WHEN TECHNOLOGICAL INNOVATION IS NOT ENOUGH

UNDERSTANDING THE TAKE UP OF ADVANCED ENERGY TECHNOLOGY

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Foreword

This *Quaderno* of the Dipartimento di Sociologia e Ricerca Sociale is aimed at presenting some reflections on the social, economic and technological forces and circumstances that encourage or discourage the take-up of advanced energy-efficient technologies within manufacturing processes in European enterprises. Its background lays in a wider research project conducted in the years 1995-1998 called SORGET, which involved four European countries.

On the basis of extended fieldwork carried out using both qualitative and quantitative methodologies, it was discovered that no single factor or limited group of factors has a simple determining role in shaping the take-up of energy-efficient technologies. Take-up occurs as a consequence of the complex interaction of a wide variety of social, economic, organisational and technological developments.

The study found that the extent to which consideration of energy issues is explicit, and how it is linked to wider corporate objectives, can be understood in terms of a firm, at any point in time, exhibiting what amounts to a "corporate stance" on energy matters. This is a way of thinking and acting about energy matters, negotiated between people and demonstrated in their daily behaviour. The crucial differences between organisations lie in the extent to which their corporate energy stances are proactive and global as opposed to reactive and local.

The data, on which the present reflections are based, were produced within SORGET (Social and Organisational Issues in The Adoption of Advanced Energy Technologies), a transnational research effort partially funded by the European Commission within the Joule Thermie Programme. The SORGET project was coordinated by Richard Holti (The Tavistock Institute) and three European partners: Silvia Gherardi (University of Trento), Peter Plougmann (The Danish Technological Institute) and Peter Groenewegen

(Free University of Amsterdam). We are indebt with our collegues for the generous contribution profused in their national reports and in the final report to the European Commission, nevertheless the final responsibility for the considerations reported in the Quaderno is on the authors.
We wish to thank all the collegues which took part in the development of the national reports and acknowledge the role of AROC (Associazione per la Ricerca sulle Organizzazioni Complesse) in supporting the Italian team (formed by Davide Nicolini and Bruno Bolognini).
We are also indebt to the Advisory Panel of European experts in energy technologies formed by: Niels O Gram, Energy Manager, Confederation of Danish Industries; Nigel Pratten, Manager, Energy Efficiency Department, Energy Technology Support Unit (ETSU), UK; F van Nielen, Managing Director MINT (Market Focused Intersectoral Technologies), NOVEM, Netherlands; W M van Rijnsoever, Managing Director MPI (Environmental Plan Industry), Gasunie, Netherlands, David White, David J White Associates, UK, and Piergiulio Avanzini, CNR, Italy.

[1] The names of the authors appear in alphabetic order and Silvia Gherardi wrote sections 1-5, Richard Holti wrote section 7 and Davide Nicolini wrote section 6 and 8.

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1. INTRODUCTION

Since the first "energy crisis" of the post-war period, in the early 1970s, a considerable amount of public and industrial funding has been sunk into the development of technologies for producing more energy efficient machinery, as well as renewable energy sources, with a view to reducing energy consumption per unit of industrial output.

Although the picture is uneven across the European Union, there is increased public and governmental concern about industrial energy consumption and in particular its link to carbon dioxide (CO_2) emissions. A number of European member states have introduced schemes to encourage enterprises to find ways of reducing energy consumption and emissions. Examples include the programmes of support for energy savings within enterprises and for the use of renewable resources within industry managed by the Danish Energy Agency and by NOVEM in the Netherlands.

The main aim of the SORGET study, was to develop a better understanding of decision making about the implementation of advanced energy technologies, so that industrial interest in achieving lower cost production can be channelled more effectively into a more environmentally sustainable mode of operation.

The project concerned the forces that encourage or discourage the effective take-up of advanced energy-efficient technologies within manufacturing processes. The project employed social science perspectives to understand the social and economic forces and organisational processes which encourage or discourage decisions within industrial companies to adopt these technologies. It examined the organisational processes that affect the course of implementation of advanced energy technologies and investigates the consequences for the effectiveness of these technologies in use. The findings of the research work allowed the drawing out of implications for regional, national and European Union policies intended to encourage rational use of energy within industry. On the basis of the understanding of non-technological barriers and incentives affecting industrial take-up of energy technologies the project offers a contribution to devise effective public policies and initiatives that can help industry to increase the take up of energy efficient technologies.

The present *Quaderno* is not at attempt to summarize the whole SORGET project, rather it is aimed at conducting some "post hoc" reflections after the study was completed and some authors had the luxury to seat and discuss the research experience without the pressure of meeting the deadlines.

The *Quaderno* begins by summarising some of the main concepts used in the literature to make sense of technological innovation and take up. After discussing the similarities and differences in the national contexts influencing the level and conditions of take-up of advanced energy technologies (AETs), we introduce the overall research design and methodology and the framework description of what AET stands for used in the research.

Next, the paper focuses on the results of the case studies carried out in each of the participating countries. It is argued that the key factor underlying the pattern of take-up (or non take-up) of particular energy efficient technologies or measures within a firm can be understood as a *scope of consideration***.** This amounts to a set of organisational routines which at any point in time effectively prescribes the range of energy-related technologies or measures to be considered for adoption. Technologies may not be adopted because they are formally investigated and then rejected, for example because the pay-back period for a return on investment capital is too large. However, technologies may also simply not be considered because they lie outside the scope of consideration, usually because their implications in terms of disrupting established production technologies and ways of operating make them too risky to be given formal consideration. The key to understanding take-up of energy technologies is not so much rational decision-making criteria as how decision horizons are shaped. The report examines the factors affecting the scope of consideration as well as the way in which it is shaped.

Finally, we derive some broad reflections to indicate some policy actions which are useful to encourage the take-up of advanced Energy technologies in manufacturing.

2. FRAMEWORKS FOR UNDERSTANDING INNOVATION IN ENERGY TECHNOLOGY

Systematic study of the diffusion of innovations originated in American rural sociology of the 1940s and its endeavour to understand and promote the adoption of new crop hybrids by Midwestern farmers (Ryan and Gross, 1943; Crane, 1972). The concepts then developed were soon adopted by other disciplines, like education, marketing and mass communication, until a sound tradition of research had been established.

According to Everett Rogers, studies based on the diffusion approach share the idea that "Diffusion is the process by which an innovation is communicated through certain channels over time among members of a social system." (1995, p. 5). The approach includes two main variants. The first has been inspired by Gabriele Tarde's studies on social imitation and views diffusion as a process of communication and influence among individuals: potential users come to know about innovations through individuals who have already adopted them, and are persuaded to follow their example by communicative processes. A second variant, closely tied to the former one, conceives diffusion as a mainly economic process based on costs/benefits calculations by potential users: the greater the cost and the risk, the slower the diffusion of the innovation will be; the higher the expected profit, the more rapidly the innovation will spread (Mansfield, 1968; Attewell, 1992; Rogers, 1995).

The majority of the studies that employ the diffusion model seek to explain why innovations diffuse slowly at the beginning, then grow suddenly and rapidly, and finally decline – a pattern represented by the S-shaped curve (Ryan and Gross, 1943; Brown, 1981) shown in Figure 1.

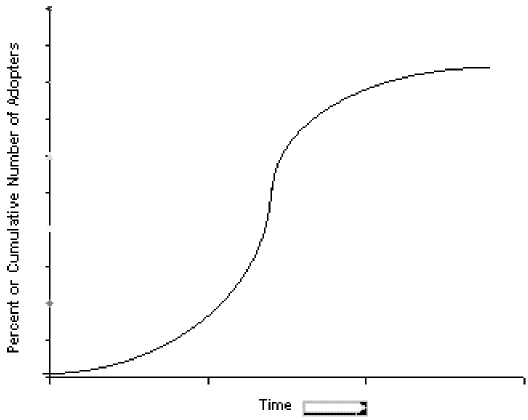


Figure 1 Curve representing the diffusion dynamic

The traditional approach explains this phenomenon as resulting from the combination of various factors: the properties of the innovation (perceived advantage, compatibility, complexity, testability), modes of communication in the social system, the characteristics of the subjects involved (whether they are innovators, followers, traditionalists, etc.) and their role in the social structure (opinion leaders), and decision processes (Rogers, 1995).
Although the diffusion approach derives from study of the adoption of innovations by individuals, and although it is based on a model of rational decision-making, it has been extended without substantial modifications to analysis of innovation in organizations (Czepiel, 1975; Rogers and Arwala-Rogers, 1976). In this case organizations are equated to supra-individual entities – in line with the traditional functionalist approach – and they are studied by applying the conceptual apparatus developed for analysis of diffusion processes in social systems. Researchers initially concentrated on drawing up typologies of forms of organizational innovativeness and on describing the structural factors that determine the diverse behaviours of organizations *vis-à-vis* innovation. Only in the early 1970s did they begin to interest themselves not only in the dynamics of populations of organizations but also in diffusion processes within organizations (Zaltman et al., 1973).
For a long period of time, the theory of diffusion constituted "normal science" (Kuhn, 1970) in the study of innovation. In the last two decades, however, a rising tide of criticism has bee directed at its basic assumptions.

It has been pointed out that, because the approach equates adoption with a learning or communication process, it emphasises the *demand* dimension, while at the same assuming that all potential users have equal access to the innovation (Brown, 1981). However, this was to neglect the role of supply and its effects on the circulation of the innovation. Every innovation is promoted by organizations and institutions, which concentrate on specific sectors in their promotional activity, so that the notion of equal access is a theoretical fiction (Brown, 1981; Attweell, 1992).
Secondly, it has been pointed out that the theory does not take account of institutional and cultural factors (local regulations, historical constraints and precedents, practices) which may encourage or discourage adoption of the innovation. Some authors have noted that this criticism also applies to the economic version of the theory, which, although it considers both demand and supply, usually ignores any institutional factor and non-monetary barrier (Granovetter, 1982, 1985; Cool et al., 1997). This criticism is echoed by scholars of the 'evolutionary theory of firms', who base their approach on the untenability of the neo-classical assumption implicit in the theory of diffusion that there is an omniscient actor who seeks to maximize profit in the presence of uncertainty (Nelson and Winter, 1982; Dosi, 1988).
Finally, it has been observed that the approach is based on the evidently positivist assumption that every innovation constitutes 'progress', so that all those who become aware of an innovation will be induced to adopt it and to diffuse it in their turn. If an innovation fails to spread, therefore, this is due to ignorance or misunderstanding of its benefits – and these will be sooner or later be eliminated by the processes of persuasion studied by the theory (Rogers, 1995). Here the theory clearly displays its functionalist and rationalist imprint and a cleverly concealed circularity: the diffusion approach presupposes a positive attitude towards progress and innovation which it then sets out to explain.
Criticisms have also been brought against the theory's application in organizational analysis, and in particular against the individualist and mechanistic nature of the diffusion model. The construction of typologies of organizations according to their propensity to innovate obscures rather than sheds light on the phenomenon. Notions like that of 'early adopter' applied to organizations give rise to an anthropomorphism which hampers rather than helps empirical research. The theory of diffusion does not make clear who is entitled to speak on behalf of an organization, and it does not

explain to what extent it is possible to regard organizations as perfectly homogeneous and coherent units.

The approach is also criticised for developing a notion of a homogeneous and uniform interorganizational field very different from that described by other authors. The adoption of an innovation does not take place in a vacuum, as implied by many of the quantitative studies on diffusion, but instead in an interorganizational field comprising a complex web of institutional pressures and strategic concerns (Powell and Di Maggio, 1991). The theory's emphasis on the individual organization and its characteristics, moreover, obscures phenomena like critical mass (Farrel and Saloner, 1987), institutional pressure (Meyer and Rowan, 1977; Di Maggio and Powell, 1983; Zucker, 1987), and fashion (Abrahamson, 1991; Czarniawska and Jorges, 1995), which determine the fate of novelties and innovations.

Furthermore, the theory of diffusion draws a rigid distinction between organization and environment, thereby ignoring recent findings on the permeability of organizational boundaries and the complex interactions that take place among productive organizations, research institutions, suppliers, and market (Nelson and Winter, 1977; 1982).

Finally, as various authors have convincingly argued, decision-making processes in organizations are much more complex than the theory of diffusion assumes, with its obsolete and simplistic model of dichotomous (adopt or not to adopt) and rational organizational decision-making (Gherardi, 1985; Grandori, 1984).

The criticisms levelled toward the diffusion model have been accompanied by the attempt to produce alternative theoretical frameworks for understanding the innovation process. Two of the most accredited alternatives for conceptaualising the innovation process besides the diffusion model are the so called "Innovation Studies", stemming from the work carried out in the Schumpeterian tradition, and the constructivist approach of the "Social Construction of Technology".

The "innovation studies" literature, broadly inspired by the Schumpeterian tradition of industrial economics, focuses on understanding the processes involved in the production and diffusion of technological innovations, and on understanding why some firms and national systems appear to be more successful at various kinds of innovation than others (Nelson and Winter 1977; 1982; Freeman, 1982).

This literature seeks to understand the nature of technological knowledge diffusion processes within an industry or sector. It draws attention on the one hand to importance of existing bodies of knowledge, both explicit and tacit, within a company in determining the likelihood of new technologies being acquired or developed in-house.

On the other hand, writers in this tradition have explored the importance of the network of relationships companies have with outside bodies - both other companies and state agencies, in shaping its access to external knowledge and possibilities of collaborative technological development (Granovetter, 1982; 1985).

Within this broad tradition, there are a number of variants on the idea that decision-making within a company on technological innovation is not guided exclusively by fully informed and rational choice of the most effective technology for the pursuit of business goals. Lack of knowledge and uncertainty about outcomes means that companies tend to look for innovations within a defined trajectory of technical issues and possibilities (Nelson and Winter, 1977). Some authors see this in terms of a pragmatic limiting of possibilities shaped by a wish to build on existing competencies (Kogut and Zander, 1992; Cohen and Levinthal 1990). Others emphasise the importance of fads and fashions which can become established with industrial networks (Abrahamson, 1991).

