ZeroGen
smarter, cleaner power

Submission for Garnaut Climate Change Review

Issues Paper 4 – Research and Development: Low Emissions Energy Technologies

EXECUTIVE SUMMARY

ZeroGen Pty Ltd (ZeroGen) is undertaking an intensive program sponsored by industry and government to accelerate the deployment of clean coal technologies (CCTs), specifically Integrated Gasification Combined Cycle (IGCC) with Carbon Capture and Storage (CCS), in an Australian context. ZeroGen will achieve this through developing an 80 Megawatt (MW) IGCC with CCS demonstration plant with up to 75% carbon capture and partial sequestration. Concurrently, a 300MW low emissions coal-fired power plant that can capture up to 90% of CO_2 emissions will be developed.

In this era of climate change, ZeroGen supports a portfolio of approaches to reduce CO_2 emissions. However, given the contribution of coal to the power generation portfolio and the large volume of CO_2 emissions this generates, the development of CCTs must be a priority for policy makers. This will not only enable the Commonwealth Government to meet its emissions target but it will also facilitate CCT transfer to other high emitting nations such as China and India which will enable these nations to sustain their drive for economic growth but with significantly reduced emissions to atmosphere. Among the alternative types of clean coal power generation technologies, IGCC is the only one that facilitates the development of the hydrogen economy. Underpinning all CCTs is the ability to safely capture, transport and store CO_2 emissions. ZeroGen is a leader in understanding and developing this technology.

ZeroGen submits that there are a host of challenges and barriers to the commercialisation of low emission CCTs. Some of these are market failures in the traditional neo-classical economic sense but others are barriers that are entry specific to the electricity generating sector. In Australia, the power generating sector is characterised by a small market, policies targeted at meeting social requirements that reduce the opportunities to increase prices, the high capital cost of generating technologies to produce a commodity which means product differentiation is extremely limited and a very limited presence of original equipment manufacturers.

Conceptually, market failures and barriers in the energy sector include appropriability issues, high technical, commercial and regulatory risks, coordination failures, the presence of spillovers, long development timelines, insufficient capacity of skilled workers, weak market drivers in the absence

of a CO_2 price signal and multiple political risks from stakeholder opposition. Individually, or in concert, these act as major disincentives for electricity generating companies to invest in CCTs. Indeed, the widespread commercial deployment of existing low emissions energy technologies such as wind generation for example, is already constrained by challenges from stakeholder protest groups. The risks to industry of investing in new low emission generating technologies such as CCTs are even higher. This presents a challenge to policy makers who are seeking to facilitate the commercialisation of low emissions energy technologies within a relatively short timeframe if the significant negative consequences of climate change are to be avoided.

ZeroGen submits that early mover technology developers generate significant and positive spillovers. These include social acceptance, a support sector, knowledge, skills and regulatory reform externalities. At this stage of the development path for IGCC with CCS technologies in particular, the efforts of early movers such as ZeroGen generate significant benefits for later movers. Given this, and the fact that ZeroGen Stage One is the world's first integration of the technologies for a demonstration project, and indeed, the objective of demonstration projects is to generate knowledge to reduce commercialisation risks, the value of the positive spillovers can be viewed in two ways. It is either the value of the feasibility study $AUD125 million (if the project does not proceed to construction) or the capital cost of Stage One ($AUD1.7 billion) if it does proceed to construction.

The role of an emissions trading scheme is welcomed by ZeroGen. The failure to assign a value on CO_2 is a major disincentive to low emission technology development. The Garnaut Climate Change Review's introduction of a scheme by 2010 will provide a major impetus to developing low emission technologies, but it alone will not be enough.

The Review also sought comments on alternative models for considering low emission energy innovation. New thinking on innovation suggests it is a non-linear, dynamic process involving a range of actors, institutions and networks. ZeroGen submits the work of Professor Michael Porter at Harvard Business School could be informative to understanding the dynamics of the electricity generation sector and the issues associated with introducing low emission technologies to be competitive nationally and internationally. This framework could be useful for policy makers seeking to understand industry structures and the opportunities for early mover technologies to be commercialised.

ZeroGen acknowledges the strong support provided by the Queensland Government and the Australian Coal industry through ACALET Ltd to support the development of CCTs. ZeroGen also acknowledges the challenges faced by the Review in allocating scarce resources across a wide spectrum of technologies. Some additional policies that could be deployed to facilitate the commercialisation of CCTs (including IGCC with CCS) include capital support to offset the high upfront development costs, accelerated tax deductions, and the application of mandatory feed-in tariffs, for example. ZeroGen Stage One's capital cost is $AUD1.7 billion for developing both IGCC with CCS low emission technology. To put this into context, the Pew Centre for Global Climate Change is calling for between $US8-10 billion to be invested in the United States of America to develop CCS technology alone.

ZeroGen also acknowledges the difficult challenge faced by the Review in allocating scarce resources among a wide range of alternatives. ZeroGen acknowledges that the costs of policy actions may be high. However, when it comes to climate change, these may be acceptable when compared to the alternative of comfortable policy inaction.

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1.0 Introduction

ZeroGen Pty Ltd (ZeroGen) commends the leadership shown by the Commonwealth Government in the public policy debate on climate change. It welcomes the opportunity to provide input into the Garnaut Climate Change Review (the Review) on the challenges to innovating low emission energy technologies to reduce carbon dioxide (CO_2) emissions.

ZeroGen's submission to the Review begins with an overview of the ZeroGen Clean Coal Power Program (the Program) in Section Two. ZeroGen's expertise is in clean coal technologies (CCTs), in particular the business of developing Integrated Gasification Combined Cycle (IGCC) with Carbon Capture and Storage (CCS) power plants in an Australian context. ZeroGen has generated unique, first-hand experiences in developing IGCC with CCS technology for low emission coal-fired power generation. The technology choice and the benefits of the Program are also considered in Section Two of the paper.

Section Three provides some observations on the challenges to low emission energy innovation both from both an Australian electricity generation perspective and a broader international power generation industry context. It provides observations on the barriers to commercialisation of IGCC with CCS technologies and considers the issue of economic spillovers in terms of commercialising low emission CCTs.

