



## GOVERNANCE OF ENERGY SYSTEM TRANSITION: THEORETICAL FRAMEWORK AND EMPIRICAL ANALYSIS IN EUROPE

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Totti Könnölä<sup>1</sup>, Javier Carrillo-Hermosilla<sup>2</sup> & Torsti Loikkanen<sup>3</sup>

### Abstract

This paper addresses system transition as a valuable perspective and develops and applies a framework for analysing energy system research and governance. This paper is based on an extensive literature review, expert consultations and empirically based-theory building. The developed framework is applied in the analysis of a selected case study of the European hydrogen energy system governance. The main result of the paper is that different governance and funding models with their practices and experiences can play an important role in the transition, but even more important may be the combined use of different modes that contribute to the development of the energy system transition. Moreover, the use of such an overarching transition framework supports the coordination efforts between many sometimes even controversial efforts in the development of energy systems.

### Keywords

Energy systems, Energy policy, Governance, Lock-in, Transitions

<sup>1</sup> Institute for Prospective Technological Studies, JRC-European Commission, [totti.konnola@ec.europa.eu](mailto:totti.konnola@ec.europa.eu)

\* The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

<sup>2</sup>IE Business School, [javier.carrillo@ie.edu](mailto:javier.carrillo@ie.edu)

<sup>3</sup>VTT Technical Research Centre of Finland, [torsti.loikkanen@vtt.fi](mailto:torsti.loikkanen@vtt.fi)

## 1. Introduction

Energy challenges require changes beyond *incremental and continuity type of<sup>1</sup>* performance improvements of present practices. They call for *transitions towards radically different systems*, major technology shifts in energy sector, towards the rapid diversification of energy production and efficiency in energy use addressed also in the recent Strategic Energy Technology Plan for Europe. Taking advantage of the need for renewal of the existing energy system at large requires, though, an insight into the process of how large socio-technological systems emerge and evolve. This knowledge can then be used to gain insight into how a transition towards a sustainable energy system can be best facilitated; how opportunities for developing new systems and profiting from new innovations<sup>2</sup> can be achieved.

System transitions are complex societal co-evolutionary processes that are typically led by gradual adaptation rather than visionary management or coordination. Still, visionary coordination of policies, regulation, corporate strategies and social learning may overcome some barriers and foster new innovation efforts providing sufficient impetus towards system transition. This paper addresses system transition as a valuable perspective and develops and applies a framework for analysing energy system research and governance. Thus, the goal is not to suggest the replacement of existing research or governance efforts but rather provide support through the theoretical framework and case studies for their combined use, identify and benefit from potential new synergies and streamline the efforts towards more coordinated common actions in Europe.

This paper considers governance and funding functions and models that are an essential part of the systems transition framework. Hence, within this framework, this report first elaborates in more detail the analysis of different governance and funding models. This paper is based on an extensive literature review, expert consultations and empirically based-theory building. The developed framework is applied in the analysis of the governance of hydrogen-based energy systems initiatives are discussed in order to illustrate how different governance modes and arenas interplay in order to support different phases of a process of system transition.

## 2. Framework for Transition Governance

Transitions towards radically different systems are complex societal co-evolutionary processes that are typically led by a series of gradual and parallel adaptations rather than visionary management or coordination. Indeed, we have elsewhere argued that desired transitions are difficult to initiate and achieve, because the prevailing system acts as a barrier to the creation of a new system (Carrillo-Hermosilla, 2006; Carrillo-Hermosilla and Unruh, 2006;

<sup>1</sup> Könnölä and Unruh (2006) define *continuity* type changes as incremental competence enhancing modifications that preserve existing systems and sustain the existing value networks in which technologies are rooted.

*Discontinuity* type changes, in contrast, are competence destroying, radical changes that seek the replacement of existing components – or entire systems – and the creation of new value networks. Distinguishing between the two can be complicated, however, by the fact that what is discontinuous at one level of analysis may appear continuous at a higher level of analysis (Unruh, 2002). The shift from hard disk drives to flash memory, for example, can be discontinuous for disk drive manufacturers, but continuous for the larger personal computer value network in which memory is an embedded component.

<sup>2</sup> *Innovation* is a systemic change process of (physical) technologies and institutions, which consists of both the elements of the invention of an idea for change and its application and diffusion in practice.

Unruh and Carrillo-Hermosilla, 2006; Könnölä, Unruh and Carrillo-Hermosilla, 2006; Del Río, Carrillo-Hermosilla and Könnölä, T, 2010). Still, visionary coordination of policies, regulation, corporate strategies and social learning may overcome some barriers and foster new innovation efforts providing sufficient impetus towards system transition. Here, it is crucial to link long-term visions with the short and medium term strategies to generate favourable industrial, policy and social conditions leading to common action towards transition.

