Facilitating Sustainable Innovations: Sustainable Innovation as a Tool for Regional Development
Co-organized by The Greening of Industry Network,
The Cartesius Institute, and The Province of Fryslân
June 26-28, 2008, Leeuwarden, The Netherlands

The Emergence of Sustainable Innovations: Key Factors and Regional Support Structures

Peter S. Hofman & Theo J.N.M. de Bruijn

Center for Clean Technology and Environmental Policy (CSTM)
School of Management and Governance
University of Twente
The Netherlands
Tel: + 31 534894541 / Fax: + 31 534894850
Email: P.S.Hofman@utwente.nl /T.J.N.M.deBruijn@utwente.nl

ABSTRACT:

The paper analyses the emergence of sustainable innovations in a selected number of firms and addresses key explanatory factors that contribute to emergence and diffusion of the innovations. The focus is particularly on regional support structures that facilitated the innovation processes, and on gaps between the needs identified within firms's innovation processes and functions provided by support structures. Ten sustainable innovation processes are analysed to gain insight in the relationship between the nature of the innovation process, the type of needs for firms, and the type of functions provided in regional innovation systems. It is concluded that especially for SMEs demand articulation remains a major barrier as users are often only involved when the innovation is ready to enter the market, while regional support functions in this respect are deficient. Moreover, SMEs have major difficulty interpreting and anticipating sustainability policies and regulations at local and national levels, leading to innovations that face major regulatory barriers or are unable to cope with policy changes.

1. Introduction

Innovations are not created in isolation. In innovation processes, entrepreneurs, start-ups and established firms interact with various organizations in the process of generating ideas, building innovative prototypes and bringing innovations to the market. The capability of a firm to innovate is therefore not solely determined by internal factors, such as its strategy, culture and organization, but also by the nature a firm's interaction with external actors, such as knowledge institutes, government organizations, users and capital providers. These interactions are shaped to some extent by firms themselves, but also significantly by the nature of the innovation system in which they operate. Innovation systems give structure to the interactions of various organizations involved in innovative processes. The national systems of innovation approach emerged as an explanation for the fast rise of Japan as an industrial power (Freeman, 1987). Crucial for the success of Japan's economic growth has been the ability to organise, mobilise, and direct efforts of a range of actors such as industries, research institutes, educational organisations and financial institutes along strategic visions set out by government in interaction with research institutes and industries (Freeman, 1988). In the innovation system discussion, Lundvall stressed the importance of interactive learning, for example between users and producers (1988), and focused on elements such as trust (and the formal institutions behind it) and mechanisms of exchange of tacit knowledge (based on skills, experience, and routines) in innovation processes (1992, 2002). Next to national also regional innovation systems matter. Explanations of success of successful regions, industrial districts and regional clusters, focussed on the importance of interactive learning, key roles of processes of information dissemination and knowledge diffusion of local private and public organisations and roles of informal networks and social capital (Morgan, 1999; Dimitriadis et al. 2005). For sustainable innovation systems the importance of building some kind of collective vision is stressed, such as regions that develop an integrated sustainability vision and focus on developing sustainable solutions in particular areas of strength (Gerstlberger, 2004). A topic that will be adressed here is what regional support structures are needed to support sustainable innovations and to what extent these differ from regular regional innovation support. The approach in the paper will be to analyse a number of sustainable innovation processes and identify key needs for support. The analysis focuses on a number of key questions:

- What are the suppport needs of firms in sustainable innovation processes?
- How do these needs differ across types of firms and innovations, e.g. SMEs vs large firms, more incremental vs sustainable (radical) innovations?
- How effective are regional support actors in providing functions in sustainable innovation processes?

The paper starts with an overview of key functions that support actors may provide in regional innovation systems. A following section analyses a set of sustainable innovations to understand the need of firms for support and the way regional innovation systems were able to provide those needs. Around ten innovation processes analysed from a range of regions and for several SMEs and larger firms. A final section draws some conclusions.