Section Four proposes policy considerations to facilitate the commercialisation of CCTs to generate baseload electricity from coal whilst simultaneously enabling deep cuts in CO_2 emissions to the atmosphere. The key findings and conclusions of the paper are summarised in Section Five.

2.0 Background

2.1 Program overview

ZeroGen's clean coal power program is a two-staged approach that will develop the world's first demonstration-scale low emission coal power plant by 2012, and one of the world's first large-scale plants by 2017.

Stage One of the program will involve a demonstration IGCC power plant producing approximately 80MW (net) near Rockhampton in Central Queensland. This is equivalent to powering approximately 50,000 homes with low emission baseload electricity. Stage One will capture up to 75% of CO_2 (for partial sequestration) that will involve transport by truck approximately 220 kilometres west to the Northern Denison Trough. The CO_2 will then be injected for safe, long-term storage in deep underground reservoirs. The estimated capital cost (as at feasibility study 14 April 2008) is $AUD1.7 billion.

The Queensland Government is providing $AUD102.5 million in funding, part of a total commitment of $AUD300 million (dependent on outcome of the feasibility study). Shell, a global leader in geosequestration technology and the provider of substantial technical services in relation to the coal gasification technology and CCS aspects of the Program, has an option to take equity.

ZeroGen has had positive discussions with the Australian Coal Association Low Emission Technology Ltd (ACALET), who through the Coal21 Fund are underwriting additional feasibility costs for Stage One valued at $AUD26 million. ZeroGen gratefully acknowledges the funding support of both the Queensland Government and ACALET.

Stage Two of the Program will be developed concurrently with Stage One in such a manner as to maximise the benefit of learnings from the demonstration plant. It will involve the development of a large-scale clean coal power plant that will generate approximately 300MW (net). This has the potential to power approximately 200,000 homes with low emission baseload electricity. The large-scale power plant can capture up to 90% of CO_2 emissions for safe transport and storage. The estimated capital cost (as at feasibility study 14 April 2008) of Stage Two is $AUD2.35 billion

(excluding CCS). It is important to note cost estimates for CCS are largely determined by the siting of the plant.

The location for Stage Two of the Program will be investigated during the pre-feasibility study and will consider all relevant areas of Queensland at this point in time. It will be subject to a range of studies that will consider variables such as coal and water supply, access to electricity transmission networks, stakeholder interests, appropriate geology for the safe storage of CO_2, and the likely capital and operating costs of various sites. Siting for Stage Two will be developed in close collaboration with the Queensland Government to ensure the economic needs of the state are met, as well as the interests of other key stakeholders. As previously outlined, the scheduled target for the operation of Stage Two is 2017. This clearly positions Stage Two as one of the earliest large-scale low emission coal power plants in Australia, and indeed around the world.

Commercialising CCTs such as IGCC with CCS will require a continual process of refinements that drive down deployment costs. The design, construction and operation of the IGCC with CCS power plant in Stage One will generate technical, regulatory, commercial, and stakeholder experiences and learnings in an Australian context. The application of these experiences will significantly reduce risks and costs associated with the large-scale deployment of the technology in Stage Two. Depending on the development schedule of other large-scale IGCC with CCS projects in Australia and around the world, Stage Two could be a first-of-a-kind plant. This will in turn generate more key learnings to reduce the risks of scaling up the technology from a demonstration and could facilitate the widespread diffusion of large-scale IGCC with CCS low emission coal power plants.

2.2 Technology choice

ZeroGen believes that given the magnitude of the threat posed by climate change, a portfolio approach must be taken to de-carbonise Australian society. ZeroGen believes CCTs occupy an important role within this portfolio, but strongly supports a range of other low emission energy technologies such as renewable power generation including wind and solar.

ZeroGen also supports the development of other forms of clean coal power generation such as post-combustion capture and oxy-fuels. Underpinning all low emission coal power generation is CCS technology. This is an area where ZeroGen has developed considerable experience and expertise.

The Program's integration of IGCC with CCS technology combines four available technology components:

1. *Coal gasification* – a process which combines coal with oxygen under pressure to produce a high hydrogen synthesis gas (syngas) which fuel combustion turbines to generate electricity.
2. *Combined Cycle Gas Turbine (CCGT)* – a gas turbine with a heat recovery steam generator using syngas as a fuel.
3. *Carbon capture* – the process of capturing CO_2, from the syngas using chemicals; and
4. *Geosequestration* – the process of compressing, transporting and injecting CO_2 for permanent and safe storage in suitable geologic reservoirs.

IGCC technology is one of the most promising technologies to produce baseload electric power utilising Australia's abundant coal reserves. IGCC technology has a number of environmental, economic and energy benefits as well as being able produce valuable by-products including transportation fuels, chemicals and fertilisers. IGCC technology facilitates CO_2 sequestration as it can almost completely separate CO_2 from the bulk gaseous discharge stream.

Each of the clean coal generating technologies of post-combustion capture and oxy-fuels are worthy of further investigation with each appealing to different market sectors. However, IGCC technology is the only CCT that paves the way to the hydrogen economy.

2.3 Program benefits and opportunities

Through developing IGCC with CCS technology, ZeroGen will produce benefits in the following areas:

2.3.1 Accelerate the widespread commercial uptake of IGCC with CCS technology

The primary objective of the ZeroGen two-stage Program is to generate knowledge and experience in IGCC with CCS to enable the widespread and rapid commercialisation of large-scale low emission coal power plants.

The prospects of commercially deploying IGCC with CCS in Australia to meet the Commonwealth Government's emissions targets are significantly enhanced by the fact that the discrete elements of the technologies are currently commercially available from established and reputable suppliers. Gasifiers and the technology for the power block (eg. gas turbines) are available from a range of suppliers around the world should any generator choose to add IGCC plants to their portfolio. However, large-scale gas turbines using high-hydrogen syngas produced from coal are yet to achieve operational experience.

