Monitoring Energy Innovation During its Growth to Maturity: Better Appreciation of Innovation in Evaluations

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Abstract

Innovation is crucial in reaching energy and economic targets. Innovation is often a long process, much of it done before actual market penetration. Policy makers cannot wait decades until it shows up in market data and need timely information on innovation for steering and communication. Over the last few years, the Netherlands has gained experience with a systems approach in monitoring of energy innovation. This approach visualizes the progress of innovation using a limited set of key dimensions for success. It helps to follow developments also in early stages of innovation processes. It shows the growth of the system in strength and chances of success. This enables better monitoring & evaluation, helps in communicating progress at different management levels and, through its structured insight into strong and weak points in the process, supports management decisions as to where further actions may be needed and by whom. This paper describes how this approach was used in monitoring and evaluation and in discovering (chances for) synergy in innovation processes.

Introduction

Innovation is crucial for economic development and a key factor in structural change towards a more sustainable (energy) economy. Many significant innovations are so-called discontinuous innovations. These require a long term view and are influenced by many stakeholders in society. Useful and timely information on progress and results of innovation processes is therefore essential for management, policy making and support. Yet, more traditional monitoring and evaluation indicators do not seem adequate in visualizing and appreciating the role of innovation, especially in the early phases of innovation. Many organizations are looking for new insight and methods [e.g. ARK, 2011; OECD, 2010; Tekes, 2011]. The Netherlands has experimented over the past few years with a systems approach in monitoring and evaluation of energy innovation processes. This was designed to facilitate decision makers in business, research and government to better assess developments in the processes and, where needed, re-direct their policies in a timely fashion.

Systems approach to show dynamics

Innovation takes time to pop up in market indicators

Successful innovations typically follow a development path along a so-called S-curve that shows market development over time (**Figure 1**). It takes many years, often one or more decades, of development and first deployment of new products, before this curve shows anything significant 'popping up above the surface' in market statistics. Unfortunately, decision makers cannot wait decades to success showing up in macro-economic figures. Progress and success of innovation policies need to be monitored and visualized in another fashion, especially in the early phases of the process[1]. During these phases, it is not market penetration that indicates success or failure, but rather the 'growth towards maturity' of the

[1] Bergek calls this the 'formative' stage [Bergek, 2005]

relevant innovation system. We need to show therefore, whether this system does successfully manage to generate and transform knowledge into products that meet the needs of buyers, and to adapt the required infrastructure and have the proper type of entrepreneurs and coalitions in the right position when the market really begins to take off. The new monitoring ('sensor') approach tries to visualize these dynamics, growth, and progress along the innovation phases.

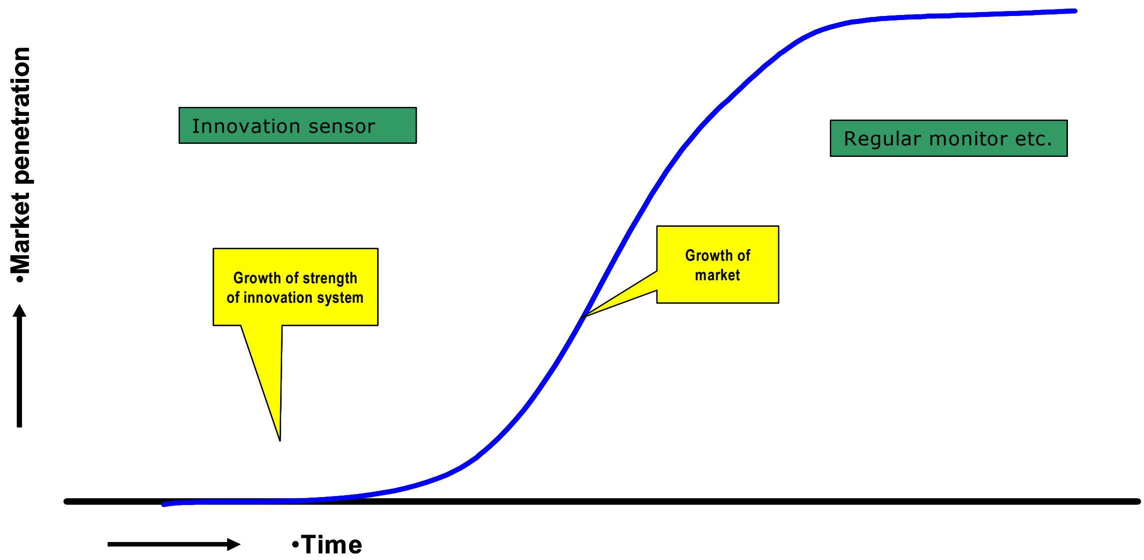

Figure 1: Successful innovation follows a typical (S-shaped) path of development and diffusion [e.g. Rogers, 1962, Moore, 1999 and many others]

Innovation is an interactive process of many parties in society. The parties that influence the development, application and dissemination of the relevant innovation, together with their interactions (relations, institutions, etc) do constitute an innovation system. System approaches towards innovation often focus on nations or sectors. Such approaches are used e.g. for national industry policies. In monitoring and evaluation, they typically look at indicators, such as economic growth, turnover, percent of R&D investments, labor productivity, labor market characteristics, education, etc.