2. Functions of regional innovations systems and support structures

With the advent of the systems of innovation approach the focus in regional development has increasingly shifted towards understanding the way processes of interactive learning can be stimulated through regional support structures. A range of actors have been identified that play a role in regional innovation systems, see figure 1. The key for successful regional innovation systems is to create effective linkages between the different groups in the system, represented by the black arrows in the figure.

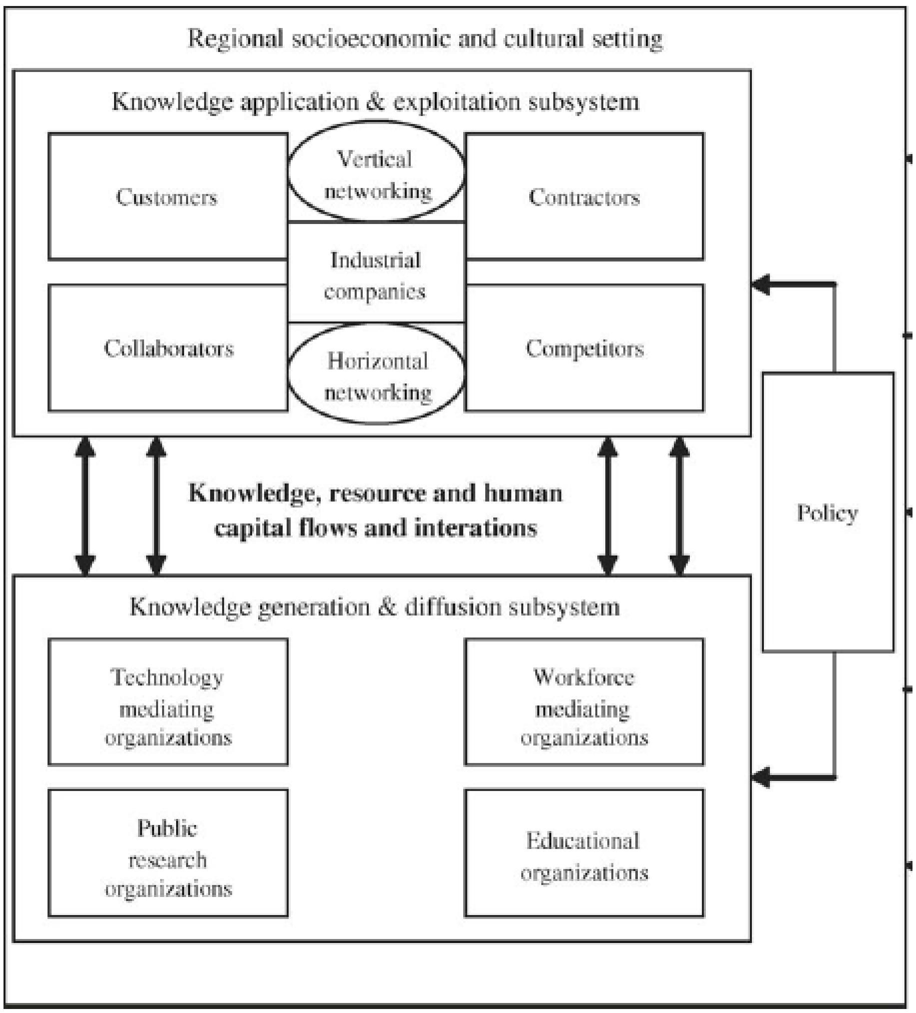

Figure 1 Regional innovation systems (Todtling & Trippl, 2005: 1205)

The industrial companies that aim to develop innovative products and bring them to market face several constraints in accessing resources, information and knowledge from other actors in the regional innovation system. Especially in the case of sustainable innovations, as they often divert more radically from existing patterns of production and consumption, various changes are required that go beyond the boundaries of firms, see table 1. Particularly SMEs face barriers ranging from more practical (lack of funds and time) to more strategic such as difficulty to access and appropriate information and knowledge, problems to generate market demand for their innovations, lack of insight in relevant regulations and polices, and lacking appropriate network partners.

