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An Innovation Systems Assessment Of The Australian Biofuel Industry

Policy and Private Sector Implications

Masters of Science [Management and Economics of Innovation]

JASON D. NIELSEN

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EXECUTIVE SUMMARY

A strong biofuel industry in Australia has the potential to provide numerous benefits to the nation and its peoples. The benefits include; reduced emissions of greenhouse gases and harmful particulate matter, a boost to rural development goals, enhanced fuel security and a lower balance of payments.

For biofuels to be seriously considered as alternatives to traditional petroleum based automotive fuels they must be economically viable. The findings from a series of Australian Bureau of Agricultural and Resource Economics (ABARE) investigations suggest that ethanol and biodiesel production would be economically viable, in the Australian context, with oil prices in the range of $US30-40 a barrel. Despite the price of oil being in or above this range for over two years a strong home grown biofuel industry has failed to develop in Australia.

The purpose of this master's thesis therefore is to identify the critical issues facing biofuel industry development in Australian and to propose possible policy and private sector strategies for dealing with them.

The goals of this thesis were realized by using an innovation systems approach to analyse the Australian fuel ethanol and biodiesel industries. The analysis was done in the following three steps; the first was to map the development of the ethanol and biodiesel industries, the second was to analyse the performance of the industries overtime and the third was to identify the mechanisms which have either induced or blocked their growth. The strategies proposed by this thesis were derived from analysing the inducing and blocking mechanisms and the related issues. The innovation systems approach was chosen because of its ability to provide insights into key industry players, their network interactions and the institutional setup within which they work together to develop, diffuse and use their products.

The data needed for the analysis stated above included information related to the development, diffusion and use of ethanol and biodiesel; that is, details about the industry actors and their activities, industry networks, product standards, excise arrangements, government policy and so on. This information was found in various

reports, newspaper articles as well as from various organizational web sites. This was complemented by insights from twelve face to face interviews with top level managers from the most influential ethanol and biodiesel producers, a large financial investment group, a university research centre and a government department.

The Australian ethanol and biodiesel industries, when viewed from an innovation systems perspective, have undergone considerable structural change since the early 2000s. Many new producer firms and other actors have entered the field, product standards have been created, fuel excise arrangements have been set and some industry networks and advocacy coalitions have also been formed or strengthened. Of the two systems the fuel ethanol innovation system is the more complete with a greater research base, a more developed distribution network, and a stronger and broader advocacy coalition lobbying its cause.

Numerous inducing and blocking mechanisms were identified as influencing the ability of the ethanol and biodiesel industries to develop, diffuse and utilize their respective biofuels. The inducing mechanisms identified include broad contextual factors such as climate change, high oil prices and rural development goals. These drivers have inspired grant schemes, government fuel contracts, formation of lobby groups and consumer demand for cheap home grown alternatives.

The overall performance of the ethanol and biodiesel industries has varied overtime with the key challenges coming from their ability to; legitimize their offerings, form markets and develop new knowledge.

Legitimation is a major challenge for both the ethanol and biodiesel industries. It is acceptance by consumers which lies at the heart of the ethanol challenge while for biodiesel it is acceptance by engine manufacturers and automotive groups that is currently blocking greater acceptance. The ethanol scare campaign of 2002-03 should serve as a reminder to the biodiesel industry that having engine manufactures and automotive groups on side is crucial for successful market development, especially for the mass market which can be highly temperamental and easily manipulated.

The ethanol and biodiesel industries both have considerable market formation challenges with the problem being most acute for the ethanol industry. The principal mechanisms blocking market formation for fuel ethanol is poor consumer demand combined with a limited distribution network. The market formation challenge facing the biodiesel industry consists of uncertainty due to up coming fuel tax credit reform, the need to choose a mass market entry blend and a limited distribution network.

Knowledge development is another challenge facing the ethanol and biodiesel industries and one with long term implications. For Australia to minimize its dependency on technology imports, and for it to be able to derive greater economic value along the whole value chain, it must overcome the current lack of research and development which characterises the biofuel sector.

Possible strategies for dealing with the biodiesel industry critical issues include; forming a biodiesel specific industry association, working closely with government agencies and engine manufactures to run credible engine compatibility trials, choosing a common mass market entry blend (e.g. B5 until support is garnered for higher blends), and forming a broad coalition of advocates to lobby governments for greater market formation and research and development support.

Possible strategies for dealing with the ethanol industry critical issues include; developing closer ties with Oil Majors, working with automotive groups to promote clear and concise information about engine compatibility, promoting fuel ethanol’s environmental and health benefits, and taking a more active stance towards supporting research and development of second generation production technologies.

The results of this thesis support the idea that those who actively seek to overcome the critical issues facing the ethanol and biodiesel industries stand to be the long term economic winners in the global quest to develop new industries that can deliver alternatives to petroleum based automotive fuels.

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ACRONYMS

AAA	Australian Automotive Association
ABARE	Australian Bureau of Agricultural and Resource Economics
ABG	Australian Biodiesel Group
ACT	Australian Capital Territory
AMA	Australian Medical Association
ARF	Australian Renewable Fuels
ATA	Australian Transport Association
BIA	Biodiesel Industries Australia
CRC	Co-operative Research Centre
CSIRO	Commonwealth Science Research Organisation
CLIMA	Centre for Legumes in Mediterranean Agriculture
DAFGS	Diesel and Alternative Fuels Grant Scheme
DEH	Department of Environment and Heritage
DEST	Department of Education, Science and Training
DEUS	Department Energy, Utilities and Sustainability
DITR	Department of Industry, Tourism and Resources
FCAI	Federal Chamber of Automotive Industries
IPO	Initial Public Offering
NAF	Natural Fuels Australia
NSW	New South Wales
PM	Prime Minister
QLD	Queensland
RFA	Renewable Fuels Australia
RIRDC	Rural Industries Research Development Corporation
SA	South Australia
SAFF	South Australian Farmers Fuel
SARDI	South Australia Research and Development Institute
SERAC	Sustainable Energy Research Advisory Committee
STI	Science Technology and Innovation
UQ	University of Queensland
VIC	Victoria
WA	Western Australia

1 INTRODUCTION

A strong biofuel industry in Australia has the potential to provide multiple benefits to the nation and its peoples. The increased use of biofuels has the potential to mitigate global climate change and provide health benefits by reducing emissions of greenhouse gases and particulate matter from the automotive transport sector (Beer et al., 2001; Lave et al., 2001; Srivastava and Prasad, 2000). An expansion of the industry would assist economic and rural development goals by creating jobs and providing new markets for traditional agricultural crops (Ames and Werner, 2001; ABARE, 2003; Biofuels Taskforce, 2005). Other benefits of a home grown biofuel industry include enhanced fuel security and a lower balance of payments as a result of reduced reliance on foreign oil imports (Weeks, 2005; King, 2006).

For biofuels to be seriously considered as alternatives to traditional petroleum based automotive fuels they must be economically viable. The Australian Bureau of Agricultural and Resource Economics have undertaken a number of studies to investigate this question. Their findings suggest that with the price of crude oil above $US30-40 a barrel ethanol derived from sugar or grain, and biodiesel made from used cooking oil and animal fats would be economically viable in the Australian context (ABARE, 2005). Considering that the current price of oil is around $US70 a barrel and that the IEA recently announced that oil could reach $US100 a barrel in the coming years, the economic viability of biofuels in Australia looks promising.

A strong home grown biofuel industry in Australia has however failed to develop. The total production of fuel ethanol for the period 2004-05 dropped to 23ML, approximately one third of that produced in 2002-03. Biodiesel production on the other hand increased over the same period though the total production was a meagre 4ML. The total production of biofuels in Australia for 2004-05 was less than a quarter of one percent of the total gasoline and diesel fuel consumed for the period (Biofuels Taskforce, 2005; AIP, 2005).

The purpose of this master's thesis therefore is to identify the critical issues facing biofuel industry development in Australia and to propose possible policy and private

sector strategies for dealing with them. These goals were realised through three steps; the first was to map the development of the ethanol and biodiesel industries, the second was to analyse the performance of the industries overtime and the third was to identify the mechanisms which have induced and blocked the growth of the ethanol and biodiesel industries in Australia.

The development of ethanol and biodiesel industries in Australia has been characterised by intense political and public debate. The major players include the federal Liberal and National parties, a small group of large and influential oil companies (Oil Majors – Caltex, BP, Shell and Mobil), automotive groups, engine manufacturers, biofuel producers and consumers. A number of strong lobby groups have emerged to support the various points of view. Because of this highly political nature any method of analysis which stops short of providing insights into the roles and influence of the key players would fail to get to the heart of what is driving (inducing) and blocking the development of the ethanol and biodiesel industries.

This study, therefore, employs an innovation systems framework of analysis because of the ability for this approach to provide insights into industry key players, institutional setup, and network interactions. The innovation systems approach is built on the concept that it is the entire “system” in which a new industry is embedded that influences its development and ultimately its success or failure (Hekkert et al., 2004).

The next section of the report describes the analytical framework used in this thesis and is followed by an explanation of the research methodology employed. After this, case studies of the ethanol and biodiesel industries are presented. Following on, recommendations for dealing with the critical issues identified in the case studies are proposed. The final section of the report presents a discussion of the results and conclusions from the analysis in relation to the goals set out here in the introduction.

2 ANALYTICAL FRAMEWORK

This section introduces the innovation systems framework used to analyse the ethanol and biodiesel industries. An explanation of an innovation system's key structural components is presented and followed by a description of innovation system dynamics with a distinction being made between structural and performance change.

2.1 INNOVATION SYSTEMS

The innovation systems framework has emerged in recent decades as an increasingly popular way for policy makers and researchers to assess the development and performance of new or existing industries. This approach has been developed through a combination of evolutionary economics and institutional theories with the central idea that innovation and diffusion is both an individual and collective act (Edquist and Hommen, 1999; Nelson and Nelson, 2002; Jacobsson and Bergek, 2004).

A variety of innovation system approaches can be found in the literature. They can be viewed in a number of different dimensions including geography and technology. Geography is central to the national systems of innovation approach first proposed by Freeman in the 1980s and the regional systems of innovation approach inspired by studies of Silicon Valley and innovative regions in Europe. Technology is what defines the technological innovation systems approach first proposed by Carlsson and Stankiewicz in 1991 and the sectoral innovation systems approach proposed by Breschi and Malerba in 1997 (Carlsson et al., 2002; Chang and Chen, 2004).

The technological innovation systems approach allows one to define the boundaries of the system based on a system's core technology or product offering (Bergek et al., 2005). Since this thesis is concerned with the study of particular products (ethanol and biodiesel) the technological innovation systems approach is the most appropriate.

A technological innovation system (from here on referred to simply as "innovation system") can be defined as the "…networks of agents interacting in a specific technology area under a particular institutional infrastructure for the purpose of creating, diffusing and utilizing technology" (Carlsson and Stankiewicz, 1991). This

definition describes three distinct structural components; “actors” (or agents), their “institutions” and the “networks” that connect them. The underlying concept is that the actors, whose actions are shaped by an institutional setup, interact through networks in a planned or unplanned manner to achieve the overall goal of developing, diffusing and utilising technology (Carlsson and Stankiewicz, 1991; Carlsson et al., 2002; Bergek et al., 2005; Jacobsson and Bergek, 2004).

The innovation systems approach expands the traditional boundaries of industry analysis beyond that of just its member firms to include all significant actors involved in the development, diffusion or utilization of its core technology or product. The actors of an innovation system therefore include firms, researchers, users, governments, distributors, media, lobby organisations, user groups, suppliers and so on (Bergek et al., 2005; Jacobsson and Bergek, 2004). Actors are not constrained to one innovation system or another and often participate in a number of different or competing innovation systems. Competing innovation systems may compete over users, alliances with producers of complimentary products, support from government decision makers and so on (Bergek et al., 2005).

Institutions set the “rules of the game”, influence expectations and acceptance of a technology. Institutions exist in the form of product standards, laws, regulations, government policy, user preferences and so on (Geels, 2004; Bergek et al., 2005).

Networks between actors constitute channels for the transfer of information and goods as well as collaborative interactions and industry co-operation. Networks include all relationships both formal and informal. Important industry networks include industry associations, business relationships, R&D collaborations, lobby groups, private sector-university networks, and so on (Bergek et al., 2005; Jacobsson and Bergek, 2004).

Conceptualising the boundaries and the components of an innovation system can be aided by schematic representation. Geels (2004) conceptualises an innovation system as linkages between “social groups” which share certain characteristics such as roles, responsibilities and norms. Geels’ conceptualisation can be seen in Figure 1.

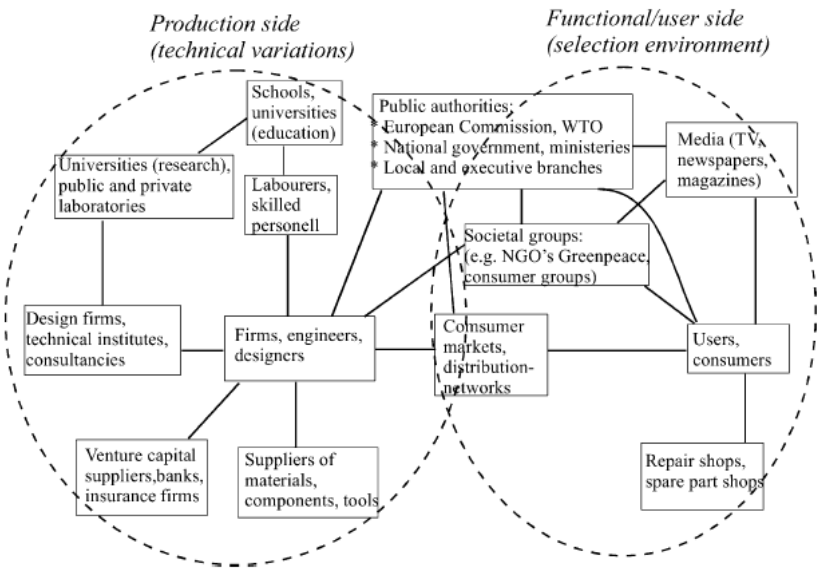


Figure 1 – Geels' Social Groups

In this thesis, Geels' social groups approach is modified in an attempt to simplify the conceptualisation. This is done by organising actors which share a similar purpose into six different "domains". Figure 2 shows the domains and provides examples of actor groups which occupy them. The lines between the domains can be thought of as networks through which information is transferred and goods or services are traded.