In our approach, we look at a combination of sector related and technological innovation systems (TIS) and at the interactions between these. The TIS focuses on those parties and relations that influence specific new technologies and/or product groups i.e. specific renewable energy or energy efficiency technologies. Sector here relates to the energy sector in a more broad sense, including those parties that provide innovative energy efficient technologies for industry and other users. Actors include companies that develop or commercialize the new technologies, research institutes that develop new knowledge, financial organizations that invest, governments that facilitate through policies and intermediary organizations that stimulate certain developments or reflect particular interests (see **Figure 2**). Various experts have further developed the TIS approach [e.g. Bergek, 2008, Hekkert, 2010, Suurs, 2009].

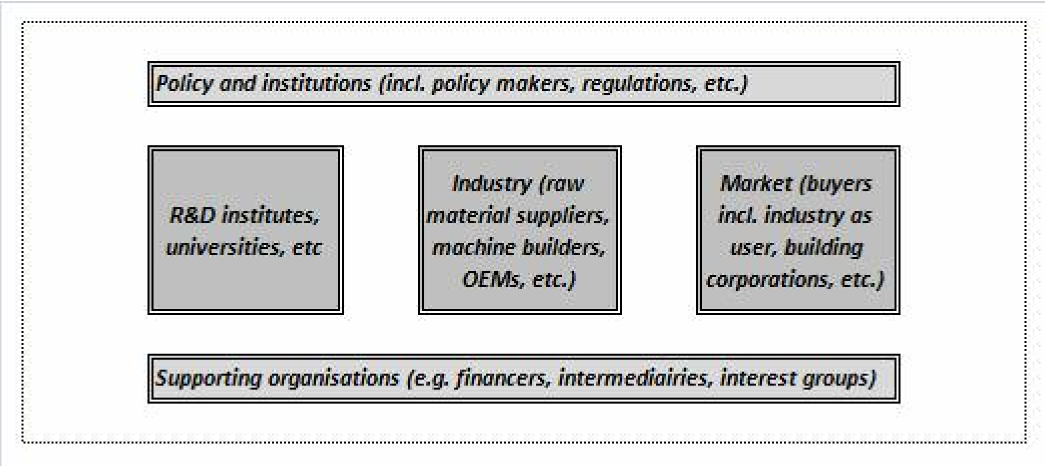

Figure 2: Structure of a (technical) innovation system (based on e.g. Hekkert, 2010)

Innovation is brought forward by the dynamics in such a system. Success requires that the growth of and changes in the relevant innovation system occur in a proper fashion, fitting with the different development stages that have to be passed in its path towards maturity (along the indicated S-curve)[2]. Innovation sciences indicate that a number of key functions herein must show proper evolution for success [e.g. Bergek 2005/2008, Hekkert, 2010. See **Figure 3** for a brief explanation of the functions]. The sensor approach monitors the dynamics and progress in structure and key functions.

F1. Entrepreneurial activities. Enterprises translate knowledge into business opportunities. Experiments with new technology develop commercially viable innovations.
F2.Knowledge development. Market parties and universities develop new knowledge.
F3. Networking and knowledge diffusion. Through collaboration, business and other parties combine their knowhow and strengths to realize products and market position .
F4. Guiding the search. Expectations, longer term policies and such with regard to the innovation in question influence the intensity and direction of development.
F5. Market formation. In (early) markets conditions for demand to materialize may not yet be well developed. Stimulation may be needed e.g. through launching customers, etc.
F6. Resources mobilisation. Innovation needs money, equipment and qualified researchers.
F7. Legitimacy. Every pioneering change faces opposition and resistance. Good information and interest groups and advice may help to overcome hesitation, doubts etc

Figure 3. The seven key processes for success [Based on Hekkert, 2010]:

By providing timely information on the dynamics, the outputs, progress, strengths and bottlenecks are made visible and managers and policy makers may be able to find the proper 'buttons' to influence the process. Assessing the developments, requires looking at indicators and their interaction. The interactions cause the dynamics in process and structure [The 'motors': Suurs, 2009] . Required policies will differ with the phase of development of the innovation process, but also with the point of view taken (e.g. is the focus on maximizing use of energy efficient technologies or on maximizing economic profits through production of new technologies? System requirements will generally differ with the focus).

Unlike most monitoring and evaluation efforts, that take a specific policy instrument or program as subject, the sensor approach primarily takes a comprehensive overall view. It

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[2] It should be noted though that in practice such processes are not linear and show feedback loops.

‘senses’ the developments indifferent of what government policy instrument supported them or what Ministry. It looks at the package of (supported) projects and activities as a whole and classifies each project or activity with regard to specific innovation systems or product groups, to innovation phase, to key functions, etc. This provides for a general picture that shows where the focus and trends lie with regard to product groups. It also gives an overview of the output of the package of governmental instruments[3]. By making an appropriate ‘selection,’ by taking a specific perspective, e.g. on a specific TIS or on a specific government program, a more focused picture can be provided. The information provides a first basis for more structural analysis of strengths, weaknesses, and trends in specific TIS.

