

Impediments to the Uptake of New and Emerging Energy Technologies

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Abstract

The Foundation for Research Science and Technology (FRST) has recognised there are significant impediments to the uptake of new and emerging energy technologies and is funding a research project to identify and analyse these impediments. The aim of the research is to explicitly draw a diverse range of perspectives and perceptions into an integrated systems framework to investigate impediments to the implementation of New and Emerging Energy Technologies (NEETs). This framework includes both supply and demand energy options for all types of energy. It incorporates engineering, economic and other social, cultural and infrastructural factors.

1 Introduction

This paper outlines some work in progress on impediments to New and Emerging Energy Technologies (NEETs). One of the purposes of presenting the results to date is to get feedback from interested parties. This work is funded by the public good science fund and was started in May 1997 and will finish in June 1998. The aim of the work is to identify the impediments to NEETs. NEET's are defined as any supply or demand energy technologies particularly renewables and energy efficiency technologies. Technology includes not only hardware but also management systems and software.

Impediments to new energy technologies are very relevant to the conference theme of sustainable cities because of the important role technology can play in improving our use resources. An important role for engineers is not only being able to develop new technologies but to understand the most effective ways to implement and choose technologies.

A brief outline of the research methodology used is presented along with a description of the human activity systems that have been identified in the technology up take process. Each of these human activity systems have a number of identifiable stakeholders, stages in technology adoption, decision making tool and impediments which are defined in sections 4 to 7. The final section shows how each of the systems relate to each other. This builds up a rich picture of the problem situation and shows the interconnections between the key parts of the problem.

2 Research methodology

Our assumption has been that the knowledge about impediments already exists within the industry and our job is to collate and organise it in a meaningful way. Our investigations so far have been based on a series of structured discussions involving six focus groups that were split into innovators, third-party financiers, commercialisers, small-scale users, large-scale users, policy makers and advocates

As will become apparent, these initial designations later gave way to new labels associated with the spectrum of activities involved in the technology innovation and adoption process. Participants in the six focus groups had a wide range of experience in a large number of energy technologies. The discussions were all recorded and copied so that three members of the research team could listen to the detailed content and the language of the discussions. These three members of the team then engaged in an analysis of the discussion material as the process for developing the soft systems framework that is described in section 3. A more detailed description of this work is given in Baines et al, (1997a).

3 Human activity systems associated with the technology adoption

The Human Activity Systems provide an empirically-based framework of activities and relationships that can be used for locating and describing impediments to the uptake of new energy technologies in New Zealand. The representation in Human Activity Systems is not an organisational description. Actual organisations in the real world (individuals, groups, businesses) often operate across several of these activity systems.

An overview of the whole technology innovation and adoption system is presented followed by a description of each of the component human activity systems. Each system has a root definition that defines what happens in the system. Associated with this is a list of apparent world views held by people in the system along with a list of transformations that happen within the system (see Baines et al, 1997a).

INNOVATION & ADOPTION SYSTEM

Root definition:

"Developing and matching a Technology to an Application"

In the case of new and emerging energy technologies, the applications involve the harnessing, transformation or end use of energy in any of its forms and settings, and the control of such processes.

Human activity systems

Diagrams to be inserted...

The middle five systems represent stages in the process from idea through to implementation while the financing and environment setting systems influence all stages of technology adoption. This does not necessarily indicate that the environment setting and financing systems are the most important just that they are relevant to each

of the stages. The boundaries between the systems are fuzzy and are not easy to represent in a diagram. For example there is an interaction between the ... systems and the .. system even though it is not show on the diagram

3.1 TECHNOLOGY GENERATING SYSTEM

Root definition

"Optimistic inventors, supported by risk-taking investors turn untested, abstract ideas into concrete prototype solutions for their own and others gain"

Apparent world views

- Innovations can solve society's problems as well as improve 'the lot' of the innovator
- Finding a better way of doing things is a socially worthwhile activity
- Innovation is a mixture of art and science
- Innovators tend to be optimists and focus on opportunities

Key transformations

- Abstract idea \Rightarrow concrete idea
- Perceived problem \Rightarrow prototype solution

3.2 BUSINESS VENTURING SYSTEM

Root definition

"Owners establish a business based on the innovation in order to maintain sufficient 'supply' to bring the new technology into the commercial marketplace"