It is worth noting that some authors in the post-Schumpeterian tradition are less concerned, on the whole, with individual agency, and focus instead on wider institutional forces, and on barriers and constraints to change. They are mainly concerned with issues of external influence and support for organisations involved in innovation or in adopting new technologies. A growing body of thought, especially among post-Fordists scholars, is that regional production systems and industrial and technological districts are increasingly important and that globalisation has its roots in regional developments. Although there are considerable differences of emphasis in terms of where different researchers place the primary explanation for the emergence of innovation and the degree to which firm level processes are influenced/determined by different national policies and frameworks for intervention, there is a general consensus that national or regional infrastructure is necessary to support, sustain or generally provide a framework within which innovation and the take up of new technologies can flourish. At the same time, most accounts stress the importance of informal, cultural and institutional ways of operating and learning (Nelson, 1983; Lundval et al., 1992; Andreasen et. al., 1995).

The socio-constructivist stream of technology and innovation studies covers a range of sociologically-based perspectives for understanding the way that technological innovations are embedded or “socially constructed” within wider social systems and frameworks of thinking and action, rather than the products of *a priori* economic rationality. Although composed by a number of different streams of research, the approach is usually described as the “constructionist perspective on technology and innovation”.

At the basis of this last approach there are two related assumptions: that technology is interpretively flexible, and that technology is at the same time created and changed by human action, yet it is also used by humans to accomplish some action, so that it becomes at the same time a product and a means in the construction process.

The adoption of a constructionist perspective on innovation produces a profound revision of some of the concepts used by the innovation theorists. For what concerns migration of innovation within local and wider contexts, constructionist authors generally dispute the notion of diffusion for being totally insensitive to the issue of interpretive flexibility and the inherent “equivocality” of technology (Barley, 1986; Weick, 1990; Orlikowski, 1992). In alternative, they purport explanatory mechanism for the “diffusion of innovation” which are consistent with their emphasis on the social, political and cultural aspects of the innovation process.

Actor network scholars, for example, conceive the spread of innovation as a process of “translation”, which they consider as the main way in which ideas travel outside their original local context (Callon, 1986; Law, 1987; Callon and Law, 1989, Law, 1992). The notion of translation implies that production and circulation are not distinct, but are instead intimately linked - indeed indissociable - consequences of a single strategy: that is, the articulation of novel networks with preforming networks, such that the products mobilised in each might circulate in the other”. Central to the understanding of the process of innovation circulation is hence the explanations of the tactics and strategies adopted by “translators” in the process of designing sociotechnical networks and imposing these on others.

Other authors stemming from the symbolic interactionist tradition emphasise the importance of non formalised communication as a mean of circulation of new knowledge and innovation. Lave and Wenger (1991) and Brown and Duguid (1991), for example, addresses the issue by introducing the notion of community of practice. The community of practice has been conceptualised as an informal aggregation defined not only by its members but by the shared manner in which they do things and interpret events. The community consists of a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities of practice It is defined not only by its members, but also by the way in which certain things are done, and how events are interpreted. In the community of practice relations are created around activities, and the activities take form through social relations, so that specific competencies and experiences become part of the individual identity and take place within the community. The community of practice constitutes the arena in which the processes of transmission of tacit knowledge and of knowledge-in- action takes place. Learning and innovation are defined not in terms of acquisition of abstract knowledge, but as a form of coparticipation in some of the actual practices of the workplace. Because communities of practice transcend the formal boundaries between organisational sub units and between organisations, they become a feasible way of explaining the dissemination and adoption of innovations (Brown and Duguid, 1991).

Finally, on a broader scale, constructionist scholars have pointed to different forms of institutionalisation and to fashion as powerful drivers of innovation. Abrahamson (1991) dismisses Roger's analysis of innovation-diffusion literature for being biased toward a rationalist and "efficient-choice" perspective of organisations' behaviour. Accordingly, the author attempts to rescue the despised notion of managerial fads and fashions as way of approaching innovation diffusion from a more sceptical and realistic perspective.

Czarniaswka and Joerges (1995) suggest that the notion of fashion represents a feasible way for keeping together the two seemingly alternative ways of conceiving innovation as an intentional and planned choice or as the materialisation of ideas, for example, suggest that the notion of fashion may provide a way of combining in a single, rich context various types of social and political actors as well as several levels of reality: the decision-maker, the professional groups inside and outside a company, the organisation, the organisational field, the institutionalised environment. Following fashion in a company can be a way of keeping abreast of the competition, a way of keeping up with the times in the interest of the people

by being in the forefront of novelty. Fashion, as a collective translation process, also function as a release from the responsibility of individual choice. To follow fashion is to be conformist and creative. Fashion is evolution without destination (an alternative to the notion of progress).
Not all organisational ideas which are in fashion at a given time are tried out by all organisations in a given space-frame; fashion has its niches, merchants of meaning cultivate their specialities. Such collectives of fashion followers are delineated in a process of structuration of organisation fields. Once a field has been structured , forces arise which prompt the organisations in the field to become more alike. Di Maggio and Powell (1983) speak of coercive isomorphism - organisations are forced or encouraged to be alike by actors outside the field -; mimetic isomorphism - organisations imitate one another when faced with uncertainty -; and normative isomorphism, related to the role of the state and the professions.

3. NATIONAL CONTEXTS: SIMILARITIES AND DIFFERENCES

It appears that since the first "energy crisis" of the post-war period, in the early 1970s, a considerable amount of public and industrial funding has been sunk into the development of technologies to produce more energy efficient machinery, as well as renewable energy sources, with a view to reducing energy consumption per unit of industrial output. Across the European Union, however, the picture is uneven.

In order to understand the patterns of take up of AETs in different countries one has to take into account differences in the national systems of innovation (Lundval , 1992; Nelson, 1993). The study reveled the existence of broad differences in national policies and levels of government assistance for encouraging energy efficiency in manufacturing, as well as differences in terms of the priority that is commonly given to reducing energy costs under these different regimes. While most European member states have introduced schemes encouraging enterprises to find ways of reducing energy consumption and emissions, approaches vary considerably between countries. In our sample we found a marked difference between the two northern continental member states (Denmark and the Netherlands) and the UK and Italy.

Denmark and the Netherlands have established widespread programmes of support for energy saving within enterprises and for the use of renewable resources in general within industry. Both of these countries are characterised by a tradition of high involvement of all industrial and political actors in the formulation and implementation of energy saving policies. These policies usually combine the imposition of energy related taxes with schemes allowing enterprises to obtain tax advantages in return for significant improvements in their energy efficiency and environmental performance. Denmark and the Netherlands have government-established voluntary agreements which allow energy intensive industries to reduce their "green tax"-level following specific and audited energy-efficiency improvements. Schemes of this kind usually also include access to subsidies and of technical know-how in the form of consultancy to innovating firms. By contrast, the United Kingdom has adopted a more laissez-faire approach. No major regulative framework has been put in place, nor specific environmental taxation or subsidy schemes. There are however a number of government sponsored initiatives to promote the take-up of energy-efficient technologies and general energy efficient management practices. Nonetheless, there is no unifying framework for these policy instruments. The basic approach is therefore to leave energy-efficiency to market forces, with increasing de-regulation of energy supply, and open competition in energy prices between suppliers.

Italy represents a middle way between the high level of public intervention typical of the Netherlands and Denmark, and the market approach adopted by the UK government in the 80s and early 90s. In Italy electric power energy production is a tight state monopoly, controlled by a large bureaucratic public corporation. A major government intervention at the beginning of the '90s was aimed at modifying the power supply side market structure and allowed a number of new actors to enter power production. Further initiatives addressing energy demands were not conceived in terms of agreements on reducing consumption, nor were they accompanied by any form of tax pressure. Instead, the government focused on specifics such as the introduction of a mandatory energy manager in firms above a certain size, on allowing actors other than the state-owned monopoly to produce power, and on providing significant financial subsidy and grants for firms interested in introducing technological innovation in the field. However, implementation of the two laws and the subsidy schemes remains incomplete, with many of the benefits provided by the legislation neutralised by the intervention of other factors, such as bureaucratic complications in the issuing of licences for self-production and redefinition of the limits on pollutants emitted by small industrial plants, etc.

In what follows the contextual data at the national level are summarised and tabled. This allows an easy comparison between the situation in the countries participating in the research.

Tab 1. General energy policy context

UK	*THE NETHERLANDS*	*ITALY*	*DENMARK*
Tendency not to differentiate between environmental issues and energy efficiency issues. Where there is slowness to adopt energy efficient technologies, they can often be sold more successfully on the back of environmentalism, particularly where regulatory pressures are present. Many initiatives around, particularly government sponsored, not systematised.	National Environmental Policy, produced in a number of versions since 1989, and includes a general policy of increasing energy efficiency, in order to make the economy more sustainable and reduce CO_2 emissions. Energy policy prioritises better usage of energy and materials, with energy efficiency targets of improving by 1.7% per year over the period 1995-2020, and increasing use of renewable sources, to rise from 1% in 1995 to 10% by 2000	Electric power energy production state monopoly. Energy saving became prominent in consequence of the two main oil crises in the early '70 and late '80. From 1982 to 1991 a number of laws for the adoption of new technologies, and for promoting energy saving . The law are very good, but they remain largely not implemented	A tradition in Denmark of pursuing a national policy on energy supported widely by the political parties, co-operation between the national authorities and a range of other agents. Plan in 1976: ensure supply system based on several sources, exploit the domestic sources (gas) taxation on energy. In 1990 new plan focus on reducing contrib. of the energy sector to global environmental problems - especially CO2 emission via decentral power planted heat, CO2 taxation for industry and subsidy on investments to improve energy efficiency, green taxes for households, R&D. New action plan on energy in 1996. "Energy 21" extends the environmental objective of the energy policy contributing to a sustainable development in society.

Tab 2 Policy instruments

UK	*THE NETHERLANDS*	*ITALY*	*DENMARK*
Laissez faire approach. No major regulative framework in place. Promotion policies focus especially on promotion of pilot project, diffusion of best practice, training.	Long Term Agreement (LTA) between Ministry of Economic Affairs and a sector or individual firms in reference to specified energy efficiency improvements. LTAs imply exemption from energy taxes Intersectoral technology programmes (mint) for the subsidising and diffusion of energy related technological innovation Energy efficiency programmes targeted to the SMEs	1991 law introduced some major modification in the power market structure, allowing a number of new actors to enter power production business. Energy saving promoted in three ways: introducing the mandatory role of the energy manager within firms above a certain size; allowing actors different than state own monopoly to produce power; providing significant financial support to firms that were interested to introduce some technological innovation in the field	*Taxation.* Green taxes consist of three elements: (1) an energy tax, (2) a CO_2 tax, and (3) a SO_2 tax. Revenues will be recycled to industry encouraging investments in energy-saving technology. *Voluntary Agreements* Enterprises with heavy processes can opt for a voluntary agreement (three years) on reduced green taxes (CO_2 tax) with the authorities. The condition is that the enterprise increases its energy efficiency. Not heavy processes firms can also make agreements about tax but conditions are harder *Subsidy on Investments* in energy-saving measures or a more efficient energy consumption, energy audit and other kinds of energy consultancy, projects on development, research and demonstration *Energy auditing, consultancy etc.* Government subsidised

Tab 3. Agencies and actors involved in the AET issue

UK	*THE NETHERLANDS*	*ITALY*	*DENMARK*
Government operates sponsoring private sector, not-for-profit organisation and independent consultancy Professional associations very active, promote initiative with the support of the industrialist community Workers' unions scarcely involved	Central government highly involved Government agencies for promotion and evaluation of meeting assigned targets Worker unions and Industrialist Agency highly active and involved	Ministry of Industry administrative function; subsidising function demanded to regions. Government R&D initiatives pursued by ex nuclear power agency ENEA. Industrialist and Workers Unions scarcely involved. Technologic innovation through local network of consulting agencies and individuals, universities, suppliers	The *Danish Energy Agency* manages the subsidy schemes on energy-saving measures and the voluntary agreements on tax reductions and handles consultancy and supervision of enterprises *The Confederation of Danish Industries and Trade Organisations* represents the interests of industrial enterprises in committees and other negotiations with the public authorities on energy issues. *Electricity Agencies* act as consultants to the enterprises. *Research Institutions, GUT S institutes, Consultants, Advisors etc.* under the GUTS network (Advanced Technological Service Infrastructure) function as partners to the enterprises in connection to projects on development of energy technology

Tab 4. **What Counts as AET**

UK	*THE NETHERLANDS*	*ITALY*	*DENMARK*
CHP, variable speed drives for motors, boilers - fuel conversion and heat recovery, advanced combustion systems, compressors and compressed air, high efficiency and steam motors, and expert systems improved control technology still considered AETs in the general UK context	Only highly innovative technologies. CHP not subsidised anymore	Dissenting views about which specific technologies can be considered AETs. In some area of manufacturing CHP generators, boilers and energy efficient engines are considered as AETs while others regard them as mature technologies. Other AETs recently implemented: high temperature heat exchangers inverted osmosis (food) new fusion technologies (iron and metallurgy), tunnel pasteurisation (food/beverage), special low level of energy consumption valves with recycling of frigories (cold); microwave production of heat for plastic forging	The governmental action plan on energy in 1996 the Danish Energy Agency includes a catalogue of the opportunities of technology in energy-saving measures for industry and other sectors. The greatest potential in electricity savings is in the area of ventilation, compressed air, pumps and processes In addition, energy savings can be found as a result of establishing industrial power planted heat - particularly within the food processing sector. Possibility of increasing the efficiency of the energy consumption through heat recovery between neighbour enterprises

Tab. 5. **Factors affecting technology take-up and perceived barriers**

UK	*THE NETHERLANDS*	*ITALY*	*DENMARK*
Cost and economical factors: Return on Investment as major criterion. Sometimes AET's ROI beyond accepted time horizon. Initial investment too high for SMEs: larger firms more likely to invest Awareness and information: well managed companies, with visionary leaders and high involvement of employees more capable than others to perceive the connection between energy efficiency, environmental issues and medium to long term business strategy. Energy managers sometimes not competent and/or not empowered enough. Short term focus, scarce information and awareness lead to the "energy is not our core business" disregarding attitude. Low institutional and external pressure and low cost of energy, scarce legislative pressure make manufacturing sector "passive" on this topic.	Economical considerations: is it worth? Low energy prices do not put high pressure Fear of disrupting existing production process Tendency to rely on thoroughly tested technology Lack of information and accessible knowledge in SMEs	Economical factors play a fundamental role: characteristics, magnitude of the initial investment, and perceived play back period crucial determinants. Typically Italian managers and entrepreneurs fail to perceive energy as a cost driver. AETs are quite common in energy intensive firms. Distinction between large companies and SMEs: higher sensitivity in bigger firms. SMEs tend to react negatively, usually perceiving adoption of AET in production process as not related to the core competence of the firm Behaviour of perceived competitors an market leaders powerful driver. Firms look at social industrial network for reassurance about the reliability of the technology. Political and normative uncertainty and bureaucratic inefficiency and complexity discourage the adoption of this kind of innovations.	Preliminary explanations emphasise that a number of **economic** and **factors connected to production**: **payback rate** must be short; **energy costs** are relatively limited and so is interest and the attention on saving ; **insecurity** of the enterprise **about consequences** of implementing new technology; **the competitive conditions; image** of the enterprise.