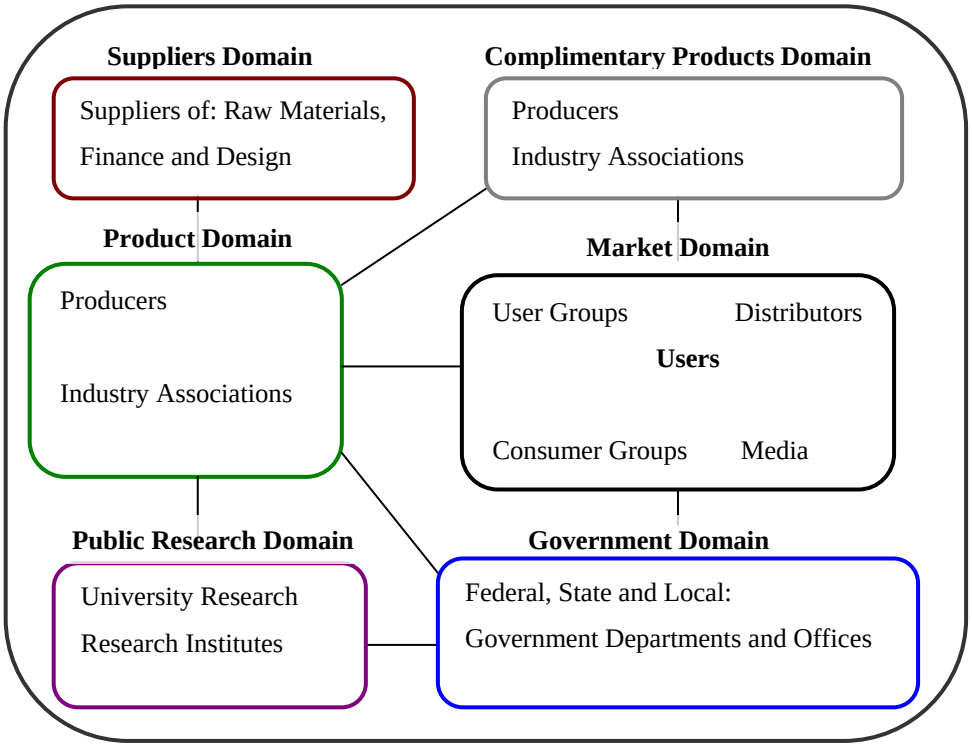


Figure 2 – Innovation System Actor Domains

2.2 INNOVATION SYSTEM DYNAMICS

Innovation systems change both in terms of their structural components and in their ability to perform their goals of developing, diffusing and utilizing innovations. The following sub-sections describe these concepts in more detail.

2.2.1 Innovation System Structural Change

Innovation systems don't just appear but rather evolve over time. The evolution process is characterised in part by changes in the system's structural components, i.e. actors, institutions and networks. Structural changes include such things as the entrance and exit of actors, creation of standards and regulations, and the formation industry networks (Hekkert et al., 2004).

The entrance of new actors into an innovation system can be significant because of the new knowledge and resources they bring to the system. New entrants also send positive signals about the potential of the field (Bergek et al., 2005).

Initially, institutions such as product standards, tax regimes, and government policy may not exist for a new product or technology. The process by which these things are established is referred to in the literature as institutional "alignment" and is a key process in the early stages of industry development (Freeman and Louca, 2002; Jacobsson and Lauber, 2004).

2.2.2 Innovation System Performance

Innovation systems change not only in terms of their structural components but also in the way in which these components contribute to the system performing its overall goals of developing, diffusing and utilizing innovations. The contribution of a structural component or set of components to a system's overall goals is referred to in the literature as a "function". An innovation system function can be thought of as a key process in the evolution of an innovation system (Johnson and Jacobsson, 2001; Bergek et al., 2005; Hekkert et al., 2004).

While the concept of functions has recently been appearing more frequently in the innovation systems literature it has been the collaboration of a number of Swedish

academics who have championed their use. The culmination of their efforts is presented in a paper by Bergek et al. (2005) and outlines seven key functions for a technological innovation system. These functions are to; (provide) incentives for firms to enter, mobilize resources, legitimize the offering, form markets, run entrepreneurial experiments, develop knowledge and (provide) positive externalities. Table 1 describes these seven functions.

Table 1 – Innovation System Functions

FUNCTION	DESCRIPTION
Incentives to Enter	Pressures or motivation for existing actors to expand or new actors to enter into the TIS. Can act as "guides" of the "direction of search".
Resource Mobilization	As the TIS expands new human (researchers, entrepreneurs, management etc) and financial (grants; venture, seed and investment capital etc) resources need to be mobilized.
Legitimation	The new technology or product must be considered appropriate and desirable by relevant actors. This is function is critical for resources to be mobilized, demand to form, and institutions to be aligned.
Market Formation	Initially a market may not exist; product supply may be intermittent, consumer demand unarticulated and distribution networks lacking.
Entrepreneurial Experimentation	The learning process whereby actors seek to find new applications, access markets and redefine traditional business models.
Knowledge Development	Concerned with the knowledge base and its evolution. Includes scientific, production, market knowledge and so on. There are various sources such as research and development, learning from doing, imitation, importation etc.
Positive Externalities	System wide effects benefits felt as a result of key events such as new entrants, first movers etc.

Innovation system functions are not only influenced by a system's structural components but also by each other through positive and negative linkages and feedback loops. An example of a negative linkage is the case where an innovation system's product or technology is not considered to be a legitimate offering by consumers resulting in poor consumer demand and problems forming markets.

Innovation system performance is influenced by factors both internal and external to its defined boundaries. External factors include the influence from competing innovation systems as well as broad contextual issues (Bergek et al., 2005).

Competing innovation systems, i.e. systems offering competing products, may influence institutions in such a way as to hinder institutional alignment to the new product offering. This is common in the energy sector where large well established corporations are very influential over governments and consumers.

The effects of broad contextual issues is perhaps best explain in terms of Geels' (2004) concepts of "mis-matches" and "windows of opportunity". Geels explains that variations in economic cycles and cultural movements can generate opportunities for new products by creating mis-matches between what is being offered and what is desired. This leads to windows of opportunity for new products offering appropriate alternatives. In the automotive fuel sector we can see that high oil prices and climate change concerns are broader contextual issues opening up opportunities for biofuels to enter the fuel mix. In functional terms the windows of opportunity can be described as incentives for firms to enter and legitimation of the biofuel offering. Broad contextual issues are generally long running, have a profound impact and thus easy to identify.

One of the benefits of the functional approach is that it provides a useful structure for identifying policy issues and setting policy goals. Once a desired functional pattern is identified it is then possible to recognize mechanisms that either induce (drive) or block development towards that functional pattern and subsequently specify policy issues related to these inducing and blocking mechanisms (Carlsson and Jacobsson, 2004; Bergek et al., 2005).

3 RESEARCH METHODOLOGY

This section of the report describes the methods used to map the development of the ethanol and biodiesel industries and to analyse their performance overtime. This analysis was achieved in two steps, the first was to map the structural change of their innovation systems and the second was to analyse system performance overtime.

This thesis employs a research methodology based on a scheme of analysis developed by a group of Swedish academics (see Bergek et al., 2005) together with the "historical event analysis" methodology described by a group of researchers at Utrecht University in the Netherlands (see Hekkert et al., 2004).
The first part of this section outlines what data was needed to achieve the research objectives. The second part describes how and where from the data was collected. The third part explains how the data was organised and managed and the fourth part describes how it was analysed. A final part presents a discussion of methodological limitations.

3.1 RESEARCH DATA

3.1.1 Data for Analysing Innovation System Structural Change

The data needed to map the structural development of the ethanol and biodiesel innovation systems consisted of names and details of actors, institutions and networks. The aim was to identify all structural components significantly involved in the development, distribution and use of ethanol and biodiesel. This included information about biofuel firms, their industry associations, raw material suppliers, fuel distributors, fuel excise arrangements, product standards, government departments, lobby groups, universities research centres and so on.

3.1.2 Data for Analysing Innovation System Performance

The data needed to assess innovation system performance was information about key events and activities related to the development, distribution and use of ethanol and biodiesel. That is, the details of what was done by whom and when. Key events and activities included such things as the opening of production facilities, announcement of major off-take agreements, release of new government policy, securing of finance

for new projects, announcement of new exercise arrangements and so on. Key activities included such things as research projects, product standard setting processes and government support programs.

3.2 DATA COLLECTION

The data for this thesis came from two main sources; literature and face to face interviews with individuals working in the biofuels field.

3.2.1 Literature

The literature for this thesis was largely found in the form of governmental reports and documents, newspaper articles, journal articles, PhD and Masters theses, patent documents and web pages. This was obtained primarily from the websites of the various organisations involved in the industry and a number of specialised databases.

Much of the literature for this thesis was collected directly from the web sites of the various organisations involved in the industry. This included government departments, firms, universities and industry associations. The websites provided information as well as the opportunity to download reports and other documents.

Useful information was also collected from a number of specialised databases. The Factiva database enabled the ability to search and download newspaper articles from the top 10 Australian Newspapers. Hundreds of newspaper articles relating to ethanol and biodiesel were downloaded from as far back as the early 1990s. This provided a very useful record of key events, important announcements as well as views and opinions. The Web of Science and Australasian Digital Thesis provided access to scientific articles and Australian theses respectively.

3.2.2 Interviews

Face to face interviews with people working in the biofuel industry were an important source of research data. Interviewees provided information about key events and their perceived importance. They also provided information about the ethanol and biodiesel innovation systems, i.e. structural components. The interviews typically lasted for one hour and were of a semi-structured nature. Examples of interview questions used in this study can be found in Appendix 1.

The interview process involved travelling around Australian for meetings with individuals working in the ethanol and biodiesel industries and related fields. Interviewees and their organisations were located in NSW, QLD, VIC and SA. They included top managers from five biodiesel companies, two ethanol companies, two industry associations, one retail distributor, one state government department, one financial investment group and one university. Table 2 provides information about the interviewees.

Table 2 - Interviewees

ORGANISATION	INTERVIEWEE	POSITION(S)	LOCATION	Notes
CSR Ethanol	Martin Jones	General Manager	Melbourne, VIC	No. 2 Ethanol producer
Manildra Group	Brian Hanley	General Manager	Nowra, NSW	No. 1 Ethanol producer
Australian Biodiesel Group (ABG)	Bevan Dooley	Technical Director	Gosford, NSW	No. 1 Biodiesel producer
Biodiesel Industries Australia (BIA)	Andrew Hill*		Rutherford, NSW	The 1st commercial biodiesel producer
QLD Dept of State Development, Trade and Innovation	Siobhan Ahern * and Phil Jardie	Ethanol Policy Officer, and Manager	Brisbane, QLD	Leading state government agency supporting ethanol industry development
Dept of Chemical Engineering (Uni QLD)	Victor Rudolph	Professor and researcher	Brisbane, QLD	Home to one of the 1st biodiesel research projects
Biodiesel Network	Adrian Lake		Gosford, NSW	Ex-Director and founder of ABG. President of BAA
Babcock & Brown Environmental Investments (BBEI)	Greg Haustorfer		Sydney, NSW	A major international financial investment group
Natural Fuels Australia	Barry Murphy	Chairman	Sydney, NSW	Ex-CEO for Caltex and non-executive director for BBEI
Renewable Fuels Australia (RFA)	Bob Gordon*	Executive Director	Canberra, ACT	Association with Manildra since 1992
South Australian Farmers Fuel (SAFF)	Andy Fischer, Mike Jureidini* and Graham Haddow	Director, Biofuels Consultant, and Business Development Consultant	Adelaide, SA	1st retail network for biodiesel
Australian Renewable Fuels (ARF)	Terry King*	Marketing Manager	Adelaide, SA	Once worked with SA Government biodiesel development program.

* These individuals were consulted during the results verification phase

3.3 DATA MANAGEMENT

The data for this thesis was managed in two separate databases. The first database managed information about the ethanol and biodiesel innovation systems' structural components, while the second managed data relating to the key events and activities

influential in their development. The databases provided a useful way to manage the data in the analysis phase.

The innovation system structural components database managed information relating to the ethanol and biodiesel systems' actors, institutions and networks. This included the name and/or description, role and date of entry. The actors were assigned to one of the six innovation system actor domains as shown in Figure 2. Managing the data in this way made it possible to see how the system had developed overtime.

The key events and activities database managed information about all the important events and activities related to the development, diffusion and use of ethanol and biodiesel. A single entry was recorded for each event or activity and included a description, date of occurrence, the name of the principal actor/s involved and their role/s in the innovation system. The events and activities were broken down into a number of categories (e.g. policy, excise, research, production etc) and ultimately assigned to one or more of the seven innovation system functions.

3.4 ANALYSIS

The analysis for this thesis involved two main tasks, namely; mapping structural change of the ethanol and biodiesel innovation systems and assessing their performance. The methods used to do this are described in the following sub-sections.

3.4.1 Innovation System Structural Change

Structural development of ethanol and biodiesel innovation systems were mapped using the innovation systems database described in Section 3.3. The database provided information about actors and their date of entry into the systems. The database also provided information about the timing of changes in institutions and the formation of networks.

3.4.2 Innovation System Performance

The performance of the biodiesel and ethanol innovation systems was analysed by assessing their seven functions, namely to; (provide) incentives for firms to enter, mobilize resources, legitimize the offering, form markets, run entrepreneurial experiments, develop knowledge and (provide) positive externalities. The functions were assessed by analysing the sequence of key events and activities related to the

development, diffusion and use of ethanol and biodiesel. This method was inspired by a number of similar case studies undertaken at Utrecht University in the Netherlands (see Hekkert et al., 2004).

The key events and activities database was used to manage the data for this analysis. Assignment of events and activities to functions was guided by the functional indicators in Table 3. Once a function or set of functions had been assigned to each event and activity it was then possible to trace the development of the ethanol and biodiesel industries in functional terms.

Table 3 – Functional Indicators

FUNCTION	INDICATORS
Incentives for firms to Enter	Gov targets, changing policy regulations (e.g. environmental), expectations/beliefs in potential.
Financial Resource Mobilization	Grants, capital investments, IPOs.
Legitimation	Depiction in the media, vocal support from key actors, favourable laws and regulations, stance of complimentary product producers, consumer acceptance, stance of engine manufacturers, auto groups and Oil Majors.
Market Formation	Supply capacity, distribution network, favourable tax regimes, standards, consumer demand and government contracts
Entrepreneurial Experimentation	Variety of business models, different pricing strategies and target markets etc.
Knowledge Development	Number of research projects at universities and research centres, PhDs and masters theses, industry based R&D, research collaborations.
Positive Externalities	Identification of system wide benefits attributed to entrance of new actors or major events.

The ability for the ethanol and biodiesel innovation systems to develop, diffuse and utilize their respective biofuels was determined based on their functional performance. The functional analysis was supported by the views expressed by individuals working in the industry as well as evidence from the structural development of the innovation systems.