The recent transition<sup>3</sup> theorising on institutional and technological changes provides a firm premise to understand the challenges related to such systemic change and the corresponding governance responses. Building on Rotmans et al. (2001) and for the purposes of this paper on energy system transitions, we characterise *system transition* as follows:

- i) It deals with a *long term* continuous change process with parallel developments in different phases (e.d. predevelopment, take-off, acceleration and stabilisation) leading to a radically new system.
- ii) It takes into account developments on *different levels* (niche, regime and landscape, e.d. micro, meso and macro levels). On these levels it addresses technological, industrial, political and societal changes.

This section deals with innovative approaches for the governance of system transition. First, different governance approaches are discussed and different functions are identified for the proactive governance of transitions. Later on, the governance functions are related to the general framework of system transitions mentioned above.

## 2.1 Functions of governance

In view of the government engagement in the transitions in a proactive role, five governance functions can be defined:

- information services, networking, setting common agendas
- strategic procurement
- financing research and education
- grants, equity support and fiscal measures (supply and demand)
- regulation and standards.

As Table 1 indicates, the role of government policies plays a major role in these governance functions, and, moreover, many of these functions are already in the agenda of policy-making of the European Union and of the Nordic countries.

Table 1. Contents and objectives of the five governance functions.

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<sup>3</sup> The term ‘transition’ was originally used to describe a non-linear rather chaotic shift process of the phases of substances from solid, to liquid to gas, and later on it has been applied in many fields, including institutional and technological studies.

<b>Governance Functions:</b>	<b>Description</b>	<b>Objective</b>	<b>Examples</b>
<b>Information services, networking, setting common agendas</b>	Cross-disciplinary, sectoral and regional/national networking Coordination of future plans and actions	Building new collaboration and/or breaking up lock-ins Supporting continuity and predictability (lower risks)	Brokerage Networks Strategic action plans -Information and brokerage -Foresight -Science parks, incubators -Social arenas, platforms -Systemic policies
<b>Strategic procurement, (pre-)market</b>	Occurs when the demand for certain technologies, products or services is encouraged in order to stimulate the market	Create demand and develop markets for innovative solutions	R&D procurement Public procurement of innovative goods Financing demonstration projects as pre-market procurement
<b>Financing research and education</b>	Financing research and education	Develop research and education	University funding R&D and demonstration programmes Contract research
<b>Grants, equity support and fiscal measures (supply and demand)</b>	The use of economic instruments to influence on (perceived) risks and opportunities	Influencing preferences (both short and long-term)	Public venture capital Loss underwriting and guarantees Tax incentives, reductions Subsidies Partnerships Reimbursable loans R&D grants, prices
<b>Regulation and standards</b>	Regulation and voluntary industry standards	Predictability of benefits for first movers; extended and shared responsibility; better performance	Regulations Standards

Different phases of the transition (*pre-development, take-off, acceleration, stabilization*, see Table 2) are likely to require different kinds of governance with different objectives, tools and engagement of stakeholders (Lund, 2007). For instance the governance in the predevelopment and take-off phases needs to focus on the collaboration towards the establishment of development platforms and supporting competition between different platforms. Even though many even radical innovations emerge from regimes<sup>4</sup>, it may be relevant that during the incubation phase the governance efforts foster also activities in which regime advocates (e.g. industrial, policy, RTD, etc.) have limited influence in order to ensure the development of competing alternative pathways and the diversity of technological options. The governance in the acceleration phase is likely to put emphasises on the measures to support the improvements in performance of the system and increasing collaboration with the regime advocates. Finally, in the stabilisation phases, the governance should seek the balance between optimization and

<sup>4</sup> “Regime” refers to the established mainstream techno-institutional policy, industrial and user system delivering a specific function in society. Carbon based energy and transport system is an example of regime.

system renewal (creating opportunities for the next wave of transition). Possible governance actions in the various phases are illustrated in Table 2.

Table 2. Governance functions and corresponding actions in the various transition phases.

<b>Functions:</b>	<b>Transition phases:</b>			
	<b>Predevelopment</b>	<b>Take-off</b>	<b>Acceleration</b>	<b>Stabilization</b>
<b>Information services, networking, setting common agendas</b>	Foster competing networks Competing strategies	Consolidation to few networks Consolidation of strategies	Emergence of the dominant network Emergence of the dominant strategies	Opening, diverging the dominant network Divergence of competing strategies
<b>Strategic procurement, (pre-)market</b>	Pre-market R&D support Demonstration projects	Solution-based lead market formation	Solution-based lead market formation	Performance-based procurement
<b>Financing research and education</b>	Pilot infrastructures and training and education for skills, RD&D nodes	Entrepreneurial skills formation		Cost management
<b>Grants, equity support and fiscal measures (supply and demand)</b>	Fostering diversity of viable options (different levels of ambition, engagement according to selected priorities; exchange of information to demonstration) Scientific excellence, quality Awards Credit guarantees Subsidies Vision-based procurement	Supporting convergence among options Priority-setting for quantity, critical mass Awards Credit guarantees Subsidies Solution, technology based procurement Lead market infrastructures, and institutions	Taxes Emission permits Performance based procurement Infrastructural and institutional expansion	Taxes Emission permits Performance based procurement Infrastructure and institution maintenance
<b>Regulation and standards</b>	Alternative enabling standards Regulatory plans Vision based regulation	Dominant standards Regulatory plans Vision based regulation	Dominant standard Regulatory support Top-Runner regulation	Regulating for performance and change

