governance: Generate findings that are useful for transition governance (modes, strategies, measures, recommendations, etc.)

To address these objectives, and recognising fundamental differences between approaches, we see integration as a process of ***bridging*** between established research approaches through agreed ***operational linkages***. The task for integration is one of **framing and structuring interactions between approaches across specific interfaces with commonly defined problems and objects**.

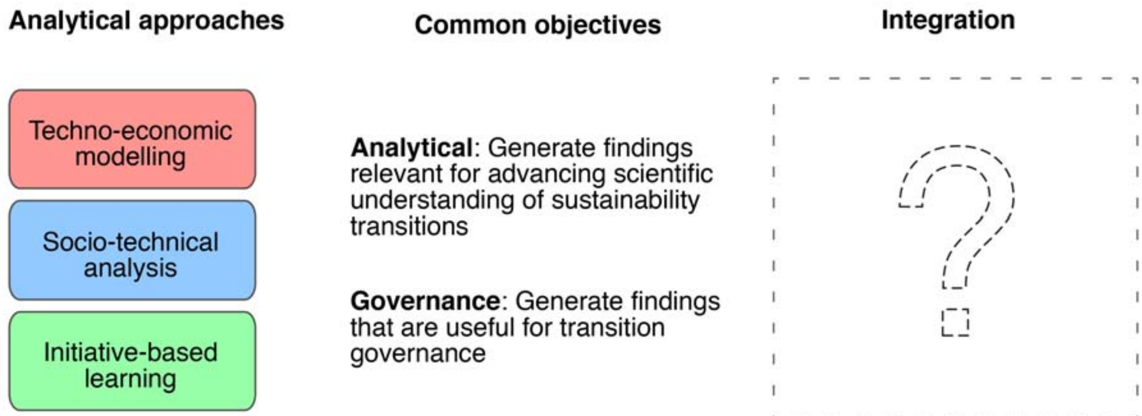

Figure 1: Schematic representation of the integration framing around common problems and goals

2.2 Overall strategy: bridging and linking

Interaction between three PATHWAYS analytical approaches is a process involving the development of operational linkages. To generate potential linkages, it is important that these semi-autonomous research activities share common concepts and agree a common problem frame requiring integration. This allows us to frame interactions between approaches. In practice, the common problem frame enabling integration is defined by:

1. a common research problem or shared normative policy goal
2. shared or spanning concepts
3. commonly defined empirical domains
4. agreed parameters, metrics, indicators and data

2.3 Establishing operational linkages

Once a problem frame is established**, bridging between analytical approaches involves structured interactions between semi-autonomous research processes through boundary-spanning concepts and agreed parameters, metrics, indicators and data**. An integration framework defines the nature, framing, and timing of these transactions. What we propose is not to achieve a fully integrated research process, but rather linkages and opportunities for collaboration, seen as an iterative cross-approach dialogue.

The structure of research activities in PATHWAYS follows an approach-based division of labour. Each approach is mobilised within a semi-autonomous research stream in a dedicated work package. These research streams are represented in Figure 2, with WP1 ('Integrated assessment of transitional change'), WP2 ('Dynamics of transition pathways'), and WP3 ('Transitions in the making') proceeding from the set of assumptions of their research tradition, but set up within a common research process.

Figure 2: Three semi-autonomous research streams supported by dedicated work packages

We propose a form of **integration as enabling *periodic, vertical linkages* between these research streams**. The PATHWAYS approach places a number of constraints on analysis in these individual work packages, ensuring that each approach is oriented towards meeting common research objectives, while contributing to sharpen the collective research frame in an iterative process.

In practice, having agreed a common problem frame, we set up a number of linking tools and procedures:

- **Linking tools** are the concepts, metrics, indicators and data that frame interactions between analytical approaches. It is a common task to define and improve these tools in the project, particularly when considering the evaluative and 'observatory' objectives of the project.
- **Linking procedures** are the step-wise procedures and protocols that structure operational collaboration. The basic outline of this procedure is: 1) to agree shared analytical problems or shared normative objectives, 2) to agree shared or spanning concepts (Figure 3), 3) agree on the dimensions of empirical domains (Figure 4), and 4) agree common data and metrics (Figure 5).

