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Transition Planning Approaches for the Path towards a Low Carbon Energy System

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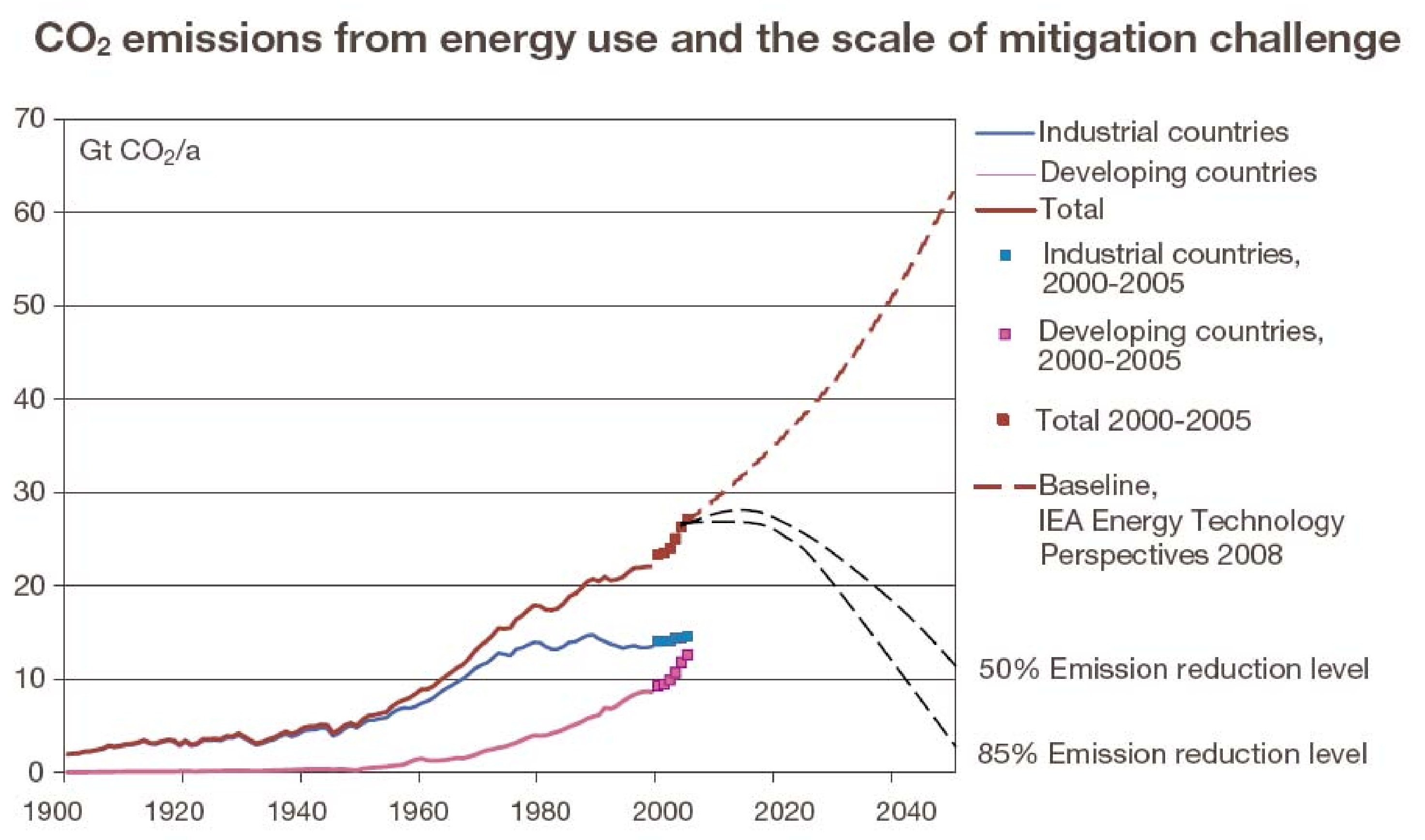
The Challenge



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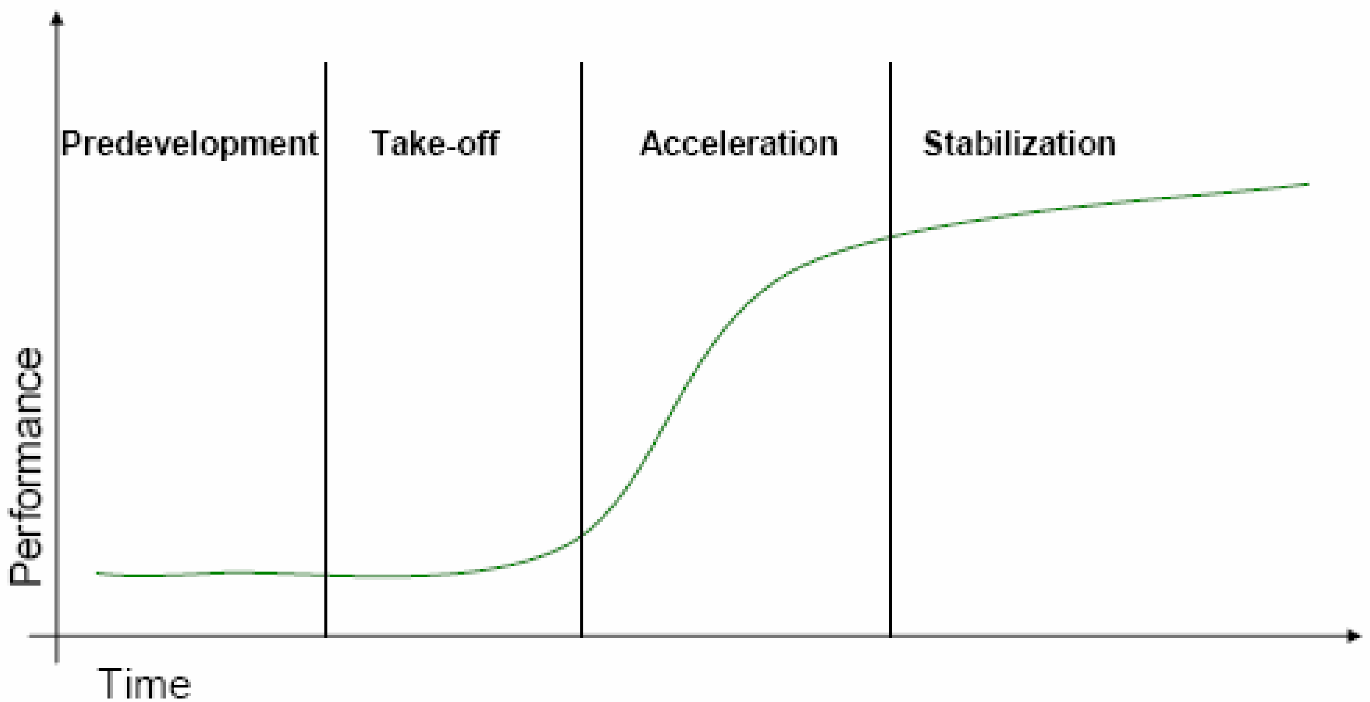
Source: Energy Visions 2050 - VTT

The Challenge

- Technological development has considerable inertia.

- Energy technology is often very capital intensive and the investments are characterized by long life-times – this slows down the changes.

The Phases of Transition



A very simplified illustration of the transition process developed to conceptualize the development and diffusion of an individual technology.

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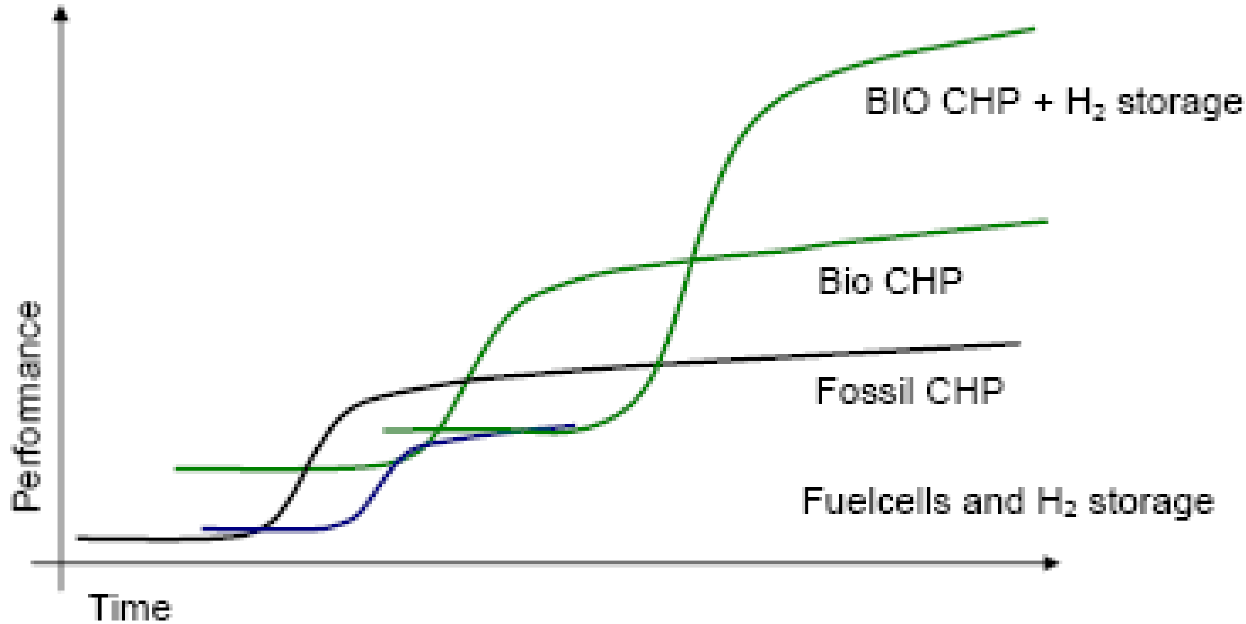
(Foster, R.N. 1986 " Innovation: The Attacker's Advantage")