Table 1 Radical innovation characteristics and type of changes required (Hofman, 2005: 48)

Innovation aspect	*Radical innovation characteristics*	*Type of change/actions required*
1) Company & technology specific aspects		
- design/embodiment of technology	offers new design, radical departure from past embodiment	find out what kind of design fits both technology and society
- production system/organisation	demands new system, procedures, organisation	gain experience with production techniques and organisation
- skills (labor, managerial, technical)	destroys value of existing expertise	re-train workforce, recruit new labor, built new expertise
- material/supplier relations	extensive material substitution; opening new relations with new vendors	search for reliable and cheap materials, find reliable suppliers
- capital equipment	extensive replacement of existing capital with new types of equipment	find, develop appropriate equipment and reliable equipment suppliers
- knowledge and experience base	establishes link to whole new scientific discipline, destroys value of existing knowledge base	tap and find new sources for type of knowledge required, built new knowledge base
2) Market and customer specific aspects		
- relationship with customer base	attracts extensive new customer group, creates new market	find out what the new market is for the innovation, what are appropriate niche markets
- customer applications	creates new set of applications, new set of customer needs	customise product to potential application and user preferences
- channels of distribution and service	requires new channels of distribution, new service, aftermarket support	modify and built up channels of distribution, service; develop competencies for maintenance
- customer knowledge	intensive new knowledge demand of customer, destroys value of customer experience	set up pilots to analyse user behaviour to product/technology, develop means for educating users
- modes of customer communication	Totally new modes of communication required	develop appropriate modes of communication

Intermediary organizations may provide various functions to overcome these barriers. Howells (2006: 720) identifies key functions such as:

- Foresight and diagnostics (e.g. technology roadmapping and needs articulation)
- Scanning and information processing
- Knowledge processing and combination/recombination
- Gatekeeping and brokering (combining knowledge of different partners)
- Testing and validation (early lab trials, pilots of innovations)
- Accreditation and standards (developing technical and industrial standards)
- Regulation (anticipating and influencing regulation)
- Protecting the results (intellectual property management)
- Commercialisation (finding lead users, marketing)
- Evaluation of outcomes (evaluation and improvement of product performance)

Smits and Kuhlmann (2004) formulate a number of function at the level of innovation systems: 1) management of interfaces; 2) providing platforms for learning and experimenting; 3) providing an infrastructure for strategic intelligence; 4) stimulating demand articulation, strategy and vision development. Existing policy instruments only fulfil part of the systemic functions, and further development of systemic instruments is called for. This especially includes strengthening of the intermediary infrastructure comprising of institutions, mechanisms and organisations aimed at improving the interface and exchange of knowledge between the supply side and demand side (Smits & Kuhlmann, 2004 : 16). Different types of of intermediary organisations have emerged in order to fulfill specific roles within innovation processes. These range from organisations that support knowledge diffusion and technology transfer to firms, organisations that provide bridges between different various actors and networks, organisations that support the search for funding, organisations that support project management, etc.

In an analysis of ten sustainable innovation processes we will assess what the type of needs of firms were, and whether they were appropriately matched by organisation providing the functions as proposed by Smits & Kuhlmann (2004) and Howells (2006).

3. Analysis of sustainable innovations

Ten sustainable innovations are analysed in detail to understand the support needs within the process and the support functions that were provided. It is based upon a range of projects in which the authors were involved (Bonnick et al, 2008; Ruud et al, 2007; Hofman, 2005, 2006). Table 2 gives descriptions of the innovations included in the analysis. The analysis will be done in three blocks: first three larger Dutch companies, then 2 Norwegian companies, then five SMEs in the North of Netherlands. The three questions posed in the introduction will be discussed in separate sections.