## 2.2 Towards multi-area and multi-mode governance of system transitions

Here we elaborate the role of governance further, taking into account multiple modes and arenas in the governance of system transitions. In the following sections 2.2.1–2.2.2 the governance is typified in four modes of governance (integration, coordination, competition and co-existence) which function on three different arenas (performing, programming and strategic orientation). The consideration of governance modes is completed by selected real-life examples of recent international policy initiatives mostly from energy field (boxes 1–6) in order to illustrate concretely how far and in which ways modes of governance of the systems transition

framework have been taken into account in these initiatives. Section 2.2.3 presents the combination of these modalities of governance, shaping the three arenas, which influence on the different phases of transition process. Section 2.4 first combines the four modes of governance and the three arenas and, by presenting examples of policy initiatives within the framework of arenas and modes of governance, conceptualizes how the actors interact.

### 2.2.1 Modes of Governance

Building on cultural theory (Thompson et al., 1990) of social organisation, we identify four different modes of governance. According to the cultural theory, social organisation can be understood in view of the extent to which an individual is bound in a unit (or social group) and in view of the degree to which an individual's life is determined by external prescriptions (rules and norms). We abstract these basic "forces" to the higher societal level of R&I governance. This allows us to understand more systematically how R&I governance can exercise its influence. Two dimensions can be illustrated as axes that form four approaches<sup>5</sup> to social organisation. Building on Tukker and Butter (2007), from the view point of governance, we define four modes, respectively (Figure 1):

- integration of R&I efforts
- co-ordination of R&I activities
- competition between R&I activities
- co-existence.

With each of the four governance modes described below, we will introduce one real-life example, presented in boxes 1–6.

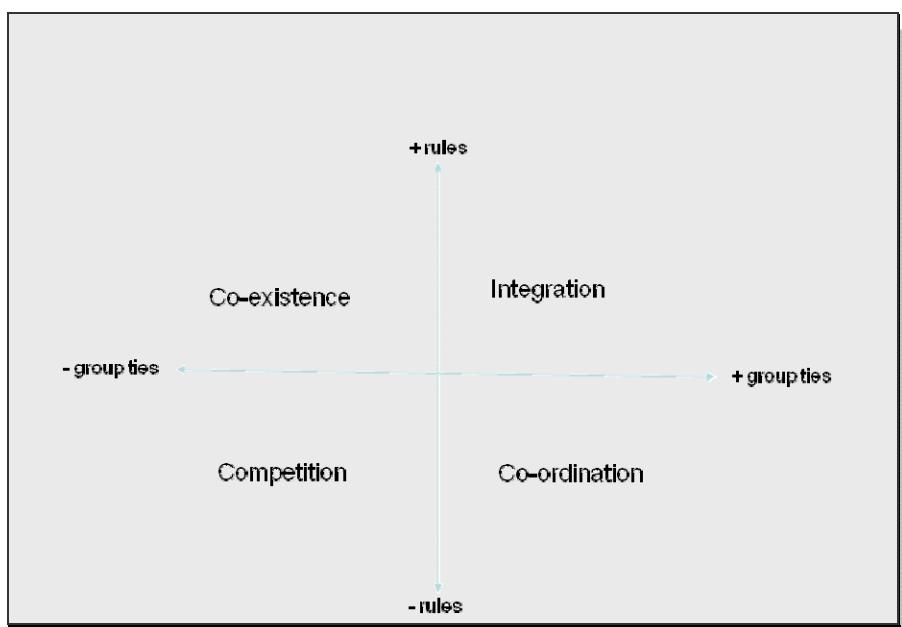


Figure 1. Modes of Governance (modified from Tukker and Butter, 2007).

<sup>5</sup> A fifth possible way of social organisation would be the solitary person who escapes from coercive or manipulative social involvement altogether. However, this is not relevant for our abstraction.

The essentials of each of the four modes of governance summed up in Table 3 and subsequently discussed in more detail.

Table 3. Modes of governance.