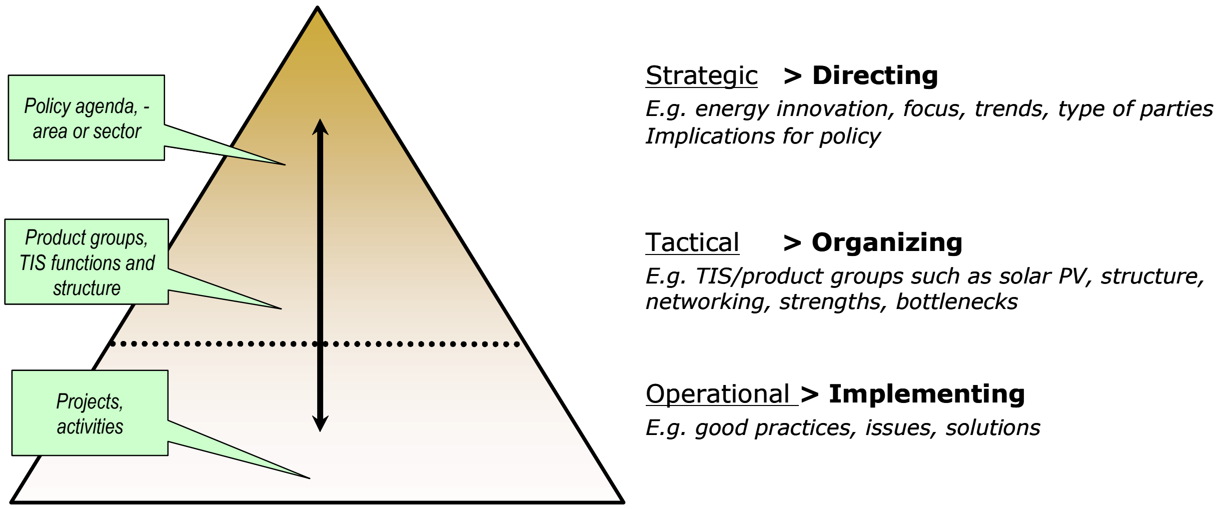

Figure 4: The sensor provides information at strategic, tactical, and operational levels for respectively e.g. managers/policy makers, stakeholders in a TIS and market parties [AgNL].

The interrelated structured information can be presented at three levels, for different target groups (**Figure 4**). Examples used for energy innovation in the Netherlands include[4]:

- Trends and developments in ‘energy innovation’ as a whole. This shows focus and progress in different themes and product groups, the growth of networks of parties that are involved in specific TIS, the shifts in type of parties, the possible bottlenecks in the process, etc. Policy makers are thus in a position to match this with their goals and take corrective action to influence the portfolio, when needed and possible. The next section shows examples of developments in some of the innovation functions for the energy innovation field as a whole.
- Trends in specific technical innovation systems, in its key functions and its structure, the progress towards next phases, the strengths and weaknesses, etc. This enables stake-holders to assess progress and possible next actions. An example is being worked out in another paper for IEPEC [Koch, 2012]. An important feature of the approach is also joint

[3] Since all projects and activities are also categorized according to the policy instruments they are supported by, also more policy instrument related reports can be made

[4] Some results of the approach have been used as an input for the development of energy innovation policies for the new government installed in 2010.

reflection on identified developments by stakeholders from market and government. This has been done for various TIS and enhances cooperation and a shared view on progress and tactics to move forward.

- Experiences and good practices in the projects at hand (what type of implementation issues are encountered? what practices may be replicated by others, etc.). This aspect relates to ‘learning effects’ and to making available know how to other market parties. This is not further dealt with in this paper.

Examples for some innovation system functions

This section gives illustrations of the approach with some examples of developments for energy innovation along some of the seven functions. The economic value of this sector (renewables and energy efficiency) is given more and more attention. This is among others reflected by the fact that Netherlands Statistics since 2011 provides specific statistical information on economic relevance of the ’sector’, using among others inputs from the ‘sensor’. The economic relevance of the sector in 2008 is illustrated in **Figure 5** [CBS, 2011] .

- employment: about.17300 person years (resp. about 11600 years)
- production: about 5160 million euro (resp. 3960 million euro)
- added value: 1710 million euro (resp. ca 1280 million euro)
- share of the sector in bbp: about 0.32 percent
- share in total production: 0.45 percent
- share in total employment: 0.25 percent

Figure 5: Economic parameters 2008 of the sector ‘renewable energy and energy efficiency’ (between brackets the data for renewable energy only) [CBS, 2011].

Added value and production per unit of employment were higher than for the economy as a whole. The employment is larger than in mining and oil industry. The most important thematic areas were in 2008: energy efficiency, wind energy, geothermal energy & heat, solar-PV, biomass/biogas. It is not easy to compare different sectors in these type of economic data, since some still are in an early stage of development and may grow, while others may be mature in market development.

Sectoral, technical innovation systems or..?