4. WHAT ARE CONSIDERED ADVANCED ENERGY TECHNOLOGIES

The broad national differences between policies and priorities given to the issue are reflected in the definitions as to what are considered Advanced Energy Technologies (AET) in manufacturing processes. For example, is some countries combined power and heat production is still considered a fairly advanced techniques while in others it is considered non innovative, well established technology.
As a result the following working definition of what counts as AET was proposed:

1. AET refers to a new or recent technology, technique or methods tested in laboratories, available on the market, but only implemented at company level to a limited extent .

2. The technology or methods must promote energy efficiency and conservation. Furthermore, the technology or methods must assist in achieving quality improvement, higher output levels, a better working environment, more competitive energy utilisation, lower costs, etc.

3. A number of areas of engineering are of relevance to the implementation of AET:

   Energy expansion/energy production
   Energy turnover (e.g. fossil fuel for heat)
   Energy and heat transmission
   Energy and heat distribution
   Energy and heat consumption
   Production and processes
   Systems, equipment, machines and components

Some examples of technologies that may be considered as fitting with the above conceptions of AET are:

• Heat recovery with the help of new technology in the shape of water vapour compression. For this process no ammonia or heat exchangers are used contrary to traditional thermal compression for heat recovery.

• New methods and techniques for recycling and heat recovery of exhaust air from foundry exhaust systems.

• Use of computer based operation and supervision systems for energy supply, energy and heat distribution and for controlling end-user consumption.

• Computer based process control in production and processes, executed as either centralised or decentralised operation systems.

5. RESEARCH DESIGN AND METHODOLOGY

The research design was based on the progressive refinement of an explanatory framework put forward at the outset of the project.
A number of case studies were carried out by partners in the four participating countries. The case studies covered the following industrial sectors:

Table 6 Case studies

SECTOR	TYPE OF PRODUCTION	NO. OF COMPANIES STUDIED	PARTICIPATING COMPANIES
Paper industry	*Integrated*	Four large companies	*Parenco, NL* *Burgo, I* *Tullis Russell, UK* *Danisco, DK*
Metal/foundry	*Integrated*	Two large and two small-medium companies	*Needstaal,NL* *British Steel, UK* *Alfer - Baxi, UK* *Valdemar Birns, DK*
Insulation/ plastic	*Decomposable /modular*	One large and one medium company	*Unidek,NL* *Sogeplast, I*
Food	*Decomposable / modular*	One large company	*Vestiyske Slagterier, DK*

Data from the 11 firms were collected through a combination of structured and semi-structured interviews and by examining secondary data sources such as corporate documents and reports. At the end of the case study work each of the partners held national Working Conferences, with interested industrialists and policy makers. Qualitative analysis of the case study and

Working Conference data provided the basis for further development of the conceptual framework.

The final SORGET framework was supported by a European survey aimed at gathering further data and testing some working hypotheses. The survey was administered by telephone in six EC countries (Germany, Denmark, Sweden, Netherlands, Italy, and United Kingdom) to firms in the paper and metal foundry industries. The results of the survey allowed further refinement of the framework and formulation of some general criteria for the development of national and European level policies for encouraging take up of advanced energy technologies in manufacturing. They also permitted identification of some specific policy actions.

6. UNDERSTANDING THE TAKE UP OF ADVANCED ENERGY TECHNOLOGY

In the companies studied we found that energy efficient technologies are usually not treated differently from other innovations. Decision patterns regarding the adoption of energy efficient technologies do not differ fundamentally from those used for other types of innovations. Firms, both large and small, tend to adopt state of the art, well-tested equipment, and they make their judgements on the reliability of a new technology mainly on the basis of information received from their formal and informal networks, and on the behaviour of direct competitors. The formal method used for investment decisions is that of investment appraisal, where future financial savings are off-set against the investment needed, and a pay-back period calculated. If the pay-back period falls within an acceptable limit (usually between one and two years), the technological investment is approved.

Even in the most progressive and aware firms, energy technologies became regarded in this way as a "predominantly technical" issue. This is a significant finding, for it partially explains why energy is so rarely prominent in top management priorities and agendas. It also indicates a possible point of organisational resistance in that, to an extent, energy technologies are perceived as being part of the "engineers'" agenda. They become pawns in typical patterns of conflict and negotiation enacted by technologically-oriented and financially-oriented managers, over which new investments are to be approved and which rejected or deferred.

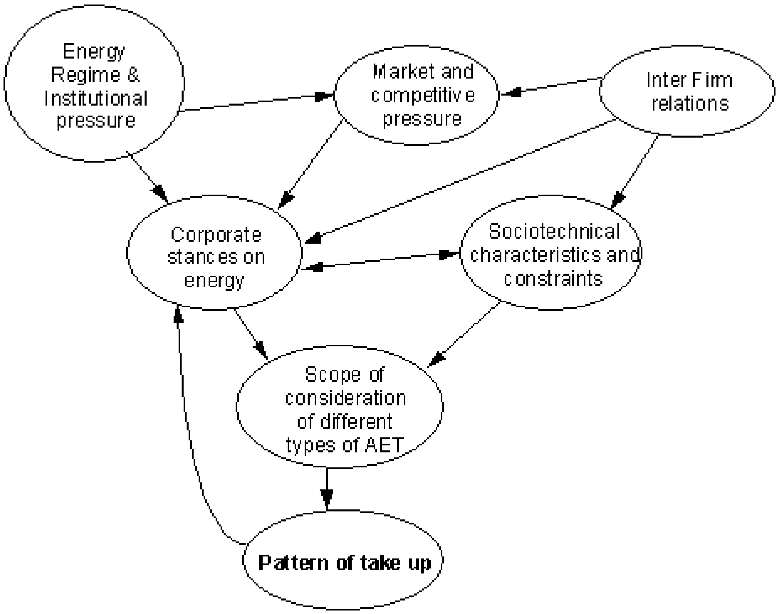
Given this common investment appraisal approach it is not surprising that, in spite of significant differences between national policy contexts, our 11 case studies revealed a number of basic issues and relationships affecting take-up of energy efficient technologies at company level. These appear to be relevant and illuminating in different companies spread across different sectors of manufacturing and countries. The issues and relationships are summarised in Figure 2.

The framework posits that the key factor underlying the pattern of take-up (or non take-up) of particular energy efficient technologies or measures within a firm can be understood as a ***scope of consideration*** (i). This amounts to a set of organisational routines which at any point in time effectively prescribes the range of energy-related technologies or measures to be considered for adoption. Technologies may not be adopted because they are formally investigated and then rejected, for example because the pay-back period for a return on investment capital is too large. However, technologies may also simply not be considered, because they lie outside the scope of consideration, usually because their implications in terms of disrupting established production technologies and ways of operating make them too risky to be given formal consideration. The key to understanding take-up of energy technologies is not so much formal decision-making criteria as how decision horizons are shaped.

The framework argues that the scope of consideration is shaped most directly by two further sets of factors: the priority given to energy considerations in strategic thinking and action within the firm, which we call the ***corporate energy stance*** (ii), and the ***socio-technical nature of the production process*** (iii), in terms of how vulnerable it is to disruption by new investments in new process technologies. The third level of explanation offered by the framework consists of examining how (ii) and (iii) are in turn shaped by ***the national energy supply and regulatory regime*** (iv), the ***nature of market pressures*** experienced by the firm (v), and the nature of its ***linkages with other firms*** (vi), including competitors and suppliers of capital equipment and knowledge.

In what follows, we now discuss some more detailed ways of conceptualising (i) to (v), and the relationships between them.

Figure 2: Conceptual Framework



6.1 Scope of consideration of different types of energy efficient technologies

The case studies and working conferences suggested that decision-makers in firms observe some basic distinctions between different kinds of energy-related technologies or measures, based on how directly or intimately these technologies are connected with core production processes and technologies. Technologies or measures that have a greater impact on core processes or which involve a wide social and technical system in their implementation are seen as more risky, and are seen as implying a wider scope of consideration. Figure 3 illustrates four basic categories of energy-related measures and technologies, and shows how they typically relate to an expanding scope of consideration.

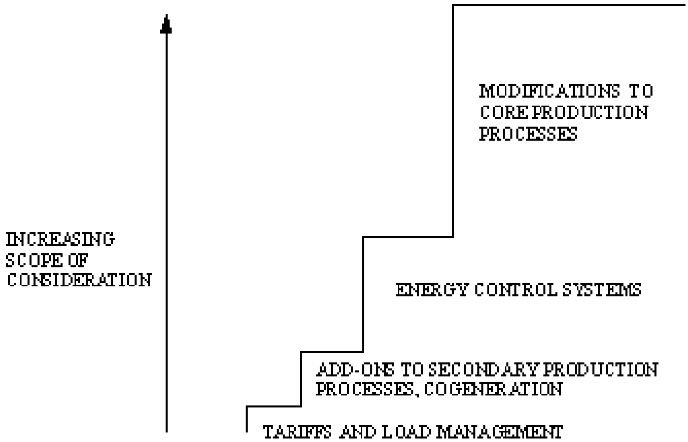
1. Technologies involved in primary or core production processes, e.g. melting metals
2. Computerised systems for monitoring and controlling energy production and consumption

3. Energy production and acquisition technologies, e.g. co-generation; technologies involved in secondary production processes, e.g. production of steam or other gasses to be used within primary production processes.
4. Re-negotiating energy supply tariffs.

While most energy is generally used in primary production processes, according to our case studies firms seldom consider introducing substantial modifications to core processes on the basis of energy considerations alone. Even in presence of a very positive innovative attitude, energy saving initiatives tend to focus on the other types of innovations leaving the core production processes untouched and unexploited in terms of energy saving opportunities. The reason is both cultural and operational: very often the identity of the firm is built around the core production process, so that energy is perceived as an ancillary competence. Managers and technicians express this by affirming that "we are not in the business of saving/producing/selling energy".

At the other end of the spectrum, the method of reducing the "energy bill" most likely to fall within the scope of consideration for firms we studied concerned re-negotiating tariffs of energy acquisition and entering into "load management" agreements. According to these, firms undertake not to consume above certain levels during defined peak consumption hours, in return for buying electricity at more favourable rates. Most of the firms we examined had in place initiatives aiming either to negotiate lower tariffs with suppliers and/or to reorganise production so that the most electricity-intensive processes could run during the part of the day when energy costs were lowest. Action to reduce the energy bill by modifying the tariff structure was considered non-problematic, both because it did not require modification of the existing production processes, and because it was based on non technical, financial and negotiation competencies that were easily understood at all levels of the organisation - most significantly at Board level.

Figure 3: Categories of Energy Efficient Technologies and Measures



Next on the scale in terms of perceived difficulty and likelihood to be fall within the scope of consideration we found innovations concerning energy generation. This was a frequently considered option, although the viability was strictly dependent on the constraints and opportunities provided by national regulations. So, for example, co-generation was extensively pursued in Italy, but only as long as favourable conditions stemming from local legislation were in place.

The take up of innovations in secondary production processes, such as the production of steam or other gases needed for primary production activities, was fairly common in our case studies. However, the prominence of the technological changes involved varied considerably. In some cases innovations were simple add-ons to existing processes, for instance new energy-efficient pumps and air compressors, while in other cases they involved some modifications of the existing production processes which required broader changes within the manufacturing process. The commonest focus for energy-related technical innovations was in fact in this area of secondary production processes and systems.

Energy-monitoring and control systems were perceived as a separate and higher level of intervention because of their nature and premises and so make up a third step of difficulty as the scope of consideration is expanded. The introduction of control systems arguably marks a shift from a local to a global perspective, and it is usually based on a number of existing, successful energy saving interventions. The challenge set by energy-control systems is not derived so much from the magnitude of the required investment, which is usually reasonably low, as from their tendency to span the boundaries of operational units. This requires the redesign of information flows and a higher level of co-ordination in processing data on energy consumption and taking action.

A further dimension for understanding the scope of consideration of energy-related technologies within a firm is of how far technologies that span the established sociotechnical boundaries of production units can be contemplated.

We found that there is a tendency for enterprises to distinguish between:

a) innovations within the boundaries of product units, e.g. within the plastic bottle production cycle:

b) innovations that span the boundaries of product units, e.g. spanning bottle production, preparation of soft drinks and bottling.

Innovations that fall within the established boundaries of production units are compatible with a narrower scope of consideration. The wider the implications of a technology, the wider the scope of consideration needs to be.

It is important to emphasise that the perceived difficulty or “height” of each step in Figure 3, or the scope of change across different portions of the production process that can be contemplated are not objectively set. The allowable scope for innovation depends both on the socio-technical characteristics of the innovation and the overall production process and on the pattern of influence within the firm regarding energy matters. It is the interaction between these that determines which energy efficient technologies can be considered as “feasible” for a specific firm, and whether the disruption associated with moving up a “step” is perceived as a barrier, or simply as a problem that can in fact be solved.