Apparent world views

- Inventors are not necessarily experienced in running a business venture
- Commercialisation involves a change of control - a process which is often difficult
- Inventors and investors generally have vastly different perceptions of the risks
- At some stage the new technology has to be finalised for market; any further development should contribute to Mark II
- To attract significant external capital requires the involvement of good business people and a sound business plan
- At some stage, the business venture will run into an accountant who will audit its preparedness for investor involvement (venture capital)

Key transformations

- Concrete idea \Rightarrow marketable prototype
- Ideas, resources \Rightarrow a prospect for attracting venture capital
- Unexamined risks \Rightarrow understood risks
- Independent technology developer \Rightarrow technology developer working in partnership
- Loosely-structured collaboration \Rightarrow formal business structure
- Uncertain 'supply' \Rightarrow more secure 'supply' (for the next stage of development)

3.3 PRODUCING SYSTEM

Root definition

"Shareholder-owned system in which production specialists assemble materials, labour and equipment to fabricate marketable products based upon a technically proven prototype, according to pre-determined technical and cost specifications and make available for sale"

Apparent world views

- You've got to make something better than is in the market already in terms of cost, quality and reliability of performance
- You must be as good as or better than your competitors in terms of quality control, production efficiency, timeliness and cost management.

Key transformations

- Prototype \Rightarrow production model
- Capital \Rightarrow production line
- Raw materials and labour \Rightarrow inventory of marketable products

3.4 MARKETING SYSTEM

Root definition

"Agents working for shareholder-owned, technology supply companies attempt to understand users and their needs for technology, promote the benefits of their technology, support purchase decisions and make profitable sales"

Apparent world views

- Potential users need to be persuaded to adopt new energy technologies
- There are very few early adopters
- Success depends on matching a product with an application (suitability)
- You have to piggyback energy improvements on other benefits

Key transformations

- Poorly-defined user need \Rightarrow user's decision to purchase/not purchase
- Application possibilities \Rightarrow application suitability identified
- Potential demand for a technology \Rightarrow actual demand defined + ideas for further technical innovation
- Ignorance of the market \Rightarrow understanding of the market
- Products needing support \Rightarrow products supported in user situations
- Technical information available \Rightarrow information given out

3.5 USING SYSTEM

Root definition

"Individuals and organisations try to solve various problems or meet various needs by seeking information on, acquiring and using new energy-related technology"

The using system has been split into *individuals* and *organisations* because of the different ways in which each group of users adopts technologies

Individual users

Apparent world views

- Comfort, convenience, reliability are more important than reducing energy per se
- Personal mobility is paramount - the motorcar rules for most people
- Perceived cost is critical
- Most people don't know what will work for them
- New technologies can be a real gamble
- New technologies can help achieve other personal needs
- It's hard to get reliable, independent information on new technologies
- Knowing someone who's done it before is a big advantage

Key transformations

- Less comfort, convenience, control \Rightarrow more comfort, convenience, control

- Users with an energy-related problem ⇒ users with a problem solved/improved
- Old, familiar technology ⇒ new less familiar technology

Organisation/business users

Apparent world views

- Reliable performance is more important than reducing energy per se
- Commercial returns will be over-riding
- We must aim to meet our shareholders/members expectations
- It's hard to get others in your organisation to embrace something new
- A consistent approach to adopting new technology can be the basis for a competitive business strategy
- It's harder to justify investment on retrofits than on new capital developments or replacements.
- It's easier to justify capital expenditure on energy when capital is already being spent on a bigger project (contrast this with short time frames for implementing capital projects in practice)

Key transformations

- Users with an energy-related problem ⇒ users with a problem solved/improved
- Dependence on an energy supplier ⇒ independence from an energy supplier
- Competition ⇒ competitive advantage
- Old, familiar technology ⇒ new less familiar technology

3.6 FINANCING SYSTEM

Root definition

"Capital-owned system in which investment managers attempt to make money by investing in/loaning to technology innovation companies while minimising their risks"

Apparent world views

- Equity capital buys a stake in ownership and shares both up-side and down-side risks
- Debt capital earns modest returns on 'secure' revenues/assets and does not share in the up-side risks
- The people involved are more important to investors than the technology involved
- Financing requires prudence; investment proposals require systematic, thorough vetting in order to reveal the risks

Key transformations

- Money (investment capital) ⇒ more money (returns/dividends/interest)
- Non-self-supporting ventures ⇒ self-supporting, profitable businesses
- Underdeveloped businesses ⇒ developed businesses

3.7 ENVIRONMENT-SETTING SYSTEM

Root definition

"Government and company-owned system for setting rules and allocating roles and resources within which people, companies and organisations are expected to operate/function"

Apparent world views

- Government shouldn't pick winners
- 'Economic efficiency' rules!