In looking at the process of ‘energy innovation’ as a whole, we did not attempt to scope it precisely as either a sectoral system, or a combination of TIS or otherwise. Rather, we use(d) a somewhat dynamic system scope, needed to cover sufficiently all relevant energy-innovation themes and shifting flexibly between type of systems. For electrical transport, for instance we also looked at elements outside the strict definition of an energy sector. System boundaries may also evolve in time: recently, increased interest in bio-based economy makes the boundaries shift further towards bio-based products outside immediate ‘bio-energy’ related applications.

The examples below stem largely from the energy transition and –innovation policy agenda of the previous government. This policy aimed at substantial innovations, supporting longer-term transition towards a more sustainable energy sector. Under this ‘agenda’ a series of programs and schemes were implemented along seven main themes: Green Raw Materials, New Gas, Sustainable Electricity Supply, Transport (Sustainable Mobility), Chain Efficiency, Built Environment and The Greenhouse As Energy Source. A wide range of possible transition pathways was made possible. The financial schemes supporting this agenda, consisted of general ones, not specifically oriented towards one of the seven themes, and more specific schemes. The sensor approach at the strategic level looked at the trends and focus for this agenda as a whole. Some examples:

Function 'entrepreneurial activities'. One of the functions relates to the role of entrepreneurs. They explore new products and technologies. An innovation system or process usually gains strength when more entrepreneurs invest in developing relevant knowledge and transferring this into commercially viable products. The Dutch energy innovation agenda over the last five years aimed among others at more valorization of innovative knowledge by bringing viable innovations more into the market. Extra funds were made available.

The sensor approach inventoried the various (types of) projects started in the relevant schemes. These were categorized in accordance to their position along the S-curve (ranging from more long term oriented research to market introduction with the first launching customers and niches). **Figure 6** shows the resulting profile of newly started subsidized projects in three consecutive periods of two years, a first indication of output.

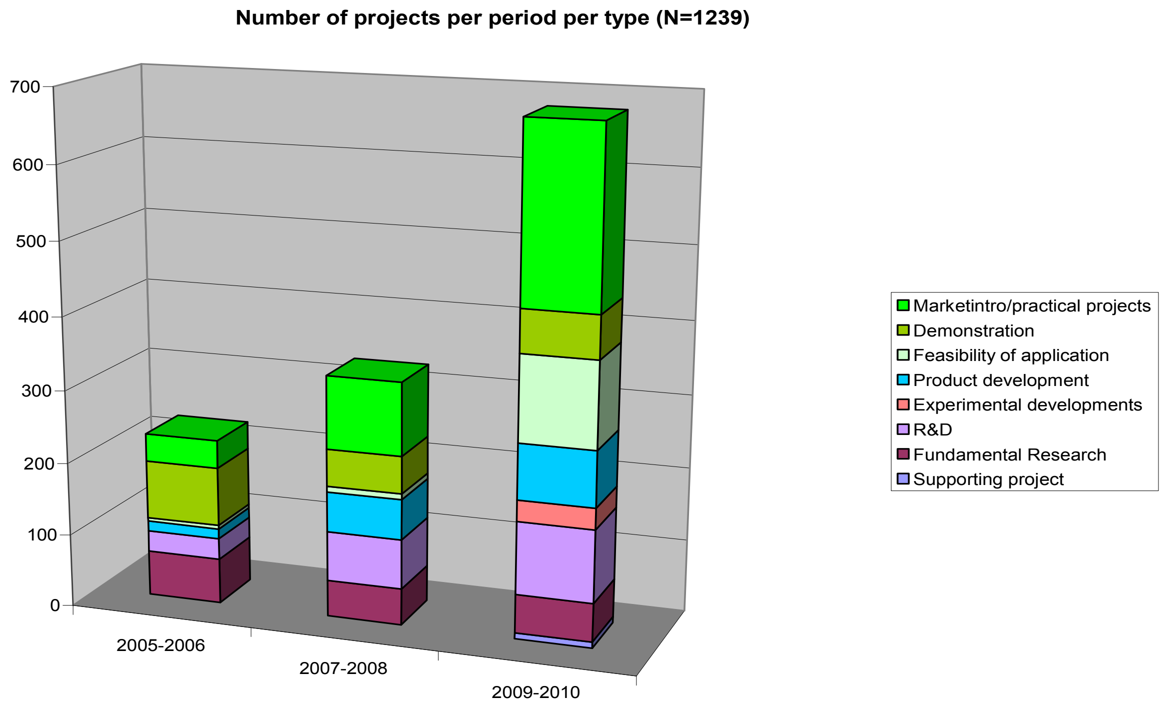

Figure 6. Number of newly started energy innovation projects per 2 year period and per type. Projects of types higher in the bars are further advanced along the S-curve.

Not only the number of new experiments per period increased, also it was clear that the increase mainly stems from projects 'close to the market',- as intended. Entrepreneurs, often working together with early customers, initiative such projects; while projects in earlier stages of the S-curve are more often related to R&D institutes.