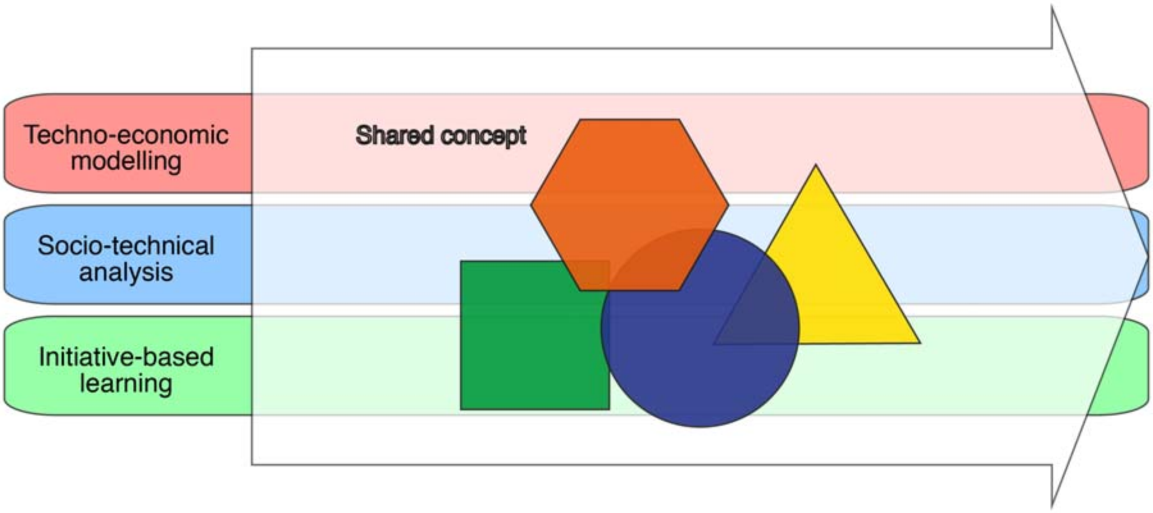

Figure 3: Shared concepts as the means towards common understanding

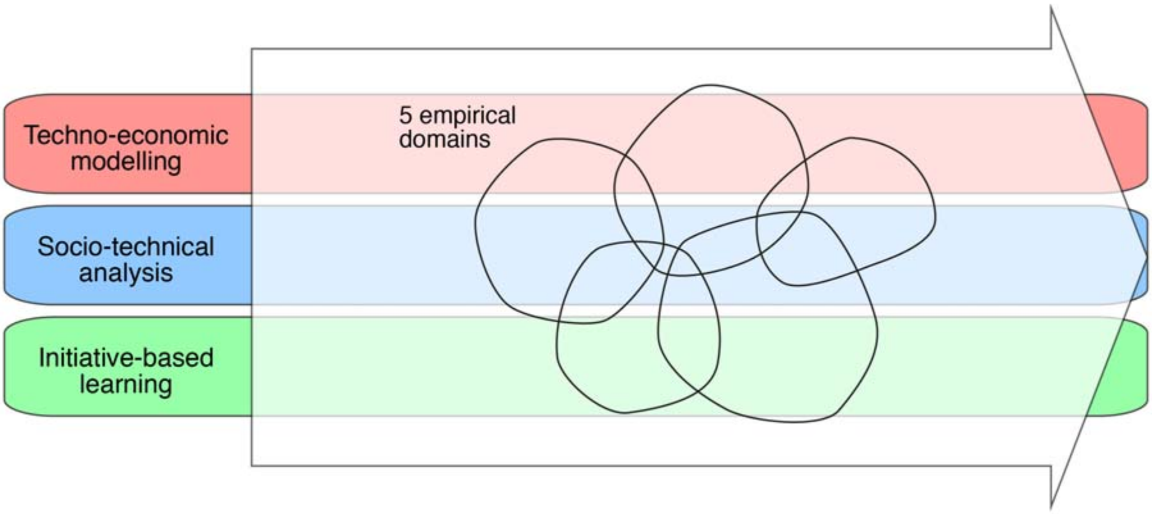

Figure 4: Empirical domains as opportunities for concrete research collaboration

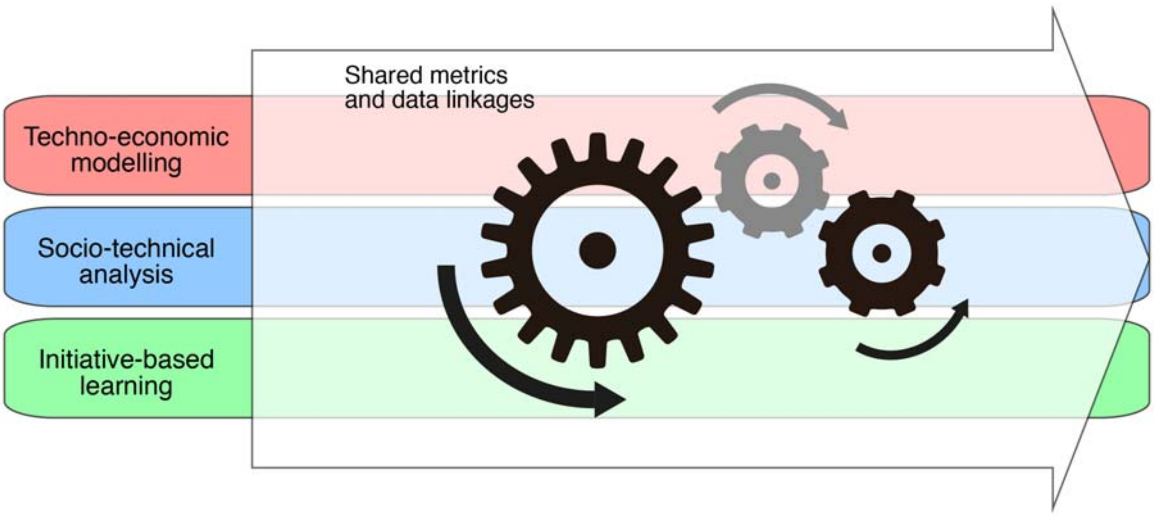

Figure 5: Shared metrics and data linkages

3 Progress with integration

In this section, we take up the four aspects defining the common problem frame (see section 2.2):

1. defining a common research problem or shared normative policy goal
2. defining shared or spanning concepts
3. commonly defined empirical domains
4. agreed parameters, metrics, indicators and data

3.1 Defining common problems and objectives

Before defining shared analytical problems or shared normative goals, we need to clarify the substantial differences that exist between the three approaches. Table 1 provides an overview of such differences, upon which we elaborate elsewhere (see Turnheim et al, *unpublished manuscript*).

Table 1: Overview of three approaches considered

	Quantitative systems modelling	**Socio-technical analysis**	**Initiative-based learning**
Transition pathway operationalisation	Model assumptions and policy goal-constraint	Analytical categories and ideal types	Materialisation of new 'proto-configurations' enabling learning
Scale	Global / national Macro	National Meso	Regional / local Micro
Primary time focus	Future-oriented	Historical	Current
Time horizons	30+ years (policy target)	30-90 years (transition time)	5-15 years (project time)
Analytical process	Optimal allocation of resources w/ fixed parameters	Detailed representations w/changing units of analysis	Detailed analysis of actors and strategies
Treatment of actors and agency	Marginal (cf. MATISSE is agent-based, etc.) Rational behaviour	Selective analysis of agency (enacted strategies)	Detailed representation, via struggles and concrete groundwork
Innovation	Mostly incremental (exceptions?)	Incremental and radical	Incremental and radical
Institutional change	Not explicitly modelled Marginal (example)	Co-evolution with socio-technical system	Collective learning, expectations, etc.
Insight into future options and action	Narrow, focussed and effective link between goals and options	Broad, detailed emphasis on uncertainties	Collaboration and participation

3.1.1 Shared analytical problems

The overarching analytical problems we are concerned with in PATHWAYS are characterising and measuring transitions pathways, in particular with the shared concepts of scope and depth of the transition, and the momentum of changes and the inertia of current socio-technical systems. Each of these represents a field for integration/linking between analytical approaches. Following the notion of vertical linkages between approaches outlined above, integration must be structured in a stepwise way between each of the three approaches in turn. The following two tables set out the alternative framings associated with each of the shared concepts and proposes integration options (Table 2 looks at linkages between quantitative systems modelling and socio-technical analysis; Table 3 looks at linkages between socio-technical analysis and initiative-based learning). These are suggestions that need to be further debated and consolidated at specific interfaces. A further interface to be considered is that between quantitate systems modelling and initiative-based learning.

Table 2: Problem framing between quantitative systems modelling and socio-technical analysis

Transition pathways	**Quantitative systems modelling vs Socio-technical analysis**
Scope	Adoption of known technical options vs co-evolutionary adjustments in institutional setting for technical change *Integration options*: • Include institutional parameters in models (drawing on concepts and data from socio-technical analysis) • Include adoption/diffusion of technical options in socio-technical analysis (drawing on concepts and data from modelling) • …
Depth	'Distance to target' of portfolio of technical options to achieve policy goal vs qualitative assessment of the novelty of socio-technical configurations (actors, technologies, institutions, narratives, norms) *Integration options*: • Include institutional etc parameters in models (drawing on…) • Include an 'objective function' or 'distance to target' concept in socio-technical analysis (drawing on…) • …
Momentum	Rate of adoption of sustainable technical options vs qualitative assessment of momentum of niches relative to regime *Integration options*: • Include analysis of niches momentum in models • Include analysis of rates of adoption of key technologies in socio-technical analysis • …
(relative) Inertia	Rate of adaption of sustainable technical options relative to the distance to target of portfolio of options to achieve policy goal vs qualitative assessment of the strength and coherence of the incumbent socio-technical regime *Integration options*: • Include analysis of 'stickiness' of regimes in models • Include quantitative analysis of rates of adoption relative to final target in socio-technical analysis • …
Relevant deliverables	**D2.3, D1.2, D1.3**

Table 3: Problem framing between socio-technical analysis and initiative-based learning

Transition pathways	Socio-technical analysis vs Initiative-based learning
Scope	Co-evolutionary adjustments in institutional setting for technical change vs extensiveness of actor-network involved in transition initiative *Integration options*: • Greater attention to actors and agency in niches in socio-technical analysis (drawing on insights from practice-based initiatives) • Greater attention to institutional context of actor-network in initiative-based learning • …
Depth	Qualitative assessment of the novelty of socio-technical configurations (actors, technologies, institutions, narratives, norms) vs Degree/type of learning (technological, relational, social) through transition initiative *Integration options*: • Include assessment of learning in socio-technical analysis • Include assessment of novelty in initiative-based learning • ….
Momentum	Qualitative assessment of momentum of niches relative to regime vs (local/regional/global) diffusion of learning from transition initiatives Integration options: • Include assessment of extensiveness of transition initiatives in socio-technical analysis • Include assessment of transition initiatives in the light of regime dynamics in initiative-based learning • …
Inertia	Qualitative assessment of the strength and coherence of the incumbent socio-technical regime vs Barriers and constraints faced by transition initiatives *Integration options*: • More detailed attention to the barriers and constraints as they influence incentives and risks for novel initiatives in socio-technical analysis • More attention to strength and coherence of overarching regime(s) as they affect incentives and risks of actors in sustainability initiatives • …
Relevant deliverables	**D3.3, D3.5, D2.1, D2.2**

Procedure: Progress on the framing of analytical problems between approaches is dealt with in an iterative fashion in different activities. An initial framing has been spelled out in a joint position paper (see Turnheim et al, *unpublished manuscript*). D3.3, D2.3, D1.2, and D1.3 offer opportunities to further specify analytical problems at different interfaces between approaches.