The functional analysis facilitated identification of the mechanisms inducing and blocking the development of innovation system performance, and hence industry development. The most troublesome blocking mechanisms were identified as critical issues for the industries and possible strategies for dealing with them were proposed.

The last step in the analysis was to validate the results. This was done by sending a summary of the key findings to a select group of "industry experts" and then engaging in feedback sessions to discuss any necessary changes and/or clarifications.

3.5 METHODOLOGICAL LIMITATIONS

A number of methodological limitations were identified throughout this thesis project. The following discussion has divided limitations between those that affect analysis of innovation system structure and innovation system performance.

3.5.1 Innovation System Structure

Innovation systems are dynamic and involve many components, making them difficult to capture completely in an analytical sense. The more that one learns about the system the more aware one becomes of other structural components (i.e. snowball effect). To overcome this limitation one must focus on the most significant system components; however deciding which components these are is prone to subjective judgement. To address the subjectivity of the process the results of this thesis were validated with a select group of "industry experts".

Institutions, in the innovation system sense, are somewhat poorly defined, difficult to identify and thus hard to describe. In the innovation systems literature "institutions" include laws, regulations, expectations, norms, culture and so on. Of these laws and regulations are tangible and easy to describe. Expectations, norms and culture on the other hand are vague, intangible institutions making them difficult to handle. This limitation has been managed by narrowing the definition of institutions and while it makes the analysis easier it is less complete.

Networks, in the innovation system sense, are well defined but due to their formal and informal nature are difficult to identify. Formal networks such as industry associations and research collaborations are easy to identify and describe. Informal networks such as business relationships, lobby groups, and so on are difficult to learn about and hard to describe in terms of dates and participation.

3.5.2 Innovation System Performance

An innovation system's key events and activities are numerous and their significance not always apparent. The significance of events such as the announcement of a new excise arrangement is quite obvious while the significance of a research project on the other hand is not quite so apparent.

To assist understanding the significance of key events and activities the opinions of industry actors were consulted; however this process has its downfalls. All industry actors have opinions about the significance of certain events (and activities) though their opinions are biased towards what is important to them and what is within their realm of interest. Opinions are also dynamic making it difficult to capture a good understanding of the significance of events which happened a long time ago.

The significance of government announcements can be particularly difficult events to assess. Governments often make announcements of their support for certain programs before they have the ability to carry them out. This makes it difficult to interpret what is real and what is public pleasing rhetoric.

The allocation of events and activities to functions can be a difficult task and the predefined functional indicators should be closely followed. Some events and activities impact on multiple functions, part of one event may relate to one function and another part to a different function. The secondary and tertiary impacts of events also make the allocation process difficult. For example, the announcement of a new excise arrangement may entice new entrants and therefore naturally seem to belong to "incentives for firms to enter" though in fact this is a secondary impact due to a link to market formation.

The process of analysing functions is complex and iterative. As more is learnt about each function the clearer they become in a process that may see early conclusions turned on their head. The result of this is that the analyst is constantly pushing the realm of their own understanding in a quest to uncover the true functional pattern. Although there are clear analytical steps prescribed for this process intuition and insight play an important role.

The fact that innovation system functions are dynamic and closely linked to each other means that the significance and robustness of results from their analysis are heavily constrained by the time frame of the analysis. It is therefore good practice to continually update the analysis in light of new events and new information.

4 CASE 1 – BIODIESEL INDUSTRY

This section presents a case study of the Australia biodiesel industry. The first section introduces biodiesel, the second describes the biodiesel innovation system and the third section presents an analysis of the system's performance. The final section presents a discussion of the critical issues facing the biodiesel industry in terms of mechanisms blocking the various innovation system functions.

4.1 INTRODUCING BIODIESEL

Biodiesel refers to any diesel-equivalent biofuel and is usually made from vegetable oil and/or animal fats. Biodiesel is biodegradable, non-toxic and has significantly fewer emissions than petro-diesel when burned. It can be used as an additive or substitute in most diesel engines with little or no modification. The gel or cloud point of biodiesel varies depending on feedstock though is usually higher than petro-diesel and calls for precautions in colder climates. Low percentage biodiesel blends can be distributed through existing automotive fuel infrastructure though certain guidelines should be adhered to avoid problems with oxidative stability, microbial contamination and material incompatibility.

Common feedstocks being used to make biodiesel in Australia include used cooking oil, tallow (animal fats), canola oil, palm oil and cotton seed oil. The choice of feedstock generally depends on the process technology being used and cost, which accounts for approximately 50-70% of the total cost of biodiesel production. It is commonly acknowledged that there is wide scope for improving biodiesel feedstock crops; to improve yield, lower cost, and "drought proof" to ensure security of supply.

The most common method for producing Biodiesel is through a process known as trans-esterification. This process has been known for over a century though much of the modern chemical techniques were described in patents issued to chemists for DuPont and Colgate-Palmolive-Peet around the time of World War II (Van Gerpen et al., 2004). While this process is reasonable well suited to large scale plants, scope exists for improvements as well as significant advancements in small scale production technologies and development of radically new processes (Rudolph, 2006).

4.2 THE AUSTRALIAN BIODIESEL STORY

The following section provides a chronological overview of the development of the biodiesel industry in Australia. It outlines key events, major actors and the most important changes in the institutional setup.

The overview is broken into three time frames. The first, pre 2001, describes the early days prior to biodiesel being recognised formally as an alternative fuel. The second period, 2001-2004, is defined by its uncertainty with regard to fuel excise status. The final period, 2004-2006, is all the time after the fuel excise arrangement was finalised.

4.2.1 Pre 2001 - Into Existence

In the late 1990s various individuals began to explore the potential of straight vegetable oil and biodiesel as alternative transport fuels. In 1999 the Diesel and Alternative Fuels Grant Scheme (DAFGS) Act was introduced to support the use of cleaner transport fuels and although it included canola oil it did not cover the use of biodiesel. It wasn't long before a small group of entrepreneurs began to lobby for biodiesel to be included in the Act. This eventuated in 2001 following the release of an Australian Greenhouse Office (AGO) commissioned CSIRO report authored by Beer et al. (2001) which praised the environmental and health benefits of biodiesel.

4.2.2 2001 to 2004 - Things Start Slowly

At the time of the decision to include biodiesel in the DAFGS Act a number of companies were already pushing ahead with plans to develop their own and/or build biodiesel production facilities. These companies included Biodiesel Industries Australia (BIA), Australian Renewable Fuels (ARF), Australian Biodiesel Group (ABG) and South Australian Farmers Fuel (SAFF). Entrepreneurial interest in biodiesel was further boosted by the Federal Government's announcement of their 350ML/yr biofuels target in late 2001.

It was also in the early 2000s that a small number of biodiesel research projects started at Australian universities. Various agricultural groups also began biodiesel feedstock crop trials which were in part funded by the Rural Industries Research and Development Corporation (RIRDC).

Significant uncertainty regarding biodiesel's excise status arose in 2002 when ethanol was brought into the fuel excise system. Prior to this biofuels had no fuel excise. The issue wasn't resolved until mid 2003 when the Federal Government announced that biodiesel would remain effectively excise free until 2008, later revised to 2011.

The commercial biodiesel industry was officially born in 2003 when the Federal Industry Minister opened the Biodiesel Industries Australia (BIA) plant in NSW. Around this time South Australian Farmers Fuel (SAFF) began to distribute small volumes of biodiesel through their small South Australian retail network. It was also in this year that the Department of Environment & Heritage (DEH) established the Australian biodiesel fuel quality standard.

Government interest and support for biodiesel was high in the early 2000s with several city councils running biodiesel trials (partially funded by the AGO), and various state government departments in SA and NSW providing funding to aid development of biodiesel production facilities.

4.2.3 2004 to March 2006 - The Industry Hots Up

Certainty for the biodiesel industry was established in early 2004 when its excise free status was finalised (on an equal basis to ethanol) and successfully extended to from 2008 to 2011. The biofuels excise extension was the result of strong lobbying by the National Party and Democrats for greater ethanol industry support. This is a nice example of how biodiesel has benefited from a strong ethanol lobby.

Following the fuel excise decision ABG and ARF moved ahead with plans to build their production facilities. A number of other companies signalled their intent to enter including Axiom, Natural Fuels Australia, Biodiesel Industries and Riverina Fuels.

The biodiesel industry began 2005 on a high with the successful IPO of ARF and strong interest due to soaring oil prices. The Federal Government's Biofuels Taskforce report however cast some doubt over biodiesel's long term economic feasibility. The report reaffirmed the Federal Government's intention to reform the fuel tax credit system in 2006, raising concerns that financial support for biodiesel use

through the Energy Grants Credits Scheme would not continue. Despite this, the year was to end on an upbeat note with the global investment group, Babcock & Brown, buying a 50% stake in Natural Fuels Australia and ABG raising over $20M in its IPO.

4.3 BIODIESEL INNOVATION SYSTEM STRUCTURAL CHANGE

In this section the structural development of the biodiesel innovation system is described. The section is divided into three sections; actors, institutions and networks.

4.3.1 Actors

The innovation system actor map, Figure 3, shows the key actors and their date of entry into the biodiesel innovation system. Actors are divided between six so called domains depending on their role and purpose in the innovation system. A discussion of the six domains and their most notable features is presented below.

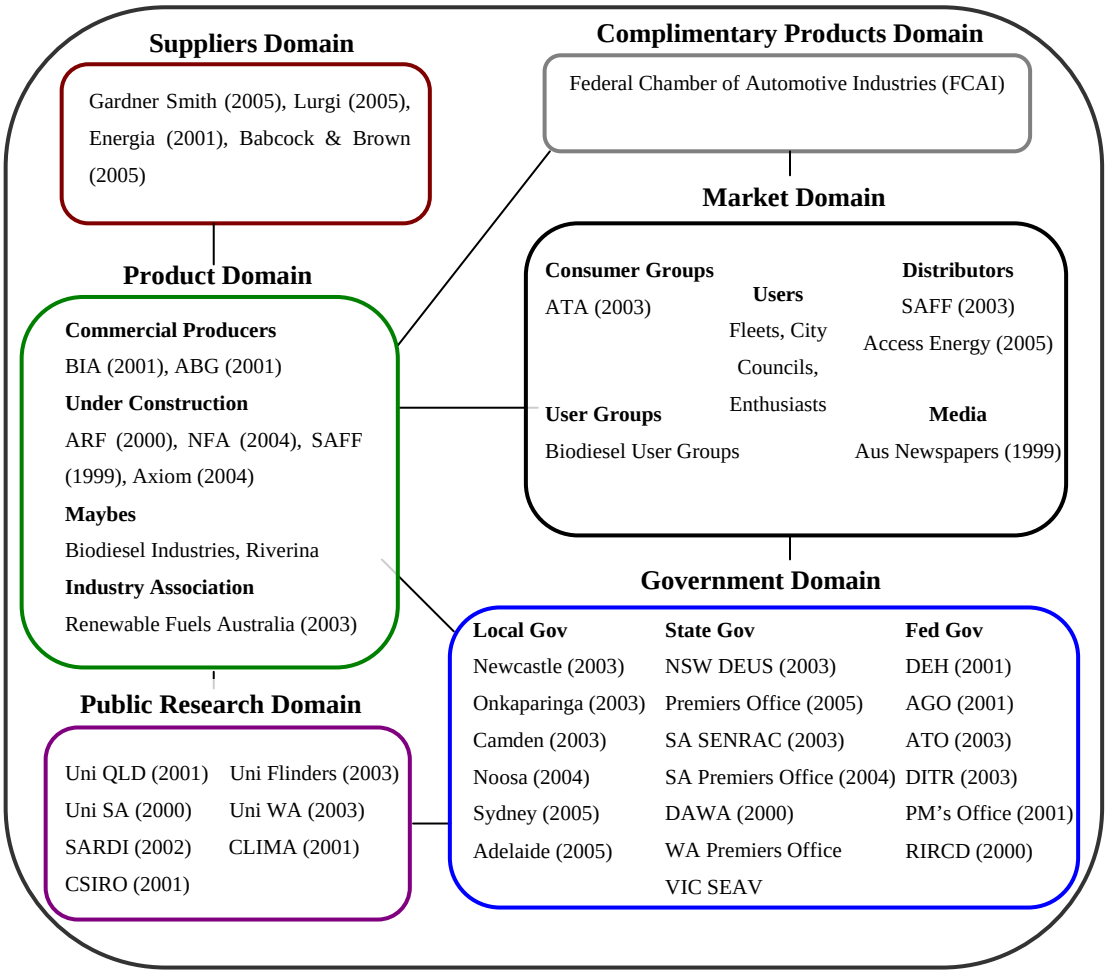


Figure 3 - Biodiesel Innovation System Actor Map

Product Domain

The product domain is populated by two commercial producers having a total biodiesel production capacity of 60ML/year. Four firms are scheduled to open production facilities within the next 18 months which, if goes all goes to plan, would bring the total production capacity beyond 500ML/yr by the end of 2007 (Biofuels Taskforce, 2005).

Market Domain

The only significant retail network distributing biodiesel is operated by SAFF in South Australian which has approximately 50 service stations. Access Energy (a subsidiary of Caltex) and one other service station in the Sydney region are trialling biodiesel distribution. The majority of biodiesel produced is distributed directly from producers to bulk users. Users include private transport fleets and city councils.

Biodiesel first began appearing in the Australia media in the late 1990s. Australian newspapers began reporting on biodiesel in 1999 though it wasn't until 2005 that total article counts for Australia surpassed 100 (Factiva Database, 2006). A graph of biodiesel related newspaper article counts overtime can be found in Appendix 2.

The principal consumer group involved in the innovation system is the Australian Trucking Association (ATA). Biodiesel user groups can be found in most capital cities and in online communities though are predominantly geared towards backyard producers.

Suppliers Domain

Key biodiesel industry suppliers include Gardner Smith - the dominate feedstock supplier, Lurgi and Energia - suppliers of European production technology, and Babcock and Brown - a key financial investor. Investment capital has also been supplied by the Australian stock market.

Complimentary Products Domain

The complimentary products domain is represented principally by the Federal Chamber of Automotive Industries (FCAI).

Public Research Domain

Significant Biodiesel research projects have been carried out at the following Australian universities and research centres: University of South Australia, Flinders University South Australian Research and Development Institute (SARDI), CSIRO, CLIMA at the University of Western Australia and well as the University of Queensland.

Government Domain

The most active Federal Government departments working with biodiesel include the Department of Industry Tourism and Resources (DITR), the Australian Greenhouse Office (AGO), the Department of Environment and Heritage (DEH) and the Australian Taxation Office (ATO).