The Phases of Transition



The technological transition of systems could be seen as a gradual co-evolution of different technologies – An interplay of different S-curves

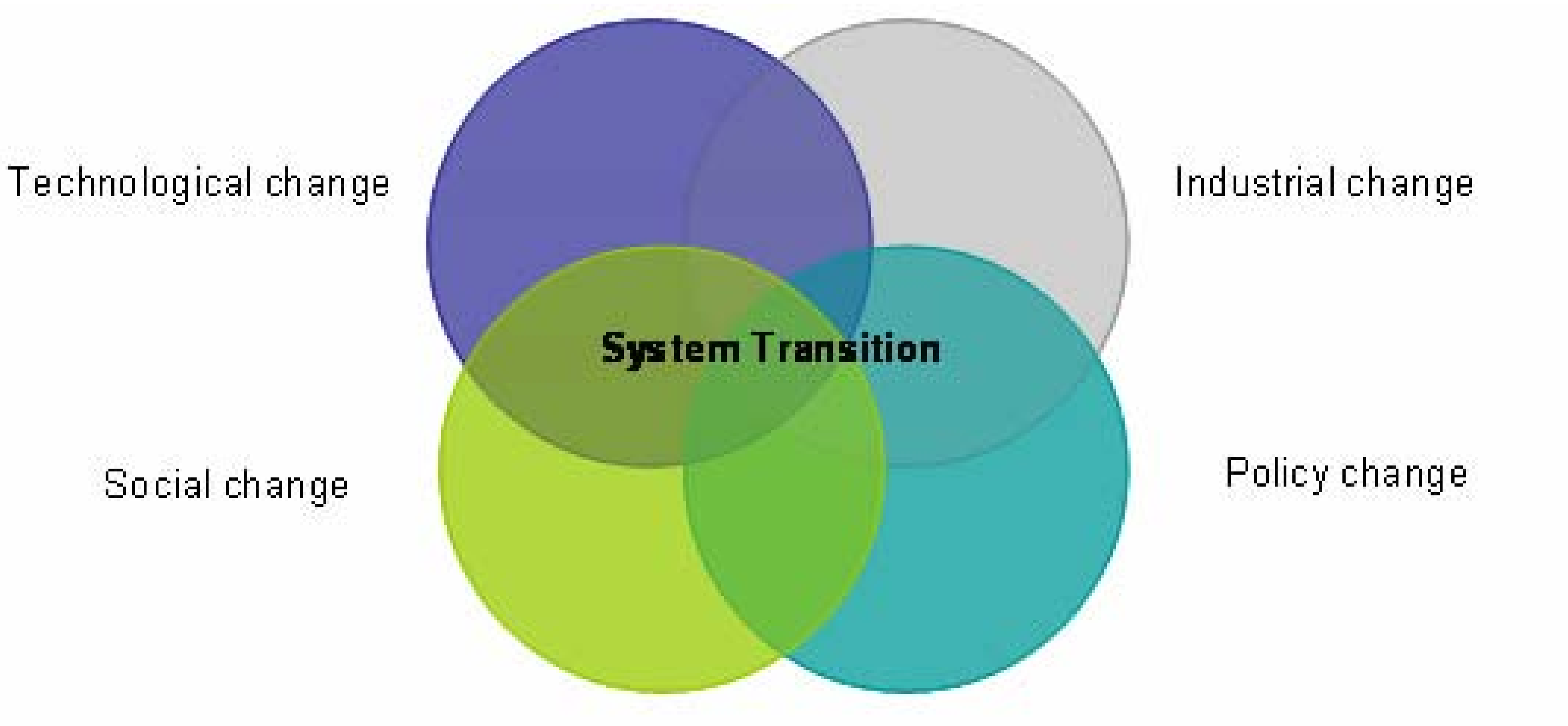
Source: "System Transition. Concepts and Framework or Analysing Nordic Energy Research and Governance", VTT, 2008

Levels of System transition

Level of analysis	Description	Examples
Landscape	Landscape forms an exogenous macro level environment that influences developments in niches and regimes.	Natural resources (e.g. global oil and gas reserves), climate change.
Regime	Regime refers to the established mainstream techno-institutional policy, industrial and user system delivering a specific function in society. The regime is dynamically stable and not prescribed by external constraints but mainly shaped and maintained through the mutual adaptation and co-evolution of its actors and elements.	Carbon-based electricity production, distribution and user system.
Niche	Niche forms the level where radical novelties emerge that deviate from the existing regime.	Solar energy systems, hydrogen energy systems.

Source: "System Transition. Concepts and Framework or Analysing Nordic Energy Research and Governance", VTT, 2008

Dimensions of System Transition



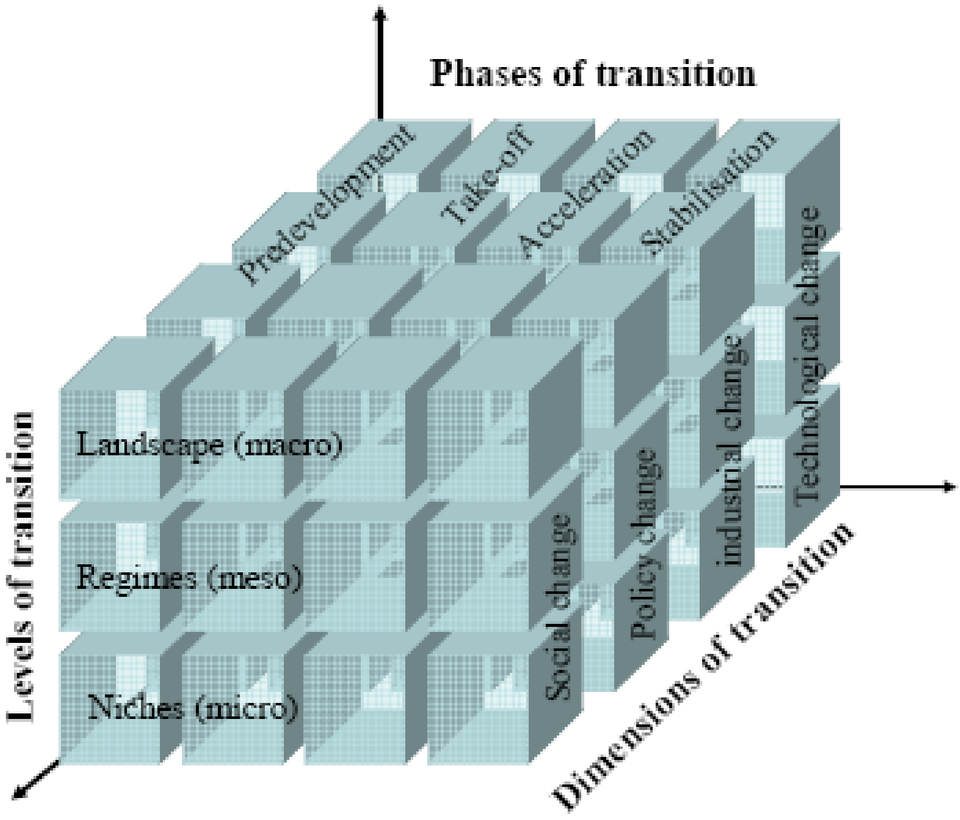
Source: Konnola T. (2007): "Industry Dynamics and Technological Roadmaps in International RD&D Management"
http://iri.jrc.es/concord-2007/papers/strand6/Konnola.pdf