Table 2 Overview of the innovations included in the analysis

Innovation	Firm	Description
1. Biomass-fired electricity plant	Large energy company, Netherlands	The biomass power plant has several innovative features, with some of them of a more incremental and some a more radical nature. Generating electricity by combustion of wood is clearly a proven technology. The plant is considered as innovative, because of its capacity and its efficiency of about 30% in the production of 24 Mwe through high temperature and steam pressures. More radical however are the logistics for the biomass input - 250,000 tonnes of annual wood input from various sources - and the fact that the product is marketed as 'green electricity', exploiting consumer appeal for its green image.
2 Phosphate product from process water	Large dairy company, Netherlands	The innovation under study concerns the application of membrane technology for removing the relatively pure phosphate from the process water due to regulatory pressures. The innovation process covers a 15 years period of trial and error. The side product that is produced turns out to be valuable and is exported.
3. Waterbased inks for printing	Large printing company	By switching to waterbased inks, the printing company will be able to ban all VOC's from its production process. The innovation is incremental in the sense that it does not change the product and the way it is marketed. The innovation is radical in the sense that it does disrupt the existing technological relationships in the chain from supply to

		production to re-use of printed paper. In the product chain, the waterbased inks cause certain problems as the regular process of de-inking, necessary for the re-use of used paper, is frustrated by the use of this type of ink.
4. Wafer production for photovoltaic panels	Start-up firm, Norway	ScanWafer, which produces the multicrystalline wafers for solar panels, was the start-up company of what is today Renewable energy corporation (REC). Since the first production line for multicrystalline wafers was opened in Glomfjord in 1997, REC ScanWafer has evolved into one of the leading manufacturers of wafers in the world. The company has become a highly successful enterprise because it has emphasized process innovations that make economies of scale possible.
5. Heating and cooling with CO2 as medium	Small start-up company, spin-off from large energy firm, Norway	This innovation involves the development of heat exchangers with CO2 as a medium. It started in academic circles in Norway, where a professor in refrigeration engineering invented ways to effectively use carbon dioxide as a medium, triggered by the phasing out of CFCs as cooling medium in the Montreal protocol. The research was financially supported by Norsk Hydro who was interested in an application of the technology for air-conditioning systems in cars, mobile air conditioning (MAC). However, the first market application did not occur in cars but in households. Eco Cute, a small, neat and efficient water heater used the technology and a license agreement between Hydro and Denso on heat pumps for tap water in Japanese homes was signed
6. Worm reactor	Start-up firm (joint-venture entrepreneur and water board) North Netherlands	A worm reactor can reduce sludge in water treatment plants by an estimated 50%. The entrepreneur developed up the idea from bio membrane projects at research institutes. Lab tests and pilot tests at a water board have taken place, key ideas are patented (reactor and worm specifics). Further testing at market scale is taking place to facilitate use by other water boards.
7. Electric bicycle	Small entrepreneurial network, North Netherlands	Drymer is a roofed, three-wheeled human-powered vehicle with an electric engine that doubles human pedaling power. It is expected to provide a mobility alternative to the car for small and medium distances.
8. Membrane reactor for wastewater	SME engineering firm, North Netherlands	The membrane reactor system is a small compact unit for waste water treatment and the water after treatment can be directly used in the household or other areas.
9. Pure plant oil as fuels	Small enterprise, North Netherlands	Pure plant oil (PPO) is derived from rapeseed for use as alternative fuel for vehicles. The project involves rapeseed farming, extraction, and conversion of vehicle engines to run on PPO. The project started in 2002 and has converted several hundred vehicles to run on PPO, but is now on indefinite status following changes in Dutch policy governing biofuels.
10. Virtual homecare	Small telecom firm, North Netherlands	The visual Care at Home is a public private partnership set by a small telecom firm in collaboration with the local health care organization, which serves approximately 50.000 people in Friesland by visiting them at their homes and providing assistance. The project is focused on e-health and its scope is to provide an alternative digital service to the traditional health care service by using audio-visual and IP technology.