A number of state government departments have been involved in industry development projects of which the most prominent have been the NSW Department of Energy Utilities and Sustainability (DEUS), various departments in the SA government and the WA Department of Agriculture for biodiesel crop trials. Various local governments have also been involved with biodiesel trials and use contracts.

4.3.2 Institutions

The significant biodiesel institutions include the biodiesel fuel quality standard, the biodiesel excise arrangement, the Energy Grants Credits Scheme and industry expectations. The so called “rules of the game” were established in 2003 and 2004 with the formation of the biodiesel fuel quality standard and biodiesel excise arrangement respectively. Institutional support through rebates to users of biodiesel began in 2001 when biodiesel was brought into the DAFGS Act (Replaced by the Energy Grants Credits Scheme in 2003). Expectations are another key feature of institutions and have been influenced by vocal governmental support, high oil prices and a strong stock market for shares in biodiesel companies.

4.3.3 Networks

A biodiesel specific industry association for commercial producers does not exist. However, the Renewable Fuel Association which was initially set up to lobby the ethanol cause began to represent the biodiesel industry around 2003. The backyard

biodiesel community has been represented by the Biodiesel Association of Australia (BAA) which was set up in 2001.

The DEH has played a significant networking role through its fuel quality standard setting activities and has distributed an online clean fuels bulletin since 2000.

A number of reasonably strong one on one networks have formed between various state government departments, research organisations and producers in NSW and South Australia. The key firms behind these networks are ARF, ABG, BIA and SAFF. ARF has an ongoing and strong relationship with the SA Government and a collaborative relationship with the South Australian Research Development Institute (SARDI) for feedstock crop development. SAFF has a collaborative relationship with various state based farmer federations and meat and live stock associations.

4.4 BIODIESEL INNOVATION SYSTEM PERFORMANCE

The following section describes the performance of the biodiesel innovation system in terms of its key functions. The analysis is supported by insights from interviews and evidence of innovation system structural change.

The function “Entrepreneurial Experimentation” is not explicitly analysed due to its strong overlap with other functions, i.e. its analysis is implicit in other functions. The analysis of “Positive Externalities” is deferred to the discussion and conclusions section of the report.

4.4.1 Incentives for Firms to Enter

The first strong incentives for firms to enter into the field came in 2001 when biodiesel was included in the Federal Governments Diesel and Alternative Fuels Grant Scheme Act (Replaced by the Energy Grants Credits Scheme in 2003) (Lake, 2006; King, 2006). This Act put air quality and alternative fuels on the national agenda and helped to create positive expectations and financial incentives to use cleaner burning transport fuels. High oil prices and relatively low biodiesel feedstock prices have further ignited entrepreneurial interest in biodiesel production (Dooley, 2005; Hill, 2005; Fischer et al., 2006).

The Federal Government (intentionally or not) has worked to create both positive and negative expectations about the biodiesel industry. Towards the end of 2001 the Federal Government proposed its 350ML/yr biofuel target creating positive expectation of a supportive framework for biofuels. However, their ABARE series of reports released between 2003 and 2005 have consistently under estimated production forecasts and expressed concerns about the economic viability of the biodiesel industry. Despite the governments cautious outlook entrepreneurial interest in the sector has continued to grow.

The fact that there are more than five new large scale biodiesel plants under construction and a host of other plants being proposed indicates that this function is performing relatively well.

4.4.2 Financial Resource Mobilization

Governmental financial assistance for the biodiesel industry has been mainly motivated by climate change initiatives and rural/economic development goals. The AGO, DITR and a number of state government offices such as the NSW Department of Energy, Utilities and Sustainability (DEUS) and the Sustainable Energy Research Advisory Committee (SERAC) in South Australia, have provided a small number of grants for biodiesel trials, training, workshops and production. This support occurred mainly between 2003 and 2004. The most significant financial support has come from the DITR which awarded $25.1M to 5 biodiesel projects as a part of its biofuels capital grants program.

Financial capital in the private sector has been relatively well mobilized coming from a variety of sources including private investors, parent companies and a favourable stock market (Hill, 2005; Dooley, 2005; Fischer et al., 2006; King, 2006). Initially, cash for projects came from private funds, as was the case for the BIA and initial ABG plant. ARF's plants have been bankrolled by its parent oil resources company Amadeus while the Natural Fuels Australia project currently going ahead in Darwin received its cash injection from Babcock & Brown Environmental Investments who bought a 50% stake in 2005. More recently large sums of cash have been raised

through the Australian stock market with ARF and ABG successfully raising in excess of $20M each through their initial public offerings.

4.4.3 Legitimation

The first major step towards legitimation for the biodiesel industry came with the AGO commissioned CSIRO report authored by Beer et al. in 2001 which proclaimed biodiesel's environmental and health benefits over petro-diesel (Lake 2006).

Since 2003 several state and local governments have begun, or stated plans, to use biodiesel in their fleets, indicating the legitimacy of the fuel in their eyes. These fuel contracts have been concentrated in states and regions where biodiesel producers are located and suggest the lobbying influence of producers (King, 2006; Lake, 2006). In 2005, the Australian Medical Association (AMA) came out as a strong supporter of biofuels suggesting that the biodiesel advocacy coalition is beginning to broaden.

Support for biodiesel from engine manufacturers and automotive groups is limited to blends up to B5 (King, 2006). This stance was revealed by the Federal Chamber of Automotive Industries (FCAI) and Australian Trucking Association (ATA) during the biodiesel standard setting process of 2002-2003 and did not change significantly in their submissions to the biofuel taskforce in late 2005 (Biodiesel Taskforce Submissions, 2005).

Although biodiesel is popular with enthusiasts and environmentalists it is a relatively new and unknown fuel in Australia. Until recently, biodiesel has largely been associated with stories of people producing fuel out of used fish-and-chip oil in their backyard, and of their occasional problems with fuel quality and blocked filters! The first significant mention of biodiesel in an Australian newspaper was in 1999 though the yearly article count for the entire country was not to surpass five until 2001 when 20 articles were recorded. Article counts had a mini peak in 2003 at 60 before a slight decline in 2004 followed by a relative explosion in 2005. Of the 184 articles printed in 2005, 100 were related to the initial public offerings of ABG and ARF. It seems that these IPO's made a considerable splash in the public sphere. This may be the first

steps towards recognising biodiesel as a commercial industry and eventually help shake its predominately backyard image.

4.4.4 Market Formation

Markets cannot be formed without products and in this respect the first significant steps towards forming a biodiesel market began in 2003 when the first commercial producer, BIA, opened its plant (initial capacity of 0.5ML/yr increasing to 19ML/yr in 2005). ABG began commercial production in 2005 with a name plate capacity of 40ML/yr. Australia's capacity to produce biodiesel is set to jump considerably from approximate 60ML/yr at present to approximately 500ML/yr by 2007 (Biofuels Taskforce, 2005).

The formation of product standards is a crucial step towards providing quality assurance and confidence for consumers. This step was achieved for biodiesel in 2003 with the formation of its fuel quality standard. It is an open issue however that the standard may need some amendments due to unforseen issues arising from Australian feedstocks and conditions (Dooley, 2005).

While on the topic of standards it is important to point out that there is no standard governing biodiesel blends nor any regulation or limit to blend ratios. The biodiesel blends used in Australia historically have varied widely between B5 and B100. Some are convinced that B5 or B20 will be the entry to market blend (King, 2006; Murphy, 2006; Fischer et al., 2006). This issue has the potential to become ugly since, as was noted above, engine manufacturers and automotive groups generally only support the use of blends up to B5.

Government assistance for the formation of a biodiesel market began in 2001 with its inclusion of biodiesel in the DAFGS Act making available rebates to consumers of biodiesel for heavy vehicle on road business use. In 2003 biodiesel came into the excise system but was made effectively excise free until 2011. The current fuel tax credit arrangements are set to be reformed in 2006 and are likely to change the support role of the Energy Grants Credit Scheme (which replaced the DAFGS in 2003) and other rebate schemes. As a result biodiesel may loose some competitive

advantage it presently has over petro-diesel for the on road business and other segments. This is creating some market uncertainty especially since the on road business this segment has been the principal target market for biodiesel producers to date (Hill, 2005).

Biodiesel users include transport fleets, a NSW coal mine, Newcastle City Council, Adelaide City Council, Sydney City Council, Mid-Murray City Council, Onkaparinga City Council and private retail customers through SAFF's retail network. Current demand for biodiesel is based on its price differential with petro-diesel and its environmental and health benefits.

The biodiesel retail distribution network is very limited. This is reflected by the dominant strategy of producers to deliver fuel directly to bulk users. The only substantial retail network providing biodiesel blends is that of SAFF in South Australia currently distributing B20 through over 50 service stations. Access Energy (a subsidiary of Caltex) distributes fuel to Newcastle city council and has recently begun B5 trials through 3 regional service stations in NSW. The Major Oil companies have historically had very little (nothing) to do with biodiesel distribution although BP has recently announced plans to build a production facility and distribute out of their Brisbane site.

4.4.5 Knowledge Development

Rural development goals have been the drivers for numerous biodiesel feedstock trials and research studies which have been carried out since the early 2000s. These have received grants from Rural Industries Research and Development Corporation (RIRDC) and run out of the WA Department of Agriculture (together with the CLIMA research centre) as well as the SARDI research centre in South Australia.

The number of scientific studies for advanced biodiesel feedstocks is generally very low compared to the potential gains in this area. The most notable scientific study in this area has been undertaken at Flinders University since 2003 and is exploring the use of algae for biodiesel production.

Although the number of production technology research projects at Australian universities has been on the rise the numbers are still low compared to the scope for improvements and innovation (Rudolph, 2006). Various research projects into biodiesel emissions and engine compatibility have been carried out at such places as the University of South Australia, Deakin University and RMIT. Biodiesel production and process research projects (including a number of undergraduate and master theses) have been carried out at the University of Queensland, University of Melbourne, Queensland University of Technology and Flinders University. These projects have been comparatively small with the exception a recently commenced project at Flinders University. The majority of research projects at universities have been funded at least in part by industry partners.

Some Australian biodiesel companies have chosen to develop their own production technology while others have chosen to import proven technology from overseas. The desire to avoid royalty payments and improve production processes have been the main drivers for the in-house development undertaken by ABG, SAFF, Biosel and Tenerre (Dooley, 2005; Fischer et al., 2006). In contrast, companies such as ARF and NFA have chosen to avoid this technological uncertainty by importing proven technology from overseas (King, 2006; Haustorfer, 2006).

4.5 BIODIESEL INDUSTRY CRITICAL ISSUES

This section presents a summary of the mechanisms inducing and blocking innovation system performance as well as a discussion of the most prominent biodiesel industry critical issues.

4.5.1 Biodiesel Inducing and Blocking Mechanisms

The inducing and blocking mechanism identified in the functional analysis above are summarised in Figure 4. The dotted lines between functions represent the most prominent inducing and blocking linkages.

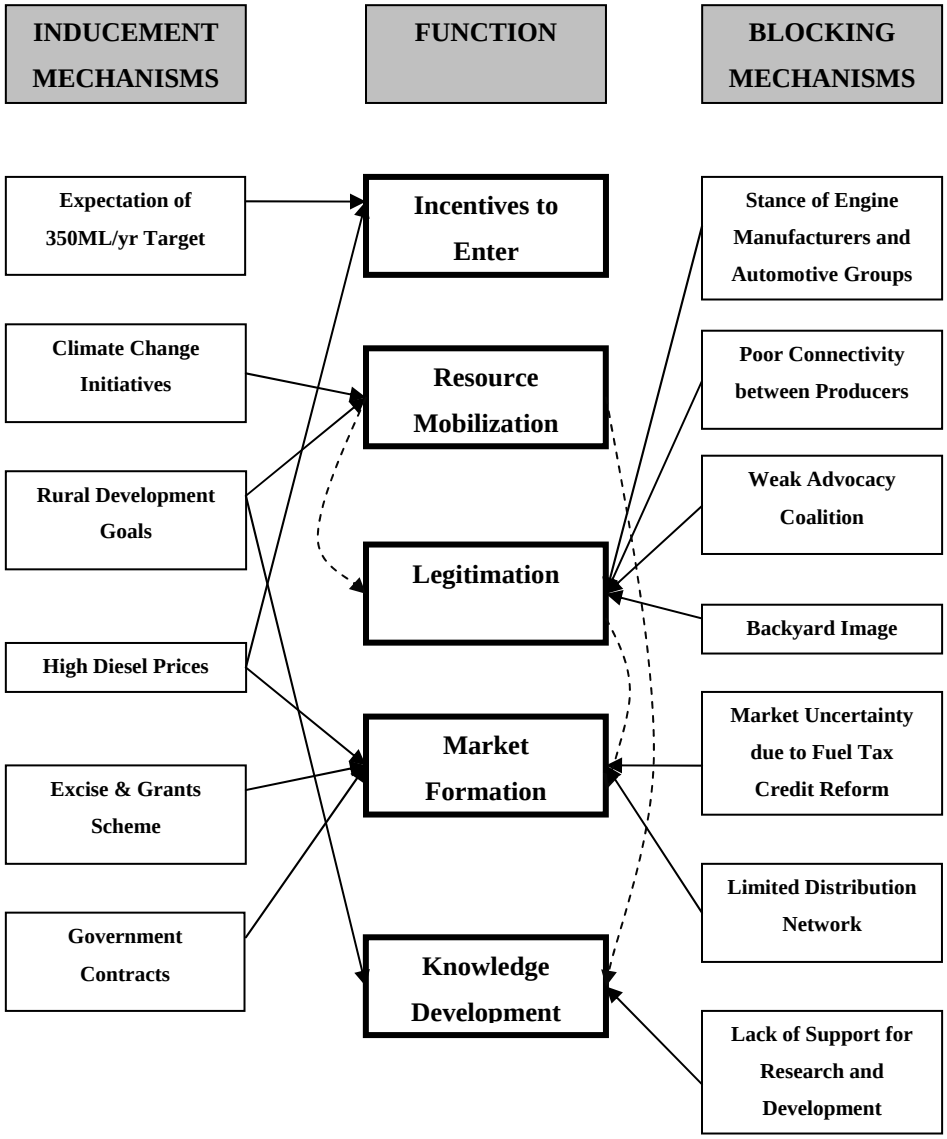


Figure 4 – Biodiesel Inducement and Blocking Mechanisms

This figure shows that the functions legitimation, market formation and knowledge development are block by numerous mechanisms and linkages. These functions form the basis of the following discussion on biodiesel industry critical issues.

4.5.2 Biodiesel Industry Critical Issues

Legitimation is a key process of any innovation system and is currently a critical issue for the biodiesel industry. While governments and bulk users continue to take up and support the fuel; mass market consumers remain generally unaware and/or lean towards a backyard image of the fuel. The dominant strategy to supply bulk users has meant that this lack of legitimacy with the mass market users has not yet significantly affected demand for the product.