- Government regulation over business activities should be minimal and be equitable for all types of business
- Companies must maintain business discipline to compete widely
- Companies will be accountable to their shareholders
- NZ is not a technologically-based society (highly industrialised)

Key transformations

- Competing interests ⇒ dominant interests
- Policy proposals ⇒ policies and regulations
- International commitments ⇒ domestic rules
- Public risks (biophysical environment) ⇒ public environmental good
- Market failure/weakness ⇒ market improvements
- General and company taxes ⇒ targeted transfers as grants, loans, subsidies

4 Identification of stakeholders in the human activity systems

Within each of the human activity systems there are a number of other distinct stakeholder groups. Quite often one person or group of people will perform the different stakeholder tasks. For example the inventor may also be the commercialiser and the marketer however they are quite different functions and hence they separation. These stakeholder groups are defined below:

Idea/technology generating system

- Inventors: People that see problem and devise a technology to solve that problem.
- Research team: People bought together to take the idea of the inventors through to a working prototype.
- Independent research organisations. Organisations that existed before the idea was conceived and they have specialist skills that can assist the research team.

Business venturing system

- Commercialises: People that take a prototype to a saleable product.
- General business people: This includes tax specialists, accountants, lawyers etc.
- Patent attorneys: They have a special role in protecting intellectual property.

Producing system

- Manufacturers/producers: Team of people responsible for producing the product or service in a form that is ready for sale
- Importers/distributors: People who get the goods or services to the retailers.
- Production engineers: Technical people responsible for designing the production process that manufacture the new technology

Marketing system

- Marketers: People responsible for making the potential end-users of the technologies aware of the technology.
- Sales people: People who sell the technology to the end-users.
- Support people: People responsible for the support and servicing of the technology.

End-users system

- Early adopters: Group of end-users that are prepared to try something new. Many of the commercialisers recognised the importance of identifying this group end-users and aiming their initial marketing efforts at them.

- End-user small. There is a significant difference in the way that small end-users decide to buy technologies compared to larger end-users.
- End-user large. These users are more likely to use formal analytical tools to make decisions about technologies such as cost-benefit analysis etc.

Financing system

- Angel investors: These investors are usually the inventor, friends, associates, FRST etc. Angel investment can be provided internally within companies.
- Venture capital: These investors have more formal procedures before investing in a company. In New Zealand the venture capital company tended to invest in companies with at least some revenue streams already.
- Debt capital: This set of investors includes commercial banks etc.

The difference between investors is described by the following table:

	<i>Angel investors</i>	<i>Venture capital</i>	<i>Debt capital</i>
<i>security</i>	shareholding	shareholding,	secure assets, revenue streams
<i>risk</i>	very high	medium/high	low
<i>return</i>	very high	medium/high	low
<i>stage in business</i>	from pre-commercialisation	from start of commercialisation	established business
<i>revenue of business</i>	negative	low or negative	positive and secure
<i>products from business</i>	technical prototypes	marketable prototypes	production units

Environment setting system

- Media: TV radio, newspaper etc.
- Policy people: This includes national and regional government policy people.
- Advocates: Groups that actively support one form of technology e.g. wind users.
- Independent information sources: This includes Consumers Institute, EECA etc.
- Politicians: National and regional.

5 Definition of NEET's- Stages in the process of technology development

Defining the stages technology goes through is a useful way of understanding the impediments of new and emerging energy technologies. There are a number of identifiable stages within each of the activity systems. It is not necessarily a linear progression from stage to stage. There will always be iterations and stops and starts. In some cases stages will be missed or merged into other stages. In some cases there are very clearly different stages and others it is more fuzzy.

Idea/technology generating stages

- Define the problem: Deciding that there is a problem worth solving.
- Idea generation: Coming up with ideas that solve the problem defined above.
- Estimate the market need: Deciding if there is a large enough market.
- Test theory of technology: Making sure the scientific theories in which the idea is based are valid.
- Proof of principle: Building experiments to test the basic principles of the idea.