Dimensions of System Transition

Dimensions of systems innovation	*Core concepts and elements*
Technological change	Dominant designs, emerging technologies, infrastructures, interoperability
Industrial change	Standards, value chains and networks, organisational hierarchies and practices, investment mechanisms, intellectual property
Policy change	Information services, networking, setting common agendas, strategic procurement, financing research and education, grants, equity support and fiscal measures, regulation and standards
Social change	Behaviour, routines, preferences, attitudes, values, user involvement

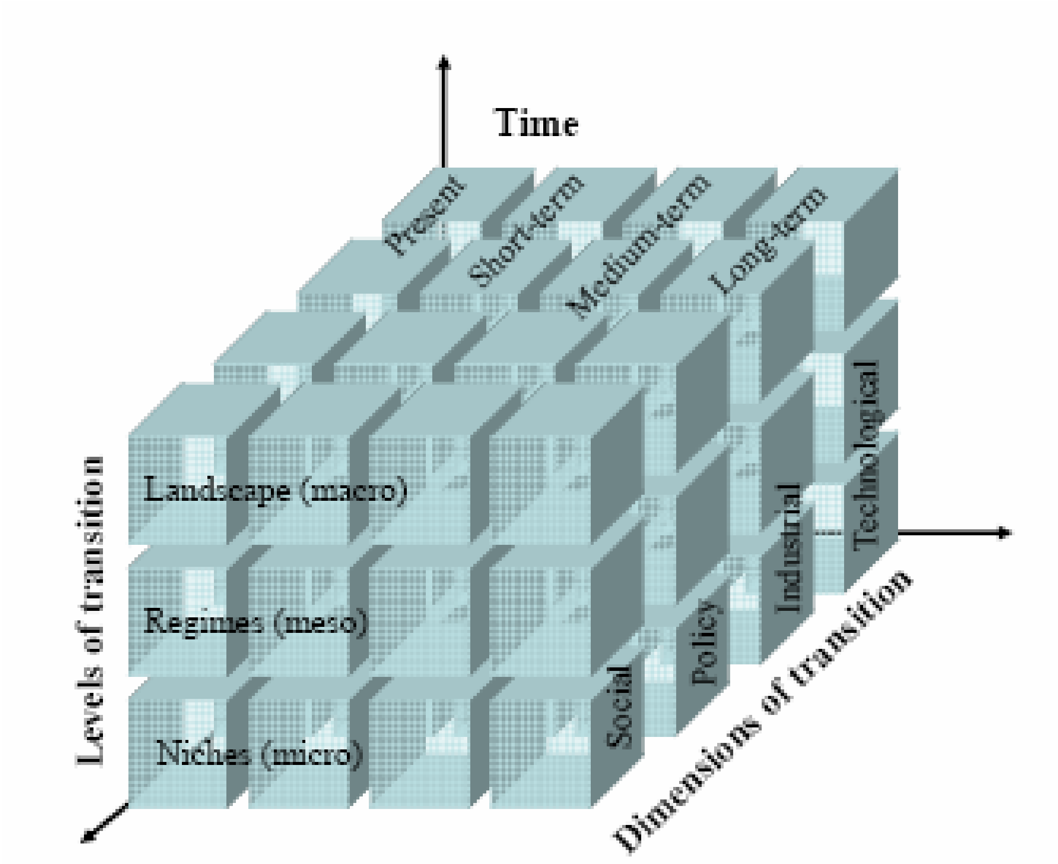
Source: "System Transition. Concepts and Framework or Analysing Nordic Energy Research and Governance", VTT, 2008

Integrated Framework for Transition Research and Governance



Source: "System Transition. Concepts and Framework or Analysing Nordic Energy Research and Governance", VTT, 2008

Integrated Framework for Transition Research and Governance



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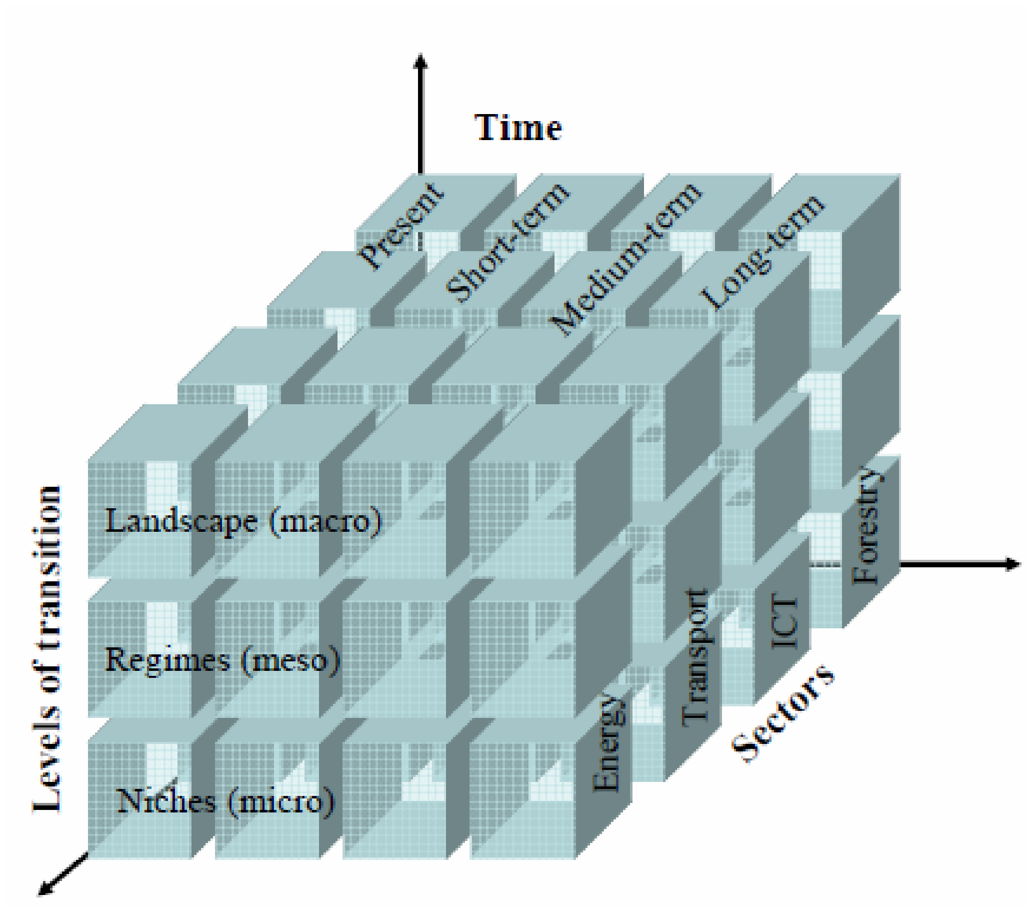
Integrated Framework for Transition Research and Governance



Source: "System Transition. Concepts and Framework or Analysing Nordic Energy Research and Governance", VTT, 2008

Initial development of Pathways

Energy system development is constrained by technical, political, institutional, and behavioral issues.

E.g.

Distribution networks handling multi-directional electricity flows or capacity constraints on the grid in geographical areas where RES potential is high, or the impact of smart metering to shape load curves, present technical challenges.

These technical developments pose to the social scientists questions of political feasibility, social acceptance and institutional or regulatory change. Maybe new regulatory frameworks or new energy system institutions are required to govern new processes, consumers maybe need to act in different ways in their relationship with the energy supply system.

Source: N. Hughes, N. Strachan "Scenarios, Transitions Theory and the Development of UK Low Carbon Pathways" Workshop report, 2009 available at www.lowcarbonpathways.org.uk

Initial development of Transition Pathways

- Engineering insight must be integrated in the pathway development process – must be part of the process even before any formal modeling takes place, in order to ensure their plausibility and usefuleness.