6.2 Socio-technical constraints on the scope of consideration of energy technologies

How the boundary of the scope of consideration is drawn around which energy-efficient technologies in which of the four steps of difficulty is first of all shaped by the nature of the firm’s production process. The essential consideration is how vulnerable the process is to disruption by various kinds of technical change. This vulnerability to disruption may be conceptualised in terms of the following aspects, which combine to shape the way in which people within the firm perceive the allowable scope for consideration of innovations.

Is the production process highly integrated in terms of how materials are transformed (e.g. continuous processing of bulk chemicals), or easily decomposable into a number of distinct transformations (e.g. batch manufacture and assembly of manufactured goods)?

More integrated production processes are likely to mean that modification at one point has repercussions on many others, which increases the perceived scope of an innovation, reducing the scope of what can be easily considered.

How modular as opposed to integrated is the hardware? Is it possible to change only one piece, and if so, what are the effects on other pieces of machinery?

Even in decomposable production processes there may be interdependencies between phases or stages of the production: the width of the paper produced by one machine needs to be compatible with that accepted by machinery dealing with the next stage of the production process. The more integrated the hardware, the greater the pressure to restrict the scope of what can be considered by what of technical changes.

How many suppliers are involved in providing and servicing capital equipment?

In some cases capital equipment requires the intervention and collaboration of a complex supply network of specialised suppliers and service companies - the supply chain - both up stream and down stream. This may affect the way in which the scope of the innovation is perceived. The more complex the network supporting a particular area of process technology, the smaller the scope of changes that can be easily considered.

What is the potential for impact of technical changes on inter-firm production flows?

Disturbance and risk may affect not only the firm but its customers. This aspect of the socio-technical system is especially important for firms constituting an intermediate link in manufacturing supply chains, and leads to narrowing the scope of innovations that can be considered.

How reliable is the innovation considered? What are the risks and consequences of failure?

In processes that are highly integrated, or when there is a tight dependency between stages the risk of failure at one point deriving from the introduction of an innovation is amplified throughout the whole process. This again narrows the scope of what can be considered.

What is the life cycle of the existing technology and its asset value?

The asset value of the existing equipment in view of its projected life cycle is a key factor affecting the scope of changes that can be considered. Limitations are especially significant for sectors where the life cycle of the technology is especially long (e.g. cement).

Are there exit barriers deriving from previous technological paths?

Technological paths derive from the history of innovations and previous technological choices. Particular decisions made in the recent or far past may either preclude some of the available options, or increase the cost of exit, again effectively limiting the scope of what can be considered.

6.3 Corporate stances on energy

According to our framework both the position of energy in the hierarchy of priorities and the balance of influence within the firm are of paramount importance to the process of take up of energy efficient technologies. For example, prior to fieldwork the research team had a hypothesis that production process characteristics might affect energy innovation readiness, so that companies who base their core production on highly integrated processes were less ready to implement energy-efficient technologies than those operating on a batch basis. However, it emerged that this is not a general rule, and the constraints set by integrated process-based production can easily be overcome through an integrated energy strategy. In our study it emerges that different organisational orientations toward energy can easily supersede more traditional "hard" organisational variables such as kind of production process, size of the firm, and even energy intensity. Two of the most "proactive" firms in our sample were, for example, a large, highly integrated and energy intensive firm, and a flexible, innovative SME with low energy intensity decomposable production process in the plastic sector. Moreover, our case studies suggest that the priority given to energy matters within a firm, including the authority, autonomy, and influence of "energy" managers or engineers, and the kinds of energy efficient innovations explored and implemented reinforce each other. Firms tend to produce consistent patterns of behaviour toward energy related matters in time.

We refer to such patterns of behaviour as "*corporate stances*" toward energy matters, where each stance describes and typifies the outcome of the daily process of action and negotiation between influential members within the organisation or one of its parts. Our case studies offered powerful illustrations of the impact of the weight attributed to various forms of energy-related expertise and the extent to which energy concerns are institutionalised in organisational routines. We found there was a dominant logic of action motivating key people which has a significant impact on the decision landscape shaping energy related innovations. We identified four basic "corporate stances" toward energy saving in manufacturing:

• First, there are firms and companies with *"proactive"* attitudes toward energy technologies and energy saving. Companies of this type perceive primary and secondary production processes, energy production processes and control devices in an integrated way and tackle energy issues with a systemic, strategic approach. They tend to give prominence to energy matters, and promote innovation and research for new solutions in this area. Accounting and reporting practices are aligned with this attitude, so that energy-related costs and savings can be measured and fed back to decision-makers. At the same time, energy becomes a normal part of the considering production requirements, and energy services are considered as one of the core functions in the firm.

• Second, some firms and companies exhibit a "*reactive", event-driven attitude toward energy issues*. While this stance does not preclude the possibility of adopting energy efficient technologies, it also tends to cast energy-related decisions as minor technical improvements focused on secondary production processes only. Within this framework, decision-making on energy issues is fundamentally fragmentary in nature and opportunity driven. In the absence of a long term, broad strategy the introduction of energy technologies proceeds incrementally, mainly through "add-ons" to the existing manufacturing processes. Another way of conceiving the "reactive " approach is to think in terms of incomplete cycles of learning: while parts of the firm develop high local levels of awareness and in energy-related innovation, organisational barriers hamper the involvement of the rest of the organisation in the learning process.

• A third “corporate stance” refers to firms, especially in low energy-intensive sectors, who appear fully aware of the importance of energy efficient technologies, but do not act, because they see insufficient return on investments. It is worth emphasising in this regard that the “investment” on which the return is calculated is often framed in terms of the perceived scope and difficulty of the initiative, and not only in plain financial terms.

• Proactive, reactive, and inactive strategies are all established ways of dealing with energy improvement and, as such, substantially differ from the lack of awareness exhibited by some firms. There is still a substantial number of firms scarcely aware or totally unaware of the existence of the opportunities provided by the intentional pursuit of energy saving through the adoption of energy efficient technologies. If they happen to adopt an energy-efficient technology they do it as a matter of course when up-grading or renewing their capital equipment. They represent our fourth stance, which we call simply “unaware”.

Because the difference between ways of considering energy issues mainly resides at the level of managerial decision premises and distribution of influence, it was not a surprise to find that these corporate stances are self-perpetuating. This feature of decision and action frameworks is well known in organisational research: managers persist in ways of thinking and acting until they are forced to reflect on their decision premises as a consequence of a major crisis or breakdown, or because of a drastic change in the external environment. Only then do they have an opportunity to reflect on the adequacy of the overall framework, and significant change may follow.

For example, in firms where a “reactive” stance prevails, innovation initiatives introduced at the local (shopfloor or sub-unit) level may not be adequate to modify existing energy perceptions at firm-level decision-making. Because energy innovations introduced in the manufacturing process conflict with established ways of perceiving energy issues (usually reinforced by reporting and accounting systems which reflect the low priority given to energy saving), they may fail to give rise to new initiatives, no matter how successful they are. They tend to remain isolated “one-offs”. The salience of energy issues remains low, and it is likely that subsequent innovations will suffer the same fate. The innovation process is in a sense “self-suppressing”, and the relative low interest for energy matters in the firm self-perpetuating.

By contrast, in more proactive firms a "virtuous circle" is established in which top management awareness of energy innovation fuels a host of initiatives. In addition to producing perceivable performance benefits for the firm, these initiatives trigger a process of learning by using, i.e. the development of further local innovations, and an intense scanning activity toward the environment that yields more opportunities for action. Initiatives followed by positive results reinforces the importance of energy as an attention rule for top managers, so that the cycle is self-sustaining and self-fuelling. These two processes are summarised in Figures 4 and 5.

Finally, firms who are completely unaware of the opportunities provided by energy efficient technologies are locked in the position of being unable to see that they cannot see.

Figure 4: The self perpetuating cycle in firms adopting a "reactive attitude" toward energy

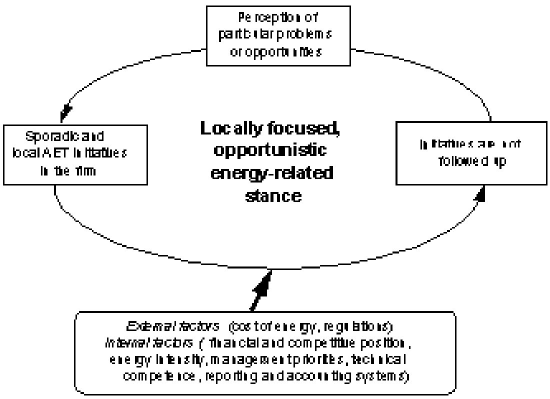
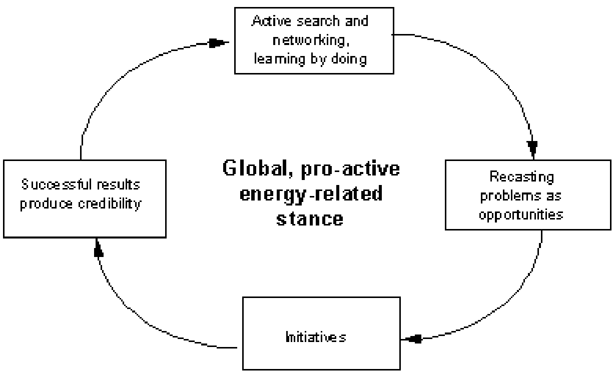
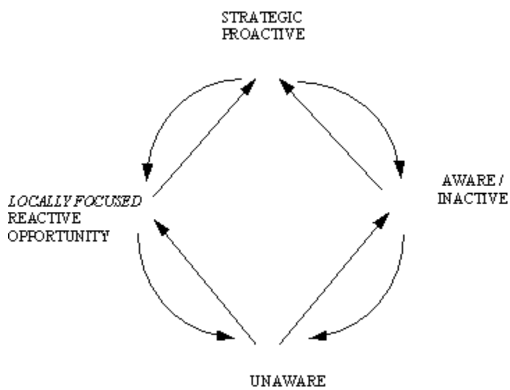


Figure 5: The self perpetuating cycle in firms adopting a "proactive attitude" toward energy



Stating that the approach to energy issues can be self-perpetuating is not meant to imply that it cannot change in time. According to our data, there are cases where manufacturing firms pursue some significant energy improvement initiatives for a period, and then "go back to sleep". There are also cases where a significant mass of isolated innovations triggers a transition to a more strategic perspective. Accordingly, the transition between "stance" is not irreversible, and it can move in either direction, so that both learning and un-learning processes can take place (see Figure 6). At the same time, on the basis of data gathered for the case studies working conferences, it is possible to hypothesise that the transition between more or less proactive "stances" always proceeds incrementally, and that higher levels of proactivity and awareness correspond to the adoption of more challenging, more complex and potentially risky energy technologies.

Figure 6: The two way transition between "corporate stances" toward energy efficiency



The corporate stance on energy is also closely related to more general patterns of influence at senior management level, particularly the balance of shorter-term financial considerations compared to longer term technological priorities. Whenever top management's dominant logic is characterised by a deep understanding of the core production technology, is proactively oriented and opportunity seeking, there is more scope for energy saving concerns than when top managers adopt a narrower financial agenda, or when priority is given to operational and problem solving activities. The two patterns of attention shape different approaches to evaluating opportunity/cost ratios on investments, for example influencing different expectations as to what is an acceptable term for the return on investment. Financially oriented management tends to impose shorter payback periods than management guided by a more strategic view of technological innovation. Similarly, short term financially-oriented investment appraisal systems, reflecting the agenda of the top decision-makers, are not suitable for exposing the profitability of investments in energy saving technology, so that in a very real sense the two patterns are self-reinforcing.

Because in even the most advanced situation energy efficient technologies tend to be perceived as a technical issue, the distribution of knowledge and competence across levels of the managerial hierarchy becomes critical. Technically-oriented managers are more apt to perceive technological opportunities than financial ones, and the lack of a common background between levels of control in a firm will produce barriers to understanding. This hampers learning processes from impacting the general strategic level of the firm. At times this can become a major cause of miss-communication and miss-interpretation of the relevance of energy issues.

The fact that energy technology innovation is usually "engineering-led" and that energy management tends to be technology-dominated is potentially detrimental to the adoption of energy efficient technologies. This is significant for it partially explains why energy so rarely features in top management rules of attention and agendas. It also indicates a possible point of organisational resistance in that to the extent that energy technologies are mainly perceived as belonging to the "engineers", they may become pawns in the typical dynamics that are played out between engineers and accountancy-based senior managers, as they negotiate which technical investments are to approved and which rejected or deferred. In our case studies, especially in the most "reactive/opportunistic" firms, we found plenty of evidence of this kind of organisational power struggle: technology-oriented people propose innovations that are assessed with suspicion by financial gatekeepers in a more or less confrontational way. Other case studies illustrated a slightly different dynamic, where energy people were considered as "service" providers by operation managers, so that concerns about energy issues tended to be poorly reflected in the planning of primary production processes and the scope for consideration of energy innovations was restricted to add-ons implemented after the main production process

had been put in place.
Finally, it is important to note that the influence of the energy manager heavily depends on the intra-organizational pattern of influence. As we shall see, one of the observed effects of national energy-efficiency frameworks and integrated, long lasting schemes set up by national regulators is the growth of influence of energy managers, and their increased financial authority in many firms. However, whilst the appointment of an energy manager (or the creation of an organisational unit to deal with energy efficiency matters) is an important step in the promotion of awareness on energy related matters within firms, that alone does not guarantee that an effective learning process will take place within the firm.