<b>Integration mode of governance</b> The proactive use of hierarchical structures with power and means to implement selected R&I activities
<b>Co-ordination mode of governance</b> Coordination of voluntary engagement in coalitions in order to develop common R&I activities
<b>Competition mode of governance</b> Optimising the market conditions for R&I
<b>Co-existence mode of governance</b> Reactive, wait-and-see until new opportunities

## Integration

Integration mode of governance relies on to the hierarchical structures and the use of power and respective means to direct the R&I system. In line with the cultural theory, the existence of strong rules and group ties refer to hierarchies, e.g. asymmetrical transactions that require accountability – hierarchical structures are used to set and execute the plans in order to direct the system. In the innovation policy literature such projects have been referred as “mission oriented” policy measures (e.g. Ergas 1987). For instance, a good example of such a hierarchical top-down approach is the Kennedy’s “Man in the Moon” project, which integrated the considerable resources and efforts to reach an ambitious goal. ITER<sup>6</sup> and Galileo<sup>7</sup> are examples of projects in which the Member States and third parties have set up hierarchical structures that enable sufficient allocation of resources for large-scale R&I activities.

## Co-ordination

Co-ordination mode builds on the egalitarian perspectives in the governance. In line with the cultural theory, strong group ties and low rules, mean that different actors are equally important. Hence, instead of hierarchical relations enforcing action, the changes are achieved through the building of voluntary coalitions of actors with equal status (symmetrical transaction) and the sense of accountability (actors consider themselves accountable to one another). Thus, mutual learning and intensive communication among actors to coordinate required common action is considered as the key element in the co-ordination mode of governance. In particular, the implementation of the Dutch transition management in the national transition platforms seems to follow the principles of the co-ordination mode of R&I governance (we will go in more detail on this case later in this paper).

<sup>6</sup> [http://www.iter.org/a/index\\_nav\\_1.htm](http://www.iter.org/a/index_nav_1.htm)

<sup>7</sup> [http://www.esa.int/esaNA/GGG0H750NDC\\_galileo\\_0.html](http://www.esa.int/esaNA/GGG0H750NDC_galileo_0.html)

In the context of the European Research Area, already in the Fifth Framework Programme (FP5) the Commission implemented a strategic shift from the funding of technological development towards a more comprehensive innovation policy with the emphasis on the open-method of coordination (OMC), which is an inter-governmental mechanism of voluntary cooperation of European policies (Arrowsmith et al., 2004; Kaiser & Prange, 2004; Schäfer, 2006). In the innovation policy field, the OMC has been implemented by introducing new networks, stakeholder forums and policy processes or, more generally, coordination tools which encourage stakeholders to co-ordinate and self-organize the formation of common RD&D agendas (Könnölä et al., forthcoming). Such coordination tools have been promoted, for example, within ‘Integrated Projects’, ‘Networks of Excellence’, ‘ERA-Nets’, ‘European Technology Platforms’ and most recently ‘Technology Initiatives’ – and in the energy sector, for instance, The International Partnership for the Hydrogen Economy<sup>8</sup>.

## Competition

Competition driven governance mode relies on the markets as a principle mechanism for social organisation. According to the cultural theory, low group ties and hierarchical rules mean that actors are offered equal opportunities, which are exploited mainly through symmetrical transactions driven by individual interests. In line with the invisible hand of Adam Smith, such fragmental transactions in the markets form all together the efficient use of resources in the system. Hence, the role of governance is limited in support of the well functioning of the markets rather than directing the markets. For instance, the development of European common markets and tax reductions as R&I incentives can be seen as examples of competition mode of governance of the R&I system. One of the most advanced approaches in this mode is ‘Japanese Top-Runner Program’ in which the “top-runner technologies” regarding energy efficiency becomes the basis of the product standard.<sup>9</sup>

## Co-existence

Co-existence as a governance mode is fundamentally a reactive approach to develop the system. According to the cultural theory low group ties and strong rules mean that despite the existence of rules there is no sense of accountability that would lead to proactive use of hierarchical structures. Still the rules limit the expression of individual interests which might drive to change. Thus, the passive approach may be adopted until the benefits are considered clearly higher than the costs of participation, e.g. free-riding. Co-existence mode of governance can be seen in the European context as a limited efforts in some Member States in the participation in the development of the R&I system both in the national and the European level. Such wait-and-see approaches may be driven partly by uncertainties in the future of the ERIS and partly by the lack of capabilities to take up more proactive modes of governance.