3.1 What are the suppport needs of firms in sustainable innovation processes?

An overview of the role of support actors in the innovation processes is provided in table 3. We first look at the three larger firms involved in sustainable innovation in the Netherlands (cases 1-3). For all three cases the innovating firms were able to tap knowledge from actors outside the firm and established effective networks for technology development. For cases 1-2 interactions with regional regulatory bodies played an important part in the innovative processes and the firms successfully negotiated leeway to move the innovations forward. For case 3 the technology network was highly international with firms along its supply chain. Further diffusion of the innovation was however hampered by the resistance within the paper recycling chain and by lack of demand. Company case 4 was rather successful to move from start-up to major player in the solar energy market. It was able to take over existing facilities and skilled workers and was supported by local and regional agencies. The company has been able to establish itself and become successful based on a strong knowledge network related to technologies. Further it has created a strong market network related to the various steps of manufacturing of silicon to multi-crystalline wafers for solar cells, modules and panels, enabled by the personal experiences, capacities, and networks of the founder of ScanWafer, Alf Bjorseth. Case 5 reflects international negotiations on technologies to mitigate climate change. With regard to the mobile air conditioning (MAC) application in cars the innovative process has mainly involved positioning of the technology through the formation of alliances and networks, and through positioning the technology as a realistic option for greenhouse gas abatement and CFC and HFC phasing out, with specific focus as CO_2 technology as an alternative for HFC-134a technology in MAC. An important factor in the process was the formation of an EC-directive involving sharpened emission standards for MAC. A ban on HFC-134a is proposed by the EC directive for new cars by 2017, and a ban on new car models with HFC-134a by 2011, with a phasing out process before that. This implies that the prospects for alternative concepts for mobile air conditioning, such as CO_2 based technology are promising. To reach the situation where CO_2 technology was considered as a serious option, a development period of around 15 years took place. In this period Norsk Hydro significantly invested in R&D to improve the concept, developed networks with various R&D centres and car makers, and collaborated in various research projects funded by industry and governments. The innovation process itself has been one of manoeuvring to create the right network partners and conditions, and to prevent other parties from hijacking the principles under the concept. Moreover it has been a highly politicized process, with the regulatory focus on global warming potential of various cooling media as one of the main issues (Ruud et al, 2007; Hofman, 2006).

Cases 6-10 all involve SMEs involved in sustainable innovations in the North of the Netherlands. The innovative process for case 6 has involved moving from the laboratory tests to pilots to market introduction and involved constant user-producer interaction as water boards offered their facilities. The entrepreneur received some subsidies but had difficulty obtaining capital from financial institutions. Also protecting intellectual property rights was problematic as the entrepreneur was interested to collaborate with a research institute but was hesitant to share the key ideas. Case 7 was relatively successful in building a working prototype, under project management of a technology center. The technology center pulled out of the project in the phase of market introduction, and the companies involved failed to find lead users for the product. The innovative process is characterized by a large number of actors collaborating (8 SMEs, several knowledge centers, receiving funding at regional, national and international level), but lacks a dedicated and committed leading company. The innovation in case 8 moved from idea to market introduction through close collaboration of the firm with water boards. Also a knowledge institute was involved with regard to testing. The product is intended for decentralized water treatment and main market opportunities exist in Eastern Europe. Demand has been stagnating because potential users lack funds, and because policies shifted from favouring decentralized systems to more large-scale centralized wastewater treatment systems. The innovation in case 9 was significantly triggered by national biofuel policies and the 2003 EU directive on biofuels. The company was able to built a network facilitated by local support and national fiscal incentives. The firms' main problem was to create stable financial conditions. Tax exemption was withdrawn as the firm had to source part of its plant oil from foreign sources. The firm had difficulty obtaining credit from commercial banks, and lacked a proper marketing strategy. In case 10 the innovating firm started the project as it saw the potential of e-health schemes and was supported by regional and national public funds. After an initial successful pilot project the firm has difficulty bringing the services further into the market as financial support was discontinued and it faced competition whereas it had earlier assumed it occupied a monopoly position.