The enabling technologies for CCS are also available in the market place. Construction of pipelines and the drilling of geologic formations to facilitate CO_2 storage in deep underground reservoirs use standard equipment widely available in the oil and gas exploration industries. The equipment to monitor CO_2 dispersal in geologic structures is also commercially available today. The challenge remains the application of these technologies for CO_2 in an Australian context.

Overall, the key challenge to the commercialisation of ICCC with CCS is the integration of these discrete elements for low emission power generation. This challenge is currently being addressed by the ZeroGen Program.

ZeroGen's two-stage approach "de-risks" the technology from the perspective of technical, regulatory, commercial and stakeholder risks by generating knowledge and learnings in these key areas in Stage One. The learnings and experience will be used to concurrently accelerate the development of the large-scale 300MW (net) plant in Stage Two. The learnings gained by ZeroGen will accumulate, providing the potential for positive knowledge feedback loops across the technology supply chain that can further reduce technology costs. This continual process of refinement could significantly enhance not only the development of this CCT in Australia but also

enhance the transfer of the technology to other large CO_2 emitting nations such as China and India.

2.3.2 Help preserve the sustainability of coal as a fuel for power generation

Coal usage, in combination with other fossil fuels, is responsible for a large portion of Australian and global greenhouse gas emissions. Coal is the lowest cost energy source for baseload power in Australia and the largest commodity export by value. Australia's coal exports were worth $AUD24.5 billion (2005–06) and the industry supports approximately 130,000 jobs, often in rural and remote regions.

Australia also has significant reserves of minerals (such as bauxite, iron ore, copper and nickel) that require energy-intensive processes. The value of these minerals is predicated on the capacity to produce and use these resources utilising Australia's low cost baseload electricity generation based on coal.

Looking forward into a carbon-constrained future, the security of these exports and industry jobs would be placed under serious jeopardy unless CCTs, such as the IGCC with CCS technology being developed by ZeroGen, are commercialised.

2.3.3 Start the journey towards a hydrogen economy

As part of the electricity generation process, coal-fired IGCC plants produce hydrogen which can be used as a transport fuel through fuel cells and potentially provide a feed stock for the manufacture of other energy products and chemicals based on coal as the energy source.

The potential for the Program to utilise coal as a large-scale source of hydrogen would constitute the first step on the pathway towards a hydrogen economy, with the possibility of leading to further reductions in fossil fuel carbon releases beyond the electricity power sector.

2.3.4 Develop and expand technical capability and ability to support IGCC with CCS technology in Australia and globally

While most of the individual technology components being investigated by ZeroGen are currently available, they have never before been integrated for power generation. There are only four coal-fired IGCC plants in the world that produce power, but none of these have CCS.

Given that ZeroGen Stage One is a world-first integration of these technologies, it has great potential to assist in the development and expansion of technical capability to support the commercialisation of IGCC with CCS technology in Australia and around the world.

2.3.5 "De-risk" the storage of CO_2 in low-permeable reservoirs

Experts agree that geological storage of CO_2 offers the most suitable near-term opportunity for reducing CO_2 emissions from fossil fuel power generation, and is possible to be achieved on a massive scale[1]. Indeed, the Intergovernmental Panel on Climate Change, the body that alerted the world to the dangers of climate change published a special report in 2005 on the opportunities of CCS to enable deep cuts in CO_2 emissions[2].

In many respects, perhaps the greatest factor affecting the commercialisation pathway of all clean coal power generating technologies is the availability of potential CO_2 storage sites and their location to large-point source emitters. The GEODISC Program has identified 48 basins as viable storage sites in Australia and the potential for storing CO_2 in various geologic formations is shown in Table 1 on the following page[3].

[1]European Commission, 2006, The European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP). Director-General for Research Information and Communication Unit, Brussels

[2] http://arch.rivm.nl/env/int/ipcc/pages_media/SRCCS-final/IPCCSpecialReportonCarbondioxideCaptureandStorage.htm

[3] Bradshaw, J., Allinson, G., Bradshaw, B., Nguyen, V., Rigg, A., Spencer, L. and Wilson, P., 2003, Australia's CO_2 Geolgical Storage Potential and Matching Potential Emission Sources to Potential Sinks. Geoscience Australia, the Australian Petroleum Cooperative Research Centre, University of New South Wales and Ophir Exploration

Table 1: Potential CO_2 storage by structure, volume and time in Australia

Structure type	Estimated time (multiples of 1998 years total emissions ~455 MT CO_2)
Depleted gas fields (future and current)	9.4
Enhanced coal bed methane (future)	3
Saline formations	1,630
Enhanced oil recovery	0.4

Table 1 clearly reveals that the geologic formation in Australia that has the greatest potential to support the large-scale deployment of CCS is deep saline reservoirs. This formation can potentially support 1,630 years of Australia's total emissions in 1998 (approximately 455 MT CO_2) or approximately 741,650 MT CO_2 in total.

This is the geologic formation being targeted by the ZeroGen Program with a view to generating leanings that will release the potential of this enormous storage resource. Paradoxically, there is limited detailed information sourced from practical experiences on storing CO_2 in this formation. Indeed, ZeroGen's drilling investigation program represents 40% of the world's exploration efforts for CO_2 wells in deep saline formations. ZeroGen takes the view that its experiences and knowledge in finding a CCS solution in this type of reservoir is valuable and can be applied to unlock this vast resource in other regions in Australia and potentially around the world.

The CCS element of ZeroGen Stage One will demonstrate key solutions to a number of commercialisation challenges. Specifically, it will generate significant knowledge and experience on issues concerning site selection, stakeholder engagement, technical risk assessment, geological characterisation, and monitoring, measurement and verification in low-permeability deep underground reservoirs. While each storage site may contain unique features, the knowledge and learnings from the Program could be used to inform the development of CO_2 storage solutions elsewhere in Australia and globally for later technology movers.