<sup>8</sup> <http://www.iphe.net>

<sup>9</sup> [http://www.eccj.or.jp/top\\_runner/index\\_contents\\_e.html](http://www.eccj.or.jp/top_runner/index_contents_e.html)

### 2.2.2 Combining governance modes

According to Thompson et al. (1990), the cultural theory considers that the different forms of social organisation co-evolve in society: there is a positive feedback system that prevents extinction of any of them. In view of governance of the ERIS, it may be beneficial to develop structures that build not only one of these modes but on the positive feedback loops between the modes. Tukker and Butter (2007) suggest that systemic transition processes require the interplay of different dimensions of social organisation. For instance, transitions may emerge through proactive co-ordination that may lead to changes in competition and integration modes of governance. Alternatively, the governance system may adopt a co-existence mode until the abrupt changes in the environment force governments to take up new measures in other modes of governance – for instance an economic recession leading to uptake of new policy measures to incentivise R&I as a mean to create new economic growth.

In terms of governance of ERIS, the challenge is to combine the different approaches in an effective way in the identified three arenas of strategic orientation, programming and performing. Here, transition processes may start for instance from co-ordination mode (transition management in The Netherlands), and moving towards competition (Kyoto Protocol) or Integration (ITER). Alternatively, transition analysis may start from the co-existence (lock-in) and radical change is made due to external factor (energy prices) and other modes are initiated.

Table 4 presents which functions of governance discussed in Table 1 correspond the various modes of governance.

Table 4. Modes and respective functions of governance.

<b>Modes of Governance</b>	<b>Functions of governance</b>
<b>Integration</b>	Strategic procurement, (pre-)market Financing research and education Regulation and standards
<b>Co-ordination</b>	Information services, networking, setting common agendas
<b>Competition</b>	Grants, equity support and fiscal measures (supply and demand) Regulation and standards
<b>Co-existence</b>	No specific governance functions applied

One recent example of the combination of different governance modes is the Lead Market Initiative<sup>10</sup> combining legislation, public procurement, standardisation labelling and certification, for instance

<sup>10</sup> (LMI) (COM(2007)860)

### 2.2.3 Arenas of governance

Towards the comprehensive understanding of institutional arrangements of governance, it is crucial to examine different arenas in which the governance appear. The typified three arenas build on the conceptual framework presented by Rémi Barré (2007) in the French Future project. The three arenas – or functional spaces – are the following (see also Schoen et al, 2008):

- **the arena of strategic orientation** of research, where visions are set concerning the future of the research system, the overarching objectives, and the level of funding for research and innovation policies
- **the arena of programming of research**, where programmatic and thematic priorities are set and where resources are allocated; in this second arena operate intermediary institutions, which prioritize, fund, regulate and interface R&I with the political processes and the stakeholders
- **the arena of research performance** in which operate the institutions which perform R&D, education and innovation (universities, research organisations, firms).

#### The arena of strategic R&I orientation

Strategic orientation refers to institutionalised mechanisms which are implemented through budgetary planning. For instance, EU and national budget allocations should be considered as key element in this function. Legal framework can be another critical factor for steering research. Regulations concerning environmental or social issues (for instance REACH) can contribute to steer research. Legislative bodies should therefore be considered as belonging to this steering arena. Also industry actors play an important role by selecting the R&I areas in which they decide to invest. The aggregated result of firms' individual strategic choices is essential in shaping the development of research. Finally, organisations of stakeholders (industry associations, or NGO...) which are involved in the production of long term visions and of strategic agendas (for instance within European Technology Platforms) identify desired futures and thus influence policymakers' strategic choices.

#### The arena of R&I programming

At the European level, the arena of R&I programming refers to the mechanisms performed by various European Commission, national ministries and agencies for translating macro-objectives (global amount allocated of resources along key orientations) in practical governance actions. These tasks cover the responsibilities for setting priorities and programming. The funding of research by industry actors plays also a role for programming the production of new knowledge.

#### The arena of research performance

The performance of research refers to the coordination of activities of all public research institutions (research organisations and universities) and of research performing firms.

The key elements of the three arenas characterising their institutional arrangements are summarised in Table 5.

Table 5. Elements characterising institutional arrangements.

<b>Strategic orientation arena:</b>
Nature and importance of institutions coordinating strategic choices
Legal and social drivers steering research strategic choices
Stakeholders forum
<b>Programming arena:</b>
Nature and importance of coordinating transnational institutions (academies and learned societies)
Extent of private funding and market drivers
<b>Performing arena</b>
Transnational research centres
Shared large facilities and infrastructures
Intensity of transnational cooperation (established/raising/weak)

### 2.3 Arenas and modes of governance

Towards the comprehensive understanding of institutional arrangements of governance in specific R&I fields the three arenas of governance provide a relevant starting point for the analysis. To conceptualise how the actors interact on these arenas we define four modes of R&I governance. This supports the characterisation of the institutional arrangements in view of both the level (the arenas) and the form (the modes) of governance (see Table 6 for examples).

Table 6. Examples within the framework of arenas and modes of governance.