Table 3 The role of regional support actors in the innovation processes

Innovation	Role of regional support structures
Biomass-fired electricity plant	In the implementation of the innovation the company clearly had to overcome several impediments related to the discussion on the character of the input (waste or biofuel), the actual various sources for the biomass, the emission standards, and the energetic efficiency of the power plant. The company was able to progress through various rounds of discussions and negotiations because it is a relatively powerful player in the Dutch electricity sector and has good established contacts both at the provincial and national level.
Phosphate product from process water	The network configuration for this case was initially a policy oriented network, constituted by the case company, its two subsidiaries, and the legal authorities for these subsidiaries, a regional waterboard and a national water directorate. The interplay between the case company and the waterboard lead to a search for a technical solution for the phosphate emissions problem. As a result the network was enlarged with several R&D organisations, which caused a shift towards a R&D oriented network. A crucial fact has been that the waterboard didn't urge for a quick solution, the application of end-of-pipe technology, but in stead has encourage the company to search for a process integrated solution. There was also a personal factor involved, the particular officer who offered the company this leeway. The network has been an important factor, although it concerned an ad hoc network, that has developed around the specific innovation process, and that was not likely to remain afterwards. As a result the company was able to transform the phosphate rich waste water stream into a valuable side-product.
Waterbased inks for printing	The network configuration in this case was predominantly R&D oriented. The firm had contacts with consultancies and R&D organisations with involvement of producers of inks, paper and printing machinery. Notably the inks producer has made a substantial effort for the innovation project also based on the long relationship it already had with the printing firm. Policy makers and legal authorities played a background role. Apart from the company's standing relationships with the inks and paper producers, it concerned an ad-hoc production chain oriented network, that emerged while the innovation project was performed. This network was also highly international due to the role of the producers of equipment, paper and inks, all foreign companies.

Wafer production for photovoltaic panels (Ruud et al, 2007)	The collaboration between SND (the Norwegian Industrial and Regional Development Fund) and the DnB Bank in northern Norway was an important factor during the initial phase. With sales contracts in place, SND agreed to cover 25 per cent of the total investment. This opened the way for additional large-scale private investors, enabling an expansion in the Glomfjord operation. The Dutch venture capital firm Good Energies also contributed financially to the establishment in Herøya. Public subsidy programmes for solar energy abroad – particularly in Japan and Germany – combined with the regional-local potential of taking over existing facilities and highly suitable workforces, laid the foundation for REC ScanWafers success. Public bodies within Norway had relatively little impact on developments during the initial stages. However, once sales contracts were signed the Norwegian authorities then provided (through the SND) significant financial support for the transition in function and ownership at the previous Norsk Hydro site in Glomfjord.
Heating and cooling with CO2 as medium (Ruud et al 2007)	Key actors were to be found within the constellation of internal Hydro employees and research institute SINTEF/NTNU. The technology itself is based on research undertaken by Gustav Lorentzen, but it was Norsk Hydro that initiated the specific R&D activities enabling worldwide patenting. Other R&D initiatives funded by the EU have strengthened the commercial efforts, but it is acknowledged that stronger regulatory standards are needed for further dissemination. Lower levels of GHG emissions than those established by the EU MAC Directive are necessary to realize even more environmentally sound Shecco-based MAC solutions. Governmental authorities have not been actively involved in either Norway or the USA to promote the introduction of Shecco Technology. The innovation process itself has been one of manoeuvring to create the right network partners and conditions, and to prevent other parties from hijacking the principles under the concept. Moreover it has been a highly politicized process, with the regulatory focus on global warming potential of various cooling media as one of the main issues.
Worm reactor (Bonnick et al 2008)	The potential for sludge reduction by the worms was coincidentally discovered in a biomembrane reactor project in a money meets ideas programme that links entrepreneurs to investors. Close relations with potential users (water boards) facilitated further development. Further funding was obtained by the applied research organization for water management.
Electric bicycle (Bonnick et al 2008)	The project is a follow-up of an earlier project where a prototype was developed called MITKA under the lead of the research institute TNO. An improved concept Drymer was developed by a regional technology center in collaboration with several firms, for the phase of market introduction a number of firms organized their own entrepreneurial network but had difficulty in establishing initial markets for the product.
Membrane reactor for water treatment (Bonnick et al 2008)	Through the Fryslan Water Alliance, the firm found some actors they can partner with for developing the product. The Friesland government provided subsidy for developing the product, while the water board effectively operated as matchmaker between the firm and the University of Twente to allow for research and testing facilities. A demonstration project was organized in collaboration with a municipality, province and the water board.
Pure plant oil as fuels (Bonnick et al 2008)	The firm was able to organize a network with a company for oil extraction, an union of rapeseed farmers, and a network of vehicle dealerships with engineers trained in engine conversion technology. Local government was supportive and helped to obtain first customers, national duty exemptions were granted but later withdrawn. The company had difficulty obtaining funds to develop the innovation.
Virtual homecare (Bonnick et al 2008)	The initial pilot project was financed by the province, and initial users are satisfied with the project. The firm has difficulty to move from pilot to market introduction as the subsidy is not continued. Initially the company expected to have a monopoly for this type of service in the region, later it became clear that other organization could also deliver the services.