2.3.6 Develop capacity on stakeholder engagement strategies to build public acceptance of clean coal, particularly CCS

A key issue in the commercialisation of CCTs is acceptance by stakeholders, particularly for CCS. While the technology is seen as a viable option to mitigate climate change[4], uncertainty surrounding the safety of CCS is a key challenge to its commercialisation, as stated below:

"*What is clear, however, is that CO_2 storage needs to be demonstrated in a variety of large-scale settings in order to convince operators, academia, regulators and – most critically – the public that it is both safe and desirable*."[5]

Experiences in this area are limited and often constrained by the actual level of activity in developing CCTs. For example, activities by developers conceiving CCT project are often confined to conducting surveys on stakeholder perceptions and attitudes. More advanced developments that move beyond conception to the actual undertaking of demonstration projects for instance, may incorporate this as well as other more sophisticated, practical and on-ground engagement activities such as the holding of public workshops as part of the regulatory approval process. ZeroGen's stakeholder engagement activities are of the latter category.

ZeroGen's comprehensive stakeholder engagement activities is critical to provide confidence not only to ZeroGen Program but to technology developers and government going forward.

2.3.7 Position Australian industries to capitalise on the growing environmental goods and low emissions technologies market

Carbon constraints are creating a growing market for environmental goods, low emissions technologies, and generating business in the provision of professional services that support the development of goods or services that reduce negative ecological impacts. Indeed, the

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[4] De Coninck, H C., Huijts, N M A., (undated) Carbon Dioxide Capture and Storage: Public Perception, Policy and Regulatory Issues in The Netherlands, Amsterdam The Netherlands

[5] The European Technology Platform for Zero Emission Fossil Fuel Power Plants, 2005, Strategic Deployment Documents. Europe

http://www.zero-emissionplatform.eu/website/library/index.html

Commonwealth Government[6] noted that the development of CCS presents market opportunities, and that any CCS technology developed in Australia could be "on-sold to other countries that are still very dependant on fossil fuels".

Within the Australian business arena there are varied views about what the ultimate cost of climate change will be compared with the opportunities that it could present. In a recent interview, Victorian Premier John Brumby likened the economic opportunities of climate change to "the industrial and information revolutions"[7] and announced initiatives aimed at positioning Victoria at the forefront of the climate change economy. Early-mover companies such as ZeroGen provide the opportunity to generate a host of skills, goods and services that can position Australian technology developers, researchers and service providers with a critical competitive advantage in this growing low emission energy technologies market.

[6] The Commonwealth of Australia (2007) "Between a Rock and a Hard Place: The Science of Geosequestration." House of Representatives Standing Committee on Science and Innovation

[7] Rintoul, S. 2008, Brumby's Energy 'Revolution', The Weekend Australian (The Nation), 5-6 April 2008, p.8

3.0 Issues for innovation and commercialisation of large-scale low emission coal power plants

ZeroGen acknowledges that the challenges of decarbonising Australia's economy and society are significant. In order to meet the Commonwealth Government's stated target of reducing CO_2 emissions by 60% of 2000 levels by 2050, significant political, societal and economic will is required.

Leading energy innovation experts such as Foxon[8] and Grubb[9] argue that radical innovation in low emission energy technologies will be required to facilitate a transition from the currently high carbon intensive energy system to a low carbon intensive technology system. Analogously, ZeroGen submits that "radical" policy innovations (compared to the existing policy paradigm) will also be required to facilitate the step change toward low emissions energy technologies in order to mitigate the catastrophic threats of climate change. ZeroGen acknowledges that while the costs of radical policy actions may be high, when it comes to climate change, these may be acceptable when compared to the alternative of comfortable policy inaction. ZeroGen also acknowledges the difficult challenge faced by the Review in allocating scarce resources among a wide range of alternatives.

ZeroGen's practical experiences in developing IGCC with CCS low emission energy technology supports the views of experts such as Foxon[10] that innovation processes are dynamic, non-linear and systemic involving a range of interacting actors, networks and institutions working in concert. This new understanding of innovation systems suggests that the pure economic notion of "market failure" alone is inadequate to guide policy interventions to support innovation to achieve socially defined objectives of emissions reduction targets.

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[8] Foxon, T. 2003, Inducing Innovation for a low-carbon future: drivers, barriers and policies, London: The Carbon Trust, viewed 6 April 2008

<http://www.garnautreview.org.au/CA25734E0016A131/WebObj/InducingInnovationforalowcarbonfuture-drivers,barriers,andpolicies/$File/Inducing%20Innovation%20for%20a%20low%20carbon%2-

0future%20-%20drivers,%20barriers,%20and%20policies.pdf>

[9] Grubb, M. 2004, 'Technology innovation and climate change policy: an overview of issues and options', Keio Economic Studies. Vol XLI. No.2, viewed 6 April 2008,

<http://www.econ.cam.ac.uk/faculty/grubb/publications/J38.pdf>

[10] Ibid

ZeroGen offers some observations based on its practical, firm level experiences in attempting to commercialise CCTs, particularly IGCC with CCS in an Australian context. Its submission also draws upon some of its broader international experiences and learnings in the technology space as well as the economics of low emission technology innovation in general.

3.1 Coal is likely to remain a significant contributor to the electricity generation portfolio

Coal will remain an important source of primary energy for Australia and many other developed and developing countries into the foreseeable future[11]. This is due to its abundance, broad geographic distribution, relative low cost and stable delivery processes. In Australia, for example, coal-fired power generation provides approximately 84% of current baseload power needs.

As stated previously, ZeroGen supports a portfolio of approaches and believes the debate has moved beyond supporting CCTs or other forms of low emission supply technology such as renewables or demand side initiatives such as efficiency improvements. The threat of climate change will require a portfolio of approaches to transition to a low carbon intensity environment. However, given the scale of CO_2 emissions from coal-fired power generation not just in Australia but around the world, it is imperative that public policies support the commercialisation of CCTs as a priority. Development of CCTs in Australia will not only assist to meet its emissions reduction target but the transfer of these technologies overseas can also assist other nations to enable deep cuts in CO_2 emissions.

3.2 Innovation processes in the conventional coal-fired power generation sector

In considering policy options to accelerate innovation in low emission energy technologies, the performance of the conventional coal-fired power generation sector in this area needs to be considered within an Australian context and broadly as an industry.