Part of this effect is a direct result of the type of subsidy schemes. However, also the more general type of subsidy schemes remained in place, while it turned out that the additional schemes showed an even higher degree of 'over-subscriptions-/applications' than the general ones. For the investment cost in these projects (not shown in the picture), patterns are similar. Though no proof of additionality, these developments at least indicated that the market responded well and could absorb the extra possibilities. Since many of the technologies in question are still not economically viable on their own and/or involve significant uncertainties and market risks, it may be assumed that the subsidized projects constitute a representative and significant part of the 'whole' picture for many of the technologies.

We also note synergies and interrelations emerging between various innovative developments and TIS. An example (**Figure 7)** shows increasing links between various (sub)systems on green gas: from single projects, more cluster-wise projects grew (linked by parties and topics) in the field of CHP applications of co-digestion. Recently a further relation grows with use of biogas for transport and with feeding biogas into gas distribution systems (after upgrading the gas to standard gas quality).

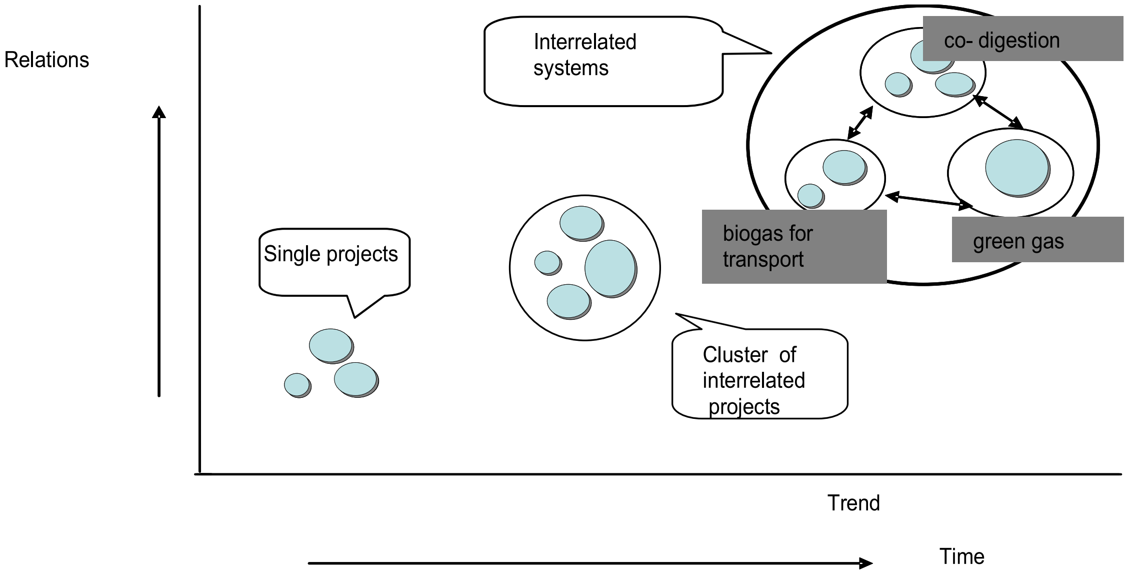

Figure 7. Technical innovation systems may show interrelations

Function: knowledge development. This function addresses questions such as: does the innovation process sufficiently succeed in providing for knowledge that is useful for entrepreneurs? Is it of proper quality for international competition? A first indicator for this is the number of patent applications in the relevant areas. **Figure 8** shows patent applications on energy in general (including more conventional energy technologies), the Netherlands (11th position for 1999-2008), performing somewhat less that in patent applications in general (8th position). For three areas (not shown in the figure) the Netherlands performs within top 10 positions: geothermal energy (10th), energy from biomass & waste (5th) and fuel cells (9th).

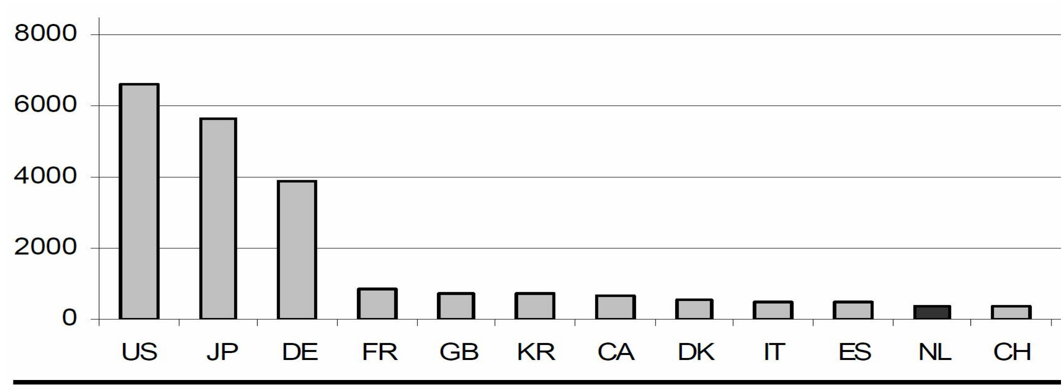

Figure 8. Number of patent applications for 'energy' sector, 1999-2008 [NL agency, 2011c]

A second indication on knowledge development in the energy innovation process is the focus taken in the projects. **Figure 9** shows the focus within the portfolio of energy innovation projects in terms of number of started projects in the considered period. Further trend analyses showed increasing numbers of projects on 'energy from biomass & waste', 'geothermal energy,' energy efficient building approaches,' and 'precision agricultural technologies',(sensing, precision fertilizing technologies, etc). This analysis shows similarities with relatively strong positions in patents, with exception of efficient building approaches. The latter may be less suitable for patents since this typically involves using a combination of different technological options.