3.2 How do these needs differ across types of firms and innovations, e.g. SMEs vs large firms, more incremental vs sustainable (radical) innovations?

The cases show a big divide between needs for regional support for SMEs and larger firms. Large, well established firms are better able to organise the innovative process and its networks. If specific needs for regional support occur they are often well place to gain access with regional partners and to negotiated with regional government bodies. The picture is much bleaker for SMEs. These generally have difficulty in getting access to finance, are faced with policy and policy shifts they feel they can not influence, and especially have difficulty in targeting and developing a market for their innovation. Especially for more radical innovations (e.g. pure plant oil, cooling with CO2 as medium, electric bicycle) key problems are related to the regulatory environment as often policy changes need to facilitate the innovation, and the development of new markets for their innovation. Effective regional support structures and intermediary organisations therefore can play a crucial role in facilitating SMEs in their innovative process.

3.3 How effective are regional support actors in providing functions in sustainable innovation processes?

Table 4 takes into account the various functions provided by intermediary organizations as proposed by Howells (2006) and assesses whether these were provided for the different innovations.

Table 4 Assessment of provision of functions (case number in brackets, ih = in house provided)

Need/Function	Needed & provided	Needed not provided
Foresight and diagnostics (e.g. technology roadmapping and needs articulation)	(1, ih)	(3) (5) (7) (9)
Scanning and information processing	(1, ih) (2)	
Knowledge processing and combination/recombination	(1, ih) (2, ih) (3, ih) (4, ih) (5, ih)	
Gatekeeping and brokering (combining knowledge of different partners)	(1, ih)	(6)
Testing and validation (early lab trials, pilots of innovations)	(6) (8) (10)	
Accreditation and standards (developing technical and industrial standards)	(5)	(9) (10)
Regulation (anticipating and influencing regulation)	(1) (2)	(3) (5) (10)
Protecting the results (intellectual property management)	(4, ih) (5, ih)	(6)
Commercialisation (finding lead users, marketing)		(7) (8) (10)
Evaluation of outcomes (evaluation and improvement of product performance)		

The table indicates that especially larger firms were able to have their needs fulfilled, either as functions were provided in house or as support actors provided them. For SMEs key functions that they need are not provided by support structures whereas they do not possess the capability to deliver them in-house. Key support structure elements that need further development are better articulation of needs and commercialization strategies. Many SMEs also have difficulty with interpreting and anticipating regulations and policy developments and are caught off guard as regulatory circumstances change (often in their disadvantage). If we look at the more broader systems innovation functions proposed by Smits and Kuhlmann (2004), we conclude in table 5 that especially for the areas of demand articulation, policy anticipation, market intelligence, strategy and vision development the five SMEs in the region of the North of the Netherlands could benefit from effective expansion of these functions in the regional innovation system.

Table 5 Functions of regional innovation systems

Regional innovation system function	
1) management of interfaces	More effective interfaces between policy and the market could allow SMEs to finetune their innovative processes with anticipated and/or uncertain policy developments.
2) providing platforms for learning and experimenting	User-producer interaction is often a crucial part in sustainable innovation. Especially in areas where certain technology clusters are missing, these platforms could support SMEs
3) providing an infrastructure for strategic intelligence	Strategic information (market development, policy development) is crucial for SMEs but goes beyond their capacity. Regional support could play a key role as provider.
4) stimulating demand articulation, strategy and vision development	Sustainable innovations often derive their potential from a connection to a sustainability vision. The cases illustrate that demand articulation and connection to regional visions is often deficient

.