[11] OECD/IEA (2008) Clean Coal Technologies: Accelerating Commercial and Policy Drivers for Deployment. Coal Industry Advisory Board

The electricity industry in Australia has been characterised as a "technology taker" because of the following factors:

- Relative to the size of the electricity industry in other countries it's market is very small;
- Particular policies have been targeted at meeting social requirements that restrict the prices generators can charge for an "essential service;"
- The generating technologies are assets that have high capital intensity but which deliver a low value commodity; and
- Limited presence by large original equipment manufacturers.

More broadly, the energy sector's efforts in energy innovation is characterised by extremely low levels of research, design and demonstration (RD&D). As noted by Grubb[12], compared to the pharmaceutical or information technology sectors where RD&D expenditures range between 10-20% of turnover, RD&D in privatised energy industries has fallen to under 0.4% of turnover. This low level of RD&D investment is a result of a range of market failures and barriers that have created disincentives for the energy sector to invest in low emission technology. These market failures and barriers are discussed below.

Given these factors, innovation in fossil-fuel power generation technologies has been generally characterised as being incremental. Indeed, this was a key lesson in the deployment of large-scale pulverised fuel generation plant in some areas of Australia during the 1980s and 1990s where plant designs were imported from North America and Europe[13]. Industry experienced significant difficulties when these imported technologies were deployed in Australian conditions. Early boiler designs were not optimised for Australian coals and the high ash content of New South Wales coal resulted in boiler tube erosion contributing to significant availability losses. It took over 10 years of operating experience to identify the problem and to develop design innovations in Australian conditions to overcome these challenges. In that period, plant availability levels rose from about 65% to better than 90% by the mid 1990s.

[12] Ibid

[13] Boyd, R.K, 2004, Application of successes in coal-based generation in developed countries to global CO_2 emissions reduction, 19th World Energy Congress, Sydney, Australia

As Foxon[14] and Grubb[15] suggest, this incremental innovation in energy technologies is deficient in meeting the demand for low carbon intensive technologies in this new era of climate technology policy. To meet societal interests as expressed by the Commonwealth Government's stated CO_2 emissions reduction target radical or "step-change", innovations to generating technologies that enable deep cuts to CO_2 emissions will be required. ZeroGen's development of IGCC with CCS low emission generating technologies represents a technological step change that is capable of assisting Australia to achieve this target.

3.3 Market failures and barriers across the innovation system

Market failures and barriers to private firms commercialising low emission energy technologies are well articulated in the Review's issue paper, Foxon[16] and Grubb[17]. Some of these are market failures as defined by conventional neo-classical economics. Others are where market failures do not occur but where the industry structure nonetheless creates innovation hurdles. Market failures and barriers to innovation in low emissions energy technologies include:

- Appropriability issues where early movers in new low emission technologies face challenges because once information and knowledge is produced and disseminated, competitors may be able to produce copies without having to incur the often high costs of conducting the initial RD&D;
- The high risks (access to significant capital; stakeholder, technical and regulatory risks) of low emission energy technology reduces an individual firms willingness to support what may be the socially optimum level of innovation;
- Coordination failures such as information asymmetries and transactions costs;
- The presence of externalities or spillovers and the challenge of "free rides";
- Technological and institutional barriers (such as regulatory uncertainty on CO_2 storage liability) that support technology "lock-in" to the existing high carbon intensive generating technology;

[14] Ibid

[15] Ibid

[16] Ibid

[17] Ibid

- Long development time-scales;
- Insufficient capacity and supply of skilled, experienced labour pool to plan, design, build and operate low emission coal power plants;
- Weak market drivers such as no price signal for CO_2 in Australia and extremely limited opportunities to generate premium prices from product differentiation (the product is an electron) relative to other consumer products such as computers or mobile phones; and
- Multiple political risks from stakeholder opposition to the construction of large new technology infrastructure such as power plants and CO_2 pipelines, as well as the geologic storage of CO_2.

ZeroGen submits that the presence of these market failures and barriers is creating significant investment disincentives in CCTs. Can these market failures and barriers be overcome? ZeroGen believes that they can and its business model offers the correct and optimal approach to developing IGCC with CCS low emission technologies at the firm or technology developer level. However, the successful commercialisation of CCTs in the timeframe required will demand industry and governments work in close partnership and for effective policies to be developed that addresses these barriers.

3.3.1 Time in the energy innovation process to meet CO_2 reduction targets

While many of these barriers can be resolved by appropriate policy interventions, ZeroGen submits that a key issue for consideration by the Review is time. Policy makers need to understand that the prudent management of large new technology infrastructure projects may mean that it can take up to a decade to advance through concept, pre-feasibility study, feasibility study and financial close phases.

As a result, policies need to consider the time required for the rapid commercialisation of low emission technologies in order to meet the Commonwealth Government's stated emissions reduction targets. Policy makers should also recognise and value the inherent option that the existence of early movers such as ZeroGen offer in developing CCTs. In other words, in the absence of early-movers such as ZeroGen, the commercialisation of IGCC with CCS could be set back by at least a decade, perhaps longer.

ZeroGen is addressing the issue of time through its two-stage approach. It has already developed and accumulated significant practical experience and knowledge of the issues associated with developing IGCC with CCS, particularly in low permeability underground reservoirs. This will be applied to develop the Stage One demonstration low emission coal power plant which in itself will stimulate the generation of even more knowledge and experience. These will be applied to accelerate the development of Stage Two and indeed, other large-scale clean coal power plants, both nationally and internationally, using IGCC with CCS into the future.

3.3.2 ZeroGen's experience with economic spillovers

As an early mover in the IGCC with CCS low emission technology space ZeroGen submits it generates a range of large and positive economic spillovers. However, as an early mover it can also be significantly affected by negative spillovers. It is encouraged by the Review's discussion paper that states that where there is evidence of large spillovers "deployment support may be warranted."[18]

It also acknowledges the challenges faced by policy makers in identifying the existence of spillovers, quantifying their scale, causality to innovation and providing a value for spillovers in low emission energy technologies. Though no means an expert in this field ZeroGen will attempt to inform discussion on this issue through its own experiences. ZeroGen proposes that positive spillovers generated by the Program include social acceptance, support sector, skills, knowledge and facilitation in the development of regulatory reforms. These are articulated below.