6.4 The impact of energy markets, regulation of energy production, distribution and consumption

Energy intensity and energy cost and tariffs play a central role in the consideration of energy related issues. They can be understood as having a profound impact on the corporate stance.
Energy-intensive firms are more energy aware than low intensive ones whether or not there are further external pressures such as energy taxes. Whenever energy constitutes a significant cost driver, it typically occupies a prominent place in the decision-maker's agenda. However, our observations suggest that intensity only operates as a form of pressure, while types of actual response change substantially from case to case.
At the same time the relative cost of energy does play a determining role: the higher the price of energy, the more prominent the issue becomes in the management agenda. We also found that energy is seldom considered in isolation: energy both as a cost and as a saving opportunity is always considered within a wider pattern of factors.
The cost of energy and the structure of tariffs are both determinants and perceived tools for dealing with energy costs. As mentioned before, besides considering energy efficient technologies, companies use negotiations on tariffs as an alternative or parallel route for achieving energy cost savings. In this sense, general measures influencing the cost of energy and the tariff structure are unlikely to produce uniform effects, and their capacity to yield

an increase in the adoption of energy efficient technologies is disputable.

The regime of energy production and distribution also play a central role. The structure of the energy market can both trigger or discourage the take-up of energy efficient technologies, or constitute a particular set of conditions which result in the diffusion of specific energy efficient technologies over others. A strict monopoly in the production of electric power combined with a highly constrained regime of energy distribution may prevent the adoption of certain types of energy efficient technologies, as may a highly liberalised production market where competition keeps tariffs at the lowest possible level.

The case of co-generation and CHP is paradigmatic here. This was frequently considered an option in all the participant countries, although its viability was strictly dependent on the constraints and opportunities provided by the local energy supply and distribution regime. For example, co-generation was extensively pursued in Italy as a feasible alternative to the constraints imposed by the monopolistic regime of energy production, but only as long as local legislation allowed the selling of the surplus energy produced. In other countries, the barriers imposed by the highly constrained regime of energy distribution (e.g. in the Netherlands), the high taxes imposed on self generation (e.g. in Italy for non CHP technologies), or low energy prices following widespread liberalisation of the market (UK) invariably acted as deterrents to the adoption of this type of energy technology.

Finally, there are significant institutional pressures on firms in the form of regulatory instruments intended to impact on patterns of energy consumption. National and transnational regulations, energy taxes and investment subsidy schemes play an important role in affecting firms' attitudes towards energy efficient technologies. National state interventions have the effect of drawing the attention of firms to the energy aspects of their production processes. Together with the cost or availability of energy (which is mostly market-determined) state interventions constitute a form of pressure and may even constitute a source of breakdown that forces the top management to change their ways of thinking and acting.

In many cases, energy issues are caught in a self perpetuating "cannot see that it cannot see" situation, in which individual managers do not consider energy efficient technologies as profitable economic alternatives simply because energy matters do not enter their decision horizons. The imposition of taxes and levies can, in principle, cure such “spot blindness” in a way similar to the effect produced by the sudden scarcity of energy during the two oil crises in the 70s and 80s. Nonetheless, the imposition of taxes alone, and even the provision of subsidies, do not necessarily produce a change in corporate stance towards energy efficient technologies, unless they are combined into schemes that require firms to stay committed for a certain period of time and that combine restrictive measures with some form of technical and know how support.

Although an analysis of the impact of different national incentives to the take up of energy efficient technologies goes beyond the scope of the current project, we have identified a number of critical factors capable of producing a shift in the priority that energy efficiency matters occupy in top management’s agendas.

Duration and stability of national programmes: A critical factors is the duration and stability of national programmes in order to deliver effective results. In both the Netherlands and Denmark the schemes’ successes appear to be related to the effect they have on management agendas. A reversed situation in Italy confirms the importance of stability in time.

Effectiveness of follow up and sanctions: Our data suggest that not only duration in time, but consistency of actions and follow-up are necessary for the success of national regulation frameworks. The effectiveness and timing of follow-up actions, control, and the imposition of sanctions in those cases where the subscribed commitment was not fulfilled is perceived as a keystone in the long term effectiveness of such initiatives.

Combination of pressure and support: We found evidence of firms which responded to tariff pressures, and even took advantage of subsidy schemes, without being forced to change their overall attitude towards energy-efficient technologies. The data illustrates that maximum effect was obtained with schemes which combined “voluntary” agreements between public and private agents with the provision of knowledge and opportunities for firms to tackle the problems posed by the imposition of the taxes in ways that radically differed from their established behaviour. In other words, schemes that combine pressure and possibility work better than punitive, restrictive measures. Moreover, within our sample it was possible to compare a range of national contexts experimenting with different forms of national regulatory frameworks. For example, the Dutch approach is based on sector agreements, which specify efficiency goals, whereas the Danish approach depends on one-to-one agreements between firms and government (via government agencies) in which specific technologies to be taken up are spelled out. Preliminary evaluations carried out in the two countries suggests that the second formula may be more compelling than the first one.

Cross national standards and regulation may produce a significant impact on the level of awareness and commitment towards energy efficiency matters. This is especially true in the perspective of an EC open market. On the one hand, the definition of EC-wide parameters (e.g. on CO_2 emission and on energy efficiency) can act as an institutional pressure promoting awareness of energy efficiency. On the other the introduction of European standards specifying energy-related characteristics for certain types of technologies may help energy efficiency to become an accepted technical parameter for significant categories of equipment.

6.5 Market and competitive pressure

The competitive position of the firm affects the relevance of energy in many ways, but does not always positively influence the take up of energy efficient technologies or the general corporate stance. For example, a general drive to reduce costs as a result of extreme competitive pressure in the market is intuitively a factor influencing the take up of energy efficient technologies. However, some qualifications apply.

In the first place, extreme market pressure, or a perceived weak competitive pressure can be one of the causes of self-locking behaviour with respect to energy innovation. Firms in financial difficulties, or simply in a tight competitive position, tend to disregard investments in energy efficient technologies or impose short - and at times too-short - payback periods for the investment. In other words, they tend to adopt a reactive rather than a proactive stance on energy matters. From our data it appears that in times of financial difficulties management tends to focus on core manufacturing competencies, disregarding alternative ways of improving business performance. Such an attitude is at times reinforced by the way firms carry out their budgeting processes: to the extent that capital and expenses are treated separately, attention is always driven away from energy improvement. The result is a self-locking pattern similar to that described in Figure 4, where defensive attitudes rule out forms of investment that could produce positive economic returns.

Firms under competitive pressure may also adopt strategies that focus on quality and reliability of production and products, hence minimising the risk of failure. Such an attitude may affect the way decision makers perceive the scope of a particular energy innovation, for example making core process innovation appear too risky in view of the possible costs of failure. Accordingly, cost saving considerations may be neutralised by pessimistic risk perceptions.

Size, too, may have a relevant impact. Large firms are more aware than small ones of the economic benefits of a general energy saving strategy. This might be a consequence of the fact that large firms are getting more used to thinking globally, and that, in general, they are more able to envisage returns on investments by using sophisticated financial planning tools. General research also suggests that SMEs have traditionally adopted a "fast-follower" position toward innovation.

In some cases we found that SMEs lack the necessary "critical mass" to trigger the self-fuelling cycle of innovation and change of attitude. In smaller, more reactive cases in our case study we found evidence of local learning cycles that had failed to permeate through to upper levels of the organisation. For example, we found instances where innovations in energy technologies had been undertaken and opportunities fully exploited. However, even though they yielded unexpectedly good results that prompted the search for more innovation, this process was confined to the specific engineering occupational community, failing to affect general perceptions at higher levels.

Finally, smaller firms may lack the necessary financial means to embark on costly investments with long term, marginal returns. In consequence, SMEs often prefer to use their available financial resources to invest in core production processes which will yield a more direct competitive advantage. Highlighted here then is the importance of forms of support to SMEs not capable of circumventing these barriers. Third party financing, SME consortia, and other innovative forms of financial support all ought to be considered feasible ways of promoting the take-up of energy efficient technologies.

One further and quite different form of market pressure may also manifest itself in shaping corporate stances and the scope of consideration given to energy efficient technologies. We found that the adoption of energy efficient technologies may be conceived not only in direct economic terms but also as a way to enhance or improve the "environmental" image of the company. Energy efficient technologies may be presented to customers and employees as proof of a commitment to improve standards in terms of the company's impact on the natural environment and employee health, its record on safety and as a well-managed company, and as part of establishing a "socially responsible" corporate image.

This kind of pressure becomes especially significant for companies competing in environmentally sensitive markets. The adoption of energy efficient technologies enhances the possibility of obtaining "green labelling", which depends on environmental and energy performance. Energy saving may then climb the scale of priorities for the firm and ceases to be perceived merely as a technological or production issue, becoming a marketing one.

6.6 The impact of inter-firm relations

The firm's inter-organisational network constitutes an important aspect which affects its stance towards energy efficient technologies and the processes of take-up. In all our case studies the behaviour of firms follows from close scrutiny of perceived competitors. Suppliers and consultants appear to a be a fundamental resource in this process of circulation of information about available technologies, the viability of the technologies, and behaviour of competitors. According to our case studies they constitute a major mechanism for information circulation that often results in the rapid spread of innovations across a sector. The presence of competitors who gained an advantage from a different way of tackling an issue, such as considering energy systematically, is likely to trigger imitation efforts by firms in the same market niche. Different levels of energy awareness apply to whole segments of an industry, so that technological competition is played out at different levels of sophistication in different sectors or segments.

Formal and informal messages on success or failure can stimulate the diffusion and institutionalisation of not only specific technologies but also of whole new attitudes or stances. This is especially important in view of the finding discussed above according to which firms, tend to adopt state of the art, well-tested equipment: the inter-organisational "grapevine" acts both as a promotion factors and as a barrier. On the one hand, it is through this channel that most of the information about reliability, profitability, and reputation of energy efficient technologies travels within industrial sectors. On the other hand, however, as data gathered during our working conference suggest, informal and formal lateral communication among firms support the circulation of not only positive and truthful comments, but also of distorted, prejudice reinforcing, and biased information. Suppliers, consultants and other external providers of know-how and information constitute the major mechanism for information circulation, performing much better than other forms of networking, such as academic or professional institutions. All this provides an argument for the promotion of publicly supported initiatives, such as benchmarking clubs, which strengthen inter-firm linkages and exchange. It is worth noting that we found evidence of a widespread dissatisfaction with the way results of R&D programmes and information on available energy efficient technologies are disseminated at firm level.

However, the role of suppliers and private consultants should not be glorified as it sometimes hinders, rather than promotes, the development of a strategic attitude toward energy matters within firms. In an effort to accommodate specific requests from clients, suppliers very often tend to reinforce the dynamics in place: firms that adopt a "reactive" approach will tend to procure innovations for different segments of the production process from different suppliers. Each will then pursue a separate logic of intervention. In some cases we found that suppliers "sold" solutions to firms which were not viable or not aligned with the existing knowledge base or practices, with the result of discrediting the initiative and of jeopardising the pursuit of energy saving initiatives. In many instances we found that private promotional agencies need to be counterbalanced by the presence of neutral, non-profit agencies capable of providing independent advice and unbiased consulting on energy matters.

Because different suppliers relate to different constituents within firms they have varying impacts on the process of take-up of energy efficient technologies. A significant distinction to be made in this regard is that between suppliers of capital goods and know-how for core and secondary production processes, and suppliers for capital goods in energy production and distribution.

The first group have a direct impact on the possibility of taking up energy efficient technologies within the manufacturing process. The key issue is the establishment of interrelations between suppliers (supply network) beside the one-to-one relation between the manufacturer and its suppliers. In fact, as mentioned above, some kinds of energy efficient technology have a substantial impact on the whole production process, especially in firms with a highly integrated production process. The lack of integration between suppliers can become a severe obstacle to the adoption of AET, in that it increases the responsibility of the firm to manage the potential repercussions that one change could have on the whole process. As became evident in some of the cases studied, support initiatives for the promotion of energy efficient technologies affecting the core production processes will have to be directed at whole segments of the supply chain, and not just at individual firms.

Suppliers of capital goods in energy production and distribution may have a less dramatic impact on the take up of energy innovation within core production processes, but are, however, an interesting source for potential innovations. There is an emerging awareness of the possibility to experiment with forms of outsourcing (e.g. buying compressed air instead of air compressors, warm water instead of boilers, etc.) that would transfer the responsibility of part of the energy related activities within a firm to a "specialised" subcontractor. This move could have a substantial impact on energy efficiency in that it would transfer some of the energy issues from firms with low energy intensity to energy-intensive and highly energy-focused ones, where investment in AET would bear a substantial economic return. It may be noted however, that the scope of action of this second group of suppliers is highly constrained by the structure, stability and flexibility of the energy market and the regime of energy production and distribution.

7. FINDINGS FROM THE SURVEY OF EUROPEAN MANUFACTURING FIRMS

7.1 Methodology and Sample

In order to deepen understanding of the take up of energy efficient technologies and in order to gather further data on the factors that facilitate or hinder the take up of energy efficient technologies members of the SORGET team carried out a telephone survey in late 1997. The survey[2] was administered in six EC countries (Germany, Denmark, Sweden, Netherlands, Italy, and United Kingdom) to firms in the paper and metal foundry industries. The two industries had been selected on the basis of the following criteria:

- sectors should be at least moderately energy intensive
- they should have identifiable technological opportunities
- they should be present in all participating countries
- they should potentially offer a sufficiently differentiated sample in terms of size, business volume and corporate structure.

Researchers were able to obtain responses from 93 firms, 42 in the paper industry and 51 foundries. SMEs accounted for 60% of the firms in the overall sample, and were largely prevalent in the foundry industry (40 out of 51 firms were SMEs, equal to 78%). On the contrary, most paper firms were large companies (26 out of 42, equal to 61%), many of them part of multinational groups. The great majority of firms were energy-intensive with energy bills counting for more than 10% of their overall expenses. At the same time, almost all the firms (96% in our sample) had promoted some sort of energy innovation in the last 10 years.