3.1.2 Common governance objectives

The role of the three PATHWAYS approaches in informing public policy and governance varies. In general terms, quantitative systems modelling has strong, but quite specific, impacts on some domains of policy (such as regional air pollution policy and international climate policy), while socio-technical analysis and initiative-based learning generally have weak links to policy. The extent to which normative goals play a role in framing 'analytical programmes' also varies across the three approaches. For instance, while policy goals (such as achieving the 2degC target in international climate policy) play a fundamental role in quantitative systems modelling, in socio-technical analysis such normative policy goals are themselves an object of analysis, while in initiative-based learning they play only a tangential role in informing the design and implementation of projects.

Nevertheless, one of the main promises of a more integrated analytical approach was that this would generate more useful, flexible and timely evidence for policy-makers and others concerned with governing sustainable development (see section 2.1). Therefore it is important to define policy and governance objectives that are tractable to more integrated analysis. These policy and governance objectives may have different forms:

- Specific policy targets (across a variety of scales and domains)
- Capabilities that are formative of transitions towards normative objectives (such as innovation and diffusion of new technologies, development of new business models, changes in consumption practices, cultural changes towards the environment, and so on)
- The identification of 'branching points' as significant bottlenecks providing focus for policy decisions

As with the definition of common analytical problems, it is possible to identify policy targets and transitions capabilities that can act as points of linkage between the three analytical approaches. In PATHWAYS this would be related to the empirical domains we are covering, but also to different scales. When mobilising different approaches to address governance approaches, it is important to clearly formulate what these specific objectives are, and how they differ in (or are interpreted differently by) each approach.

Procedure: Progress on the framing of common governance objectives across approaches will be dealt with in an iterative fashion in different activities. An initial framing has been spelled out in more detail in a joint position paper (see Turnheim et al, *unpublished manuscript*). In D4.3, a literature review of the treatment of governance by each approach will work towards establishing common ground in this direction. In D1.2, governance and institutional aspects will be considered insofar as they can be integrated into modelling strategies.

In deliverables D1.4, D2.5, and D4.4, corresponding insights are to be generated with respect to informing European and national roadmaps, developing future-oriented analysis of transitions pathways, and comparing transition pathways with respect to governance dynamics, respectively.

3.2 Defining shared concepts

Substantial progress has been made in terms of achieving **common understanding** and definition of the problem at hand, and related common or shared concepts related to transition pathways:

Definitions and pathways characterisation. We have clarified the definition of transition pathways, defining elements (goal constraint, lead actors, depth, scope), and a typology of ideal transition pathways (A, B, 0) (see Annex A).

Characteristics of pathways in the making. We have related these to different layers of explanation commonly mobilised in socio-technical analysis (actors strategies, innovation (technologies and markets), and institutional change), as well as intermediate notions that allow us to capture transformative change (niche momentum, regime inertia and path dependence).

These concepts are not set in stone, but provide important fixation points for further refinements based on collective reflection (e.g. in workshops), and operational specification in different work packages. Current progress is illustrated in Figure 6, which mobilises representations from each approach, linking them around a common framing. Furthermore, Figure 6 explicitly represents differences between approach in terms of timescales and level of aggregation.

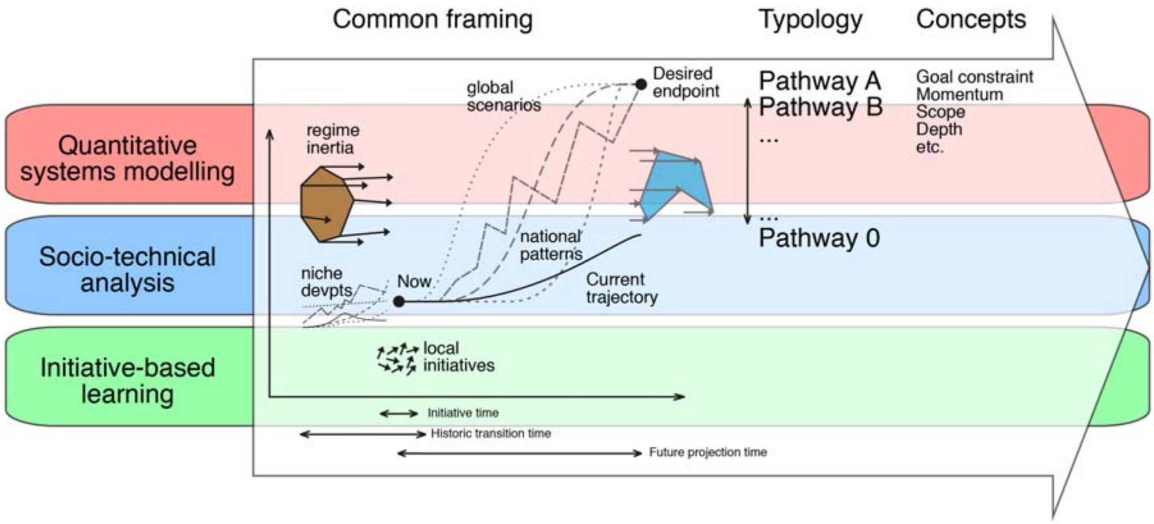

Figure 6: Operationalisation of shared concepts

Procedure: Progress on defining shared concepts is seen as an iterative process throughout the lifetime of the project, with framings becoming sharper as the project progress, particularly through workshops. The current state of play is reported in Annex A. A joint position paper specifies shared concepts further (see Turnheim et al, *unpublished manuscript*). Substantial further opportunities ahead include a number of planned workshops, and deliverables D2.5 and D4.4 in which a forward-looking analysis of pathways, and an analysis of governance dynamics, respectively, will contribute to a sharpening of concepts and the provision of a more definitive framing. D1.2 also discusses how integrated assessment models interpret the notions of interacting elements, momentum and inertia in transition pathways.

3.3 Defining and mobilising empirical domains

The empirical work of the project focuses on transitions in five empirical domains, offering opportunities for analysis through the perspective of the different approaches in different work packages (see Table 4; see also Figure 4). Via such common empirical focus, it is possible to achieve very concrete forms of operational integration around data requirements in each domain, but also in relationship to analytical assessment of domain-specific developments, as well as related policy recommendations to unlock the potential for sustainability transitions pathways.
A main objective here is to enable **methodological linkages** and empirical data flows at the interface between WPs:

- Ensure empirical consistency and correspondences through cases (domains and countries) across approaches
- Enable the sharing and mobilisation of findings across approaches.

A related challenge is about adjusting assumptions and methodologies to take alternative findings into account. The consideration of multi-scalar aspects of interactions is also anticipated as a challenge.

Procedure: These linkages around empirical data within domains are led by domain leaders, who structure the research interactions through regular methodologically-focussed meetings, and feed this back to the task force on theme A (tools and procedures). There are also very clear linkages with different deliverables with an integrative inclination in the second half of the project (e.g. D1.3, D2.3, D3.3).

The structure of integrative work ahead is defined for each domain in relation to empirical findings and priorities, as foreseen by domain leaders.