3.3.2.1 Social acceptance spillovers

Social acceptance is vital to the commercialisation of low emissions coal-based energy technologies.

Indeed, ZeroGen submits it is vital to the successful development of any large infrastructure project. Corporate history is littered with examples where societal concerns about the negative impacts of projects have resulted in them either being delayed or stopped. Indeed, efforts to

commercially develop existing low emission energy technologies such as wind farms and the construction of dams for hydro-generation can often be controversial. These can be delayed or stopped by social concerns over habitat loss, noise and the impact on wildlife such as rare and protected parrots.

Following the general theoretical framework of innovation, the integration of IGCC with CCS technologies can be considered new or novel as they are obviously not commercialised and widely deployed at large-scale. As a consequence, social acceptance is integral to the approvals process by government and in providing confidence in the technologies across a range of influential stakeholders such as individual citizens (particularly landholders in the sequestration zone), communities, investors, researchers and indigenous groups.

As an early mover, ZeroGen's stakeholder engagement strategy has been deployed since 2006 at a time when the issue of climate change and the need for low emissions baseload power to reduce CO_2 emissions to atmosphere was relatively novel and not subject to the widespread media coverage and informed debate the topic generates today. Given this, the Program has expended considerable resources to inform and educate stakeholders at multiple levels and wide geographic locations about climate change and the benefits of IGCC with CCS to generate low emissions baseload electricity. The Program experienced first hand the lack of information possessed by stakeholders on CCS technology and in particular concerns about catastrophic failures both in the CO_2 storage and distribution system.

This paucity of knowledge of the critical technology underpinning all clean coal technologies was also experienced by other researchers.[19] Through surveys, it was found that 93.4% of respondents thought climate change was an important issue to Australia. However, 67.4% were unaware of CCS as one of the key weapons in the fight against climate change.

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[18] Garnaut R. 2008, Issues Paper 4- Research and Development: Low Emissions Energy Technologies

[19] Ashworth, P. Mayhew, M. Millar, F and Boughen, N. (2007) An Integrated Roadmap of Communication Activities Around Carbon Capture and Storage (CCS) in Australia and Beyond. Centre for Low Emissions Technology/CSIRO Report no. P2007/975

ZeroGen has also had to allocate resources to manage the risk of negative spillovers from the activities of other firms and events within Australia and overseas impacting on the Program. For example, during the early phases of its community engagement meetings, it had to respond to legitimate questions about the safety of sequestration after concerns were raised about the leakage of CO_2 that occurred naturally at Lake Nyos in Africa. ZeroGen's activities to inform and educate stakeholders about the ability to safely store CO_2 not only benefits the Program's development activities but also generates social acceptance benefits to later-movers in this technology.

To mitigate the lack of information on IGCC with CCS and to build awareness and acceptance, particularly for CCS, numerous communication mechanisms were, and are continuing to be implemented. These include:

- Community workshops (attended by senior staff to answer questions raised about Stage One; but more broadly IGCC with CCS technology, climate change and other forms of low emissions technologies) and the establishment and operation of community liaison groups;
- Numerous and frequent face-to-face meetings;
- Presentations (in excess of 100 to date) to a wide range of audiences locally, nationally and internationally; and
- Dissemination of information through the media, website and fact sheets.

As a result of ZeroGen's activities, it has to date gained significant momentum and achieved a range of outcomes. These include securing the in-principle support of the citizens impacted by the drilling program, and the communities where the IGCC plant is proposed to be built and the CO_2 stored. It has gained financial support from the Queensland Government and the Australian coal industry. It has also gained support from WWF-Australia (the Australian arm of the world's largest environmental non-government organisation) and the Construction, Forestry, Mining and Energy Union (CFMEU) which is Australia's largest union representing workers in the energy and mining sectors. Clearly, ZeroGen's investments in generating social acceptance have created wider benefits for later followers who may have been previously uninformed or ill-informed about CCS.

These investments facilitate the societal acceptance of IGCC with CCS, particularly CCS, and may be enjoyed "at no cost by later movers in the industry"[20].

Stage One stakeholder engagement strategy is currently being implemented and is scheduled for the completion at the end of the feasibility study in late 2009. At this stage, ZeroGen estimates its direct investment in planning, designing and executing the stakeholder engagement strategy to build social acceptance at up to $AUD5 million. Extrapolating from this Program-specific estimate, and assuming a range of caveats, a broader engagement program that builds social acceptance for CCTs, particularly CCS within a state or national geographic boundary could cost more than $AUD5 million.

It is important to note that the social acceptance spillover being generated by the Program can also be accrued to late movers in other countries. Given that ZeroGen is the world's leading developer of IGCC with CCS technology, other stakeholders such as governments, researchers, technology and service providers have also referred to it in their discussions and presentations to build social acceptance of the technology in their jurisdiction. The exact cost estimates of this spillover are beyond the scope of the submission. However, suffice to say that it is large and important in building confidence which enhances the potential of successful technology transfer and uptake in these countries.

As a result of ZeroGen's activities to promote the social acceptance of IGCC with CCS, particularly CCS, it was approached by the Central Research Institute of Electric Power Industry (CRIEPI) based in Japan. The mission for CRIEPI is to conduct research that will advance understanding on the issues of electricity power generation and to disseminate this not only in Japan but around the world. The organisation sought to learn how ZeroGen engaged with stakeholders to build social acceptance so that its strategies could be considered for adoption to reduce this risk to transferring the CCS technology to Japan. ZeroGen has executed a memorandum-of-understanding with CRIEPI to share its knowledge through a series of meetings and workshops. The first of these is scheduled for June/July 2008.