7.2 *Results of the survey*

Firstly, the survey aimed at identifying what kind of initiatives firms had undertaken in the energy efficiency area and when. Energy efficiency technologies were divided in three groups according to their distance to the core production processes:

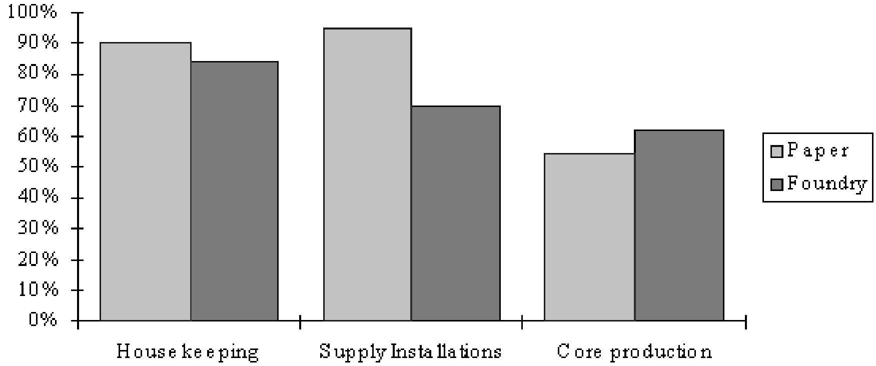
Housekeeping initiatives, i.e. initiatives targeted at saving energy without affecting the production process (e.g: lighting, plant heating and cooling systems, building envelope, plant ventilation systems).

Supply installations, i.e. installations - no matter how big - that do not require extensive modifications and adaptation of existing production processes, such as energy efficient pumps, combined heat and power systems, electronic systems for optimum control of frequency and speed and any other system for the recovery and conversion of heat from primary production processes.

Core production process and cycle modifications, which include energy efficiency motivated modifications to the core production processes such as in the case of the introduction of pulse or low energy dryers, low energy refiners, fractionation systems, vacuum forming/moulding systems in the paper industry, or introduction of energy efficient melting furnaces heating retaining ovens in the foundry industry.

The survey found that housekeeping and supply installations are more widespread than core production process and cycle modifications. In particular, more than 90% of respondents in the paper industry affirmed that they had undertaken at least one housekeeping or supply installation initiative, while only 54% had adopted core process-related energy efficient technologies. In the foundry industry we observed the same trend, although the level of take-up was generally lower: while 84% of the firms had taken up housekeeping innovations, 62% had intervened in their core processes. The distribution of the take-up is summarised in figure 1 below.

Figure 7
How many firms in the sample adopted at least one AET initiative



The survey was also designed as a way to provide empirical support for a number of working hypotheses stemming from the conceptual framework set out in the previous section.

Institutional and market influence
Almost all respondents (about 85%) affirmed that energy related behaviour of their firm was not affected in any way by standards or regulations at the EC level. About 60% stated that they considered existing regulation and standards of no relevance.
Promotional initiatives at the national level were considered of scarce impact with regard to the level of take up of AETs: in the vast majority of cases respondents ranked very low or low the importance of public subsidies, awareness campaigns, public provision of training and technical support, imposition of levies and taxes and promotion of financing schemes. As we will discuss later, in this case national differences apply, but the overall result is quite consistent across the sample.
While institutions seem to have only a limited impact, market considerations appeared to be more important: on a scale from 1 to 5, respondents ranked on an average 3 the level importance of both environmental image for their firms and importance of the behaviour of competitors in energy matters. Notably, however, the results yielded a relevant variance, suggesting a significant difference of opinions, with the level of importance within the paper industry higher than in the foundries.

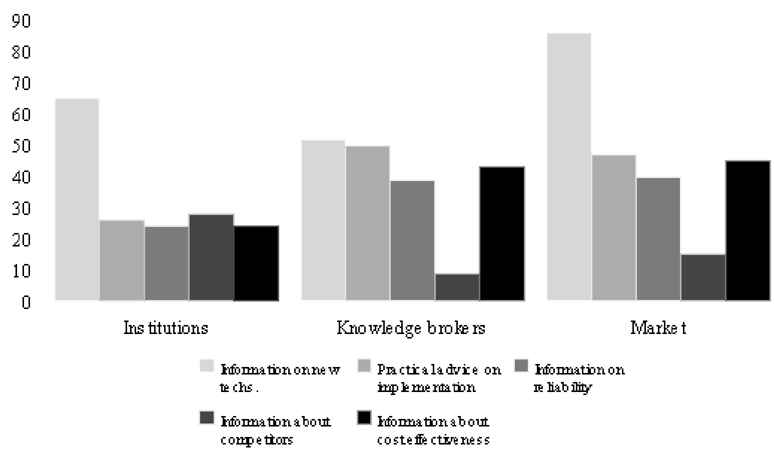
Sources of input about energy efficiency matters

The survey attempted to identify which were the sources of input upon which firms rely with respect to energy matters and their perceived importance. Sources of input were combined into three categories: "institutions" comprising government agencies and professional bodies; "knowledge brokers", including research institutes, firms' own R&D and consultants; and "market", comprising trading partners, suppliers of capital goods, suppliers of materials, suppliers of energy, and other firms (competitors).

According to the survey, the influence of the input received from the different sources on energy is in general quite low (average 2.2 on a 1 to 5 scale). Firms receive different input from the various types of sources: information about the existence of new technological opportunities is relatively widespread, and it is derived especially from institutions and suppliers of capital goods and energy. Practical advice about implementation and information about cost effectiveness is obtained through consultants and suppliers, usually from the technology suppliers. Suppliers of capital goods and consultants also constitute the most important source of data on the reliability of the innovation, while the (scarce) information about the behaviour of competitors is derived, according to our informants, especially through publicly supported industry benchmarking initiatives. Figure 8 summarises the different input provided by the various agencies.

Figure 8

Sources of information about AET



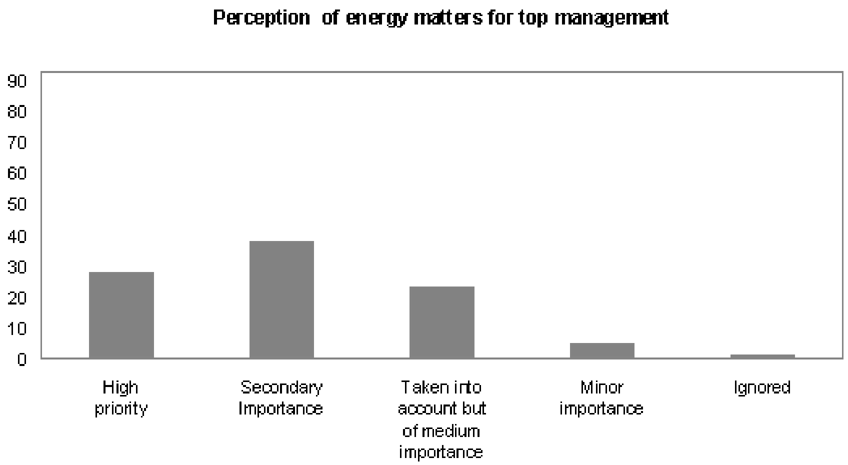
The internal landscape

The survey investigated the status of energy matters within our sample. It was found that 44% of firms within our sample have a formal or explicit energy policy, mostly endorsed at the director or senior level. However, energy matters are in firm control of operation managers, which in more than half cases were in charge of the definition, implementation, and monitoring energy policy. Only in about 1 out of 3 cases firms did have specific personnel with energy matters.

The survey found that cost-cutting is the most important reason for giving attention to energy issues (mean score 4.6 on a 1 to 5 scale of importance), while pressure from customers or business partners, and linkages to other aspects of the manufacturing strategy scored medium low (mean scores between 2 and 3 on a 1 to 5 scale of importance).

In general, in most firms in our sample the issue was perceived of secondary importance, as shown in figure 9.

Figure 9



Constraints to the take up of advanced energy technologies

Finally, the survey identified what kind of technical, economical or social factors hinder the take up of energy efficient technologies.

The results suggest that the take up of AETs is prevented especially by economic and social factors. Asked to identify which factors could hinder or had hindered the take up of AETs in their firms, respondents indicated a long payback period in 54% of the cases, relevance of the size of the investment (41%) and difficulty in finding the necessary capital (34%), the perception of the unreliability of the innovation (43%), an excessive risk of failure (35%). Technical factors such as co-ordinating a complex supply chain, solving the problems posed by a high degree of integration of production or by the effects of the innovation on other parts of the process were considered of minor importance, and usually perceived as secondary issues.

Is there a "maturity" pattern?

In view of the results of the qualitative study we were interested to test whether some sort of learning curve effect apply to energy innovations, that is, whether the take up of "less committing" energy innovation prepares the way for the take-up of more complex innovations which, by their very nature, require the mobilisation of different and broader patterns of actors and resources within the firm. At the same time, we were interested to find out whether a track history of innovations in the energy area within the firm had any impact on the take up of new technologies. The two behaviours would suggest that a "maturity model" can be used to explain the dynamic of take up of energy innovation.

In order to investigate the presence of this "maturity" model we tested the following hypotheses:

H1a: *The take-up of less complex energy innovations is a predictor of increasing level of overall take up of energy efficient technologies.*

H1b: *The take-up of less complex energy innovations is a predictor of the take up of more complex ones.*

H1c: *The take-up of energy innovations in the past is a predictor of increasing level of take up in the future.*

The correlation coefficient in a one-tailed Pearson Product Moment Test between housekeeping initiatives and the overall level of take-up revealed a high level of significance ($P<.001$) thus supporting H1a. Similarly, we found a significant correlation between house-keeping innovations and the take up of core process, with a level of significance for a Pearson Test of .015. H1b was thus also supported.

Finally, to investigate the relationship between take-up over time and overall take-up, we ran a further correlation test. The one-tailed test yielded a significant correlation between the take-up of energy innovations in the past and an increasing level of take up in the future ($P < .001$), thus corroborating H1c. However, the nature of our data rendered this particular finding somewhat problematic. Therefore no definitive conclusions should be drawn from our study on the existence of a strong maturity dimension in the pattern of take up of energy-efficient technologies.

The influence of institutional and regulatory pressures

According to our qualitative research, different institutional and regulatory patterns apply in the countries explored in our survey. Denmark and the Netherlands have developed a system of policies and initiatives (such as voluntary agreements and energy related tax schemes) which determined a quite high level of institutional pressure on firms to regard energy issues more centrally. Such institutional pressure decreased to a medium level in the case of Sweden and Germany, where only some of these initiatives were in place, and appeared to be quite low in the United Kingdom and Italy, although for different reasons.

In order to explore this issue in more detail we tested the following hypothesis:

H2a A *higher degree of institutional pressure promotes a process of institutionalisation of energy matters within firms*

H2b A *higher degree of institutional pressure affects the level of importance of energy matters within the firm*

H2c A *higher degree of institutionalisation of energy matters within firms affects take up of energy efficient technologies*.

In order to test H2a we studied the correlation between the three groups of countries with different institutional pressures and what we considered a reliable indicator of the level of institutionalisation of energy issues within the firm, i.e., the presence of energy managers who were actually responsible for implementing energy policies *and* monitoring energy issues. The results of a Cramer's V Test revealed a significant correlation between institutional pressure and level of institutionalisation of energy issues within the firm ($P<.001$), thus corroborating our hypothesis H2a.

The same statistic was used to test H2b, that is, the existence of a correlation between high institutional pressure and level of importance of energy matter for top managers. Again a significant correlation was found ($P=.04582$). Therefore H2b was supported.

Finally, using Cramer's V Test we studied the correlation between the level of institutionalisation of energy issues within the firm and the three different types of energy innovation, to test our H2c. The test yielded no significant correlation between level of institutionalisation and housekeeping initiatives or supply installations, while a weak correlation was found between levels of institutionalisation and core production process and cycle modifications *(P< .20)*. H2c was hence partially supported.

Effects of size and market characteristics

Finally, we wanted to control for the impact that the different characteristics of the firms in our sample produced on the level of take up. First we were interested to explore if size had an effect on the level of importance of energy issues for the top management of the firm and on the overall take up of energy innovation. The hypotheses were thus the following:

H3a: *The bigger the size of the firm the higher will be the level of importance of energy matters on top managers' agenda and the level of take up of energy efficient technologies.*

H3b: *The bigger the size of the firm the higher will be the level of take up of energy efficient technologies.*

While no significant correlation was found between size and perceived importance for top managers as stated in H3a, the results of a Cramer's V Test supported the hypothesis H3b that a large size of the firm was positively correlated with the level of take up. The hypothesis was supported for all three types of innovation ($p<.05$). These results are consistent with the results of previous studies which established the importance of size as a predictor of take up of technological innovations (Mohr, 1969; Swan and Newell, 1995).

Finally, we were interested to study the impact of the different characteristics of the two industries. While the paper sector is a highly concentrated, trans-national industry in which a few large groups compete within a global market, the foundry industry is still a somewhat fragmented sector, characterised by a very high number of firms with smaller, locally-based market niches. We reasoned that industries such as the paper one, which operates within an international horizon, may be more sensitive to the behaviour of competitors than a more locally oriented industry such as a foundry, for which institutional pressure may bear more significance. While the data confirmed that the level of importance attributed by the paper firms was higher than in the foundries, we were interested to understand whether such difference was reflected in the level of take up of energy innovations. It was therefore hypothesised that:

H4: *The behaviour of competitors assumes an increasing importance within a global competitive market.*

In order to test H4 we performed two separate correlations between the three types of innovation and behaviour of competitors in the two industries, and then we compared the results. No significant correlation was found either within or between industries, so H4 was not supported by our data.

The role of corporate stance on energy

We set out to test whether the level of importance attached to energy matters within the firm affects the overall take up within the firm. The hypothesis was therefore the following:

H5: *A high perceived level of importance of energy for the top management of the firm is positively correlated with a high level of take up of energy efficient technologies.*

The correlation coefficients of a Pearson Product revealed that while housekeeping and core process initiatives are significantly correlated with the level of importance for top managers(P=. 027 and P=. 05), in our sample this does not apply to the add-ons (P= .21, not significant)

The role of different kinds of market pressure

The survey also established that "cost cutting" represents the most important reason for attention given to energy issues, while other reasons such as pressure from customers or business partners, and linkages to other aspects of the manufacturing strategy were considered of a lesser importance to determine the relevance of energy issues. Accordingly we wanted to test whether these different prevailing "innovation rationalities" within the firms did actually affect the take up of energy efficient technologies. The related hypothesis was, then:

H6. *Within firms the reason for giving attention to energy issues affects the level of take up of energy efficient technologies and the type of initiatives undertaken*

To explore this we ran a multiple regression analysis between each of the four different innovation rationalities and the take up of the different types of energy innovation. No significant correlation emerged apart from a weak one between the perception of energy saving as a cost cutting issue and housekeeping initiatives (Sig. T: .14).