4. Discussion and conclusions

The paper analyses the emergence of sustainable innovations in a selected number of firms and addresses key explanatory factors that contribute to emergence and diffusion of the innovations. The focus is particularly on regional support structures that facilitated the innovation processes, and on gaps between the needs identified within firms's innovation processes and functions provided by support structures. Ten sustainable innovation processes are analysed to gain insight in the relationship between the nature of the innovation process, the type of needs for firms, and the type of functions provided in regional innovation systems. It is concluded that especially for SMEs demand articulation remains a major barrier as users are often only involved when the innovation is ready to enter the market, while regional support functions in this respect are deficient. Moreover, SMEs have major difficulty interpreting and anticipating sustainability policies and regulations at local and national levels, leading to innovations that face major regulatory barriers or are unable to cope with policy changes. Key functions that could more effectively build regional support systems are therefore the stimulation of demand articulation and vision development, organizations that can provide strategic intelligence that SMEs can not obtain in house, and interfaces between policy and business that allow firms to better cope with policy uncertainty and anticipate policy developments.

References

Bonnick, A., D. Mora, N. Quiblat, D. Jiang, G. Zheng (2008) *Sustainable Innovation and the Role of Regional Actors*, Report prepared for the MSc of Energy and Environmental Management, CSTM-University of Twente, Leeuwarden.

Dimitriadis, N., M. Simpson, A. Andronikidis (2005) Knowledge diffusion in localized economies of SMEs: the role of local supporting organizations, *Environment and Planning C*, 23: 799-814.

Freeman, C. (1987) *Technology Policy and Economic Performance: Lessons from Japan*, Pinter, London.

Freeman, C. (1988) Japan: a new national system of innovation? in Dosi, G. et al. *Technical Change and Economic Theory*, Pinter, London: 330-348.

Gerstlberger, W. (2004) Regional innovation systems and sustainability, selected examples of international discussion, *Technovation*, 24:749-758.

Hartman, C.L., P.S. Hofman, and E.R. Stafford (2002) Environmental Collaboration: Potential and Limits, in: De Bruijn, T.J.N.M. and A. Tukker, *Partnership and Leadership – Building Alliances for a Sustainable Future*, Kluwer Academic Publishers, Dordrecht: 21-40.

Hofman, P.S. (2005) *Innovation and Institutional Change, the Transition to a Sustainable Electricity System*, dissertation, University of Twente, Enschede.

Hofman, Peter S. (2006) *Scenarios for Industrial Transformation: Perspectives on the CondEcol Case Studies.* ProSus Report no. 4/06, ProSus, University of Oslo.

Howells, J. (2006) Intermediation and the role of intermediaries in innovation, *Research Policy*, 35: 715-728.

Klerkx, L. and C. Leeuwis (2008) Balancing multiple interests: Embedding innovation intermediation in the agricultural knowledge infrastructure, *Technovation*, 28, 6: 364-378.

Lundvall, B-A. (1988) Innovation as an Interactive Process, in: Dosi, G. et al (1988) *Technical Change and Economic Theory*, Pinter, London.

Lundvall, B-A. (ed.) (1992) *National systems of innovation, Towards a Theory of Innovation and Interactive Learning*, Pinter, London.

Lundvall, B-A., B. Johnson, E.S. Andersen, B. Dalum (2002) National systems of production, innovation and competence building, *Research Policy* 31: 213-231.

Ruud, A., W.M. Lafferty, R. Marstrander, O. Mosvold Larsen (2007) *Exploring the conditions for adapting existing techno-industrial processes to ecological premises: A summary of the CondEcol project*, ProSus report 2007/1, University of Oslo.

Smits, R. and S. Kuhlmann (2004) The rise of systemic instruments in innovation policy, *International Journal of Foresight and Innovation Policy*, 1 1/2: 4 -32.

Todtling, F., M. Trippl (2005) One size fits all? Towards a differentiated regional innovation policy approach, *Research Policy*, 34: 1203-1219.

Visser, R., M. Jongen, G. Zwetsloot (2008) Business-driven innovation towards more sustainable chemical products, *Journal of Cleaner Production*.