Table 4: Relationship between domains and empirical research in work packages

	WP1 (models)	WP2 (cases)	WP3 (cases)	Linkages
Electricity	PowerACE IMAGE LEAP WITCH	DE: 8 niches & regime UK: 6 niches & regime	DE UK	Concepts Methods and data Analytical output Policy advice
Heat/buildings	IMAGE LEAP WITCH	SE: 6 niches & regime DE: 6 niches & regime UK: 6 niches & regime	SE DE PT	Concepts Methods and data Analytical output Policy advice
Mobility	MATISSE IMAGE WITCH	UK: 8 niches & regime NL: 6 niches & regime	UK SE NL	Concepts Methods and data Analytical output Policy advice
Agri-food	IMAGE PowerACE	NL: 8 niches & regime PT: 6 niches & regime HU: 4 niches & regime	UK DE	Concepts Methods and data Analytical output Policy advice
Land use & biodiversity	IMAGE	PT: 7 niches & regime NL: 6 niches & regime	PT NL	Concepts Methods and data Analytical output Policy advice

3.4 Agreeing common parameters, metrics, indicators and data

There is a dual nature to metrics and indicators within the project, as they provide 1) a means for operationally linking model-based approaches with more case-driven approaches (socio-technical analysis and initiative-based learning) on an operational level (see Figure 7), and 2) a means for the evaluation of the phenomenon at hand (see Figure 9).

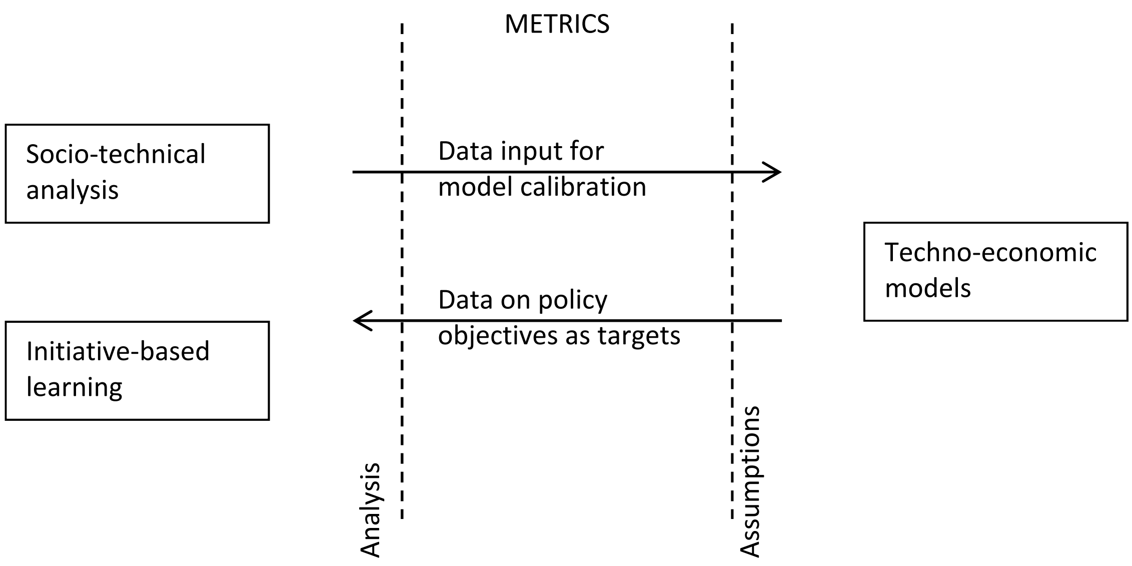

Figure 7: Metrics as enabling linkages between approaches on an operational level

3.4.1 Common metrics as tool to support greater operational linkages

Achieving greater consistency in the metrics mobilised in and across approaches is crucial to developing an integrated stream of analysis for the evaluation of transition pathways. As far as possible, core dimensions of the phenomenon at hand and qualitative concepts are to be translated into quantitative metrics or estimations.

While the integration objective drives us to seek common metrics, we also recognise that each approach may have developed its own metrics aligned with their analytical frameworks. For instance, inertia and momentum are currently considered and operationalised differently within each approach. In a first step towards greater integration, it is important to confront existing metrics and seek active linkages. A further step towards integration consists in the development of common metrics and data flows enabling joint analysis as far as is possible.

Figure 8 provides an illustration of how data flows and joint analysis can be structured in model-led integration strategies in the energy domain. Here, a first step consists in improving model parameters with input from socio-technical case studies and analysis (niche analysis from D2.1 and regime analysis from D2.2). A second step consists in linking data between different existing models (here, IMAGE/WITCH and PowerACE). A third step consists in generating 'more complete' model outputs as scenarios and pathways. A fourth step consists in qualitatively evaluating such modelling output from the perspective of socio-technical analysis and initiative-based learning, as a form of 'feasibility check'. Such a process should be considered as iterative, with multiple opportunities for the cycling of data.

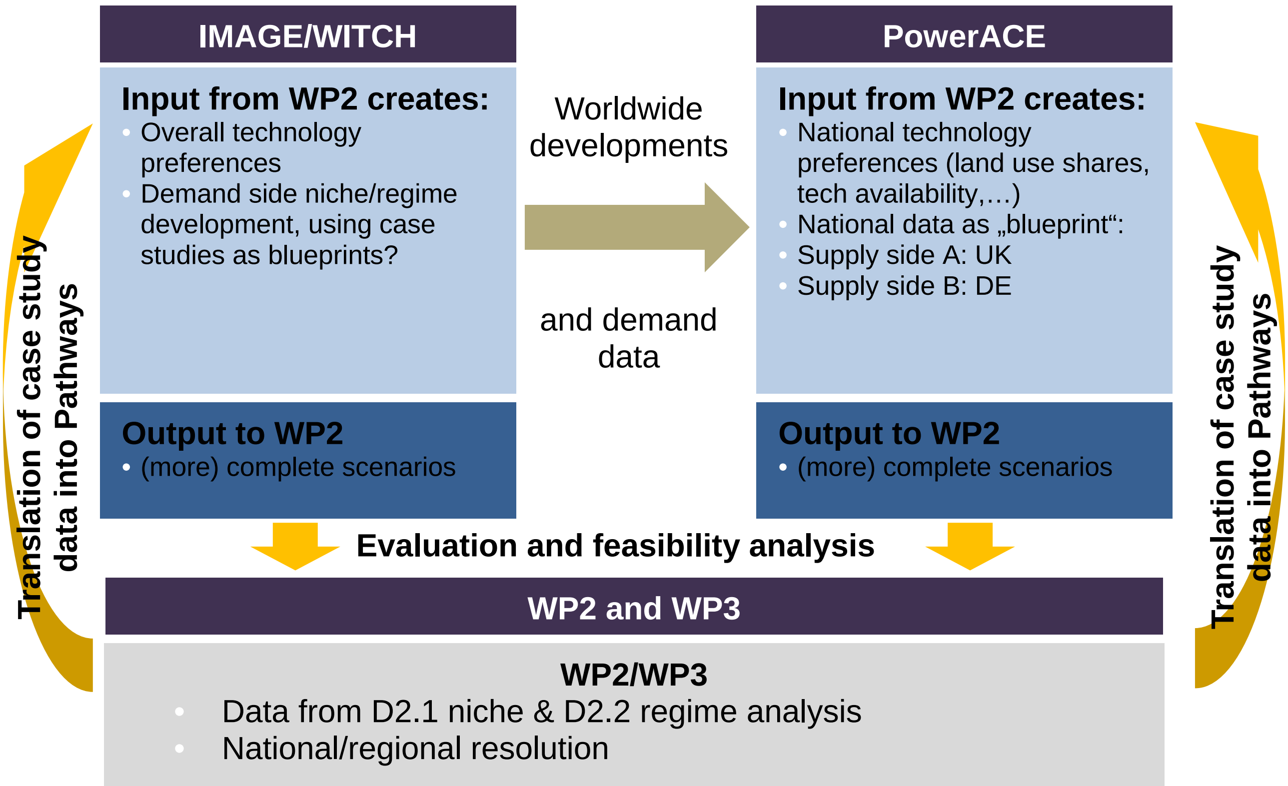

Figure 8: illustration of data flows in model-led integration strategies in the energy domain

<u>**Procedure**</u>: Linkages around data and metrics are the object of trial-and-error processes in each empirical domain, which are tasked with overseeing cross-approach empirical sense-making. Individual work plans set out by domain leaders structure the integrative work ahead in each empirical domain.