Legitimacy is also lacking in the eyes of engine manufacturers and automotive groups who generally only support biodiesel blends up to B5. For markets to form smoothly this blend issues must be resolved. The issue is complicated by the fact that the industry has no agreed or standard market entry blend. Some producers support B5 or B20 and others support no limit. Without from support engine manufacturers and automotive groups for blends higher than B5 biodiesel will struggle to gain confidence amongst users who may fear damaging their engine or voiding their warrantees. This issue highlights the need for a biodiesel specific industry association to co-ordinate market entry blends and negotiate engine compatibility trials so as to avoid a showdown with engine manufacturers over vehicle warrantee issues.

Another market formation issue is the uncertainty regarding the fuel tax credit reform set to take place in 2006. If the Federal Government gets its way, biodiesel will loose some of its competitive advantage over petro-diesel in the heavy vehicle on road business segment and others. This will mean that the private retail market will become the segment with the biggest competitive advantage for biodiesel. If this occurs it will have wide arching implications including the need to expand retail distribution networks, build mass market awareness of the fuel, shake its backyard image and either support B5 as the mass market entry blend or garner support for higher blends from engine manufacturers. At this point in time, the reform measures have not yet arrived in parliament and the industry still has a chance to influence the outcome. The industry must therefore endeavour to form a broad coalition of advocates to pressure the government to continue to provide the competitive advantage it now enjoys or otherwise provide support for mass market development.

A less urgent issue, but one with long term implications, is the low number of research projects at Australian universities and the lack of governmental support for biodiesel research and development. If the industry is to continue to grow and expand it will need to develop advanced feedstocks and more efficient production processes. This will only happen with a wider interest in biodiesel research and development, of a nature currently only present in South Australia.

5 CASE 2 – FUEL ETHANOL INDUSTRY

This section presents the case study of the Australian fuel ethanol industry. The first section introduces basic fuel ethanol concepts, the second describes the ethanol innovation system and the third section presents an analysis of system performance. The final section presents a discussion of the critical issues facing the ethanol industry.

5.1 INTRODUCING FUEL ETHANOL

Ethanol is a colourless alcohol made from sugar, starches or ligno-cellulosic material. It is biodegradable, non toxic (safe to handle) and has significantly fewer emissions than regular petrol when burned. Anhydrous ethanol (99.9% water free) can be used as an alternative fuel to petrol or as an octane boosting petrol additive. Most modern spark ignition engines require no modifications to use petrol blends containing up to 10% ethanol (E10). E85 is a higher blend gaining popularity in some overseas countries but requires special engine modifications. Ethanol has the ability to be used in diesel engines when blended with special emulsifiers (diesohol) or with extensive engine modifications. Ethanol blends can be distributed through existing automotive fuel infrastructure though some modifications and guidelines must be adhered to avoid problems with water absorption and corrosion.

The feedstocks currently being used in Australia to produce ethanol are waste starch from wheat flour milling and C molasses, a by product from sugar cane processing. The new ethanol plants currently under construction in Australia will use dedicated grains such as sorghum, wheat and barley as their feedstocks. Ligno-cellulosic feedstocks (woody plant material) have been proclaimed as the future of ethanol though no technically viable conversion technologies currently exist.

The production processes for making ethanol have been known for millennia though immensely refined and upgraded in recent years. The principal processes for ethanol production are fermentation, distillation and dehydration. Yeasts are used to ferment sugars and starches to a mixture containing around 10% ethanol. The mixture is then distilled to yield ethanol at about 96% strength. The final step in the process is to dehydrate the mixture to remove the remaining water and yield pure ethanol.

Ethanol production from ligno-cellulosic feedstocks is the so called holy grail of ethanol due to the low cost of feedstocks and superior greenhouse benefits. Many millions of dollars are currently being invested in research and development around the world with a number of promising new technologies in the pilot stage.

5.2 THE AUSTRALIAN FUEL ETHANOL STORY

The following section provides a chronological overview of the development of the ethanol industry in Australia. It outlines the key events, major actors and the most important institutional changes.

The overview is broken into three time frames. The first, pre 2001, describes the early days. The second period, 2001-2004, is defined by the ethanol scare campaign and the formation of a strong ethanol lobby. The final period, 2004-2006, is all the time after the ethanol fuel excise arrangement was finalised.

5.2.1 Pre 2001 - Early Days

Although fuel ethanol has a long history in Australia, the first modern steps towards creating an ethanol industry began in 1992. In this year the Manildra Group began delivering ethanol to the fuel market in the Sydney region through independent fuel distributors. The Renewable Fuels Association in Canberra was created by Manildra around this time to lobby the ethanol cause.

Ethanol research also has a long history in Australia with considerable research into fuel ethanol production being undertaken between 1980 and 1992. The main centres for research during this period were the University of NSW, University of Melbourne and University of Queensland.

During the 1994-95 federal budget the Australian Democrats pushed for the creation of an ethanol “Bounty” to provide a production subsidy for fuel ethanol. Following this decision CSR, a company long involved with industrial ethanol production, entered into the fuel market though in very small volumes compared to Manildra.

In 1996, with the change of government, the ethanol “Bounty” was deemed to be ineffective and the program was dropped. In the mid to late 1990s the Australian

Greenhouse Office (AGO) began to support fuel ethanol production and in 1999 provided $1M to Manildra for a plant upgrade. During this period of renewed interest a number of ethanol plants were proposed in sugar and grain producing regions. In 2001 the AGO granted over $16M towards ethanol projects in Queensland.

In 1999 the Federal Government introduced its Diesel and Alternative Fuel Grants Scheme Act which offered grants to operators of commercial heavy vehicles for fuels including ethanol. In 2000, the Fuel Quality Standards Act was introduced and the proposed ethanol limit in petrol was adjusted from 7.8 to 10%.

5.2.2 2001 to March 2004 – Strong Ethanol Lobby and Scare Campaign

In 2001 the Queensland National Party began to re-vocalise its strong support for the ethanol industry as a means to aid the then struggling sugar industry. In early 2001 Manildra stated that 20% ethanol in petrol had no adverse impacts on car engines, an idea which engine manufactures and automotive groups strongly opposed. This resulted in a committee being formed by the Department of Environment and Heritage (DEH) to set the ethanol limit in petrol.

Late in 2001 the Federal Government released its 350ML/yr biofuel target to be met by 2010. During 2002 it became apparent that the ethanol content in petrol was reaching levels as high as 28% in the Sydney region. In response to this, automotive groups, engine manufacturers and Oil Majors went public about their engine compatibility and engine warranty concerns. At this time various reports of engine damage emerged in the Sydney region though were later found to be false.

By October 2002 the National Party and the sugar industry lobby was gaining strength and putting intense pressure on the Federal Government to introduce a 10% ethanol mandate. The government stalled the debate by commissioning an ABARE report and making moves to protect the national market from cheap imports by introducing a temporary fuel ethanol excise and corresponding production credits for Australia producers. The federal opposition began to probe the motivation behind the excise change amid accusations that it had been done to please Manildra bosses. The issue eventually evolved into a political scandal that became known as the “mates’ affair”.

Reports of engine damage and related fears reached a peak in 2002-2003. This “scare campaign” caused Oil Majors (and other distributors) to set up “no ethanol” signs on their bowsers to alleviate consumer concerns about engine damage. It was also around this time that BP cut short its E10 trial in the Brisbane region. In early 2003, in an attempt to stabilise the crisis, the Federal Government took the initiative to set the ethanol limit in petrol to 10%.

In the 2003-2004 budget the Federal Government proposed an extension of the excise free period to 2008. Their ABARE report released at the end of 2003 found that there were considerable barriers to achieving the 350ML/yr target by 2010, with low consumer confidence being a primary concern. In March 2004 the Nationals and Democrats pressured the government to extend the excise free period to 2011.

5.2.3 2004 to Feb 2006 - Era of New Hope

In early 2004 the DEH introduced a labelling standard for ethanol; prior to this there was no need to communicate the presence of ethanol in fuel. A number of independents dealt with this change by branding their ethanol blends.

In 2004 the Queensland Government continued to show their strong support and leadership by releasing their Queensland Ethanol Industry Blue Print which outlined actions for promoting the ethanol industry. Following this, Caltex and BP began their E10 trials in north Queensland, a main sugar producing region of Australia.

In 2005 the QLD Government ran one of the first ethanol industry conferences and announced their $7.3M Ethanol Industry Action Plan. It was also this year that soaring petrol prices sparked nationwide interest in cheaper home grown alternatives and the Federal Government convened a Biofuels Taskforce to report, yet again, on the feasibility of its biofuels target. In September 2005, the taskforce released its report amid fierce public debate about the legitimacy of ethanol.

By mid 2005 a growing number of fuel distributors, including United Petroleum and Shell, began to market branded ethanol blends. In late 2005, in what was seen as a major break through the Industry Minister announced that Australian car

manufacturers had agreed to provide “E10 compatible” labels on all the new cars they produced. Towards the end of the year, E10 blends were launched in the ACT to service Federal Government fleets and the NSW state government, under pressure from the National Party, announced plans to include E10 in its future fuel contracts.

A string of positive ethanol industry developments have taken place since late 2005. These include; the green light for the Queensland Dalby Bio-refinery project, the submission of voluntary biofuel actions plans to the PM by Oil Majors, an off-take agreement between Caltex and the Dalby project, CSR’s go ahead for upgrade of its Sarina facility in north QLD, green lights for the Australian Ethanol project in Swan Hill and the Primary Energy project in WA, and the announcement that BP would enter into off-take agreements with both CSR and Primary Energy.

5.3 FUEL ETHANOL INNOVATION SYSTEM STRUCTURAL CHANGE

In this section the structural change of the fuel ethanol innovation system is described. The section is divided into three sections; actors, institutions and networks.

5.3.1 Actors

The innovation system actor map, Figure 5, shows the key actors and their date of entry into the ethanol innovation system. Actors are divided between six domains depending on their role and purpose in the innovation system. A discussion of the six domains and their most notable features is presented below.

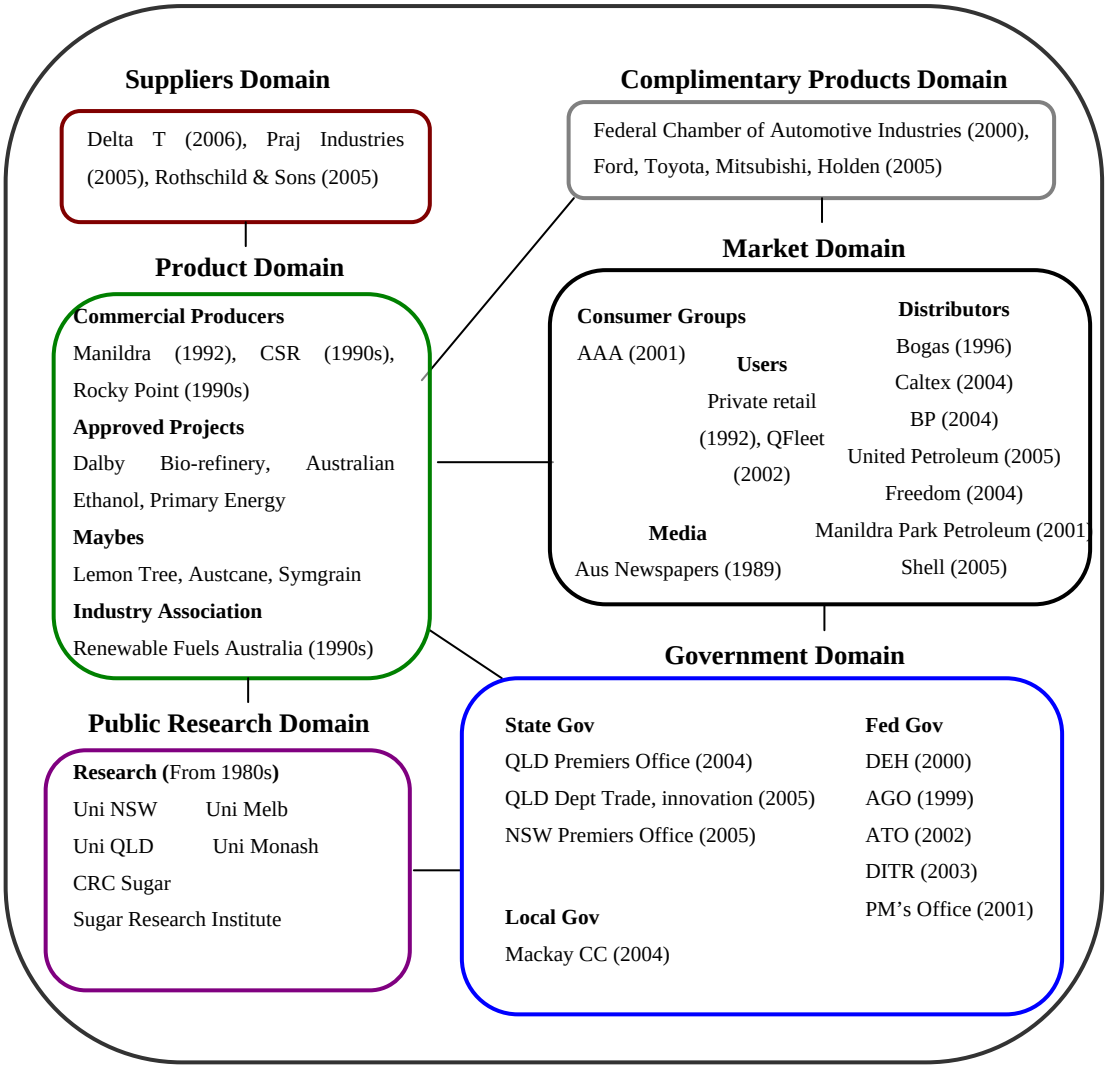


Figure 5 - Ethanol Innovation System Actor Map

Product Domain

Since the early 1990s the Manildra Group has been the principal producer and strongest lobbyer for the fuel ethanol industry in Australia. CSR and Rocky Point Sugar have also produced fuel ethanol though in comparatively small volumes. In the past six months three companies have secured finance for ethanol production facilities in addition to CSR confirming its plans to boost capacity.

Market Domain

Ethanol is mainly distributed through independent fuel distributors. Caltex, BP and Shell distribute ethanol blends through a limited number of sites though on the whole Oil Major participation rates have been very low.

The Australian media has been highly involved in the ethanol debate especially since the scare campaign of 2002-2003 which together with sugar industry concerns and the mates' affairs lead to an explosion of newspaper articles (see Appendix 2 for a year by year count).