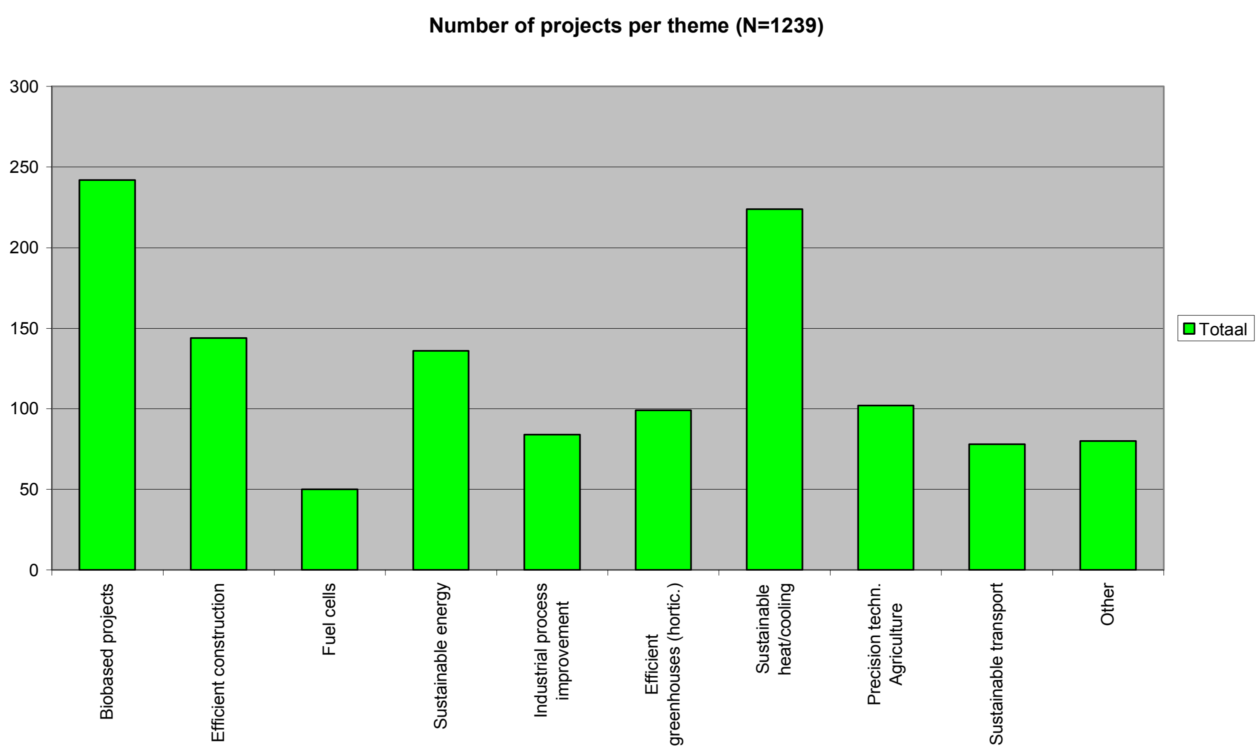

Figure 9. The focus in the projects [NL Agency, 2011d]

Function: Networking and knowledge diffusion. The way parties transfer knowledge relevant for their role, and form strategic coalitions to complement strengths and weaknesses in know-how and market positions is a third key function of innovation systems. In successful innovations one may generally expect a gradual shift in focus within networks from a relatively heavy role of R&D institutes in earlier phases, gradually to more innovative entrepreneurs working together with launching customers. When the innovative products show some success in the first market niches, successful larger scale take off usually shows development or involvement of market leaders, the new product gradually becoming 'a standard ' solution in the market.

Network analyses are part of the monitoring methodology, used to see whether the network may move into a next phase or extra actions are needed. These analyses are usually related to specific TIS. As a more general illustration of the relative shifts, **Figure 10** shows the developments in time with regard to type of parties that took the lead in applying for subsidy projects. For companies, herein a rough distinction is made between those that develop and/or market the innovative systems and those that act as launching customer. This is a very indicative approach since only the 'lead party' is taken along, while in most projects more parties participate.