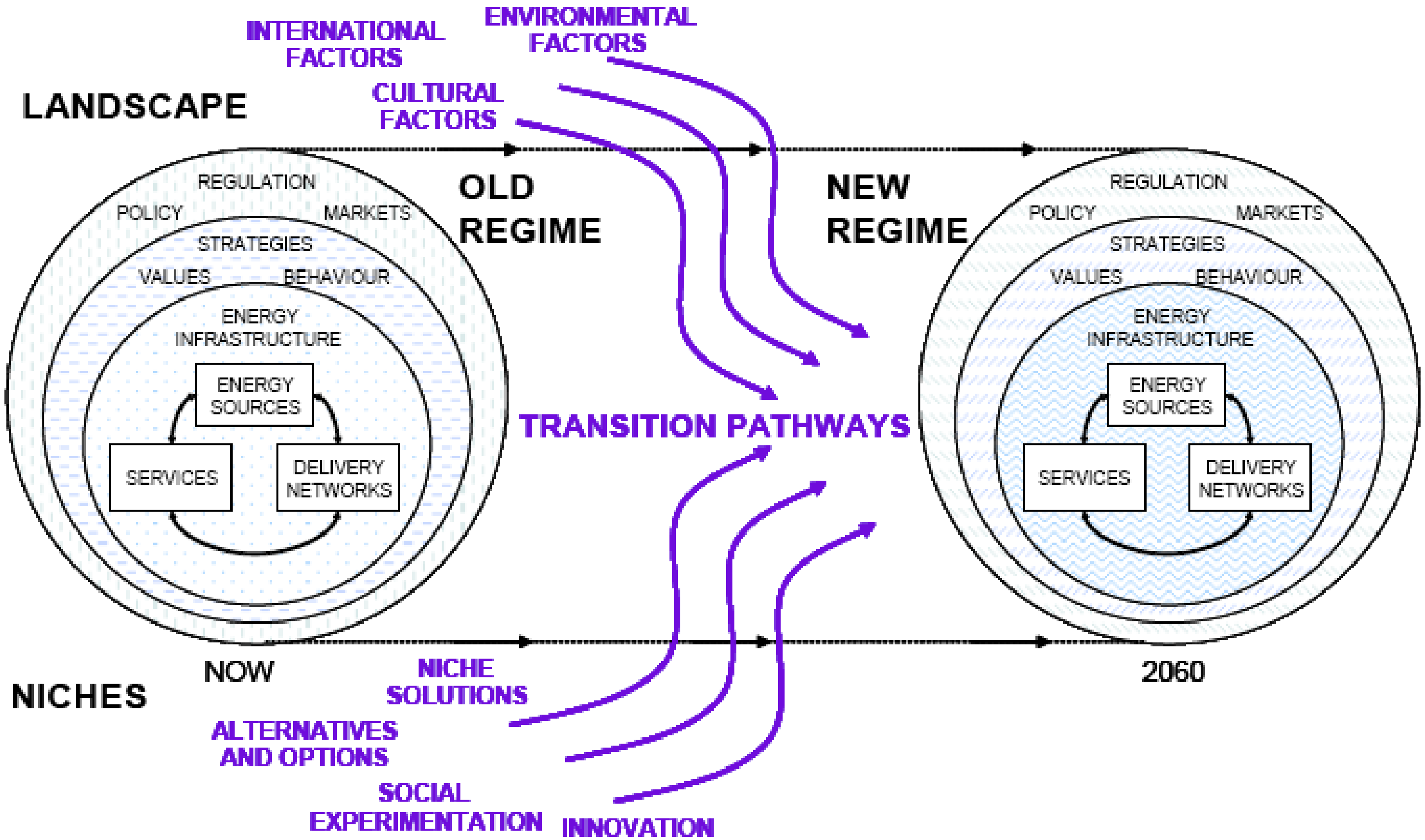
- The energy systems' evolution is strongly conditioned by the past and the existing infrastructure.

- The process by which transition pathways happen is a co-evolving relationship between technological systems and societal actors.

  An electrical engineering model can not be setup to give answers to how highly decentralized electricity system can evolve from the existing one. Nor can a social-science approach, give a realistic account of how this process can occur since constraints are posed by technical aspects of the infrastructures and technologies.

Source: N. Hughes, N. Strachan "Scenarios, Transitions Theory and the Development of UK Low Carbon Pathways" Workshop report, 2009 available at www.lowcarbonpathways.org.uk

Possible transition pathways and influencing factors



Source: Transition pathways for a UK low carbon energy system: exploring difference governance patterns", T. Foxon, G. Hammond, P. Pearson, J. Burgess T. Hargreave inhttp://www.lowcarbonpathways.org.uk/

Hydrogen Infrastructure and Transition modeling

Road mapping analyses combine the use of different kind of models:

- Life Cycle Analysis Models (LCA)
- Technology Engineering Cost Models (TEC)
- Hydrogen Infrastructure Development Models (HID)
- Market Transition Analysis Models (MTA)
- Energy Systems Models (ESM)

Source: " HyWays – IPHE project WP3 report" available at http://www.hyways-iphe.org/

Hydrogen Infrastructure and Transition modeling

- **LCA** models estimate emissions and energy use per unit of final demand for a particular fuel production pathway. Must be made consistent with detailed Technology Engineering Cost models.
- **TEC** models specify how each process is expected to be designed and operated. They can involve high degrees of technological detail and usually perform some degree of process optimisation.

Both categories have no Spatial representation and refer to snapshots or a single point in time.

Source: " HyWays – IPHE project WP3 report" available at http://www.hyways-iphe.org/

Hydrogen Infrastructure and Transition modeling

- Infrastructure Development models assemble the information on technologies from TEC models and explore how infrastructure technologies can be introduced over time and over a spatial representation of a single city or a regional market.
- They have a fair degree of spatial detail in order to situate plants and delivery systems (sometimes using GIS). They take the final demand projection as given, and focus in the infrastructure development.

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Source: " HyWays – IPHE project WP3 report" available at http://www.hyways-iphe.org/

Hydrogen Infrastructure and Transition modeling

- Market Transition Analysis (**MTA**) models explore how the supply and demand of a fuel or technology and the required infrastructure can evolve over time in response to economic signals and policy incentives.
  - TEC models provide technology characterisation and costs
  - HID models provide insights on the manner and cost of infrastructure development in specific applications and this can be generalised in the MTA models.

Market outcomes like consumer demand, industrial investment, fuel, technology and feedstock prices are simultaneously determined in MTA.

Source: " HyWays – IPHE project WP3 report" available at http://www.hyways-iphe.org/

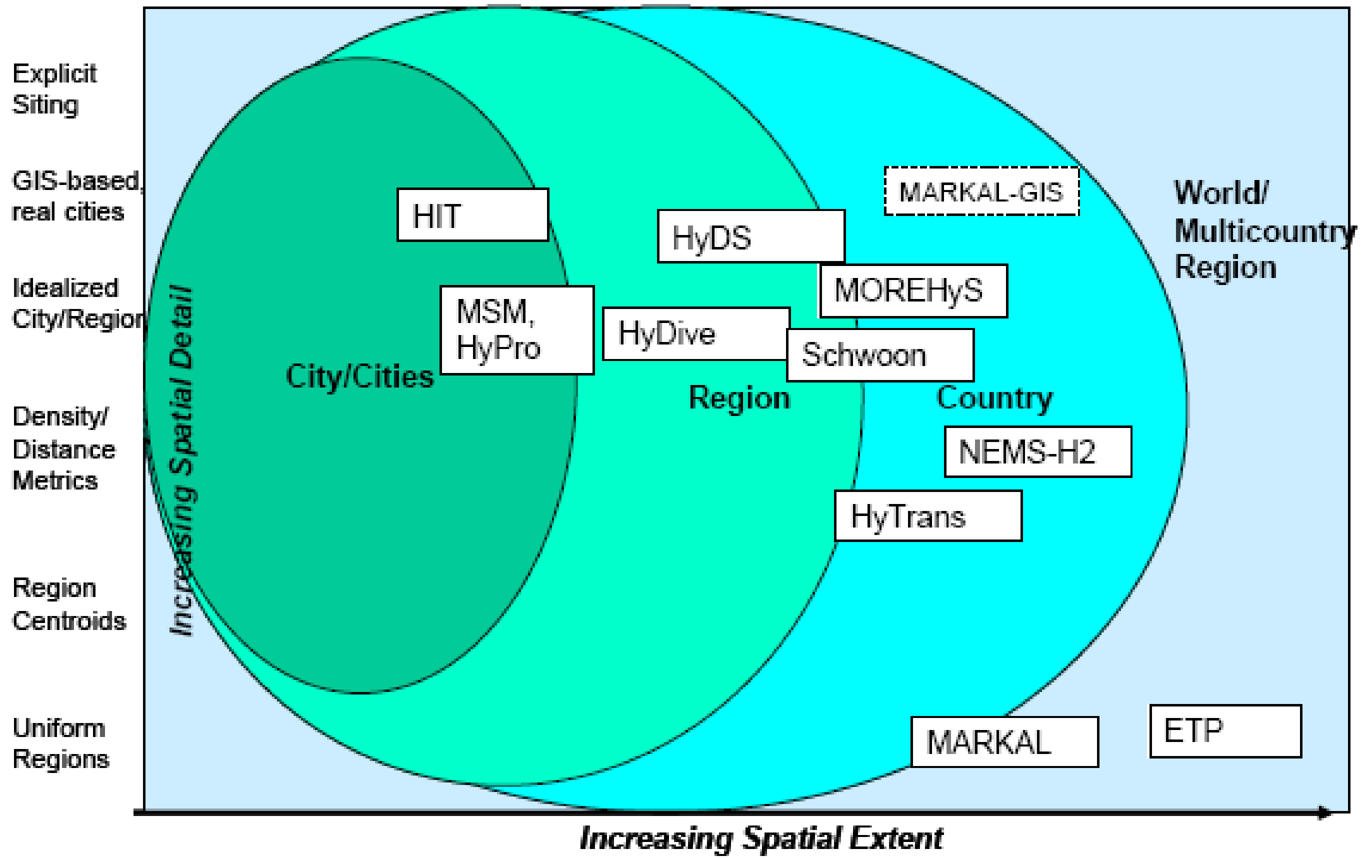
Hydrogen Infrastructure and Transition modeling

Large Energy System Models (ESM), broader the analysis to multiple sectors and fuels at national and international scale.