	<b>Integration</b>	<b>Co-ordination</b>	<b>Competition</b>	<b>Co-existence</b>
<b>Strategic orientation</b>	FP7 Work Programme Lead Market Initiative (LMI)	Open Method Coordination (OMC) CREST Lead Market Initiative (LMI) International Partnership of Hydrogen Economy (IPHE)	Common markets, National R&I strategies Lead Market Initiative (LMI)	No transition agenda setting
<b>Programming</b>	Art. 169, 171 (ERA-NET Plus, JTI)	Era-NETs, ETPs	National programmes	No transition program setting
<b>Performing</b>	ITER	Partnering for stronger proposals	National project execution	No transition R&D

## 2.4 Arenas and modes of governance and phases of transition

Arenas and modes of governance can be linked with the transition phases to pinpoint the evolutionary perspective in the transition governance. Indeed, the governance of transition requires holistic view, how different modes on different arenas can interact to support transition in its different phases. In D1, we defined the following main transition phases:

- **predevelopment** (incubation) with the diversity of experimentation activities
- **take-off** of the process of transition
- **acceleration** of the change process with the increasing returns of economies of scale that support the diffusion of new solutions and lead to structural change
- **stabilization** with the decreases in the speed of societal change.
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In Figure 2, the governance arenas and governance modes are combined with the phases of transition in order to provide an overall idea of the dimensions to be taken into account in the governance.

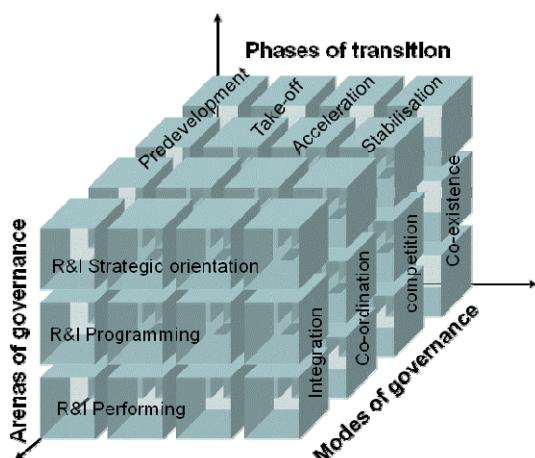


Figure 2. Linkages between the arenas and modes of governance and the phases of transition.

In order to develop action plans for systems transition it is beneficial to adopt agent based view that encourages the identification of key promoters and inhibitors of change. Towards this end, we elaborate and adjust the framework developed in D1 and consider the four dimensions of change also as groups of change agents in the system:

- technological change refers to R&D actors
- industrial change refers to industrial actors
- policy changes refer to policy-makers
- social change refers to third sector (non-governmental organisations, NGOs).

When the dimensions of change and agents are combined with the modes and arenas of governance it is possible to construct a framework to be used in the analysis of the transition governance initiatives and related activities within the system (see Table 7).

Table 7. Framework for the governance of systems transitions.

Strategic orientation	Dimensions of change and agents	Integration	Co-ordination	Competition	Co-existence
	Technological (R&D)				
	Industrial				
	Policy				
	Social (NGOs)				

Programming	Dimensions of change and agents	Integration	Co-ordination	Competition	Co-existence
	Technological (R&D)				
	Industrial				
	Policy				
	Social (NGOs)				

Performance	Dimensions of change and agents	Integration	Co-ordination	Competition	Co-existence
	Technological (R&D)				
	Industrial				
	Policy				
	Social				

### 3. Case Study on the Governance of Hydrogen Initiatives

The aim of section 3 is to illustrate how different governance modes and arenas can interplay in supporting the different phases of transition process. For this purpose Chapter 3 presents an empirical case study that is built on the system transition framework or at least on some key elements characterizing the system transition framework. The study examines the European R&I governance for hydrogen energy systems, its development and deployment. Hydrogen and fuel cell based energy systems is one of the areas in which European governance and research seem to have gradually evolved from co-existence to coordination and integration modes of governance as well as from the development of common strategic orientations towards the common programming and R&I performing.

#### Governance modes and arenas

Even though the co-existence of national research programmes is still reality, there have been major advances in the coordination and integration modes of governance in the European and international level. The International Partnership for the Hydrogen Economy (IPHE, see also

Box 3 of this study) has provided m ultinational and multi stakeholder platform for the coordination of RD&D efforts in the field of hydrogen and fuel cells. The coordination mode of governance has also been strongly supported within the FP5 and FP6 in a number of activities in different sub-areas and geographical regions. For instance in the FP6, some 300 M€ were invested in the area covering fields such as energy systems, surface transport and aeronautics, materials, SMEs, new and emerging science and technology, training actions, and international co-operation. In particular, the HY-CO Era-Net has been a relevant mechanism to coordinate national programmes and launch joint calls. HY-CO has also provided an interface with the European H2/FC Technology Platform (HFP) both in HFP Member States Mirror Group of and interacted with the HFP Advisory Council.