We were also interested to understand to the extent to which high priority given to green issues and energy-saving awareness were related within firms in the two industries. Accordingly, we hypothesised that

H7. *The level of importance of green issues and environmental concerns in the firm are positively correlated with the level of take up of energy-efficient technologies.*

The study of the correlation coefficients in the two industries revealed that almost no significant correlation emerged in either the paper or the foundry industry between importance of green issues for the firm and level of take-up of energy efficient technologies (the only significant correlation was found in the foundry industry with the core process innovations). Neither H6 or H7 were therefore supported by our data.

Table 7: Summary of results of the hypothesis testing.

IS THERE A "MATURITY" PATTERN?	
H1a: *The take up of less complex energy innovations is a predictor of increasing level of take up of energy-efficient technologies*	Supported
H1b: *The take up of less complex energy innovations is a predictor of the take up of more complex ones.*	Supported
H1c : *The take up of energy innovations in the past is a predictor of increasing level of take up in the future.*	Supported[3]
THE INFLUENCE OF INSTITUTIONAL PRESSURE	
H2a *A higher degree of institutional pressure promotes a process of institutionalisation of energy matters within firms*	Supported
H2b *A higher degree of institutional pressure affects the level of importance of energy matter within the firm*	Supported
H2c. A *higher degree of institutionalisation of energy matters within firms affects take-up of energy-efficient technologies.*	Partially supported

EFFECTS OF SIZE AND MARKET CHARACTERISTICS	
H3a. *The bigger the size of the firm the higher will be the level of importance of energy matters on top managers' agenda.*	Not supported
H3b: *The bigger the size of the firm the higher will be the level of take up of energy efficient technologies*	Supported
H4: *Behaviour of competitors assumes an increasing importance within a global competitive market.*	Not supported
THE ROLE OF THE CORPORATE STANCE	
H5. *A high level of importance of energy matters for the top management of the firm is positively correlated with a high level of take up of energy efficient technologies*	Supported
THE ROLE OF DIFFERENT KINDS OF MARKET PRESSURE	
H6. *Within firms, the reason for giving attention to energy issues affects the level of take-up of energy-efficient technologies and the type of initiatives undertaken*	Not supported
H7. *The level of importance of green issues and environmental concerns in the firm are positively correlated with the level of take up of energy efficient technologies.*	Not supported

7.3 Implications for the Conceptual Model

The results of the survey substantially support many of the findings of our qualitative research, whilst at the same time suggesting some significant refinements.

Differences between types of energy-related innovations

The results of the survey confirm what we found in the field research, namely that different types of energy technologies are treated differently within firms. The differential level of take-up of house-keeping initiatives and add-ons versus core process innovations, combined with the high priority accorded to the perceived potential disruption and the risk that the new technology is likely to produce on the core production processes, confirm that firms tend to behave quite differently with respect to innovative energy technologies that get closer to the core production processes.

Patterns of innovation and corporate stances toward energy efficient technologies

The results of the survey also support the idea that within firms it is possible to identify patterns of growth of energy efficient technologies across different levels of difficulty and risk. Our findings that the take up of less complex innovations is likely to positively influence the take up of more complex ones and that, in general, the take up of less complex innovations is likely to be associated to a higher level of take up suggest that some kind of development or learning process takes place within firms. Moreover, the finding that the take-up of innovation in the past is a predictor of succeeding innovations suggests that the model may follow a "maturity" dynamic whereby the firms acquires more confidence and trust in the value and benefits of investing in energy innovation during time.

The maturity model can be explained in very practical terms as a process of increasing institutionalisation of energy issues within the firm, e.g. the appointment of an energy manager or the issuing of energy policy and programmes, a phenomenon already observed in the case studies. This establishes a recursive pattern, by virtue of which energy people and energy issues become together more important within the firm and together increase the level of take-up of energy efficient technologies. Accordingly, the results of the survey supports the usefulness of the concept of "corporate stance" toward energy matters, where the stance typifies a daily process of action and negotiation between influential members within the organisation or one of its parts, as well as the resulting priority of energy in the agenda of the firm's management. The survey also supports the notion that corporate stances towards energy innovation are results as well as premises of the dynamic of take-up of energy technology: they are stable in the short-term but subject to change as result of strong pressures, and influenced through a number of factors.

The influence of socio-technical characteristics of production

The survey suggests that the socio-technical characteristics of production processes, such as solving the problems posed by the high degree of integration of the production, and dealing with the effects of the innovation on other parts of the process are perceived as playing only a minor role in encouraging or discouraging investment in energy efficient technology. A much greater role is played by the general priority allocated to energy in management deliberations.

Factors that influence the corporate stance towards energy innovations

The survey helped deepen our understanding on which factors influence the corporate stance toward energy matters and the take up of energy.

Institutional pressure

In the first place the survey revealed the fundamental importance of state institutional pressure as a way to influence the internal landscape of the firm prompting greater attention for energy issues. The survey confirmed that institutional pressure can both raise the profile of energy with top management and help internal energy specialists to gain a more influential position, thus supporting take up of energy efficient technologies and the overcoming barriers posed by a limited scope of consideration. At the same time, the results of the survey confirmed that institutional forms of pressure which are stable and consistent in time, and which combine pressure with support are more effective in promoting a more proactive stance toward energy matters within firms than other forms of government intervention. The survey in fact indicates that institutional initiatives which do not combine promotion with pressure, such as simple awareness campaigns, or public assistance for training, are likely to have only a limited impact.

The role of market pressures and economic rationality

The survey also confirmed the significance of market influences. Firms respond to the behaviour of competitors. This is true of all firms, and it is not a prerogative of large ones only, as previously hypothesised in our study. The survey corroborated the relevance of size in the dynamic of take-up of energy efficient technologies. We found that while there are not substantial differences in the level of awareness with regard to energy issues, contrary to what we hypothesised on the basis of our qualitative study, there is in fact a significant difference in the level of take up. It appears that while large companies may embark in large strategic projects, SMEs take a more reactive attitude that very often consists in waiting until a piece of equipment is obsolete to replace it with a more efficient one. Finally, contrary to our expectations, we found that market pressures to respond to environmental

and energy concerns are not necessarily related, and in fact they are dealt with quite separately, especially within large firms.
Business economic rationality plays a determinant role in the take up of energy innovations, however, it also reveals an apparent inconsistency. On the one hand it suggests that economic reasons lie at the core of the decision making process about whether to take up an energy innovation, while on the other it shows no significant relation between the reasons given for paying attention to energy issues and actual take up.
A possible explanation may be that economic and financial categories are used by top and middle managers as the accepted way to describe and account for the complex social and technical processes that determine which innovation is considered and eventually taken up. Economic and financial concerns are taken into consideration and addressed by all the different actors within the firm, although each of them use economic categories to support their own distinct agenda. Accordingly, economic categories and ways of reasoning are important ways for talking about energy innovation issues, however, their role in influencing in framing options for take up is less determinant that it may appear. Institutional pressures stemming from public policy and from messages passed through inter-firm linkages are at least as significant in terms of framing the scope of options that can be considered.

Inter-firm linkages
The survey confirms the importance of linkages with competitors, suppliers and research and development organisations in particular as sources of information on new energy related technologies, their reliability and what is involved in implementing them.

7.4 Limitations of the survey and the implications for its results

Some of the procedures used to sample the firms and to obtain access may have a significant impact on the results of the survey are therefore worth reporting. As indicated above, firms to be surveyed in the present research were identified with the help of Industry and Professional Bodies and Government or Government related Energy agencies. In most cases the collaborating institutions - usually the energy department or energy office -

provided a list of potential contacts drawn from their own databases. Because of the nature of the collaborating agencies this meant that the contact firm had a track history of interest, and, occasionally, of action in energy efficiency initiatives.

It must be noted that this sampling procedure was functional for the general objectives of SORGET, to deepen understanding of the factors that facilitate or hinder the take up of energy efficient technologies. In order to study enablers and barriers we needed to focus on cases in which the take up had been at least attempted and possibly succeeded. However, this strategy yielded some descriptive statistics that cannot be considered representative of the entire population of the two industries, especially for what concerns absolute frequency values. For example, it must be noted that the level of take up of energy efficient technologies revealed by our survey is very high compared with anecdotal evidence and researchers' expectations. While the apparent differences between types of innovation are established, the overall very high level of take-up is probably an effect of our sampling procedures.

Similar caution needs to be applied to the results of our inquiry into the level of information available to companies about energy efficient technologies. While declaring their dissatisfaction at the ways in which information about energy efficient technologies is circulated and disseminated, a large majority of the firms in the survey confirmed that they actually received a broad range of information about energy innovation. This again runs against the expectations of the researchers and may well be a result of the particular sample surveyed. Finally, care should be taken in extending the results of the survey beyond our sample, especially in the foundry industry. In order to obtain robust data on this fragmented sector, a much bigger sample than we were able to use needs to be approached.

8. CONCLUSIONS

A first, very general, conclusion from the work of the SORGET project as a whole is that no single factor or limited group of factors has a simple determining role in shaping the take-up of energy efficient technologies within manufacturing processes. Our research has led us to posit a framework which explains take-up as a consequence of a complex interaction of wide variety of social, economic, organisational and technological developments. The range of phenomena that need to be included in the picture is however perhaps related to a second overall conclusion: that few enterprises address energy saving as a strategic priority of the first level. Most enterprises give energy attention if and when they see it as relating to primary business objectives.

The extent to which consideration of energy issues is explicit and how it is linked to wider corporate objectives can be understood in terms of a firm, at any point in time, exhibiting what amounts to a “corporate stance” on energy matters. This is a way of thinking and acting about energy matters, negotiated between people and demonstrated in their daily behaviour within the organisation. The crucial differences between organisations lie in the extent to which corporate stances are proactive and global as opposed to reactive and local, in the way that key organisational actors address energy issues. The corporate stance is closely linked to the scope of energy technologies that come up for consideration within the organisation. More proactive companies are more likely to consider technologies that impinge directly on the primary production process. These entail a greater risk of disruption to production, and are unlikely to be even considered in firms where managers habitually think of making local piece-meal changes only. Our research suggests that at any point in time, significantly different but stable and self-perpetuating stances may exist in otherwise broadly similar enterprises. However, stances also change over time, often in response to external pressure. For example, firms may become more pro-active in response to public policy measures, in the form of pressure to increase energy efficiency, combined with external support to increase the firm's capability to act strategically and pro-actively. However, for public policy instruments to have this kind of impact, they must offer consistency and stability. If enterprise decision-makers perceive uncertainty about how long a particular form of pressure or support will be on offer, they may consider making investments premised on the particular policy too risky.

This leads us to consider the key elements of a pro-active corporate stance on energy. The associated broad scope of consideration of energy technologies is linked to decision-makers operating within a medium or long-term perspective in terms of how they see their business and its development. If managers are tied to short-term horizons, they are unlikely to consider extensive investments.

There are two further key inter-linked elements that make up the energy-related corporate stance. First, the extent to which top management gives explicit priority to looking at energy use and efficiency, and scope of measures they allow themselves to consider. Second, the technological capability which the firm can bring to considering and implementing various energy-efficient measures and technologies. The most strongly proactive and global stances appear to require considerable technological capability in terms of both the firm's core production process and energy technologies. This combined capability needs to be present or at least acknowledged at senior management level, as well as within the process engineering function. This kind of technological capability is unlikely to exist without top management commitment to energy-efficiency, and is indeed likely to foster further commitment.

This leads us to a consideration of the relationship between a pro-active and strategic stance on energy efficiency and the general capability to innovate. The model of the pro-active firm emerging from our research has many of what research into technological innovation in general has shown to be the features of the "innovative" firm, able to initiate and manage technological innovation. Such firms have pervasive technological skills, including at senior level. However they also have routines for scanning the environment for market and technological opportunities for considering and selecting options and for implementing change projects. It may be productive to think of energy-efficiency as a further dimension of the “learning organisation”. The practical implication is to seek to build in the dimension of energy efficiency into support that firms are given on technological innovation in general.

Whilst this research has stemmed from concerns of how to encourage take-up of energy technologies, it is worth considering whether it is desirable or appropriate for all branches of manufacturing to adopt stances that are more pro-active on energy matters. It may be much more important to focus attention on more energy intensive sectors. There are arguably greater benefits to be gained here than might be suggested by modelling exercises based on assessing the energy saving potentials of particular pieces of machinery and then assessing the unexploited potential take-up of each technology. The potential for greater energy efficiency stems from the corporate stance and the associated capability for innovation. With a highly pro-active stance, the potential for energy savings is likely to exceed significantly the sum of the savings potentials of a number of discreet pieces of machinery. The pro-active stance looks for energy saving at a systemic level as well as at the local level.

On the basis of the result of the case studies, working conferences and survey it is possible to formulate some general criteria for the development of national and European level policies. These indicate some policy actions which are useful for encouraging take-up of advanced energy technologies in manufacturing, as well as giving warning of measures that may prove counterproductive.

Policy makers should balance pressure and support. Because energy efficiency cannot be achieved at the expense of other important factors such as competitiveness and level of employment, special attention needs to be given to considering in advance the systemic effects of any policy initiative. Interventions aimed at promoting take-up of advanced energy technologies at European, national or regional levels need to be informed by a coherent and comprehensive perspective. Above all, they will need to carefully balance pressure on the enterprise and support for change. Any form of pressure in terms of taxes or levies should be complemented by an effort to increase support to firms, both in terms of access to relevant knowledge and capital, and in terms of an increased flexibility in the regime of production and distribution of energy.