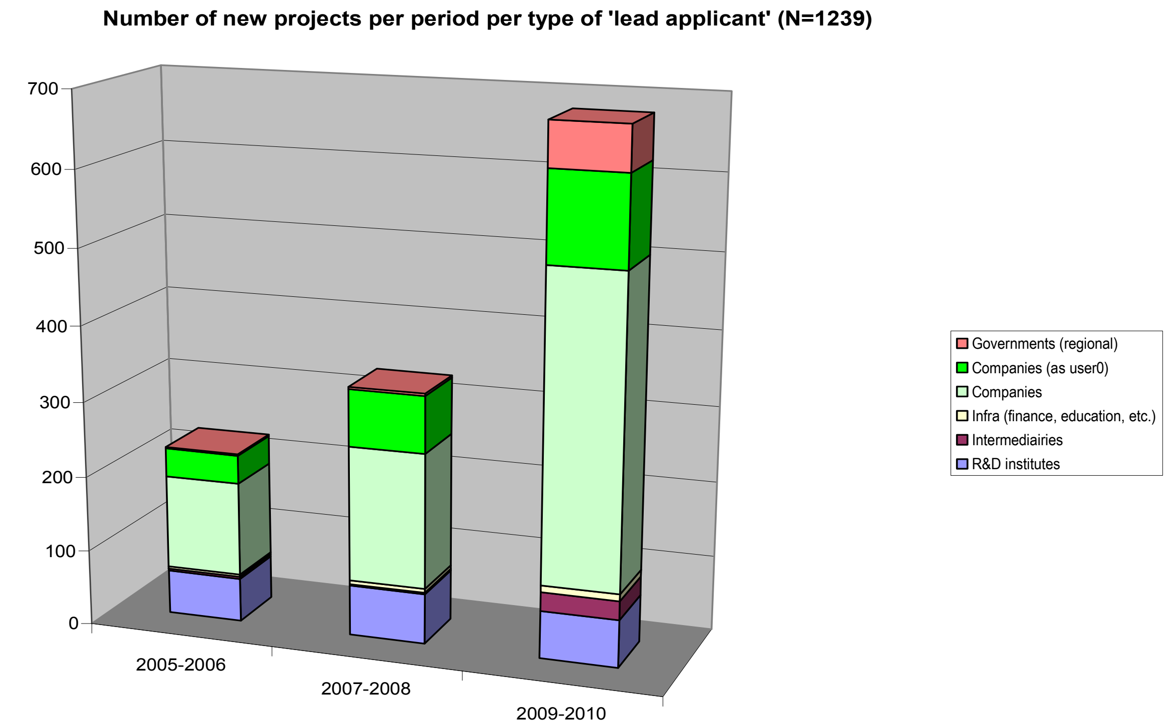

Figure 10. Number of newly started projects per type of lead applicant

This figure should be interpreted with extra care since it considers a full package of energy innovation systems, which differ in phase of development. Nevertheless, this full package with technologies in different stages of development again shows the growth especially related to businesses, again an indication of a relative more close-to-the-market character of the total package of projects over the last few years. This is further illustrated by the 'popping-up' of regional governments as launching customers notably in building related projects.

Again, these are merely illustrations of trends. More meaningful graphic pictures of developments in networks are performed, where the differences in phases of development are better appreciated and other participants are taken along. Analyses at TIS level may show e.g.

where parties are emerging more and more as central players in the networks. These may indicate the development of new business cases with the innovations.

Function: Market formation. Innovations usually have to flourish first in niche markets before breakthrough to main stream markets may occur. Such markets offer relative advantages for users and possibilities for further learning curve effects and cost reduction. From the energy project portfolio the sensor gives a first indication of whether such niches emerge and for what technologies. **Figure 11** shows the markets where the different projects are aimed at, distinguishing between projects that are still in development (R, green color) and projects close to or in the first markets (P).