Data linkages are further specified in specific tasks leading to deliverables in each WP:

- D3.3 provides an understanding of the kind of insight and qualitative data emerging from WP3 initiative-based learning case studies, and a discussion of their relevance to socio-technical transitions analysis in WP2.
- D3.4 is specifically concerned with data linkages as it promises the operationalisation of variables about niches-innovations for modelling analysis in WP1
- D2.3 envisions an integrated analysis of niche developments (D2.1) and regime dynamics (D2.2) in each empirical domain, with a view at assessing the feasibility of transitions pathways developed in WP1. While it may not generate directly data that can be directly mobilised, it will provide a way to qualitatively modulate the more quantitative data generated in WP1.
- Within WP1, working documents will contribute to examining assumptions across models, and discussing opportunities for the operationalisation of notions related to transitions pathways, discussed in D1.2.
- D1.3 provides an opportunity to take up data and insight generated in WP2 and WP3 leading to an improved set of scenarios for the different empirical domains

3.4.2 Indicators for the evaluation of transition in the making

Data-led integration strategies, while leading to fruitful refinements and mutual enhancement of approaches in practice, are also limited as not all data and information is commensurate, and approaches offer fundamentally different kinds of explanation. Consequently, a major aspect of integrated analysis relates to how different types of explanations can be combined and mobilised as different lenses to inform a common problem. The challenge with developing an integrated chain of analysis is to develop operational linkages around different types of explanation. We suggest bridging both via the research process (facilitating collaborative interaction around analytical tools, empirical data, etc.) and the outcomes and fresh outlook that a joint approach can deliver (integrated assessment) to a variety of decision-making publics. The extent to which such an integrated approach is feasible also hinges upon the balance that can be struck between achieving a sufficient degree of common understanding, and respecting approach-specific constraints, assumptions and analytical dimensions.

We seek to reap the benefits of complementarities between approaches and methods to achieve richer and more multi-dimensional evaluations of the phenomenon and related governance objectives, as illustrated in Figure 9. While metrics concerns data flows and operational linkages, indicators are about the *evaluation* of sustainability transition pathways. Indicators are primarily aimed at engagement with real-world processes, such as support to policy action.

Our central evaluation device is a typology of ideal sustainability transition pathways, against which we can make sense of real transition processes. For these transition pathways to become effective means of evaluation, we need to develop clear and reliable indicators that take different layers of explanation into account when observing real world transition and seeking out patterns.

These indicators of sustainability transitions in the making should inform us about the essential phenomenological attributes of transitions pathways:

- *goal-setting* (orientation towards collective normative objectives),
- *momentum* (relative to inertia and incremental change in existing regimes),
- *depth* (degree of radicality of systems change) and
- *scope* (number of dimensions that change in socio-technical systems).

These shared concepts can be seen as vehicles for bridging they are interpretively flexible enough to allow for the mobilisation of the different kinds of information offered by each approach, yet specific enough to enable systematic analysis and cumulative knowledge development. On a more practical level, they enable to capture the rich diversity of sustainability transitions in the making, and to selectively evaluate opportunities or define priorities to *support*, *shape* and *modulate* the dynamics of transitions.

Furthermore, developing indicators of transitions pathways on the basis of these notions promises insight about:

- the current state and direction of transition dynamics [where are we, where are we heading?]
- policy objectives and system performance
- the desired transition trajectory (scope, depth, urgency) [what do we aim for?]
- the required changes and their feasibility [how can we feasibly get there?]
- possible branching points and expectable/desirable regime dynamics change, including markers for
    - acceleration / regime shifts
    - the combination of momentum and destabilisation
    - shifts from one pathway to another

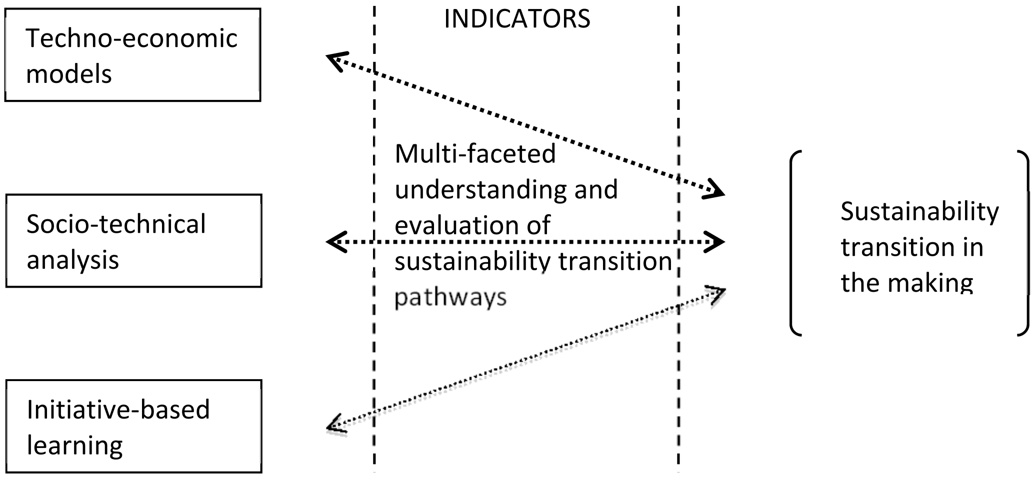

Figure 9: Indicators for the evaluation of transitions in the making – a triangulation process

Procedure: A number of deliverables are tasked with the evaluation of sustainability transitions pathways towards the end of the project, mobilising common understandings and objectives. These include:

- D1.4, which specifically evaluates the outcomes of modelling analysis (iteratively enriched via multiple integrative 'transactions' and opportunities) and their implication for European and national roadmaps and strategies
- D2.4 and D2.5, which further the evaluation of transitions pathways from a socio-technical analytical perspective. Specifically, D2.4 provides a comparative analysis of transitions pathways in different countries, and D2.5 bridges with future-oriented modelling by developing a forward-looking evaluation of transitions pathways

In these deliverables, a WP-specific interpretation of the evaluative objectives (goal-setting, momentum, depth and scope) is put forward. These findings are brought together and compared in D4.4 in a multi-faceted evaluation of sustainability transitions pathways.

3.5 Timing of linking procedures

Interactions between the approaches are not continuous, so that there is a need for agreement on the timing or periodicity of linking procedures. Inputs from one research stream to another are organised in time. Figure 10 represents the integrative research process as structured by the periodic interaction of semi-autonomous research streams within 'integration windows'. In practice, these windows materialise 1) through partner workshops and stakeholder workshops around specific questions, 2) around research sub-problems in task forces (see section 1.3), 3) via empirical material in domains groups (electricity, heat, mobility, biodiversity, land use), and 4) around specific deliverables.