Initiatives will have to be targeted at the top level of firms, attempting to attract the attention of decision makers. Issues need to be framed in a *language and a context appropriate for top management audiences.* There is a need for policy makers to promote a shift of perception of energy saving in manufacturing from a negative/apocalyptic view (i.e. focusing on the environmental problems and social costs related to CO_2 emissions) to a positive one. As in the case of other environmental issues, energy saving can be see as a potential emerging economic sector located at the intersection of manufacturing and service activities. Efforts should be made to raise awareness that energy saving may well become a trigger for the emergence of new business opportunties and new high tech jobs.

Promoting the take-up of advanced energy technology in manufacturing should be especially focused on the most energy intensive sectors. Different strategies may be necessary to promote different kinds of energy efficient technologies and to reach firms of different size in different sectors. The most energy intensive sectors are likely to be the receptive audience and fertile ground for change, however.

Relatively small price or tax variations alone are a weak means of influencing substantial change in a firm's stance towards energy matters. Care should be taken in using tariffs and prices as a form of pressure for energy saving. Apart from possible negative repercussions on national competitiveness, the use of tariffs alone has shown itself incapable of raising the status of energy issues amongst overall management priorities. By the same token, complete liberalisation of the energy market is hardly a panacea. More research is needed to understand the complex and perhaps counterintuitive consequences of the liberalisation of energy markets.

In general, energy efficiency should not be promoted as an isolated issue, and should always be related to the development of wider business, technological and strategic capabilities within the firm. Pursuing energy efficiency as an aim in itself on the basis of rational or environmental considerations may reveal itself as unproductive. A more powerful stance is likely to be seeking to influence greater energy efficiency activity as part of encouraging more general organisational learning and technological innovation.

Mobilise relevant actors. Appropriate initiatives should be taken to mobilise the top management of large firms and other relevant actors in the corporate landscape through the collaboration of EC and national- level sectoral organisations. Sector-level voluntary agreements and "white papers" should be instigated, to raise awareness of energy efficiency in manufacturing.

Consideration should also be given to the involvement of trade unions at all levels. Otherwise trade unions may see energy efficiency measures as for example undermining employment levels.

Promote voluntary agreements. Voluntary agreements between regulators and firms constitute a powerful tool to promote the take-up of energy conservation initiatives and should hence be encouraged. Voluntary agreements should be promoted especially in energy intensive sectors and industries characterised by medium and large enterprises (e.g. automotive, paper, chemicals, pharmaceuticals). Voluntary agreements should always include a broad range of technical, financial and support initiatives to help firms to reach their target. Amongst these are: technical and training provision with the formula of a fee waiver linked to the implementation of an agreed plan; training programmes for energy managers and special investment financing schemes.

Introduce national and EC level standard. Introduction of energy efficiency standards and mandatory energy labelling systems for manufacturing equipment at the European level should be considered. Standards and labels may refer to both the energy efficiency of the hardware used in the manufacturing process or to the energy content of products themselves. Considerations should be made to incorporating such standards with existing systems of certification such as that of the ISO.

Apply direct market pressure through public purchasing of energy efficient products or from firms with energy-efficient processes. Policy initiatives making it mandatory for public agencies to prioritise the purchase of energy efficient materials and services from energy efficient companies may be helpful in influencing the market. If these measures are widespread throughout Europe, there will be minimal dangers of relative economic inefficiencies. EC and National governments could in this way exercise their influence as powerful customers for many of the energy intensive industries.

Strengthen the role of energy specialists within firms. Support should be provided for developing the capabilities of firms with energy technologies through a number of policy instruments focusing on energy managers and energy engineers:

- Encouraging networking and benchmarking activities, as well as forums and associations among energy managers.

• Supporting and encouraging training programmes for internal and external energy consultants addressing technical, marketing and change management issues.
• Promoting the creation of energy efficiency specialisation and courses in high education institutions.
• Improving the diffusion of information on energy innovations and energy saving initiatives.
• Stimulating the introduction of energy efficiency measures within widely used benchmarking models, e.g. the Business Excellence Model of the European Quality Foundation, or the European Environmental Management Standard.

Facilitate the emergence of new forms of financial and contractual relations in energy services. Policy makers should encourage the development and diffusion of alternative forms of financial and contractual arrangements in the area of energy services. This may involve for example removing contractual, financial, and bureaucratic constraints which hamper the trial and diffusion of innovative forms of energy services outsourcing arrangements. Pressure should be put on public and private sector financial institutions to facilitate financing, contracting and leasing arrangements for energy saving investments. These may be especially effective in conjunction with other initiatives such as voluntary agreements. Amongst others, the following schemes may be considered: access to targeted facilitated investment funds, provision of financial guarantees to back up energy efficiency related investment plans, and reduced tax rate on profits linked to implementation of energy saving plans.

Focus on the later stages of innovation in energy technologies. The emphasis of EC and national-level financing and support strategies should be more evenly distributed between the successive stages of technological innovation. More attention and support should be provided for the later stages of the innovation process, that is, to demonstration in use and diffusion. At the same time, EC and national funds for R&D should always be linked to energy considerations and targets.

Promote dissemination of information on advanced energy technologies. Support for research and development on new technologies should be balanced with the promotion of technical exchange activities and information dissemination such as the support of networks and forums, and sponsorship of energy-related events and trade fairs. Other forms of dissemination may also be explored, such as regulatory requirements that demand public utilities to deliver consultancy and support on energy efficiency, promotion of regional level information and dissemination centres, and support of local clearing house agencies to encourage the exchange of information between suppliers and users.

It should be noted, however, that the latter type of initiative may be of limited success in certain industrial sectors, and may be most effectively addressed towards energy-intensive SMEs.

9. REFERENCES

Abrahamson, E., “Managerial Fads and Fashions: The Diffusion and Rejection of Innnovations”, *Academy of Management Review*, 16, 1991: 586-612.

Andreasen L.E., (Ed.*), Europe’s Next Step: Organisational Innovation, Competition and Employment*, Frank Cass Ltd., 1995.

Attewell, P., “ Technology Diffusion and Organizational Learning: The Case of Business Computing”, *Organization Science*, 3, 1, 1992: 1-19.

Barley, S., “Technology as an Occasion for Structuring: Evidence from the Observation of CT scanners and the Social Order of Radiology Departments”, *Administrative Science Quarterly*, 31, 1986.

Bijker, E. and Law, J. *Shaping Technology/Building Society: Studies in Sociotechnical Change.* Cambridge Mass.: The MIT Press, 1992.

Brown, J. and Duguid, P., “Organizational Learning and Communities of Practice: Toward a Unified View of Working, Learning, and Innovation”, *Organizational Science*, Vol.2, 1, 1991.

Brown, L. A., *Innovation Diffusion: A New Perspective,* New York: Methuen, 1981.

Callon M., “Some Elements of a Sociology of Translation”, in J., Law (Ed.) *Power, action and Belief*, London; Routledge and Kegan, 1986.

Callon, M. and Law, J., “On the Construction of Sociotechnical Networks: Content and Context Revisited”, *Knowledge and Society,* Vol 8, 1989.

Cohen, W. and Levinthal N., “Absorptive Capacity: A New Perspective on Learning and Innovation”, *Administrative Science Quarterly*, 35, 1990.

Cool, K., Dierickx, I., Szulanski, G., “Diffusion of Innovations within Organizations: Electronic Switching in the Bell System, 1971-1982”, *Organization Science*, 8, (5), 1977: 543-559.

Crane, D., *Invisible Colleges*. Chicago: University Press, 1972.

Czarniawska, B. and Sevón, G. (eds.), *Translating Organisational Change*, Berlin, de Gruyter, 1996.

Czarniawska, J. and Joerges, "Winds of Organizational Change: How ideas Translate into objects and Actions", in S., Bacharach, P., Gagliardi and B., Mundell (Eds.) *Studies of the Organisations in the European Tradition. Research in the Sociology of Organizations*, Vol. 13, 1995.
Czepiel, J. A. "Patterns of InterorganizationalCommunications and the Diffusion of a Major Technological Innovation in a Competitive Industrial Community", *Academy of Management Journal*, 18, 1, 1975: 6-24.
Di Maggio, P., J. and Powell, W., "The Iron Cage Revisited: Institutional Isomorphism and Collective rationality In Organizational Fields", *American Sociological Review*, 48, 1983.
Dosi, G. (ed.), *Technical Change and Economic Theory*. London: Pinter, 1988**.**
Dosi, G., "Sources, Procedures and Micro Economic Effect Of Innovation", *Journal of Economic Literature*, vol. XXXVI, Sept., 1988.
Eberhard, J. and Gruber, E., *Obstacles to Rational Electricity Use and Measures to Alleviate Them,* Butterworth Heinemann Ltd. 1992.
Freeman, C., *The Economics of Industrial Innovation*, Oxford 1982.
Gherardi, S., *Sociologia delle decisioni organizzative*, Bologna, Il Mulino,1985.
Grandori, A. ,"A Perspective Contingency View on Organizational Decision Making", *Administrative Science Quarterly*, 29, 1984.
Granovetter, M. , "The Strenght of Weak Ties: A Network Theory Revised" in P. Marsed (ed.) *Social Structure and Network Analysis.* Newbury Park, CA: Sage, 1982: 105-130.
Granovetter, M., "Economic Action and Social Structure: The Problem of Embeddedness", *American Journal of Sociology*, 91, (3), 1985: 165-179.
Håkansson, H., *Corporate Technological Behaviour, Co-operation and Networks*, Routledge, London 1989.
Kogut, B. and Zander, U., "Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology", *Organizational Science*, Vol. 3, 3, 1992.
Kuhn, T. *The Structure of Scientific Revolution* (2nd Ed.). Chicago: University of Chicago Press, 1970.
Latour, B. , *The Pasteurization of France,* Cambridge; Harvard University Press, 1988.
Lave, J. and Wenger, E., *Situated Learning: Legitimate Peripheral Participation*, Cambridge; University Press, 1991.

Law, L. "Technology and Heterogeneous Engineering: the Case of the Portuguese Expansion", in Bijker, W. E., Huges, T. P. and Pinch, T. (Eds.), *The Social Construction of technological Systems*, Cambridge, Ma; MIT Press, 1987.

Law, J., "Notes on the Theory of the Actor Network: Ordering, Strategy and Heterogeneity", *Systems Practice*, Vol. 5, No. 4, 1992.

Lundval, B.A. (ed.), *National Systems of Innovation: Towards a Theory of Interactive Learning*, London and New York; Pinter, 1992.

Mansfield, E., *Industrial Research and Technological Innovation*, New York: W. W. Norton, 1968.

Meyer, J. and Rowan, B., "Institutionalized Organizations: Formal Structure as Myth and Ceremony", *American Journal of Sociology*, 83, 1977: 340-361.

Nelson, R. R. (ed.), *National Innovation Systems: A Comparative Analysis*, New York/Oxford: Oxford University Press, 1993.

Nelson, R. and Winter, S. G., "In Search of a Useful Theory of Innovation", *Research Policy* vol. 6, 1977.

Nelson, R. and Winter, S. G., *An Evolutionary Theory of Economic Change*, Cambridge 1982.

Nicolini, D. and Meznar, M., "The Social Construction of Organizational Learning", *Human Relation*, Vol. 48, N°. 7, 1995.

Nonaka, I., "Redundant, Overlapping Organisation: A Japanese Approach To Managing The Innovation Process", *California Management Review*, Spring 1990 pp 27 -38

Orlikowski, W., "The Duality of Technology: Rethinking The Concept of Technology in Organizations", *Organizational Science*, Vol. 3, 3, 1992.

Powell, W., DiMaggio, P. (eds), *The New Institutionalism in Organizational Analysis.* University of Chicago Press, Chicago, 1991.

Rice, R. and Rogers, E., "Reinvention in the Innovation Process", *Knowledge: Creation, Diffusion, Utilization*, I , 4 (June), 1980.

Rogers, E. M., *The Diffusion of Innovation. 4th Edition*, New York; Free Press, 1995.

Rogers, E. M., Arwala-Rogers, R., *Communication in Organizations*. New York: Free Press, 1976.

Ryan, B., Gross, N. C., "The Diffusion of Hybrid Corn Seed in Two Iowa Communities", *Rural Sociology*, 8, 1943: 15-24.

Schot, J., “The Policy Relevance of the Quasi-Evolutionary Model: The Case of Stimulating Clean Technologies”, in R. Coombs, P. Saviotti, V. Walsh (Eds.), *Technological Change and Company Strategies. Economic and Social Perspectives.* London: Academic Press, 1992: 185-200.
Steger, U., *The Greening of the Board Room: How German Companies are Dealing with Environmental Issues*, Island Press, 1993.
Tushman, M. and Anderson, P., “Technological Discontinuites and Organizational Environments”, *Administrative Science Quarterly*, 31,1986, 439-465.
Utterback, J. M., *Mastering the Dynamics of Innovation. How Companies can Seize Opportunities in the Face of Technological Change.* Boston Harvard Business School Press, 1994.
Weick, K. E. ,“Technology as an Equivoque: Sense making in New Technologies”. In P. Goodman and L. Sproull (Eds.), *Technology and Organizations*, S. Francisco, Jossey Bass; 1992.
Woodward, A. E., Ellig J. and Burns T. R.,” Municipal Entrepreneurship and Energy Policy: A Five Nation Study of Politics”, *Innovation and Social Change*, Gordon and Breach, 1994.
Zaltman, G., Duncan, R., Holbek, J., *Innovations in Organizations*. New York: Wiley and Sons, 1973.
Zucker, L., “Institutional Theories of Organizations”, *Annual Review of Sociology*, 13: 443-464, 1987.

NOTES

[2] Contacts and access were mostly obtained with the help of professional bodies, government agencies, and members of the Advisory Panel. Interviewers contacted the firm and identified the relevant respondent. Respondents were then sent a brief explanatory brief pack describing the aim of the project and the nature of the interview. Each in-depth interview required about 20-25 minutes.

[3] The nature of the available data rendered this particular finding somewhat problematic. Therefore no definitive conclusions should be drawn form our study on the existence of a strong maturity dimension in the pattern of take up of energy efficient technologies.