- They provide system wide balances of energy and fuel supply and demand for all fuels and sectors.
- They provide basic price projections that underlie the market conditions in which specific fuel carriers (e.g. hydrogen) compete in the HID and MTA models.
- They can integrate the impact of diverse national energy and climate policies.

Source: " HyWays – IPHE project WP3 report" available at http://www.hyways-iphe.org/

Hydrogen Infrastructure and Transition modeling



Spatial Extent w.r.t. Spatial Detail in the case of Hydrogen transition analysis models.

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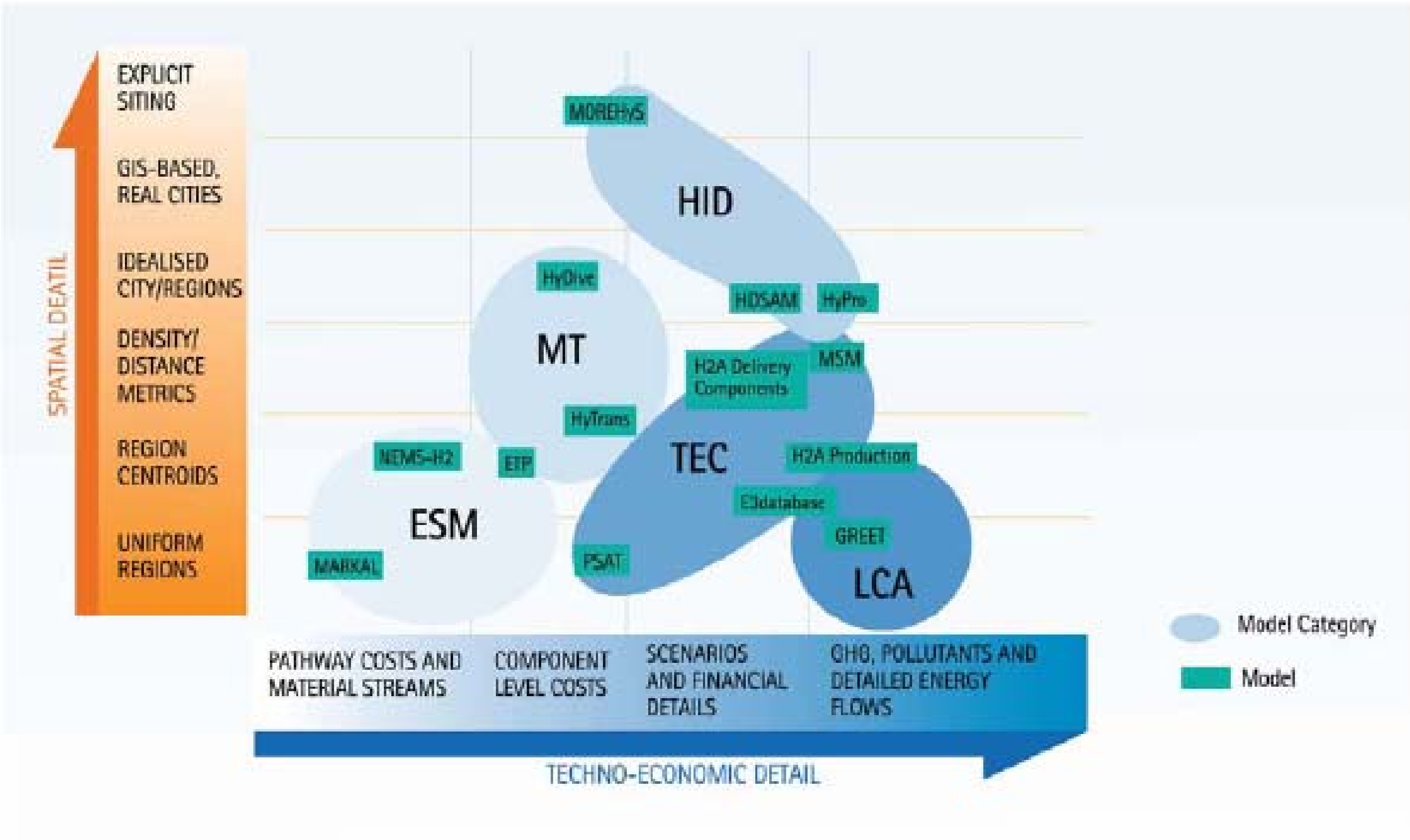
Source: " HyWays – IPHE project WP3 report" available at http://www.hyways-iphe.org/

Hydrogen Infrastructure and Transition modeling



Techno economic detail w.r.t spatial detail of Hydrogen transition planning models

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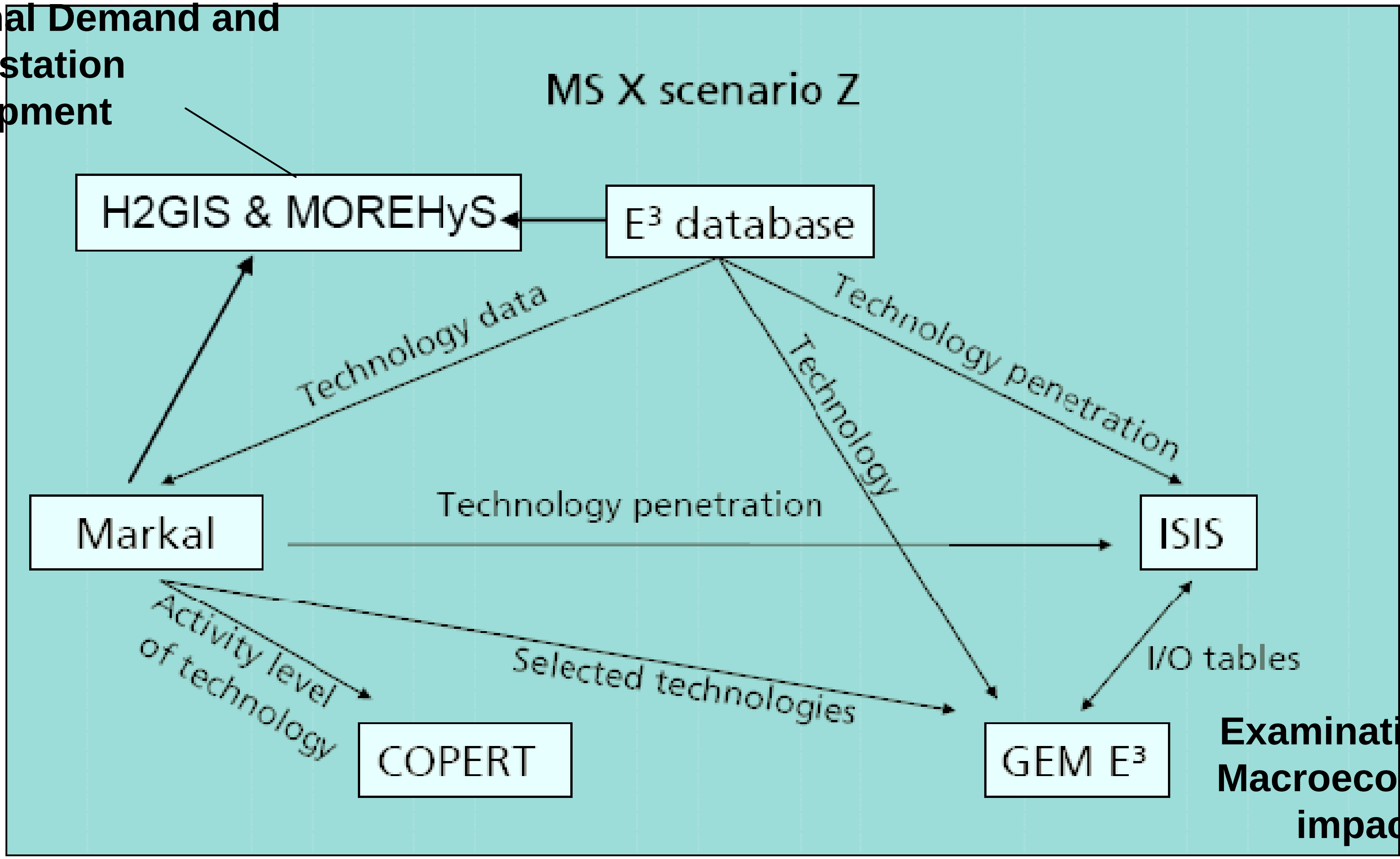
Source: " HyWays – IPHE project WP3 report" available at http://www.hyways-iphe.org/

Models and Linkages in the HyWays project

Regional Demand and Filling station development



Examination of Macroeconomic impacts

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Source: " HyWays – IPHE project WP3 report" available at http://www.hyways-iphe.org/

The Dutch transitions approach

The Dutch Ministry of Economic Affairs, Ministry of Housing, Spatial Planning and the Environment, Ministry of Agriculture, Nature and Food Quality, Ministry of Transport, Public Works and Water Management, Ministry of Foreign Affairs and the Ministry of Finance,

launched the Energy Transition approach in 2006 aiming to attain a sustainable energy supply within 50 years.

http://www.senternovem.nl/energytransition/index.asp

The Dutch transitions approach

Main points

1. Analysing historical dynamics of transitions using multi level perspective.

2. Transition management

3. Socio technical scenarios.

Analysing historical dynamics of transitions

Analysing historical dynamics of transitions using multi level perspective:

Landscape (Macro level): broader political, social and cultural values (change slowly),

Socio-technical regime (Meso level): technologies, infrastructure, skills, institutions (creates incremental innovation),

Niches (Micro level): spaces where technological and social learning can occur (radical innovation).