In the national and regional level further advances have also emerged to coordinate activities among different stakeholders and national initiatives, for instance the Scandinavian Hydrogen Hyway Partnership (SHHP) constitutes a transnational networking platform that catalyses and coordinates collaboration between three national networking bodies – HyNor (Norway), Hydrogen Link (Denmark) and Hydrogen Sweden (Sweden). Furthermore, the collaboration consists of regional clusters involving major and small industries, research institutions and local/regional authorities. SHHP coordination activities include the development of joint implementation plan merging the three individual national plans, aiming at a large scale demonstration in Scandinavia as well as the development of standards and certification. Furthermore, SHHP has taken first steps towards integration mode of governance through the joint purchasing of hydrogen vehicles.

In Europe, the major leap towards the integration mode of governance was taken, when May 30, 2008, the EU's Competitiveness Council adopted the regulation on the establishment of the Joint Technology Initiative (hereinafter referred to as "JTI"). It will be implemented through Joint Undertakings within the meaning of Article 171 of the Treaty. The Fuel Cell and Hydrogen Joint Technology Initiative (FCH JTI) was established as a result of the work of European Technology Platforms, already set up under the Sixth Framework Programme covering selected aspects of research in their field. FCH JTI should combine private-sector investment and European public funding, including funding from the Seventh Framework Programme.

In May 2003 a Hydrogen and Fuel Cell High Level Group presented a vision report on "Hydrogen Energy and Fuel Cells – a vision of our future", recommending, inter alia, the formation of a fuel cell and hydrogen technology partnership and a substantially increased RTD budget, as well as a demonstration and pilot programme to extend the technology validation exercises into the market development arena. In December 2003, the Commission facilitated the creation of the HTP, bringing together all interested stakeholders in a joint effort to move towards achieving the High Level Group's vision. In March 2005, the said Technology Platform adopted a Strategic Research Agenda and Deployment Strategy, aimed at accelerating the development and market introduction of fuel cell and hydrogen technologies in the Community.

The technology challenge facing fuel cells and hydrogen is of great complexity and scale and the dispersion of technical competencies is very high. Therefore, in order to achieve critical mass in terms of scale of activity, excellence, and potential for innovation, this challenge needs to be tackled in a focused and coherent way at EU level. This and its potential contribution to the Community policies, in particular energy, environment, transport, sustainable development and economic growth, call for the JTI approach in this sector. The objective of the JTI on "Fuel Cells and Hydrogen" is to implement a programme of RTD activities in the fields of fuel

cells and hydrogen. These should be carried out, building on the EHFC TP, with the cooperation and involvement of stakeholders from industry including small and medium-sized enterprises (hereinafter referred to as “SMEs”), research centres, universities, and regions.

Between 2008 and 2017, the FCH JTI will have a budget of EUR 1 billion. The investment will be shared by its two founding members, the European Commission and the European Fuel Cell and Hydrogen Joint Technology Initiative Industry Grouping, a non-profit organisation uniting the sector's key players (New Energy World IG).

To that end, the FCH Joint Undertaking should be able to organise competitive calls for proposals for projects to implement the RTD activities. Research activities should respect fundamental and ethical principles applicable to the Seventh Framework Programme. Further financing options may be available, inter alia, from the European Investment Bank, in particular through the Risk-Sharing Finance Facility developed jointly with the European Investment Bank.

#### FCH JTI will in particular

- aim at placing Europe at the forefront of fuel cell and hydrogen technologies worldwide and at enabling the market breakthrough of fuel cell and hydrogen technologies, thereby allowing commercial market forces to drive the substantial potential public benefits
- support R&I in the Member States and countries associated with the Seventh Framework Programme (hereinafter referred as “Associated countries”) in a coordinated manner to overcome the market failure and focus on developing market applications and thereby facilitate additional industrial efforts towards a rapid deployment of fuel cells and hydrogen technologies
- support the implementation of the RTD priorities of the JTI on Fuel Cells and Hydrogen, notably by awarding grants following competitive calls for proposals
- aim to encourage increased public and private research investment in fuel cells and hydrogen technologies in the Member States and Associated countries.

It can be summarised that the HY-CO Era -Net together with the HTP offered sufficient coordination mode of governance that have lead to the establishment of FCH JTI, e.d. integration mode of governance. Even though the competitive calls have been chosen as an important instrument to support the excellence of new RD&D efforts in HFC JTI, it seems that competition mode of governance opportunities in terms of the development of market incentives have not been addressed sufficiently, which may become increasingly important when the R&I efforts lead to a wider market application. There seems to be an important challenge ahead how to integrate hydrogen and fuel cell issues for instance in lead market initiatives. Furthermore, despite the efforts in IPHE and some individual FP6 and FP7 research projects, there seems to be a lack of coordination to include a wider set of stakeholders to create a better understanding on civic and societal aspects. Finally, considering the EU27, there seem to be major differences between the governance approaches chosen by different member states. Whereas some member states like Germany, France, Great Britain and Denmark has been highly active in coordination and integration efforts, several countries have rather chosen the mode of co-existence. There difference may also require further attention. Table 8 positions the main European initiatives for development of hydrogen based energy systems in the developed framework for analysis.