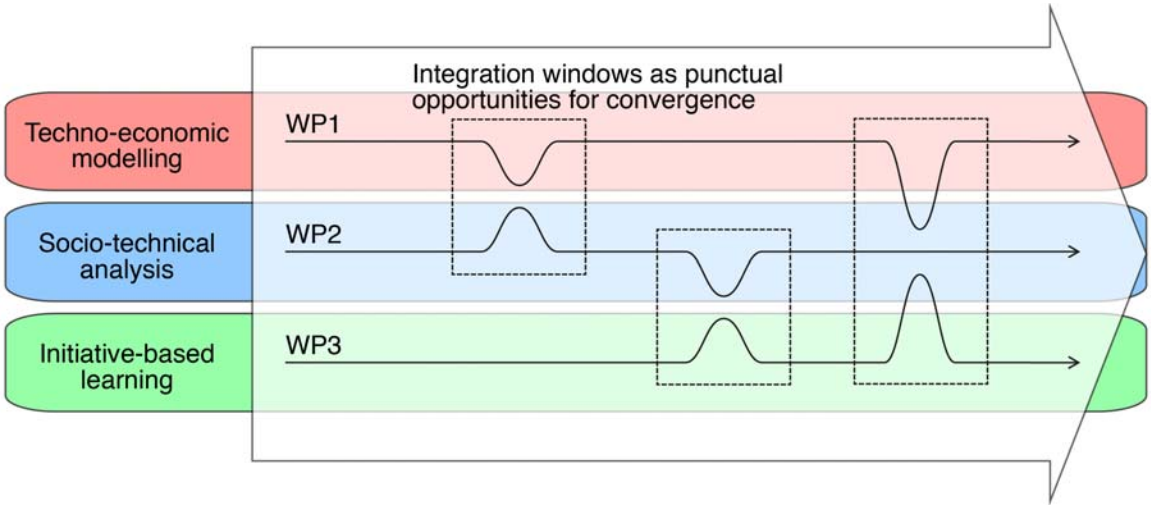

Figure 10: A schematic representation of the research process as punctuated by windows for convergence

Linking procedures consist of analytical templates, datasheets, and project outcomes (e.g. deliverables) seen as the operational *interface* to enable operational linkages, and so support a collaborative and integrative research process.

Meetings and workshops. In practice the different working groups (thematic taskforces, domain groups, and WP groups) establish their own work plan and meetings, in line with project and integration objectives. Coordination at project level is ensured by regular meeting opportunities.

Taskforces. Integration activities in WP4 are structured around 3 main taskforces, each dealing with specific aspects of integration: 1) tools and procedures, 2) visualisation and representation, and 3) governance and policy. These integrative task forces make up the 'enabling architecture' that guide the search for integration opportunities. The task forces have their own work programme based on a *contrast, compare, combine* approach. Progress is regularly fed back to and from other project activities, through workshops, and planned activity reports (T4.1, T4.2, T4.3).

Empirical integration. Empirical progress in the project is structured around 5 domains, which each approach tackles in their own way and at their own analytical level (see
Table 4). Nonetheless, for each domain, empirical progress across work packages can complement each other in the collection and generation of data. For instance, the niche innovation cases studied in T2.1 provide input for the further development of scenarios in T1.3, in turn providing further input for pathway evaluations in T2.4. Data sharing is organised by domain leaders, allowing each domain to progress according to its own empirical priorities and research opportunities.
Planned deliverables. A number of project deliverables are specifically relevant to integration, and have been mentioned above where relevant.

Table 5 provides an overview.

Table 5: Project deliverables directly relevant to integration

Ref	Deadline	Description
D4.1	M18	Draft report on tools and procedures for linking approaches
D4.3	M18	Report reviewing the literature on policy and governance of sustainability transitions
D3.3	M18	Comprehension of case studies for MLP transition analysis in WP2
D4.2	M22	Report on representing and visualising transition pathways
D2.3	M22	Integrated analysis of D2.1 and D2.2 to assess feasibility of transition pathways
D2.4	M28	Comparison of transition pathways in different countries
D3.4	M29	Operationalisation of variables on niche-innovations, lifestyles and behavior for WP1
D1.2	M32	Report on institutional and actor representation in IAM
D2.5	M32	Forward-looking analysis of transition pathways
D1.3	M32	Improved set of scenarios based on interaction with WP2, WP3
D1.4	M34	Evaluations of project outcomes for European and national roadmaps
D4.4	M34	Report on comparative analysis of transition pathways, dynamics and governance

4 Conclusion: towards an interdisciplinary chain of analysis for the evaluation of sustainability transition pathways?

In this document, we have outlined some general principles about integration across three approaches, each offering a different lens for the analysis of sustainability transitions pathways. We have provided a frame for integration, as well as set up some procedural elements for collaborative research in this direction. We here provide some elements of a conclusion with by providing an outlook on the evaluation of transitions pathways via the establishment of such an interdisciplinary chain of analysis, hence setting the way forward for integrative analysis in the PATHWAYS project.

By integration what is here meant is a research strategy of aligning, bridging between largely separate analytical approaches, and iterations of such interactions. Integration is a procedure based on shared concepts, information and targets.

The first aligning step is to adopt a broadly shared problem formulation and framing that can act as channels for dialogue between the three approaches for evaluating sustainability transitions pathways. The basic set-up rests on a shared framing around transitions pathways to achieve normative goals, the construction of pathways and agreement on basic analytical concepts that can be handled by each of the different approaches (different time horizons, analytical constructs and representations), and a broad view of how different representations of transitions can be made to converse.

Evaluating transition efforts requires agreement about the specific normative objectives to be met. For a given empirical domain the aim of the assessment will be to characterise goal-setting, momentum, depth and scope of systems changes leading to a transition, e.g. what is meant by the momentum of a sustainability transition? How can it be measured and evaluated?

A second bridging step is to orient analysis towards specific governance problems, explicitly mobilising different *kinds* of information in the assessment of transition strategies, to specify the empirical domains of the analysis to be carried out (setting clear boundaries, scales and temporalities), to establish the common metrics and data that will be transferred (and enable the consolidation of operational linkages) between analytical approaches, and to specify the type of assessment sought. A generalised schematic of transfers between approaches in an interlinked chain of analysis is given in Figure 11, which represents how neighbouring perspective can be actively mobilised via bridging procedures.

For a given empirical domain (electricity, heat, mobility, etc.) and context, approaches can be oriented towards a joint evaluation of current trajectories towards specified objectives (e.g. emissions reductions targets, biodiversity targets). Quantitative systems modelling can help translate objectives in terms of techno-economic requirements, i.e. preliminary future scenarios balancing a set of options over time. Socio-technical analysis, with its detailed appraisal of real-world niche momentum, current regime dynamics and interactions, can contribute to initial model parameterisation, but also critically-question the feasibility of transitions scenarios. Modelled pathways can also be strengthened through the development of rich narrative storylines. Initiative-based learning from local sustainability projects can benefit from being framed in the context of niche-regime relationships, and according to their contribution to policy targets. Real-world experiments can be seen as 'pre-figurations' of alternative socio-technical-ecological systems, drawing attention to the kinds of struggles encountered on the ground, and so deliver crucial lessons for the feasibility of different options for future-oriented scenarios.

Compounded, such steps result in a consolidated form of transition assessment, bridging between approaches via shared flows of information and bringing multiple dimensions into perspective. At each step, dialogue and information exchange proceeds via the shared concepts of *goal-setting*, *momentum*, *depth* and *scope* of transitions pathways. Concrete outcomes include realistic prospective scenarios to meet policy objectives, detailed supportive narrative storylines, and enriched evaluative capacity in relation to current transition efforts.

By bridging between approaches to transitions pathways it is possible to achieve a more multi-dimensional evaluation of transitions as they unfold, informing governance decisions and practices. Past and current transitions can be assessed by analysing recurring patterns and measurable variations. Future projections can be used to explore different alternative trajectories and their potential implications. Sustainability transitions pathways can be further operationalised so as to enable collaborative research, maximising the transferability of concepts and empirical evidence across approaches.

Specifically, an integrated evaluation of sustainability transitions should compose with the respective strengths of quantitative systems modelling, socio-technical analysis and initiative-based learning:

1) an ability for developing future projections/scenarios: explicit goals based on policy intentions and targets, and an assessment of how we can get from the present to these objectives,

informed by,

2) (focussed) in-depth analysis: an understanding of the recent past and present (the degree of inertia of regime trends, possible alternatives), an understanding of where are we currently heading (niche momentum, regime transformation, etc.),

including

3) (generalizable) lessons about the scaling of experimentation: an understanding of what is happening on the ground, emerging trends-in-the-making, the determinants of successful implementation and scaling up, etc.