The Australian Automotive Association (AAA), together with its state based member associations, has been very vocal in the public debate about fuel ethanol blends.

Complimentary Products Domain

The complimentary products domain has been primarily represented by the Federal Chamber of Automotive Industries (FCAI) and to a lesser extent the four Australian automotive manufacturers; Ford, Toyota, Mitsubishi and Holden.

Public Research Domain

Ethanol production research in Australian has a history spanning a number of decades. Research has been led by the University of New South Wales, the University of Melbourne and the University of Queensland.

Government Domain

The main government departments involved with ethanol industry development have been QLD's Department of State Development Trade and Innovation, the Department of Industry Tourism and Resources (DITR) and the Australian Greenhouse Office (AGO). The Department of Environment and Heritage (DEH) and the Australian Taxation Office (ATO) have been involved with ethanol standards and excise arrangements.

5.3.2 Institutions

The significant ethanol institutions include fuel quality standards, fuel excise arrangements and industry expectations. The "rules of the game" were established between 2003 and 2004 with the formation of; the ethanol limit in petrol, ethanol labelling standards and the ethanol excise arrangements. The PM's Office and the QLD State Government have had a big influence on positive expectations for the industry with their strong vocal support. The high oil price in recent years has also

had a positive impact on industry expectations. Conversely, engine manufacturers, automotive groups and Oil Majors had a negative impact on expectations during the ethanol limit in petrol debacle of 2002-2003.

5.3.3 Networks

Ethanol inter-industry networks are headed up the Renewable Fuels Association (RFA) which has been bringing together industry players for over a decade. It was originally founded by the Manildra Group for the purpose of lobbying the Federal Government and that still seems to be its principal goal. The strong policy stance taken by the organisation has lead to differences between producers and resulted in some members leaving the group.

The ethanol industry has also successfully formed a strong network of advocates who have been instrumental in garnering political support over the past five years or so. This is particularly the case in QLD where ongoing co-operation has lead to the formation of a Clean Air Alliance which includes members from the sugar industry, ethanol industry, Australian Lung foundation and more.

Industry and university networks have been patchy with occasional strong ties between the University of NSW and the Manildra Group. The CRC Sugar at the University of Queensland runs an ethanol program and is involved in a broad network which includes the Sugar Research Institute, CSR and others. Despite these networks and collaborations, and various negotiations over the years, no large scale ligno-cellulosic project has managed to get off the ground.

5.4 ETHANOL INNOVATION SYSTEM PERFORMANCE

The following section describes the performance of the fuel ethanol innovation system in terms of its key functions. The functional analysis is guided by key events and activities which have influenced development of the ethanol industry. The analysis is supported by insights from interviews and innovation system structural change.

The function “Entrepreneurial Experimentation” is not explicitly analysed due to its strong overlap with other functions, i.e. its analysis is implicit in other functions. The

analysis of "Positive Externalities" is deferred to the discussion and conclusions section of the report.

5.4.1 Incentives for Firms to Enter

The Federal Governments Diesel and Alternative Fuels Grant Act (1999) (Replaced by the Energy Grants Credits Scheme in 2003) and 2001 biofuels target of 350ML/yr by 2010 have all helped create positive expectations about cleaner burning transport fuels and the role the government will play in supporting them.

The high price of petrol in recent years has made the fuel ethanol business proposition increasingly favourable resulting in many new plants being proposed (in excess of 10) in sugar and grain producing regions of Australia.

5.4.2 Financial Resource Mobilization

A large proportion of financial resources mobilized by government towards the creation of an ethanol industry have come from the Australian Greenhouse office (AGO). In 1999 the AGO awarded a $1M grant to Manildra to upgrade its plant, then in 2001 awarded $8.8M to BP for trials and blending facilities in QLD plus $7.35M to the Mossman ethanol project. The DITR has also allocated significant funds with the allocation of $12.1M in biofuels capital grants to 3 ethanol projects in 2004. The QLD government has been another big financial supporter of the industry allocating $7.3M towards its Ethanol Industry Action Plan in 2005 (Ahern and Jardie, 2006).

The private sector has struggled to raise capital for ethanol projects in recent years. A common argument used for lack of investment capital has been the failure of Oil Majors to enter into bankable off take agreements (Gordon, 2006). Large Australian financial investment groups, such as Babcock & Brown and the Investec Group, have also chosen to refrain from investing in Australian ethanol projects despite investing in ethanol projects overseas.

The big breakthrough for private sector finance mobilization came with the securing of project capital for the Dalby Bio-refinery project in late 2005. The deadlock was broken when NM Rothschild & Sons decided to back a Dalby stakeholder partnership which included Petro Fuels and Lubricants, Queensland Fuel and regional farmers.

Since the Dalby breakthrough, CSR has announced a $15M upgrade of its Sarina facility ($4.16M from capital grants) and Australian Ethanol has raised $12.45M through a share offer to enable them to go ahead with the Swan Hill plant.

Investments in ethanol storage and distribution facilities were identified by the Queensland Governments Ethanol Action Plan as a barrier to wider ethanol distribution (QLD Government, 2005). In Australia, approximately 400 service stations out of an approximate total of 7500 currently sell ethanol blends. Therefore, fuel distributors still have considerable investments to make before they are ready to begin retailing ethanol blends.

5.4.3 Legitimation

The greatest success in convincing governments of ethanol's legitimacy has been through the advocacy coalition headed up by the National Party and QLD's powerful sugar lobby. This group was influential in the creation of the Federal Governments' biofuels target and the strong position taken by the Queensland Government since the early 2000s (Ahern and Jardie, 2006). More recently the National Party has been able to influence other state governments to take a more active stance in supporting ethanol by entering into E10 fuel contracts (e.g. NSW in 2005). By the end of 2005 all major political parties were coming out in support of the ethanol industry; thereby cementing its legitimacy at this level.

Ethanol has struggled to find outright legitimacy among engine manufactures and automotive groups. During 2002, when reports started emerging about high levels of ethanol in petrol in the Sydney region, engine manufacturers and automotive groups joined Oil Majors in condemning the fuel and warning users of engine compatibility problems and vehicle warrantee concerns. While it is true to say that these groups had some valid concerns, the way they handled the issue ensured the doom of consumer confidence in ethanol. In the time since the lows of 2002-2003 this important group of actors has come out as cautious supporters of E10, though their lack of a clear message has been the cause for confusion and wide interpretation in the media. Late in 2005, in what was seen as a major break through, the Industry Minister announced

that Australian car manufacturers had agreed to provide “E10 compatible” labels on all new cars produced.

The stance of Oil Majors towards ethanol has evolved from passive resistance, to down right rejection, to acceptance and modest support. In 1992 the Australian Institute of Petroleum released a report stating that fuel ethanol was not suitable for the Australian market. Prior to 2001, Oil Major involvement was best described as a passive rejection evidenced by the absence of off-take agreements (Gordon, 2006; Hanley, 2005). In the first show of support by an Oil Major, BP began ethanol trials in Queensland in 2002. The trial was cut short however due to the scare campaign of 2002-2003 which resulted in Oil Majors putting up “no ethanol” signs on their bowsers. Since that time Caltex, BP and Shell have shown their modest support for ethanol through trials and some distribution (Ahern and Jardie, 2006). Late in 2005, the Oil Majors collectively responded to a request from the Federal Government to submit confidential volunteer biofuel action plans. Since late 2005, both Caltex and BP have entered into significant ethanol off-take agreements indicating their growing support for the industry.

Independent fuel distributors have been champion supporters of the fuel ethanol industry. Their branding, marketing and discount strategies over the past few years have had a large role in the re-building of consumer acceptance and providing of legitimacy to the fuel (Ahern and Jardie, 2006).

Consumer acceptance of fuel ethanol has been characterised by an initial ignorance, followed by strong rejection and in more recent times a cautious curiosity. Prior to 2002, fuel ethanol was something of an unknown; there was no labelling and it was distributed through a small number of outlets. The “no ethanol” scare campaign of 2002-2003, together with the “mates’ affair” and the intense pressure on the Federal Government to support the sugar cane industry, brought ethanol crashing into the public’s conscious. Supporting this assertion is an analysis of fuel ethanol related newspaper articles which grew from 64 in 2001 to 279 in 2002 and peaked at an all time high of 422 in 2003 (See Appendix 2). In an effort to calm the ethanol backlash

the Federal Government took the initiative in 2003 to set the ethanol limit in petrol to 10% and in 2004 introduced mandatory labelling.

Understanding consumer acceptance of fuel ethanol was one of the purposes of a national survey of motorists' attitudes undertaken by the Australia Automotive Association (AAA) in 2003. The survey found that 63% of respondents had reservations about buying ethanol with the main reason being concerns of engine damage and lack of information. In a bid to improve information to consumers the FCAI created an extensive, if somewhat confusing, list of vehicles compatible with E10. The Biofuels Taskforce of 2005 expressed the need for this list to be simplified for motorists. The AAA ran a similar survey in 2005 and found that the number of motorists with reservations had slightly reduced to 56%. It also found that out of those who believed that their car could accept ethanol the majority still had concerns about buying it.

The extremely high petrol prices during 2005 inspired renewed public debate over the legitimacy of fuel ethanol. The tone of the debate this time around, was some what calmer than in 2002-2003. The debate of 2005 saw the emergence of a growing number of advocates for the ethanol industry of which included the Australian Medical Association (AMA) and all major political parties.

5.4.4 Market Formation

Product supply plays a central role in forming markets and in this respect the first market forming activities began in 1992 when Manildra began modest fuel ethanol production (name plate capacity of 18ML/yr). CSR entered into the market briefly between 1994 and 1996 (ability to supply 5ML/yr). In 1999 Manildra upgraded its facility to a total capacity of 100ML/yr, with 80% being earmarked for the fuel ethanol market. With renewed interest in fuel ethanol and high petrol prices CSR once again began to distribute small volumes to the fuel market in the early 2000s. The Rocky Point sugar facility in south east Queensland has been the only other producer of fuel ethanol with a 1ML/yr capacity. The scare campaign of 2002-2003 however has reduced consumer demand for the fuel to such an extent that Manildra's current production is below 50% capacity (Hanley, 2005)!

Distribution is another important feature of market formation and it has proved to be one of the limiting factors for the Australian fuel ethanol industry (Gordon, 2006; Hanley, 2005). Initial distribution of ethanol began through independent fuel distributors in the Sydney region. In 1994, Bogas (a subsidiary of Caltex based in Gosford NSW) ran ethanol trials through 26 service stations and by 1997 they were distributing through 100 service stations. In 2001, a joint venture known as Manildra Park Petroleum began to also supply ethanol to the Sydney region. By early 2002 a total of 250 service stations were distributing ethanol blends in and around Sydney. This distribution network was significantly reduced by the ethanol scare campaign of 2002-2003 and it wasn't until 2005 that it began to recover. A number of independents in QLD started distributing ethanol in 2004 and the number of outlets there has continued to grow quite rapidly. In mid 2005 United Petroleum launched ethanol blends in South Australia and Victoria.

The participation rate by Oil Majors in ethanol distribution has historically been quite poor (Gordon, 2006; Hanley, 2005). BP and Caltex have led this group with product trials in 2004 and the start of distribution throughout Queensland in 2005 (Ahern and Jardie, 2006). Caltex has since begun supplying some of rural NSW while BP has moved into the ACT. Shell joined in late 2005 with its Optimax Extreme E5 blend in NSW, QLD and VIC. More recently both Caltex and BP have announced significant off-take agreements, signifying their intentions to expand E10 distribution.

The effective excise free status of ethanol is of course another very important factor in its market formation. Ethanol was officially brought into the excise system in 2002 and will remain effectively excise free until 2011, after which point this status will gradually diminish by 30% by 2015. This closing window of opportunity is something closely monitored by project proponents (Ahern and Jardie, 2006; Jones, 2006)

Another important market formation effort has been the creation of protected market spaces through government E10 fuel contracts (Ahern and Jardie, 2006; Jones, 2005). The first of these efforts began with the Queensland Government in 2002/2004 and has since expanded to the Federal Government and the Mackay City Council. The NSW Government has announced it will follow suit from mid 2006.

Ultimately, a mass market for fuel ethanol will only form once there is consumer demand for the product. In this regard ethanol is struggling. An idea supported by a national survey of motorists' attitudes towards ethanol undertaken by the Australia Automotive Association in 2005 which found that only 25% of respondents were happy to buy ethanol blended fuel (AAA, 2005).

Consumer demand has been driven by a number of factors but is strongest in Queensland where distributors have marketed the fuel to sugar producing regions, aiming for support of the local community for their sugar cane industry. Fuel discounts and the prospect of improved octane ratings are other strong drivers for demand as shown by the success of branded blends coming from the likes of United Petroleum and Shell. Demand based on advantages such as greenhouse and health benefits seem less developed with the AAA survey indicating that only 20% of those who were happy to use ethanol did so for its environmental benefits (AAA, 2005). Government contracts however have been promoted for their climate change advantages. Indeed, the Mackay City Council contract was entered into through their Cities for Climate Protection program.

5.4.5 Knowledge Development

Ethanol production research in Australia is reasonably well established. The Australasian Digital Thesis database (2006) showed a total of 8 master's and 11 PhD thesis related to fuel ethanol published between 1980 and early 1990s. The main centres for this research were the University of NSW, University of Melbourne and the University of Queensland. From the mid-1990s to 2000s no PhDs were published in this field though the UNSW and University of Melbourne continued with some ground breaking research and began publishing more theses in the early 2000s. The University of Queensland has continued to be a home for ethanol research at various levels with publications in recent years of various undergraduate engineering theses related to ethanol production and use in motor vehicles. The University of Queensland is also home to the Co-operative Research Centre (CRC) for Sugar which runs a reasonably large sugar bio-refinery project looking at ethanol production. Another centre for ethanol research has been the Sugar Research Institute located in north

Queensland. All in all, academic research in the ethanol field has been reasonably strong though with a distinct lack of any scale large ligno-cellulosic projects.

Various Federal Government offices and departments have also been central in producing knowledge relate to fuel ethanol. This includes the Beer et al. report commissioned by the CSIRO in 2001 and the Orbital report commissioned by the DEH which focused on engine compatibility. The office of the Prime Minister and the DITR together released a number of ABARE reports and taskforce studies looking at the ethanol industry's viability. In addition, the Queensland Government and a number of industry groups have been involved in visits to and from Brazil and the USA to learn from their successful ethanol industries (Ahern and Jardie, 2006).

The technology of choice for the majority of new ethanol plants is largely imported from the overseas and much of engineering is done by contract through foreign engineering companies (Jones, 2005).