So transition pathways are formed through the dynamic interaction of technological and social factors at the three different levels

Geels 2002 "Technological transitions as evolutionary reconfiguration processes: a multi level perspective and a case study", Research Policy 31.

Transition management

A process to steer or modulate the dynamics of transition through interactive, iterative process between networks of stakeholders.

Perform “transition experiments” (strategic learning projects).

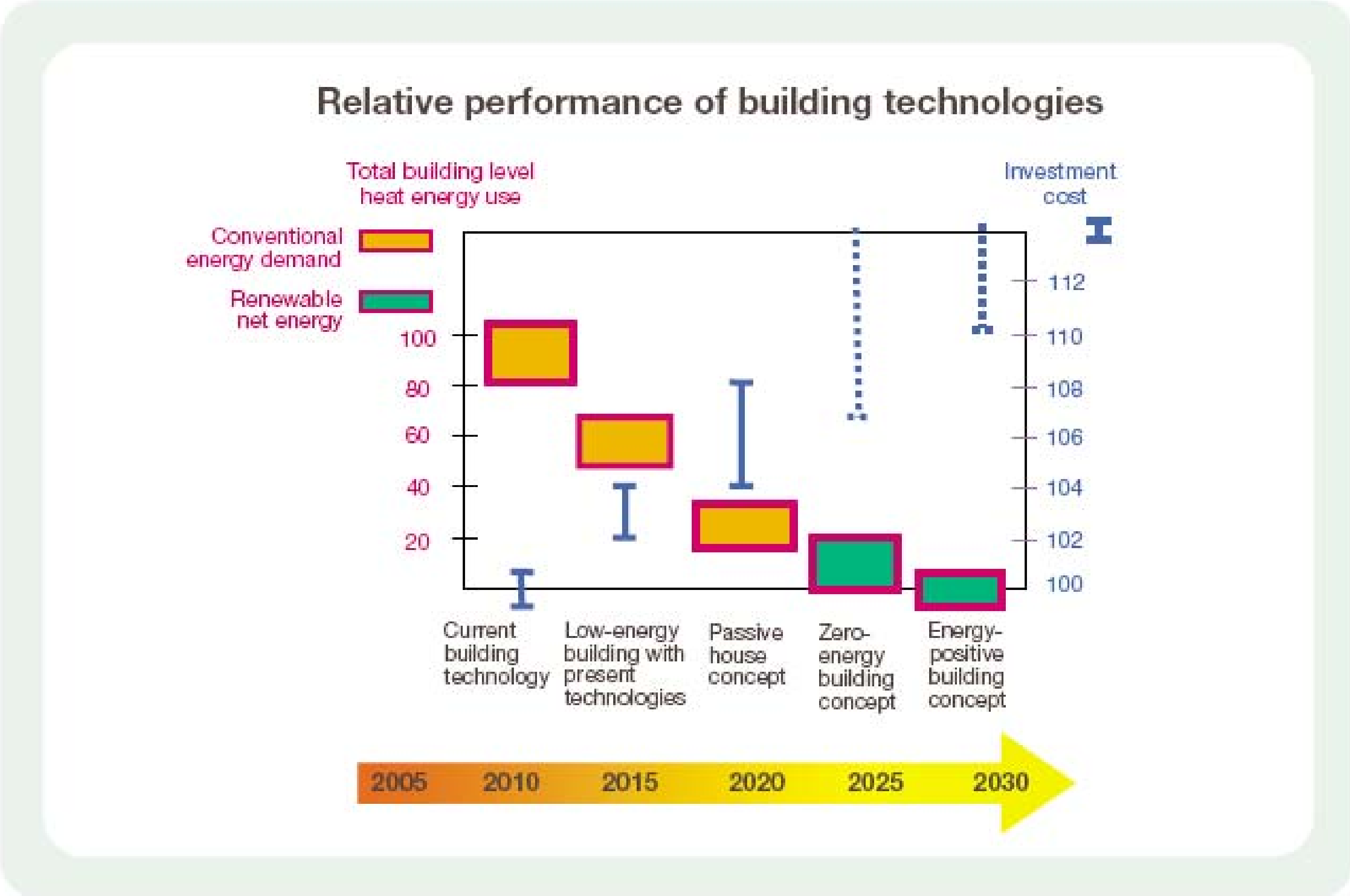
Socio technical scenarios

Explore the potential future development of the socio-technical systems:

- incorporate qualitative elements (social networks, learning processes) and quantitative (price and performance of technologies),
- focus on the potential for radical technological change,
- take a systems approach to examine complementarities as well as competition between technologies,
- analyze meso and micro level dynamics

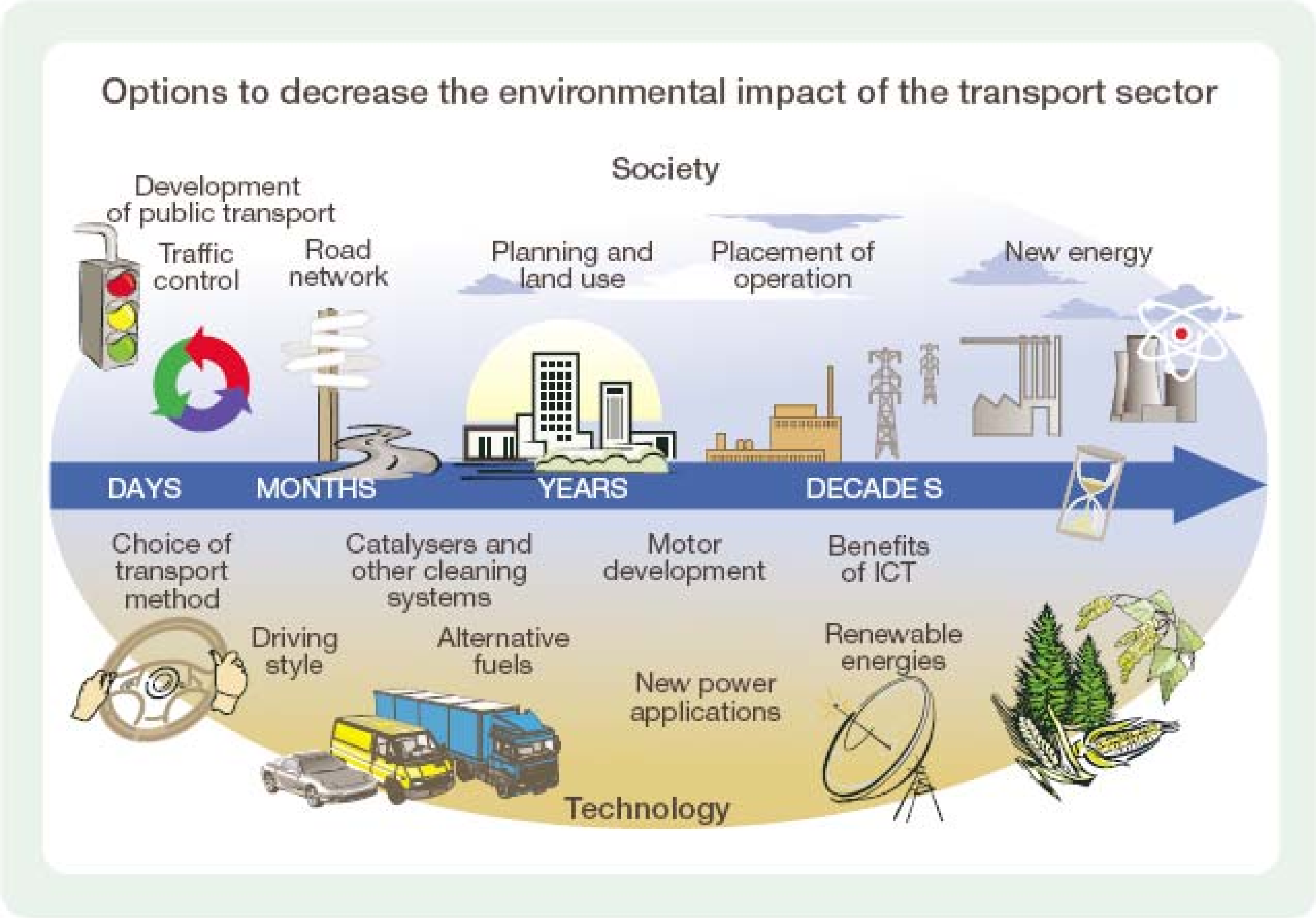
Make a scenario, Analyse it, Reflect on the output and develop policy recommendations.