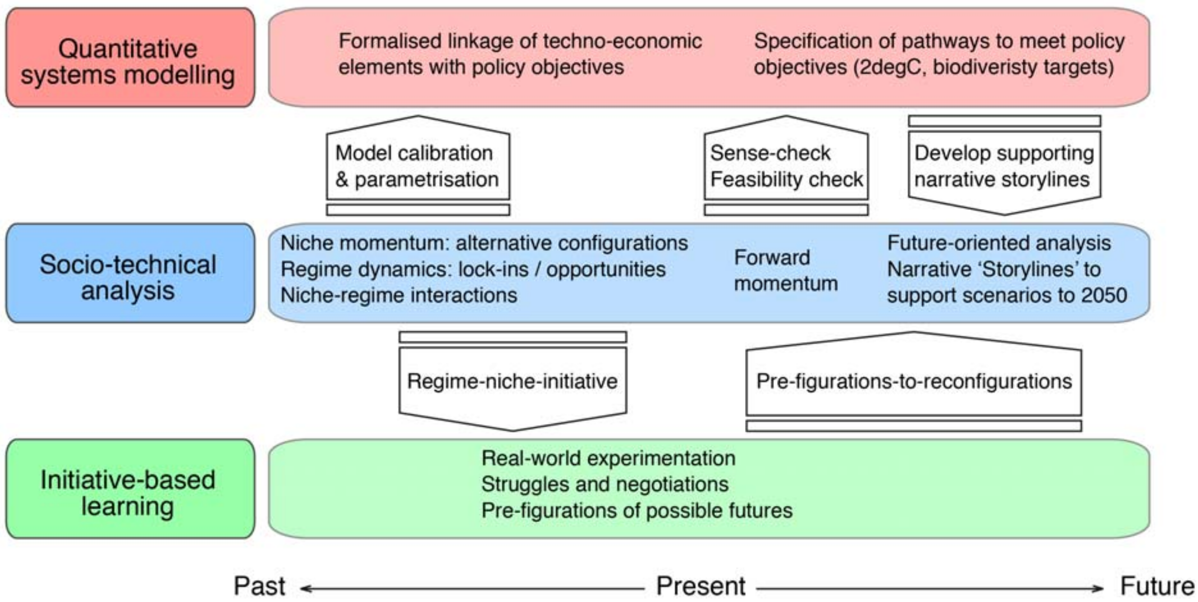

Figure 11: Schematic representation of steps in an interlinked chain of analysis of future-oriented transitions pathways

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Annex A: Definitions and pathways characterisations – current progress

A note on definitions and pathways

The purpose of this note is to provide some background on definitions and pathways within the PATHWAYS project, as a follow up on discussions within WP4 and the Manchester workshop (July 2014).

In the context of our three approaches, a simple conceptualisation of transition pathways based on a limited number of ideal types should allow to:

- focus modelling efforts through the formulation of alternative scenarios to achieve sustainability objectives, and investigate the implications of different pathways and the feasibility of their assumed requirements;
- generate a simple analytical selection grid for the identification of patterns and deviations in real-world cases, and guide the further investigation the determinants of critical branching points;
- evaluate the ambition of local projects in the frame of wider transition trajectories, and investigate the kinds of strategic options available to actors within the dynamic contexts offered by transition pathways seen as alternative future options.

A.1 Definitions of transitions pathways

Defining and characterising transition pathways is crucial for the advancement of the project. They provide a common ground for each WP, but also an opportunity to iteratively explore and revise possible divergence.

We define **transition pathways** as "patterns of changes in socio-technical systems unfolding over time that lead to new ways of achieving specific societal functions."
In addition, we recognise that:

- Transition pathways involve varying degrees of reconfiguration across technologies, supporting infrastructures, business models and systems of provision, as well as the preferences and behaviour of consumers
- Transition pathways are motivated and harnessed specifically for the end-purpose of reducing negative environmental impacts in the case of *sustainability* transitions;
- Transition pathways imply substantial (and rapid) departures from the current trajectories
- Different research communities and approaches tend to emphasise different elements of what may change in transition pathways. Such an understanding of transition pathways is compatible with and enables 1) scenario-based simplification typical of formal modeling, 2) co-evolutionary representations of long-term change, and 3) attention to the groundwork of strategic agents of change.
- It is relevant and useful to characterise idealised forms of pathways to understand and analyse different modalities of change.

A.2 Towards a typology of transition pathways

We first formulate the defining elements of transition pathways and spell out different ideal types. We then further specific some essential characteristics of transitions that may be mobilised as analytical tools and metrics to trace and monitor transitions in the making.

We build on Geels and Schot (2007), according to whom transition pathways differ according to three defining elements: 1) the kinds of actors involved (relative to the established regime), 2) the depth of change (degree of radicality relative to initial system), and 3) the scope of change (number of socio-technical dimensions involved).

Based on these defining elements, we identify two fundamentally different pathways (A and B), which can be seen as two highly different routes for the realisation of similar outcomes: the re-configuration of existing socio-technical configurations to achieve ambitious performance objectives:[1]

- **Pathway A** (technical component substitution) assumes that sustainability objectives can be achieved by an adjustment of the existing regime or adoption of radical innovations, but without a full reordering of the existing societal structures. While the technical components of the socio-technical regime change in this pathway, many other elements (e.g. user practices, lifestyles, governance arrangements) remain close to the existing regime. This pathway tends to be advocated and enacted by incumbent actors.
- **Pathway B** (broader regime transformation) leads to a shift to a new socio-technical system, based on the breakthrough of radical niche-innovations that entails not only technical changes, but also wider behavioural and cultural changes, new user practices, institutions. Incumbent industry actors may be overthrown by new entrants, or enter into new alliances with them. There is also a greater role for social movements, civil society actors, and multi-level governance (with new relations between cities and local administrations, national governments and transnational policy-makers).

In order to put these ambitious transformations in perspective, we also suggest a baseline pathway,[2] which represents the consequences of not engaging seriously with sustainability transitions, or failing to do this on time (too little, too late):

- **Pathway 0** (established trajectory) entails missing to achieve sustainability objectives by failing to divert from the established trajectory. Radical innovations fail to break through because the regime is dynamically stable. There is no radical change of existing socio-technical elements and no substantial shift away from undesirable regime performance, despite pressure on various dimensions (e.g. market stagnation, user dissatisfaction, ambitious policy discourse, etc.), and incremental efforts to address performance issues (new product development, policies, etc.). This pathway is mainly enacted by incumbent actors whose actions reinforce regime rules.

Table 6 provides an overview of the main transition pathways based on defining elements.

Pathways 0, A and B described above are ideal types that can be mobilised as heuristics to make sense of transition efforts: they are abstract constructions that accentuate features of the phenomenon under study so as to enable analytical comparison of alternatives. In practice, a multitude of alternative pathways may be analysed, based on variations across the defining elements of change.

Pathways A and B in theory both allow meeting ambitious long-term system performance objectives (e.g. the stabilisation of average global warming to 2°C by 2100, or 80% emission reductions by 2050 on 1990 levels). There is no *a priori* preference between pathways A and B. However, inherent in the PATHWAYS approach is an understanding that a given trajectory may be more suited to a particular context, given the history and momentum of the domain (see section 0). It is also possible to envision transition trajectories to unfold initially according to a Pathway A kind of development, and later on to lean more towards a Pathway B development as different actors get involved, different strategies are played out and the systemic nature of change becomes more multidimensional.

Such a formulation of transition pathways also provides a focussed problem and research context for contrasting research outputs and complementing research processes so as to generate a richer understanding of sustainability transition and strategies for shaping them.

[1] E.g. *sustainability* objectives.

[2] Pathway 0 does not represent a transition per se, as it does not involve a substantial departure form initial system performance in terms of key physical indicators. Any transition has a beginning, a middle, and an end.