Private sector ethanol R&D has been inconsistent. CSR no longer has a R&D department but does support research through direct funding. Manildra was quite involved in ethanol R&D projects through the 1990s working closely with Peter Rogers from UNSW and others. A proposal was made by Manildra and others in the mid 1990s for a ligno-cellulosic pilot plant though it never eventuated due to lack of funds (Hanley, 2005). Other private sector R&D is limited to only a few instances such as the activities of Apace Research Ltd which has led to a multi patented emulsion technology used to produce diesohol (diesel/ethanol blend) and a Global Fuel Solutions project which is currently developing a direct ethanol injection technology to be used for diesel vehicles (supported by DITR and QLD Government).

5.5 ETHANOL INDUSTRY CRITICAL ISSUES

This section presents a summary of the mechanisms inducing and blocking innovation system performance as well as a discussion of the critical ethanol issues in terms of the mechanism blocking legitimation, market formation and knowledge development.

5.5.1 Ethanol Inducing and Blocking Mechanisms

The inducing and blocking mechanism identified in the functional analysis above are summarised in Figure 6. The dotted lines between functions represent the most prominent inducing and blocking linkages.

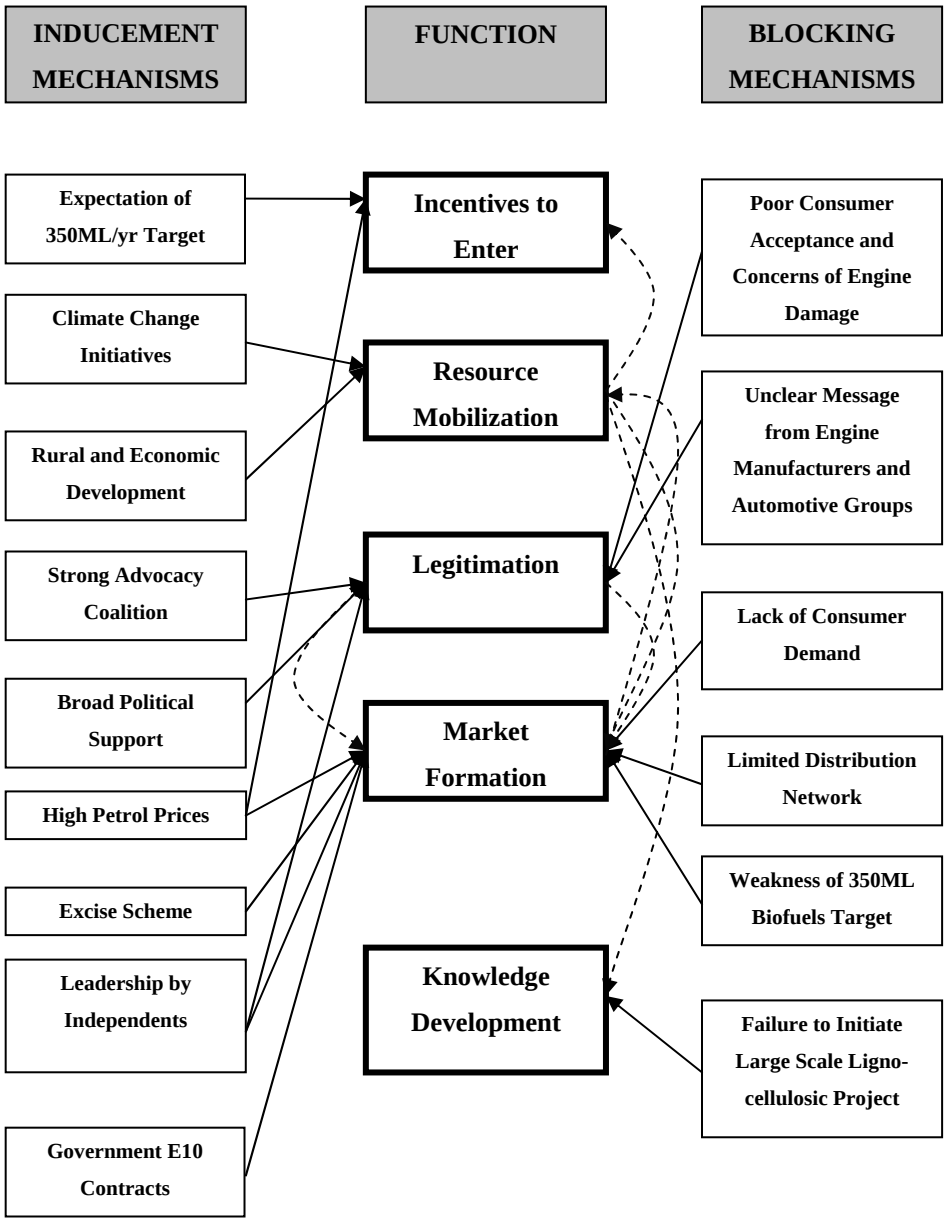


Figure 6 – Ethanol Inducing and Blocking Mechanisms

This figure shows that the functions legitimation, market formation, knowledge development and resource mobilization are blocked by numerous mechanisms or

linkages to other functions. These functions form the basis of the following discussion of ethanol industry issues.

5.5.2 Ethanol Industry Critical Issues

Fuel ethanol has struggled to be legitimized. There has been a general lack of acceptance by consumers with lingering concerns of engine damage. The situation is exacerbated by unclear messages from engine manufacturers and automotive groups.

Market formation efforts are being blocked by; poor access to markets due to a limited distribution network, poor consumer demand and the need to for retailers to investment in ethanol storage and distribution infrastructure. Some ethanol proponents have blamed the weakness of the 350ML/yr target for the market formation failures and they continue to lobby for an ethanol mandate.

The long battle to mobilize investment capital into new projects seems to be easing as three ethanol plants have secured project funding in the last 6 months. The breakthroughs have come through stakeholder partnerships and a general increased attractiveness of biofuel investments as the result of high oil prices.

The lack of any large ligno-cellulosic research projects in Australia is a long term issue for the industry. For Australia to minimize its dependency on imported technology and derive value from the whole value chain it must invest in future technologies and build local research competencies.

6 RECOMMENDATIONS

6.1 BIODIESEL INDUSTRY

The following table summarises the critical issues facing the biodiesel industry and suggests possible policy and private sector strategies for dealing with them. The government departments considered suitable for carrying out the policy strategies are shown in brackets.

Critical Issue	Policy Issue	Possible Strategy	Private Sector Issue	Possible Strategy
Stance of Engine Manufacturers and Automotive Groups	Fuel Standards & Industry Development (Federal)	Facilitate independent and credible engine compatibility trails (e.g. B20) and promote dialogue between stakeholders. (DEH, DITR)	Industry Networks, Product Compatibility Trials, Market Development Strategy.	Collaborate (through industry association) with engine manufacturers in engine compatibility trials, develop working relationship with automotive groups, employ unified market development strategy (e.g. B5 as entry to mass market blend and higher blends for bulk users).
Poor Connectivity between Producers	Industry Development (State & Federal)	Facilitate formation of industry association. (DITR)	Inter-Industry Networks	Form independent industry association for the purpose of co-ordinating and negotiating industry wide strategies as well as improving information diffusion between producers.
Weak Advocacy Coalition	Industry Development (State & Federal)	Facilitate formation of broad alliance between stakeholders like QLD's Clean Air Alliance. (DITR)	Advocacy Coalition	Form network of advocates and work together to promote the benefits of biodiesel to the various decision makers i.e. users and government
Backyard Image	Industry Development (State & Federal)	Facilitate high profile demonstration projects. (AGO)	Education and Marketing	Promote the industry as commercial, large scale and professional. Make the distinction between backyard and commercial industry, avoid "used fish-and-chip oil" image.
Market Uncertainty due to Fuel Tax Credit Reform	Tax Policy (Federal)	Keep industry informed of all possible outcomes. (DITR)	Lobby and Market Development	Form advocacy coalition to pressure politicians of desired outcome. Be prepared to alter target market if the economics make it necessary.
Limited Retail Distribution Network	Industry Development (State & Federal)	Continue to work on volunteer biofuel action plans with Oil Majors. (DITR, PMs Office)	Industry Networks, Legitimation	Develop dialogue with and update Oil Majors of biodiesel industry news, progress and issues. That is, demonstrate to them the industry's legitimacy.
Lack of Support for R&D	STI Policy (State & Federal)	Develop targeted science, technology and innovation policy. (DEST)	R&D Strategy, Support of Public Research	Fund public research and enter into collaborate partnerships for large scale R&D projects.

6.2 FUEL ETHANOL INDUSTRY

The following table summarises the critical issues facing the fuel ethanol industry and suggests possible policy and private sector strategies for dealing with them. The government departments considered suitable for carrying out the policy strategies are shown in brackets.

Critical Issue	Policy Issue	Possible Strategy	Private Sector Issue	Possible Strategy
Poor Consumer Acceptance and Concerns of Engine Damage	Industry Development (State & Federal)	Provide highly visible ethanol demonstration. Promote distribution of clear concise vehicle compatibility information. (DITR)	Engine Compatibility Information	Work with fuel distributors, engine manufacturers and auto groups to distribute engine compatibility information to consumers.
Unclear Message from Engine Manufacturers and Automotive Groups	Industry Development (State & Federal)	Encourage dialogue between stakeholders; promote benefits of a clear policy for consumers. (DITR)	Industry Networks	Work with auto groups on their ethanol policy. Promote a clear policy which best suits users.
Lack of Consumer Demand	Environment & Health (State & Federal)	Promote advantages of ethanol through Greenhouse Initiatives/Cities for Climate Change and Clean Air Initiatives. (AGO, State Gov)	Education and Marketing, Advocacy Coalition	Work with fuel distributors to market product to various segments. Form broad advocacy coalition to promote environmental and health benefits of ethanol. E.g. Aus Medical Association, Aus Lung Foundation, AGO etc.
Limited Retail Distribution Network	Industry Development (State & Federal)	Continue work on volunteer biofuel action plans with Oil Majors and provide assistance to distributors to convert their facilities. (DITR, PMs Office)	Industry Networks, Legitimation	Develop dialogue with Oil Majors and other distributors and update them on ethanol industry news, issues and progress towards consumer acceptance. That is, demonstrate to them that consumer demand is beginning to swing in ethanol's favour.
Weakness of 350ML Biofuel Target	Industry Development (Federal)	Government should continue to consider the benefits provided by use quotas or mandates (PMs Office)	Advocacy Coalition	Work together with a broad coalition of advocates to lobby governments in an effort to persuade them of the benefits of biofuel use quotas and mandates.
Failure to Initiate Large Scale Ligno-cellulosic Project	STI Policy (State & Federal)	Initiate consortium of universities, research institutes, producers etc to undertake 2nd Generation research and pilot project (DEST)	R&D Strategy, Support of Public Research	Take an active role in 2nd generation R&D and work together with research partners.

7 DISCUSSION AND CONCLUSIONS

This thesis set out to identify the critical issues facing biofuel industry development in Australia and to propose possible strategies for dealing with them. This was to be achieved through the following steps; to map the development of the ethanol and biodiesel industries, to analyse their performance overtime and to identify the primary mechanisms inducing and blocking their growth. The following section discusses the results of the thesis in relation to these goals.

The ethanol and biodiesel industries, when viewed from an innovation systems perspective, have undergone considerable structural change since the early 2000s. Many new producer firms and other actors have entered the field, a degree of institutional alignment has been achieved (revealed by formation of product standards and fuel excise regimes) and some industry networks and advocacy coalitions have been formed or strengthened. Of the two systems the ethanol innovation system is the more complete with a greater research base, a more developed distribution network, and a stronger and broader advocacy coalition lobbying its cause.

Numerous inducing and blocking mechanisms were also identified as being linked to the development of the ethanol and biodiesel industries. Inducing mechanisms include broad contextual factors such as climate change, high oil prices and rural development goals. These drivers have inspired various grant schemes, government fuel contracts, formation of lobby groups and consumer demand for cheap home grown alternatives.

The overall performance of the ethanol and biodiesel industries, as assessed through their innovation system functions, has varied overtime with the key challenges coming from their ability to legitimize their offerings, form markets and develop new knowledge.

Legitimation is a major challenge for both the ethanol and biodiesel industries. It is acceptance by consumers which lies at the heart of the ethanol challenge while for biodiesel it is acceptance by engine manufacturers and automotive groups that is currently the main blocking mechanism. The ethanol scare campaign should serve as a

reminder to the biodiesel industry that having engine manufactures and automotive groups on side is crucial for successful market development, especially for the mass market which can be highly temperamental and easily manipulated.

Market formation is another challenge for both the ethanol and biodiesel industries though it is the ethanol industry for which the problem is the most acute. The principal mechanism blocking market formation for fuel ethanol is poor consumer demand combined with a limited distribution network. The biodiesel industry's market formation challenges mostly lie ahead and include market uncertainty due to up coming fuel tax credit reform, the need to choose an entry to mass market blend and a limited retail distribution network.

Knowledge development is another challenge for the ethanol and biodiesel industries and an issue with long term implications. Biodiesel and ethanol production technologies have considerable scope for improvement and/or radical innovation. This means that for Australia to minimise its dependency on technology imports, and derive greater economic value along the whole value chain, it must overcome the current lack of research and development which characterises the biofuel sector.

Possible strategies for dealing with the biodiesel industry issues include; forming a biodiesel specific industry association, working closely with government and engine manufactures to run credible engine compatibility trials, choosing a common mass market entry blend (e.g. B5 until support is garnered for higher blends), and forming a broad coalition of advocates to lobby governments for greater market formation and research and development support.

Possible strategies for dealing with the ethanol industry issues include; developing closer ties with Oil Majors and other distributors, working with automotive groups to promote clear and concise information about engine compatibility, promoting fuel ethanol's environmental and health benefits and taking a more active stance towards supporting research and development of second generation production technologies.

The identification of “positive externalities” at this early stage in innovation system development has been difficult though the existence of emerging industry clusters and relatively strong growth in QLD (ethanol), NSW (biodiesel), and SA (biodiesel) suggest that positive externalities are being felt in those regions. Biodiesel has also enjoyed positive externalities as a result of a strong ethanol lobby which successfully lobbied the Federal Government to extend the biofuel free excise status from 2008 to 2011. This supports the idea of synergies exist between the ethanol and biodiesel industries and that there are benefits to be had from working together to overcome common problems.

The results of this thesis support the idea that those who actively seek to overcome the challenges facing the ethanol and biodiesel industries stand to be the long term economic winners in the global quest to develop new industries that can deliver alternatives to petroleum based automotive fuels.