- Test if it is novel: Searching to see if this idea has already been developed.
- Build a prototype: Building a product or system that solves the problem.

Business venturing stages

- Forming a company to commercialise: Establishing a company with the purpose of market entry.
- Design for manufacture: Designing the product/system so that it can be manufactured in the numbers required at a cost to allow a profit.
- Detailed product testing: Testing of products/systems under a wide range of potential operating conditions.
- Market trial: Trialing the products/systems in real applications and getting detailed feedback from the end-users of the technologies.

Production stages

- Test production: Initial production runs to test the manufacturing processes.
- Commercial production: Producing products for sale.

Marketing/support stages

- Initial marketing. Marketing a new technology is more difficult than for an existing technology so this has been identified as a specific stage.
- Initial sales: The first sales of a new technology also appear to be driven by quite different factors to those of established technologies.
- Initial technology support: Servicing, maintenance and repair of technology.
- Accelerating market penetration: This stage involves the marketing and sales of technologies that already have a level of market penetration.
- Established technology: At this stage the technology is commonly used and is no longer considered new and emerging.

Using stages

- Awareness of technology: The first stage for the user is that they have to become aware that the technology exists. This is often through the media, friends etc.
- Awareness of need/opportunity: The second stage is that the user has to become aware that there is an opportunity for this technology for them e.g. becoming aware that standard light bulbs are inefficient.
- Evaluation of technology/opportunity: The user has to make some sort of evaluation on whether or not to buy the technology.
- Decision to purchase technology: Even if the user has made an evaluation of the technology/opportunity and it was favourable they may not necessarily purchase the technology straight away.

6 Identification of decision making tools

The following is a list of decision making tools that have been identified from the focus groups. The tools are described in more detail in Baines et al. (1997b). The classifications of decision tools will be expanded as part of the second phase of the research.

INFORMAL

- Advice from friends or family
- Advice from business associates
- Advice from consultants/ experts
- Brainstorming

- Informal group discussions and/or debate
- 'People' judgement

FORMAL

- Economic analyses (using CBA, and associated criteria such as IRR, payback period, NPV)
- Technical analyses (based on feasibility of construction etc.)
- Scientific analyses (scientific feasibility, and will it do what it is supposed to)
- Business tools (due diligence, strategic and business plans, operations research tools)
- Risk analysis (standard approaches, and worst case scenarios)
- Structured meetings (using Delphi approaches, meeting support)
- Unstructured meetings (using criteria based on economic, technical and scientific analyses to assess the results of the analyses listed above)
- Brainstorming (can be formal or informal)

7 Classification of types of impediments

There are numerous ways in which impediments to new and emerging energy technologies can be classified. The list of impediments is explained in more detail in Baines et al, (1997a).

End-users impediments

- Complexity of technology
- Lack of trust in manufacturers
- Limited availability of technology
- Poor quality information
- Poor performance by marketing people
- Competition from marketers of other products
- Lack of capital
- Cultural constraints of organisation
- Lack of energy champion
- Risk of inadequate support
- Need for quick return
- Public policy environment
- Consistency of public policy
- Compliance costs (RMA/OSH)
- Volatility business environment
- Constraints of decision-making tools
- Fragmentation of business units

Marketing system impediments

- Fraudulent claims of other technologies
- Businesses not good at marketing
- Fear/reluctance to invest in something new
- Lack of knowledge of user circumstances
- Insufficient money market adequately

Productions system impediments

- Communication between inventor and manufacturer

Business Venturing impediments

- Good people not available
- Inventor's not good at business
- Wrong time for market entry
- Different perception of risks (investors/inventors)
- Lack of capital for innovation
- Technologies have better chances overseas

Technology generating

- Difficulty in establishing intellectual property
- Poor communications between inventors and investors
- Lack of supportive tax regime for R&D in NZ

Financing

- Often the first investors are not the real beneficiaries
- Failure to present a credible business plan
- Benefits are captured by more than one person
- Industry uncertainty

Environment setting

- Light-handed economic control
- Unrealistic expectations on agencies like EECA
- Untested assumptions by advocates about NEET's
- Public doesn't often recognise the problem

8 Building a “rich picture” (conceptual model) of the overall NEET problem situation.

The aim of this section is to build up a picture of the problem situation. The method that has been chosen to do this is a series of matrices that show the connections between the stakeholders, stages of technology development, decision making tools and impediments. This clearly shows who is involved, at what stages, the decision tools they are using and the impediments they come up against. The matrices also give an indication of the strength of the relationship. It should be emphasised that the relationships indicated on the matrix have been filled out based on the discussions from the focus groups and they will undoubtedly need to be modified as we get more information.