Table 6: Ideal pathways and their defining elements

	Pathway 0	**Pathway A**	**Pathway B**
Departure from existing system performance	Minor (no transition)	Substantial	Substantial
Lead actors	Incumbents (established industry and policy actors)	Incumbents (established industry and policy actors)	New entrants, civil society, etc.
Depth of change	Incremental change	Substitution change (radically new components are incorporated as adjustments to existing system architectures)	Radical transformative change (fundamentally new ways of doing, new system architectures)
Scope of change	Dynamic stability across multiple dimensions	1-2 dimensions: technical **component** and/or market change, with socio-cultural and practice elements unchanged	Multi-dimensional change (technical **base**, markets, organisational, policy, social, cultural, consumer preferences, user practices)

Open issues:

What is the relationship between scope and depth? Are they fully independent? The current formulation of Pathways A and B seems to assume a linear relationship between scope and depth. Are we, for instance, missing a low-depth/high-scope and high-depth/low-scope pathway formulation?

How can these pathway descriptions become more dynamic so as to include sequences of change and their timing?

What about shifts from one Pathway to another?

A.3 Further specifying characteristics of pathways in the making

Further to the identification of ideal transition pathways via their defining elements, it is possible to specify a number of analytical transition characteristics, outcomes, and metrics based on the three approaches.

Ideally, we should be able to generate a comprehensive set of metrics, indicators and analytical dimensions that allows us to **trace and monitor transitions in the making**, and to provide clear linkages with the defining elements of transition pathways.

A.3.1 Interacting elements of change (layers of explanation)

The literature on socio-technical transitions identifies different interacting elements of change as different layers of explanation for long-term change:

- Actor strategies
- Innovation (including technology, market, behaviour, etc.)
- Institutional change (rules)

Typically, socio-technical transition analyses will consider long-term change along these three main layers of explanation. These layers of explanation are fundamentally interrelated: institutional change (/stability) is enabled by (/constrains) the groundwork of actors; innovation is the product of strategic activity but also generates strategic responses by actors; etc. These 'layers' are interrelated and interdependent, but can also handily be considered separately for the purposes of analysis.

The groundwork of **actors and their strategies** can be described and traced over time. Different transition types will involve different sets of actors (e.g. entrepreneurs, policymakers, civil society, consumers, etc.) and their positioning in relation to the established regime (e.g. incumbents, new entrants). It is useful to refer to stylised characterisations of actor strategies (e.g. defensive-reactive-proactive, etc.) for the purpose of documenting change over time.

Some aspects of **innovation** can be easily quantified (adoption rates, learning curves, infrastructure vintage and rollout, cost/performance profiles, etc.), while other aspects (direction of change, compatibility with existing systems, acceptability and legitimacy, momentum, etc.) may require more narrative styles for an accurate tracing over time.

Institutional change (such as e.g. the formation and stabilisation of new values) is difficult to measure quantitatively. To take account of changing institutions (regulatory, socio-cognitive and normative) over time, it is useful to rely on discourse analysis and/or selected interviews in specific professional communities related to the domain in questions. Change in regulatory institutions (e.g. new policies) can more easily be measured over time as discrete events.

Table 7 illustrates different interacting elements as they may be played out in different transition pathways.

Table 7: Interacting elements in transition pathways

	Pathway 0	Pathway A	Pathway B
Actors positioning and strategies	Defensive incumbents downplay problems (deny and lobby against change). New entrants do not introduce major changes to the status quo	Reactive incumbents (seek for compatible solutions) Collaborative/co-opted new entrants (tailor novelty to existing systems)	Challenged/struggling incumbents New entrants coalesce around alternative socio-technical visions and aspirations
Innovation	Projection of current innovation rate within the existing regime	Novelty is incorporated in existing system (add-on, end-of-pipe, etc.)	Multiple innovative elements (devices, infrastructures, business models, systems, etc.) interact to generate new socio-technical assemblages
Institutional change	Institutional stability	Minor institutional adjustments on regulations and normative interpretations. Cognitive aspects unchanged	Major changes across all institutional forms (new ways of thinking, doing, and warranting)

Open issues:

How can these be considered/operationalised across the three approaches (in terms of metrics, variables or subsystems, input parameters, etc.)?

How can data be systematically collected so that the empirical work within each approach can permit research crossovers?

A.3.2 Momentum and inertia

In Manchester, it was suggested that inertia and momentum should be considered more centrally as features of transition pathways that can be analysed over time. These measures of speed and directionality (of regime and niches, respectively) are crucial to monitoring transitions, and ultimately to identify critical branching points.

Niche momentum (temporality and acceleration, but also directionality and flexibility). It is crucial to develop an ability to estimate the momentum of niche-innovations, and its ability to 'make it' in relation to the existing regime – whether in a more synergetic relationship as in Pathway A component substitution, or in a more competitive relationship as in Pathway B reconfiguration. 'Typical' (S-curve-like) innovation development trajectories are qualified by changing momentum in terms of market penetration, learning rates and costs (e.g. initially sluggish, acceleration and take-off, stabilisation), but also in terms of framing and directionality (e.g. initial diversity of invention, increasing focus around dominant design, path creation attracting specialisation of components around successful design, etc.). In practice, however, developmental trajectories can be much less linear, with ups-and-downs, hypes and disappointments, detours and dead-ends, etc., as WP2 and WP3 will document.

Regime inertia and path dependence. It is important to develop an understanding of how stable and resistant to change current regimes are, as this will ultimately affect the ability of novelty to break through (displacing or complementing the regime) and the qualitative attributes of such a process.

There is a practical value in analytically distinguishing regime and niche dynamics, as it allows the generation of rich data across approaches. Inertia and momentum are currently considered and operationalised differently within each approach, as roughly sketched out in Table 8 below.

Table 8: Operationalisations of momentum and inertia across approaches

	Niche momentum	Regime inertia
WP1	Market availability: Cost profiles of technological options (as input parameters) Technological diffusion scenarios (as modelling outcome)	Capital stock renewal: historic investments (infrastructure, equipment) as barrier/opportunity for change ? explanation for real-world under-achievement?
WP2	Developmental process 3 dimensions of evaluation (techno-economic, socio-cognitive, politico-institutional)	Resistance to change / lock-in 3 dimensions of evaluation (techno-economic, socio-cognitive, politico-institutional) Powerful actors
WP3	Replication of initiatives generating momentum towards 'global niche' Success criteria of initiative How to measure?	Background motivation for the emergence of alternatives Barrier to initiative implementation 'Local feel' for regime contestation?

When analysing sustainability transitions with reference to a PATHWAYS typology, we might be able to observe distinguishable characteristics in terms of niche momentum and regime inertia. Table 9 suggests how niche momentum and regime inertia might be played out in different transition pathways.

Table 9: niche momentum and regime inertia in transition pathways

	Pathway 0	Pathway A	Pathway B
Niche momentum	Low momentum	High momentum of mainly technological niche innovations. Niche development follows a more add-on development pattern, with some interaction with existing regime.	High momentum of niches as emerging socio-technical configurations, including new institutional and behavioral components Niche development more likely to follow an accumulation pattern, gaining momentum in isolation from regime.
Regime inertia	Stable regime	Stable regime with punctual/localised regime deficiencies.	Highly contested regime.

Open issues:

How well do regime inertia and niche momentum allow capturing different transition patterns?

How can these be considered/operationalised across the three approaches (in terms of metrics, variables or subsystems, input parameters, etc.)?

How can data be systematically collected so that the empirical work within each approach can permit research crossovers?

How can we exploit existing data sets (e.g. UN indicators - emissions per year, Gini indices of social disparity, economic growth, etc.)

How can we link these system performance metrics to indicators of the phenomenon at hand (inertia, niche acceleration/momentum, etc.)?

How can we make the above less linear?

A.4 Work ahead

On-going	Refine pathway characterisations in light of project findings
On-going	Further specify intermediate notions (momentum, change, etc.)
On-going	Further specify the tools for pathway evaluation
On-going	Translate pathways elements and characteristics into workable metrics & indicators