Visions of technology development



Source: “Energy Visions 2050”, VTT 2009

Visions of technology and society changes



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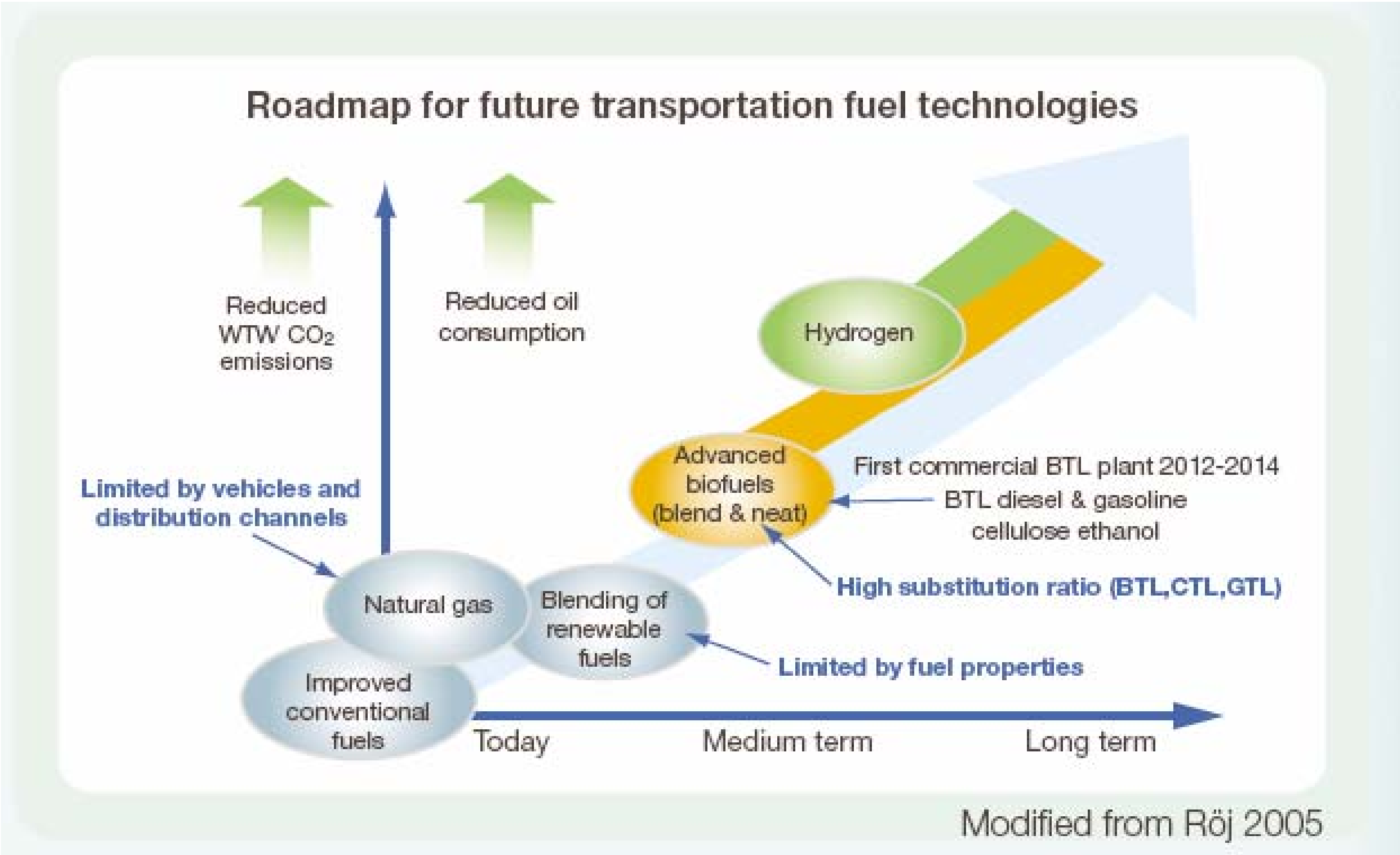
Source: “Energy Visions 2050”, VTT 2009

Visions of technology development



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Source: "Energy Visions 2050", VTT 2009

Scenarios in Energy Vision 2050 - VTT

Characteristic	Baseline	2°C Market	2°C Boosted	Regional world
Development of economy	Globalisation	Globalisation	Globalisation	Regional policies
Costs and potential of new technologies	Moderate development	Moderate development	Boosted development	Moderate development
Level of required return on energy efficiency investments	Moderate	Moderate	Low	Moderate
GHG emission reduction objective	None	2°C warming limit	2°C warming limit	Regional emission targets

Source: "Energy Visions 2050", VTT 2009

Energy System Models

TIAM (TIMES Integrated Assessment Model) has been used in Energy Visions 2050 by VTT in order to model the various scenarios for the energy system development.

TIAM is a global partial equilibrium model, developed under the sponsorship of ETSAP.

TIAM

- TIAM includes 15 regions, has 42 demands for energy services in all sectors.
- The model computes a partial equilibrium on world-wide energy and emission markets that maximizes the discounted present value of global surplus (minimizes the system cost).
- It includes explicit descriptions of more than one thousand technologies and one hundred commodities in each region. Each technology has its own technical and economic parameters.
- It explicitly models CO_2, N_2O and CH_4 from all sources directly related to energy and processes.
- There is a climate module that allows the user to simulate climate targets.

UK Transition Pathways project

The UK Transition pathways to a Low Carbon Economy project. (http://www.lowcarbonpathways.org.uk/)

Follows the approach of research in three directions:

1. Transitions scenarios and historical analysis
2. Technical and Social analysis
3. Whole systems appraisal

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Source: http://www.lowcarbonpathways.org.uk

Transitions Work Stream

- Multi-level transitions approach to understand how interactions between technological and social factors give rise to transition processes.

- Quantification of dynamic interactions between technological, social, economic and environmental factors relevant to transitions.

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Source: http://www.lowcarbonpathways.org.uk

Scenarios Work Stream

- Are energy forecasts realistic and feasible in terms of engineering, institutional, social processes, required policy interventions, international assumptions?
- Which assumptions and timelines are required in transitional pathways?
- What key uncertainties exist? (e.g., technical, regulatory, international events, conflict between policy objectives)

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Source: http://www.lowcarbonpathways.org.uk

Historical Analysis Workstream

- To learn from analyses of the technological, institutional, socio-economic and environmental aspects of selected past energy system and related transitions, to advance the analysis, development and interrogation of prospective low carbon pathways.

- Extend existing approaches to the historical and prospective analysis of transition pathways; identify key lessons from selected case studies of past energy system transitions and pathways.

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Source: http://www.lowcarbonpathways.org.uk

Technical and Social Analysis

Understanding Supply-Side and Demand-Side Participation In Transition Pathways:

- Quantitative and qualitative assessment of the possibilities for and implications of Supply Side (through network interactions) and Demand Side Planning (both automated and that requiring human intervention) and Distributed Generation.
- Map the existing energy network; identify key processes and practices binding producers and consumers in the network, promoting or impeding selected transition pathways.
- Understand different perspectives on the environmental, technological, economic, social and political issues associated with selected transition pathways.

Source: http://www.lowcarbonpathways.org.uk

Technical and Social Analysis

- Investigate how a range of energy users perceive and value DSP and DG characteristics
- Explore what technical, social and behavioural changes are required to move DS and DG options from niche application to regime level
- Examine whether DSP and DG can deliver significant and cost-effective services to the energy system.
- For DSP and DG the focus will be on residential and SME sectors as these offer the prospects for greater DSP/DG innovation than do the well established – and better studied - industrial/commercial sectors.

Source: http://www.lowcarbonpathways.org.uk

Sustainable Generation Sources

- A major transition is unavoidable in the move to a low carbon electricity generation system.
- Both technical and institutional change is required and these are closely linked.
- The long term transition is to electricity generation largely from renewable energy sources (and perhaps fusion).