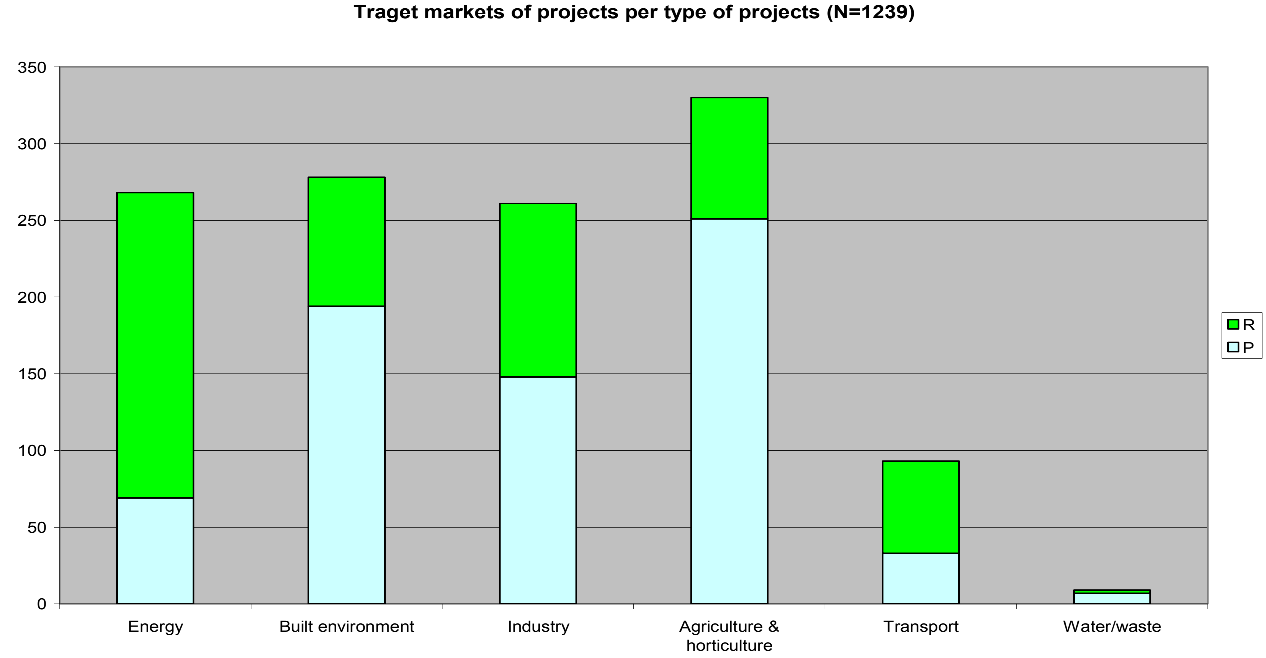

Figure 11: The target markets for the R&D (green) and closer-to-market (blue) projects

This may give a first indication where ‘close-to-market’ projects focus upon and whether these may grow into the ‘niches’. Following trends may be noted from this:

- Emergence of more projects (and launching customers) for electrical vehicles in city distribution applications and in pool/lease cars. This may be explained by its fit with the concentrated short distance transport (often in historical city centers with narrow streets)
- (Niche) markets for energy-efficient/semi-closed greenhouses in horticulture, although the recent economic crisis seems to hamper investment possibilities. The horticulture sector is a sector with rapid distribution of innovations, while energy cost constitute an important part of production cost
- A shift in market for co-digesters from stand alone situations for combined electricity and heat production towards biogas production for direct applications (e.g. transport) or for green gas supply systems (after upgrading gas quality) [see also Koch, 2012]
- For some market segments, R&D projects are seen in the portfolio, although systems are also in the market place. When zooming in on these projects, it was noted that such R&D is generally directed towards ‘next’ generation systems (e.g. solar PV).

Further indication of market developments in early markets may be obtained from the number of systems that make use of fiscal instruments such as the energy investment deduction scheme (EIA). This allows companies that buy relative innovative energy systems to use some tax deduction. **Figure 12** shows the top 10 applications indicated in this scheme for 2010. More than 1 billion € was indicated in 2010 as investments under this scheme. Increases were noted in wind energy, geothermal energy, solar PV and the use of CO2 in horticulture[5], -decreases in CHP and waste heat systems. In our approach we combine these data with data from other relevant schemes on renewable energy systems and sustainable heat systems (heat pumps, etc.). Taken together these provide a picture of trends in early markets over the years and thus insight into progress in the (market formation function of the) innovation process of the technologies in question. It helps to see what technologies show good progress or in which TIS this function is still weak, possibly needing reinforcement to help the TIS move into its next phase.

Top ten EIA-technologies 2010 (based on amount of investment)				
Position	Technologies	Reported investments (in million €)	% of total	# applications
1 (1)	Generic processes	211	18%	591
2 (5)	Energy performance existing housing (rental)*	189	16%	256
3 (2)	Heat pumps (buildings)	115	10%	1.639
4 (6)	Wind turbines	78	7%	147
5 (8)	Energy efficient cooling/freezing installations	71	6%	515
6 (42)	Transport for delivery gaseous CO2 to horticulture	53	5%	9
7 (12)	Solar PV systems	32	3%	760
8 (19)	Geothermal energy	27	2%	77
9 (17)	Recovery hot/cold air from ventilation	24	2%	486
10 (9)	Heat storage in aquifers	24	2%	68
Between brackets the position of 2009 is indicated.				
*Temporary extension of the EIA				

Figure 12: Top 10 systems in 2010 in energy investment reduction scheme (in terms of investments involved)[Agentschap NL, 2011b]

Conclusions and recommendations

The chosen approach enables us to follow and visualize developments and trends in innovation processes. It provides information at various levels of management, including the overall level of energy innovation and the level of specific TIS. The approach visualizes the dynamics, outputs, progress and trends in time in the innovation process. By showing that 'things are moving (forward)', it helps in appreciating the role and importance of innovation, its dynamics and the role of governmental (and other) policies herein.

It also gives insight into the role of policies in the innovation processes. It thus helps in assessing the developments, in managing or influencing the processes in a more timely, efficient and effective fashion. It also helps identifying among others changes in focus, the emergence (or not) of central players in innovation networks, and the strengths and weaknesses in key dimensions of innovation processes. It may be instrumental in

[5] and in energy performance of rental houses (this topic was a temporary addition to the list of applicable systems and is not further analysed)

identification of interrelations and possible synergies between various innovation systems and/or various policy instruments.

The tool is useful in cooperation between stakeholders e.g. in (joint) reflections. This enhances a good understanding of the process and a shared view on progress and the tactics to move forward.

This approach was implemented in the field of energy innovation, but is based on more general principles from business and innovation sciences. Thus, its basics may be used also in other areas.

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