[20] Garnaut R. 2008, Issues Paper 4- Research and Development: Low Emissions Energy Technologies

Another dimension in valuing spillovers concerns time. Changing societal norms, practices, values and beliefs to accept the merits of safely storing CO_2 can take decades. Analogously, the positive spillovers generated by ZeroGen can be valuable to later movers over this long time horizon.

3.3.2.2 Support sector spillovers

ZeroGen's early mover activities in terms of the development of supporting technologies and services to IGCC with CCS have also resulted in support sector spillovers. ZeroGen's engagement of lawyers for advice on the impact of CO_2 liability and associated regulatory reforms have assisted these supporting firms to build capacity. This knowledge can be used to advise other clients who are later movers more effectively and in a faster time frame in the future.

As stated previously, ZeroGen's drilling activities account for approximately 40% of the world's CO_2 exploration in deep, low permeable underground reservoirs. Given the paucity of data on CCS in deep, low permeability reservoirs, ZeroGen has engaged a range of geotechnical service providers to assist in developing a CO_2 storage solutions specific to this type of formation that offers one of the greatest opportunities for the large-scale, safe storage of CO_2. The services provided by these firms include reservoir modelling, monitoring, measurement and verification techniques. ZeroGen's engagement of these support service providers and the knowledge they have gained obviously assists these firms to build their capacity in this new area. This can be made available to later movers.

ZeroGen's early mover efforts to quantify both the ability of the Northern Denison Trough to safely store CO_2 and its storage capacity are also illustrative of spillover benefits and its value. At the commencement of Stage One's drilling program in 2006, ZeroGen used an oil and gas exploration rig which, depending on target location, depth, weather and time can cost up to $AUD5 million a rig. The decision to use this type of rig was because this was the orthodox approach at the time. Since then however, ZeroGen has challenged this orthodox approach and is using available but "unorthodox" mineral rigs to drill its other test wells. This has never been undertaken before in any clean coal project.

The application of the mineral rig technology has resulted in a cost reduction of 50% compared to the "orthodox" technology in the 12 months since Stage One's drilling program commenced. ZeroGen submits that this has been a key breakthrough in developing a CO_2 storage solution. The "unorthodox" use of mineral rigs can be used by later movers.

Intuitively, it could be argued that if ZeroGen had not generated this breakthrough other later movers would also have used oil and gas exploration technologies to undertake their onshore CO_2 storage investigations. Assuming similar geologies and technical objectives, the value of this spillover could be the differential between the cost of using the "conventional" oil and gas exploration rigs and "unorthodox" mineral rigs in the drilling programs of later movers. Depending on the scale, location, depth and weather for example, this differential could be many tens or hundreds of millions of dollars.

Through its early mover activities in CO_2 storage, ZeroGen has also attracted considerable interest among domestic and international specialist equipment manufacturers and suppliers. ZeroGen has been approached, for example, by specialist steel and cement manufacturers seeking to develop corrosive resistant steel and cement for CO_2 rich environments in deep underground reservoirs. In the case of anti-corrosive cements, this is critical to reducing the risk of CO_2 leakage. Once again, the knowledge gained by these manufacturers in developing their products will be available to later movers.

3.3.2.3 Skills spillovers

The basis of competition at this stage of the innovation continuum for IGCC with CCS technology is design. Standards are not uniform and the dominant design is yet to emerge. ZeroGen, through its engineering services consultant, has engaged 35 engineers to work on the design and construction of the power plant. These engineers will develop skills that will be available to later movers.

3.3.2.4 Knowledge spillovers

Knowledge spillovers occur where the knowledge gained by one firm can result in external benefits or costs to other firms, industries or society. ZeroGen submits that it is generating knowledge

spillovers and has also benefited from the knowledge of other sectors. As stated previously, IGCC technology is traditionally applied in the petro-chemical industry and there is public knowledge generated by firms in this area used by ZeroGen. Knowledge in the core technology of CCS has, at base, been generated by the oil and gas industry. Knowledge is also being applied from the power generation industry to guide innovation efforts. The availability and application of this knowledge has been central to developing solutions to reduce commercialisation risks.

As the Review suggests knowledge spillovers can be large if the innovation occurs visibly in the marketplace and not behind closed-door research facilities such as that undertaken by pharmaceutical and consumer electronic companies. In ZeroGen's case, the Program is highly visible given it will involve the construction of an IGCC power plant, and the trucking and safe storage of CO_2. Indeed the fundamental objective of Stage One as a demonstration plant is to generate and disseminate knowledge to reduce technical, commercial, regulatory and stakeholder acceptance risks. Intuitively, ZeroGen submits that given this, it will generate large and positive knowledge spillovers.

The issue of internalising intellectual property rights through patents to commercialise IGCC with CCS low emissions technologies is also highly complex. The opportunities for commercialising IGCC with CCS power plants are significantly enhanced by the fact that the fundamental technology components are commercially available in isolation, or in other contexts. Paradoxically, however, the existence of technology providers which enhances commercialisation also means that ZeroGen has to acquire the rights to use the background intellectual property from the relevant equipment or technology supplier. As a result, compared to other industries such as pharmaceuticals or consumer electronics, potential revenue streams from the generation and protection of intellectual property in IGCC with CCS may be limited. It is also highly unlikely to be sufficient to offset the significant up-front capital and operating costs of IGCC with CCS power plants.

While the components of IGCC with CCS technology are commercially available, the key to ZeroGen's efforts to commercialise the technology involves their integration and application for low emission power generation, which has never been undertaken before. This integration nexus is likely to generate new intellectual property that can be patented to generate revenue streams and indeed, ZeroGen is already actively progressing opportunities in this area. However, as stated

above, potential revenue streams from intellectual property in themselves are highly unlikely to generate sufficient returns to cover the large upfront costs.

3.3.2.5 Regulatory spillovers

As the Review notes, early movers may bear the costs of resolving legal or regulatory issues with government and other industries. This would benefit later movers from reduced regulatory uncertainty, reduced sovereign risk and the creation of established contractual arrangements. ZeroGen has been actively engaged with the Queensland Government's Department of Mines and Energy regulatory reform process on the administration of geosequestration tenure. Submissions to the discussion paper closed on 3 August 2007.