Source: http://www.lowcarbonpathways.org.uk

Sustainable Generation Sources

- Explore the technical and institutional changes required as part of the transition to a low carbon energy economy. Attention should be given to the technical transition process and the role of stepping stone technologies such as CCS and nuclear.

The key objectives are to:

- Outline alternative concepts for a sustainable electricity generation system
- Consider the scale and timing of the CCS (and possibly nuclear) required to provide the stepping stone to a sustainable system

Source: http://www.lowcarbonpathways.org.uk

Sustainable Generation Sources

- Make a quantitative assessment of the reliability and operability of the identified sustainable system configurations.
- Explore in outline the electricity needs of a sustainable electric transport sector and the potential of this to provide major controllable loads to be used for system balancing.
- Address the issues of technical feasibility and reliability that are a prime concern of the electricity supply sector, especially when faced with demanding technical change.

Source: http://www.lowcarbonpathways.org.uk

Feasibility of Infrastructures Supporting Low Carbon Energy Systems

Quantitative assessment models and analyses illustrating clearly the feasibility of energy infrastructures relating to the low carbon transition pathways at the national, regional and local levels and with particular emphasis on electricity.

While drawing on tested approaches, the application of these methods to the low carbon energy system transitions requires original and incremental model development on existing platforms.

Source: http://www.lowcarbonpathways.org.uk

Feasibility of Infrastructures Supporting Low Carbon Energy Systems

Develop an energy infrastructures modeling base to study the feasibility of energy infrastructures in the various transition pathways and specifically to identify:

- the feasible energy infrastructure transitions that must occur to facilitate the shift to low carbon transport, electricity, buildings and commerce/industry
- the manner in which electricity, gas, heat, and hydrogen infrastructures can be optimised in a coordinated manner over full transition pathways.

Source: http://www.lowcarbonpathways.org.uk

Feasibility of Infrastructures Supporting Low Carbon Energy Systems

Develop electricity infrastructures modeling base to study the feasibility of electricity infrastructures in the various transition pathways and specifically to address the following issues:

- electricity transmission grid evolution to facilitate a low carbon energy systems;
- feasible local electricity distribution networks evolution for the connection of low-carbon buildings with high penetrations of micro-generators;
- the role of network technologies, long- and short-term energy storage and demand response in supporting infrastructures for low carbon transition pathways.

Source: http://www.lowcarbonpathways.org.uk

Whole Systems Appraisal and Joint Working - Integration and Learning

- To employ a toolkit of techniques to explore and evaluate the 'whole system' implications of the selected transition pathways;
- To outline the energy and carbon implications of the pathways;
- To provide an indicative assessment of the environmental impacts of differing pathways using aggregate metrics, such as carbon and environmental footprints;
- To compare and contrast the broad sustainability costs and benefits over a range of scales

Source: http://www.lowcarbonpathways.org.uk

Methodology of the UK approach for developing transition pathways

Iterative process:

- Develop initial set of outline pathways
- Investigate and compare them using a range of modeling and assessment tools and criteria to asses their plausibility and to identify areas where more detailed specification is needed.

Source: http://www.lowcarbonpathways.org.uk/

Methodology of the UK approach for developing transition pathways

Develop initial outline by:

1. Characterize the existing energy regime
2. Identify dynamic processes at a niche level
3. Specify interactions giving rise to or influencing transition pathways.

Source: http://www.lowcarbonpathways.org.uk

The ATEsT project

- The 3rd implementation pillar of SETPlan relates to activities addressing future European energy infrastructure networks and systems transition planning.
- In this context, an FP7 Support Action named ATEsT (Analysing Transition Planning and Systemic Energy Planning Tools for the implementation of the Energy Technology Information System) was launched in October 2009.
- The aim is to address the methodologies and modeling toolbox required to support the decision making of the SET-Plan in the priority area of transition planning of the deployment of low carbon technologies and their supporting infrastructures.

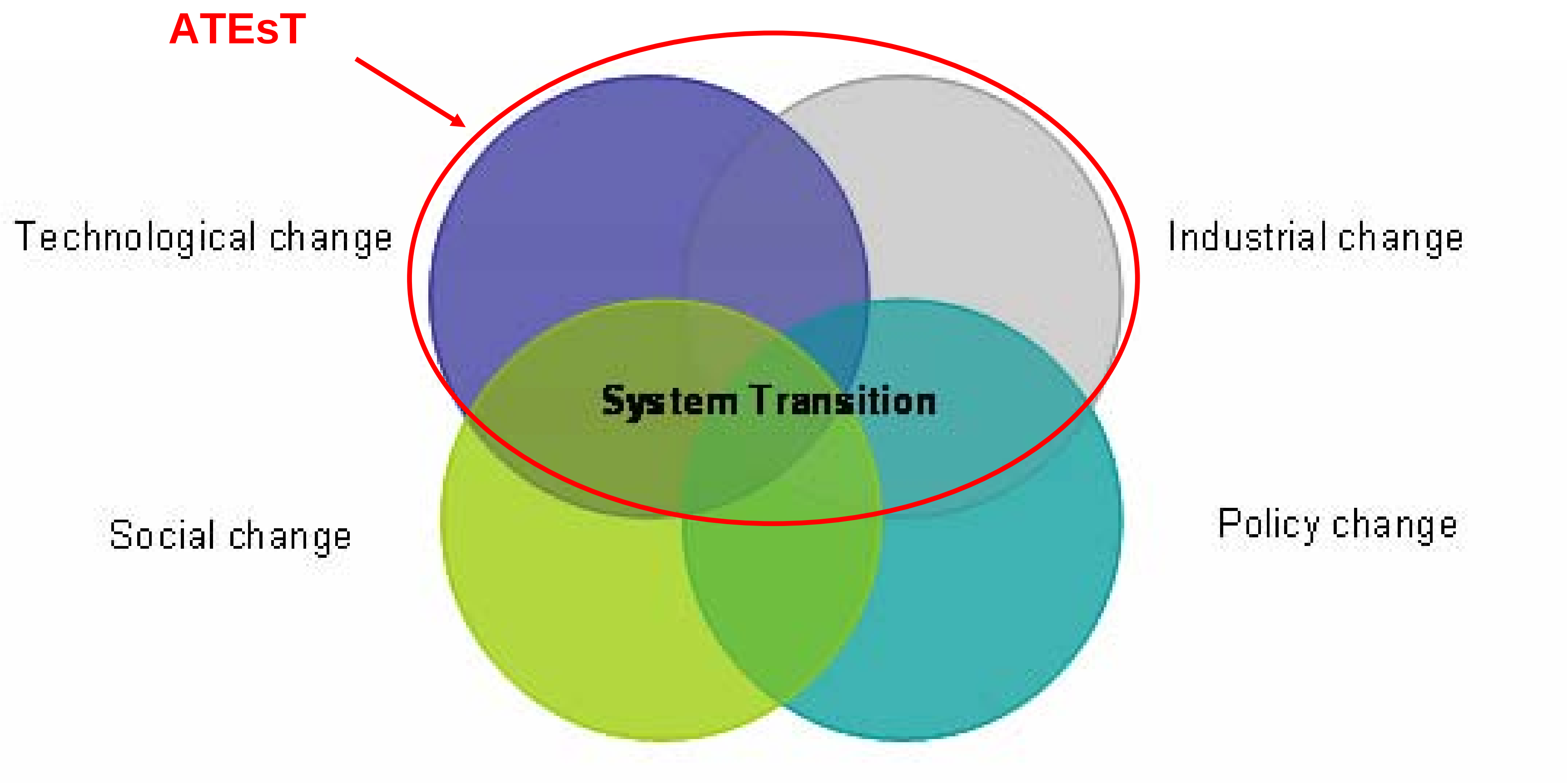
The ATEsT project

The “tools” that will be evaluated in the framework of ATEsT are methodologies for the analysis of energy policies and mathematical models that can be used in order to simulate the development of the energy system or analyse the transition planning in the energy system.

The objectives of the project are to:

- Review models/tools used in European Countries.
- Identify and recommend common tools and/or methods to be used in the MS and in SETIS.
- Identify and recommend existing sets of data, and provide a roadmap for the development of the data.
- Identify the roadmap for the improvement and development of the tools and methods in order to cover the needs of the SET-Plan implementation.

The ATEsT project



Courtesy: Tiina Koljonen, VTT

The ATEsT project

In this framework an open call for existing models will be launch by the end of the month in order to gather all the available information on modeling approaches in Europe and the rest of the world.

More information at:

www.atest-project.eu

“forecasts are the mirrors of our ignorance not the embodiments of our understanding;

energy transitions are protracted, generation-long affairs”

“Energy at Crossroads”

Vaclav Smil, 2006