The clear conclusion that can be drawn from this section is that there are a large number of interactions between the various stakeholders, stages in technology adoption etc and that the whole problem situation is very complex. The method presented below is one way of communicating the complexity in a way that is hopefully understandable.

Relationship between stakeholders and stages of technology development

The matrix in figure 2 shows the relationship between the different stakeholders and the stages the technology goes through before it is implemented. This gives a picture of not only who is involved at the different stages but how involved they are. The shaded dot indicates that the stakeholder is generally very involved in that stage of the process, the half circle indicates they are moderately involved in the stage, the circle indicates that the stakeholder is occasionally involved in the stage and no mark

indicates that the stakeholder is not involved in the stage at all. This matrix may be useful because it allows someone who is involved in implementing a technology to get a feel for who will be involved at the different stages. As an example it is clear to see that before the prototype stage it is pointless going to a normal bank for financing and one must find an angel investor.

Matrix one to be inserted....

In some cases the matrix show up the very obvious e.g. all of the end-users are involved in the 4 end-user stages of technology adoption. What is more interesting is looking at the stages in the interaction between the marketing stages and the different end-user types. For example the end-users defined as early adopters are a particularly important set of end-users for new technologies and initial marketing efforts should be focused on them.

Because of lack of space it is not possible to include the other matrices that have been developed. However some of the conclusions from other matrices are listed below. Details the other matrices are in Baines et al. (1997b).

Relationship between decision making processes and stakeholders

- informal decision tools are used quite frequently by small end-users while the larger end-users tend to use more formal decision making tools. This would indicate that details cost benefit analysis may not be the best method to sell technologies to householders and you may require more person to person marketing strategies.
- “debt capital” investors using mainly formal tools and that “angel investors” using more informal tools. The venture capitalist uses a mix of both types of tools.
- The “business venturing” and “idea/technology generating” systems uses a wide range of decision tools.
- Commercialisers and general business people rely on informal decision making tools more than one may have thought.

Relationship between decision making tools and stages in the process

- The two phases in technology uptake where the most number of different decision making tools are used, appears to be “forming a company to commercialise” and the “decision to purchase a technology”. This may indicate that these are two of the key decision making steps in the uptake of a new energy technology.
- The decision making tools used for the final decision to purchase appear to be mainly informal.

Relationship between the impediments and the stages in the technology adoption process

- The area with the most significant level of impediments is that of achieving initial sales. This also shows up from the “using system” perspective under the decision to purchase technology.
- The lack of capital and good people appears to be a significant impediment at all stages of bringing a technology to market. In part this could be attributed to a lack of a supporting environment (e.g. R&D tax incentives etc.) for the innovation industry.

- There are a large number of impediments to forming a company to commercialise. This indicates that forming a company to commercialise is a critical part of the technology adoption process.
- The combination of complexity of technologies, lack of an energy champion and fragmentation of business opportunities mean that the awareness of the need for a new technology is often lacking.

9 Summary / conclusions

The research to date has identified 7 different “human activity systems” that are involved in the uptake of new technology. Associated with each of these activity systems are a number of identifiable stakeholders, stages in the technology uptake process, impediments and decision making systems. Relationships between each of these factors have been documented through the use of matrices. This is a useful way of representing the complexity of the problem of energy technology adoption. Some of the key problem areas are highlighted in a fairly straight forward way. The problem definition is also in a form which makes it possible for others to usefully contribute to the work in a structured way. The next stage of the work will involve expanding our understanding of relationships through a series of case studies interview and focus groups. Feedback is always welcome.

References

Baines et al... 1997a “Innovation and Adoption Systems” on web page <http://pacwww.chch.cri.nz/electrot/team/barriers.htm>

Baines et al... 1997b “Document 2..” on web page <http://pacwww.chch.cri.nz/electrot/team/barriers.htm>