Table 8. Main European initiatives for development of hydrogen based energy systems.

Strategic orientation	Dimensions of change and agents	Integration	Co-ordination	Competition	Co-existence
	Technological (R&D)	FCH JTI	IPHE, SHHP		
	Industrial	FCH JTI	HTP, FCH JTI, IPHE, SHHP		
	Policy	FCH JTI	Hy-Co,FCH JTI IPHE, SHHP		
	Social (NGOs)		IPHE		
Programming	Dimensions of change and agents	Integration	Co-ordination	Competition	Co-existence
	Technological (R&D)	FCH JTI	HTP, FCH JTI, IPHE, SHHP		
	Industrial	FCH JTI	HTP, Hy-Co, FCH JTI, IPHE		
	Policy	FCH JTI	Hy-Co,FCH JTI IPHE, SHHP		
	Social (NGOs)		IPHE		
Performance	Dimensions of change and agents	Integration	Co-ordination	Competition	Co-existence
	Technological (R&D)	FCH JTI, SHHP	Hy-Co,FCH JTI, SHHP	Hy-Co,FCH JTI	
	Industrial	FCH JTI, SHHP	Hy-Co,FCH JTI, SHHP	Hy-Co,FCH JTI	
	Policy	FCH JTI	Hy-Co,FCH JTI		
	Social				

### Transition phases and dimensions

Until today the R&I efforts in the area have focused largely on the pre-development and take-off phases and only recently on the issues on the acceleration and stabilisation phases. However, in order to promote the transition to the wider application of fuel cells and hydrogen based energy systems it is crucial to address acceleration and stabilisation issues. Towards this end, it is crucial to address wider techno-institutional conditions present in the energy sector that may lock-out emerging energy solutions such as hydrogen based energy systems. From the viewpoint of the dimensions of systems transition, it can be concluded the following:

- Technological change: Framework programmes and diverse national programmes have supported technology development. Considerable efforts have been made to develop new technologies, but still major obstacles exist for instance in the hydrogen storage and the efficiency of fuel cells.

- Industrial change: There are a has gathered together companies from different sectors, which has materialised in the HTP and further on in the industry engagement in the FCH JTI. The multitude of studies on the role of standardisation and regulation has been made but much need to be done in order to develop favourable market conditions.
- Policy change: In particular, the HY-CO Era-Net has created important basis for the European cooperation among the Member states. This cooperation has also supported the increased engagement of the Commission and finally its key role in the FCH JTI. However, policy support to standardisation and regulatory changes have been limited.
- Social change: The most of the main initiatives in this sector seem to have paid limited attention on the social change dimension. Some FP projects though have specifically addressed the social change aspects, in particular the project International Partnership for the Hydrogen Economy (IPHE). It is likely that once the field evolves and the technologies become more mature also social aspects and related stakeholders will play more important role, which may not have been the case until today.

#### 4. Conclusions

In this paper, we have addressed the need for an analytical comprehensive framework of the system transition governance. The energy research in general is extensive field and different techno-economic and social aspects have been analysed in many studies. Hence, in analysing the potential use of system transition approach, it is important to know whether, how far and in which ways different elements and dimensions related to this approach have already been examined in the context of analysis. The existing research competencies are an important starting point for the future research within the system transition framework. The research efforts are, however, often scattered and fragmented vis-à-vis the versatile aspects and dimensions of the framework. In conclusion, a wider utilization of the system transition approach raises several new needs and topics to research agenda.

Governance and funding functions and models are an essential part of the transition framework. Hence, within the system transition framework, we analysed such governance and funding models, as well as the practices and accumulated experiences of these models, especially in order to be able to assess their utilisation in the development of the energy system transition.

Based on the findings in this paper, we conclude that energy system transition is a complex techno-economic and social long-term change process in which governance efforts can play an important role. On a basis of presented empirical case the interplay between different governance modes and arenas is crucial. An important aspect of governance for system transition is cooperation and mutual engagement of public and private actors and stakeholders ('coordination mode' of governance). However, due to the multi-level nature of system transition, a mixture of modes can also be very effective. For example, at the local level, the 'competition mode' may yield valuable outcomes due to the stronger incentives for local stakeholders to

engage in a competitive process, and awareness of local circumstances and ‘fitting’ of technological options. In conclusion, different governance and funding models with their practices and experiences can play an important role in the transition, but even more important may be the combined use of different modes that contribute to the development of the energy system transition.

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