8 REFERENCES

ABARE (2004), *Revised assessment of biofuels industry viability*, Report to the Department of Industry, Tourism and Resources, Canberra

ABARE (2005), *Biofuels: An Assessment of their Viability*, Report to the Biofuels Taskforce, Canberra

Ames, J., and Werner, C. (2001), *Revitalizing the Farm Economy Through Renewable Energy Development*, Policy Report to the Environmental and Energy Study Institute, Washington D.C

Australasian Digital Thesis Database (Accessed in March 2006)

Australian Automotive Association (AAA) (2005), *Motorists Attitudes*, Report prepared by ANOP Research Services for the AAA, Australia

Australian Institute of Petroleum (AIP) (2005), *Submission to the Australian Government Biofuels Taskforce*, Canberra

Beer, T., et al. (2001), *Life cycle emissions analysis of alternative fuels for heavy vehicles*, Report to the Australian Greenhouse Office, Canberra

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. and Rickne, A. (2005), *Analyzing the dynamics and functionality of sectoral innovation systems – a manual*, Paper presented at the DRUID Tenth Anniversary Summer Conference 2005, June 25-27, Copenhagen

Biofuels Taskforce (2005), *Report of the Biofuels Taskforce to the Prime Minister*, Canberra

Biofuels Taskforce Submissions (2005), *Submissions to the Biofuels Taskforce*, available at: http://www.dpmc.gov.au/biofuels/submissions_list.cfm

Carlsson, B., and Jacobsson, S. (2004), *Dynamics of Innovation Systems-Policy-Making in a Complex and Non-deterministic World*, Paper presented at the 'International Workshop on Functions of Innovation systems', the University of Utrecht, June 23-24th, 2004

Carlsson, B., and Stankiewicz, R. (1991), *On the nature, function, and composition of technological systems,* Journal of Evolutionary Economics, Vol. 1, pp. 93-118

Carlsson, B., Jacobsson, S., Holmen, M., and Rickne, A. (2002), *Innovation system: analytical and methodological issues,* Research Policy, Vol. 31, pp. 233-245

Chang, Y., and Chen, M. (2004), *Comparing approaches to systems of innovation: the knowledge perspective*, Technology In Society, Vol. 26, pp.17-37

ABARE (2003), *Appropriateness of a 350ML Biofuels Target,* Report to the Department of Industry, Tourism and Resources, Canberra

Edquist, C., and Hommen, L. (1999), *Systems of innovation: theory and policy for the demand side*, Technology in Society, Vol. 21, pp. 63-79

Factiva Database (Accessed in March 2006)

Freeman, C., and Louca, F. (2002), *As time goes by: From the Industrial Revolutions to the Information Revolution*, Oxford University Press, Oxford

Geels, F. W. (2004), *From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory*, Research Policy, Vol. 33, pp897-920

Hekkert, M. P., Suurs, R., van Lente, H., and Kuhlmann, S. (2004), *Functions of Innovation Systems: A new approach for analysing socio-technical transformation*, Paper presented at the International Workshop on Functions of Innovation Systems, Utrecht University, Utrecht

Jacobsson, S., and Bergek, A. (2004), *Transforming the energy sector: the evolution of technological systems in renewable energy technology*, Industrial and Corporate Change, Vol. 13, No. 5, pp. 815-849

Jacobsson, S. and Lauber, V. (2006), *The politics and policy of energy system transformation – explaining the German diffusion of renewable energy technology*, Energy Policy, Vol. 34, No. 3, pp. 256-276

Johnson, A., and Jacobsson, S. (2001), *Inducement and Blocking Mechanisms in the Development of a New Industry - The Case of Renewable Energy Technology in Sweden*, In: Coombs, R., Green, K., Walsh, V. and Richards, A. (eds): Technology and the Market: Demand, Users and Innovation. Edward Elgar, Cheltenham/Northhampton

Johnson, A., and Jacobsson, S. (2001), *The emergence of a growth industry: a comparative analysis of the German*, Dutch and Swedish Wind Turbine Industries

Lave, L., Griffin, W., and MacLean H. (2001), *The Ethanol Answer to Carbon Emissions*, Science and Technology, Vol. 17, No. 6, pp. 73-78

Nelson, R. R., and Nelson, K. (2002), *Technology, institutions and innovation systems, Research Policy*, Vol. 31, pp. 265-272

Van Gerpen, J., Shanks, B., Prusko, R., Clements, D., and Knothe, G. (2004), *Biodiesel Production Technology*, Report prepared for the National Renewable Energy Laboratory (NREL), Colorado

QLD Government (2005), *Queensland Ethanol Industry Action Plan 2005-2007*, Report for the Queensland Government, Brisbane

Srivastava, A., and Prasad, R. (2000), *Triglycerides-based diesel fuels*, Renewable & Sustainable Energy Reviews, Vol. 4, No. 2, pp. 111-133

Weeks, J. (2005), *National Energy Commission Report Endorses Biofuels*, Biocycle, Vol. 46, No. 3, pp. 58-61

Interviewees

Ahern, S., and Jardie, P. (2006), *Department of State Development, Trade and Innovation*, Brisbane, QLD, 12th of January

Dooley, B. (2005), *Australian Biodiesel Group* (ABG), NSW, 20th of December

Fischer, A., Jureidini, M and Haddow, G. (2006), *South Australian Farmers Fuel* (SAFF), Adelaide, SA, 30th of January

Gordon, B. (2006), *Renewable Fuels Association*, Canberra, ACT, 18th of January

Hanley, B. (2005), *Manildra Group*, Nowra, NSW, 19th of December

Haustorfer, G. (2006), *Babcock & Brown Environmental Investments*, Sydney, NSW, 17th of January

Hill, A. (2005), *Biodiesel Industries Australia*. Rutherford, NSW, 21st of December

Jones, M (2005), *CSR Ethanol*, Melbourne, VIC, 9th of December

King, T. (2006), *Australian Renewable Fuels* (ARF), Adelaide, SA, 30th of January

Lake, A. (2006), *Australian Biodiesel Group*, Gosford, NSW, 16th of January

Murphy, B. (2006), *Natural Fuels Australia* (NFA), Sydney, NSW, 18th of January

Rudolph, V. (2006), *Department of Chemical Engineering*, University of Queensland, Brisbane, QLD, 12th of January

9 APPENDICES

9.1 APPENDIX 1 - SAMPLE INTERVIEW QUESTIONS

- What is your personal relationship to the biodiesel/ethanol industry?

- What is your company's history in relation to the biodiesel/ethanol industry?

- What is your process technology? New/Old? Where from? R&D/innovation?

- What feedstocks are used in your process? What issues are related to the feedstocks?

- Who are or will be your main customers? How will your distribute your fuel?

- Are the financial resources for your biodiesel projects sourced internally or externally?

- Is your organisation involved in any significant collaborations, networks or industry associations? (i.e. with universities, business-business, farmers…etc)

- How competitive is the industry and what relationship do you have with your competitors?

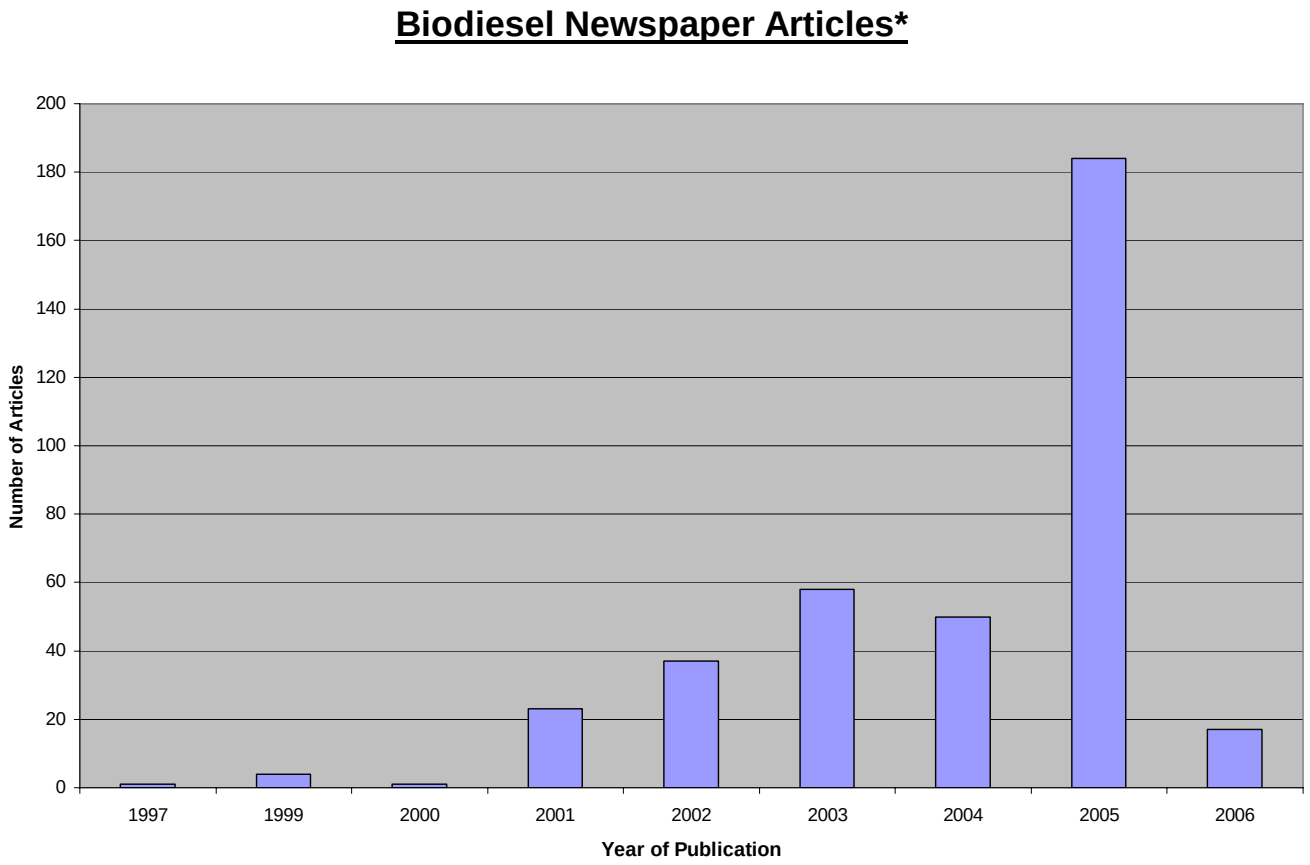
- What have been the key events or turning points for your biodiesel/ethanol business? (i.e. what over the past 5 years or so has made your business more or less viable)

- In your eyes, what role does/should the federal & state governments play in the development of the biodiesel industry?

- What is your company's vision of the future for biodiesel/ethanol?

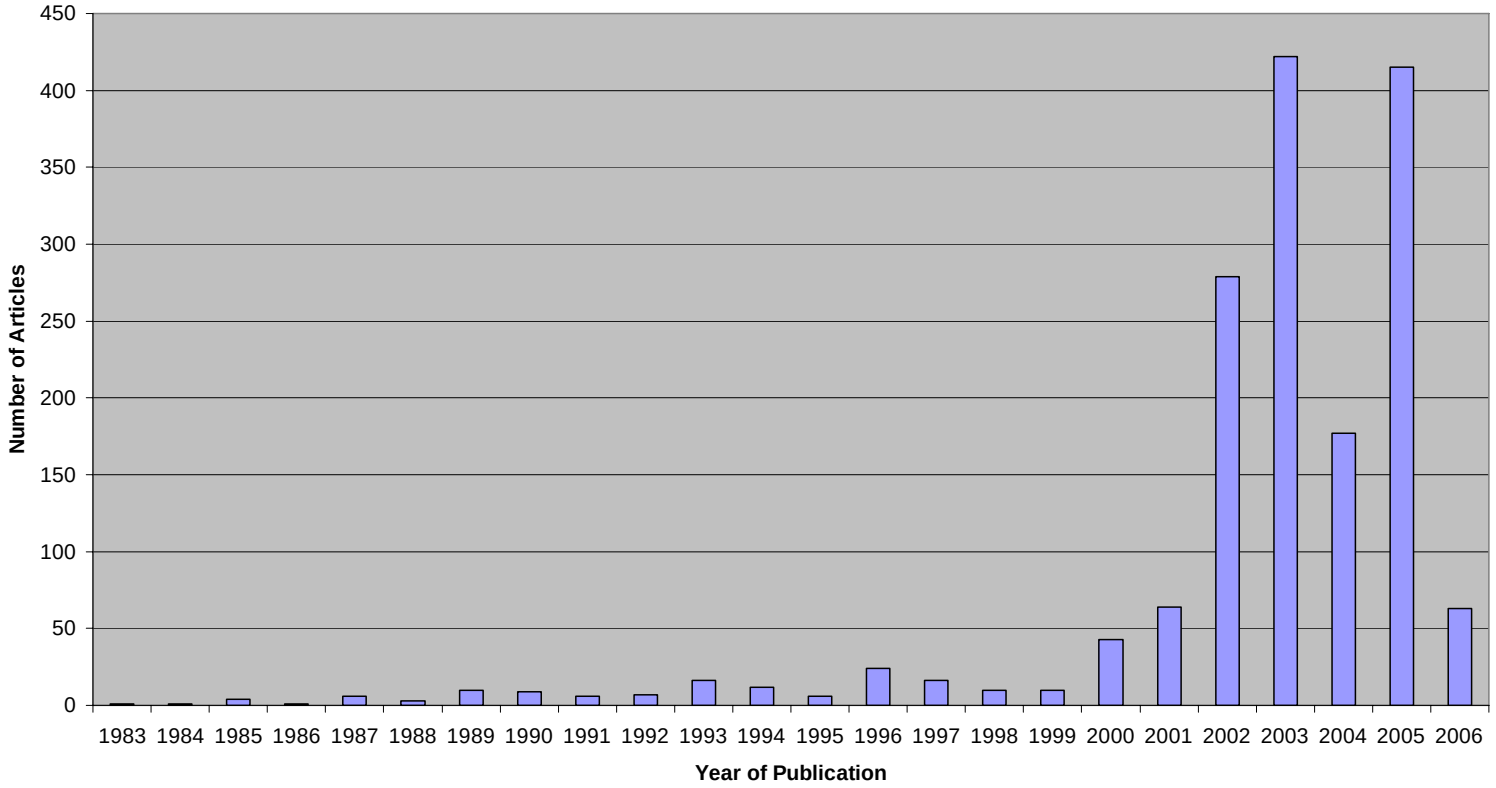
- What are the critical issues for achieving your vision?

9.2 APPENDIX 2 – BIODIESEL AND ETHANOL NEWSPAPER ARTICLE COUNTS



*Results obtain from the Factiva Database for the "Australian Group of Newspapers" during March 2006

Ethanol Newspaper Articles*



*Results obtain from the Factiva Database for the "Australian Group of Newspapers" during March 2006