This relatively high level of activity reflected not only an interest in long-term storage liability issues. Given ZeroGen intends to conduct its trial CO_2 injection program in late 2008/early 2009 it needed to also understand its legal rights in the short-term in regard to this key activity. Additional transaction costs were also incurred as discussions were also held with other firms in the gas industry and other government departments such as the Environmental Protection Agency to formulate a position. As an early mover, ZeroGen's allocation of scare resources to this activity to develop a regulatory framework will benefit other later movers.

3.3.2.6 Estimated the Value of Spillovers

ZeroGen submits that estimations of the value of CCT spillovers is challenging. More work must be done to identify the spillovers, estimate their scale, value and the degree by which the actions of early movers create fundamental change in the innovation process or whether these changes would have occurred anyway. While this is not ZeroGen's area of expertise, in the interests of stimulating policy debate, some observations are offered below.

ZeroGen submits that the fundamental challenge to commercialising CCTs such as IGCC with CCS low emissions energy technologies is the absence of practical, contemporary information and knowledge. ZeroGen's experience in this area can be considered using the colloquial expression, "In the land of the blind the one eyed man is king". With no latent background in sequestration or gasification it has learned the hard way in the field and from many different experiences.

Demonstration projects that generate information, knowledge and experiences are required as a reference to inform the future development of the technology. As argued above, the information, knowledge and experiences generated by early movers such as ZeroGen are positive spillovers. Intuitively therefore, the potential value of the spillovers generated by demonstration projects such as ZeroGen could be their cost. In ZeroGen's case, the capital cost of Stage One is approximately $AUD1.7 billion.

Conceptually, the new systems approach to innovation suggests that it is a complex process that matches technical possibility and market opportunities against a dynamic background of people, networks and institutions. Therefore, it could also be argued that the development of feasibility studies for CCTs endure these experiences particularly at this stage of the innovation continuum. Accordingly, another potential proxy for the value of the spillovers is the cost of the feasibility study for demonstration projects particularly if the project does not proceed to construction.

Intuitively, and using ZeroGen as an example, if Stage One did not proceed to construction these positive spillovers could be accrued by other later movers. Following this logic, the potential value of spillovers for IGCC with CCS low emissions technology is the cost of the feasibility study for ZeroGen Stage One which is approximately $AUD125 million. These costs also take into consideration the market rate for the provision of services required to conduct the feasibility study.

3.4 Barriers specific to IGCC low emission energy technology innovation

In terms of barriers to developing IGCC with CCS low emissions technology, the National Association of National Utility Commissioners[21] based in the United State of America identified the four highest ranking challenges to IGCC deployment as:

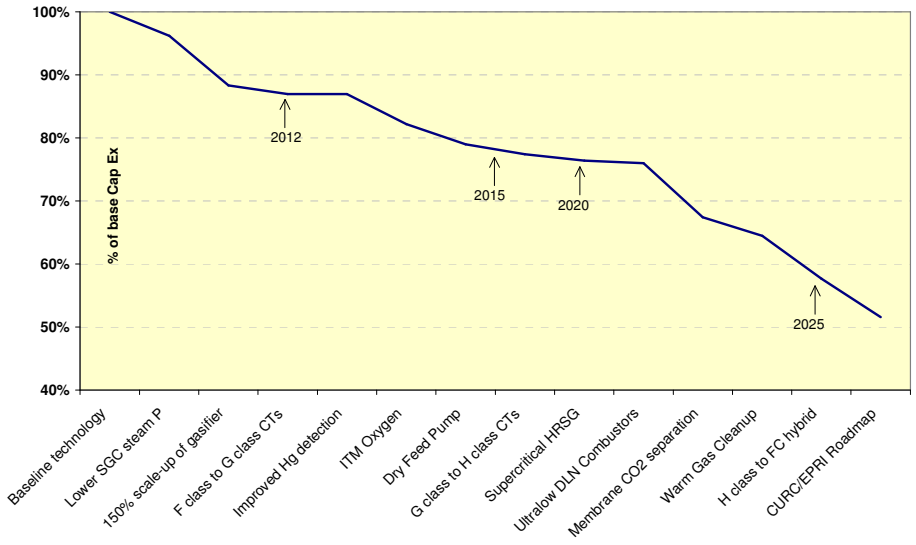
- Higher upfront capital costs;
- Issues over plant reliability without subsidies;

[21] O'Brien, J. N., Blau, J. and Rose, M., 2004, An Analysis of the Institutional Challenges to Commercialization and Deployment of IGCC Technology in the U.S. Electric Industry: Recommended Policy, Regulatory, Executive and Legislative Initiatives. U.S Department of Energy National Energy Technology Laboratory Gasification Technologies Program and National Association of Regulatory Utility Commissioners

- Increased risk associated with up-front development costs; and
- Low plant availability in the early stages of operation.

The Electric Power Research Institute (EPRI), via the "CoalFleet for Tomorrow" initiative, suggests that over the next two decades there is a targeted technology roadmap for plant improvements that reduce capital costs (refer Figure One). These cost reductions clearly enhance the potential to commercially deploy IGCC plants.

Figure One: EPRI IGCC Plant Improvements and Capital Costs Roadmap



3.5 Barriers specific to CCS

The Organisation for Economic Cooperation and Development (OECD) and International Energy Agency's (IEA) Coal Industry Advisory Board (CIAB)[22] recently noted that in order for CCS technologies to be implemented successfully in the next four decades, a number of actions need to be undertaken as a priority. These include:

- Establishing a clear, balanced legal framework for CO_2 transport and storage;
- Promoting public understanding and acceptance of CCS;

[22] OECD/IEA (2008) Clean Coal Technologies: Accelerating Commercial and Policy Drivers for Deployment. Coal Industry Advisory Board

- Funding CCS research, development and deployment;
- Establishing tax incentives and loan guarantees for CCS, RD&D and commercial projects;
- Supporting commercial opportunities for use of CO_2 for enhanced oil recovery (EOR) and enhanced coalbed methane production as a means for developing CCS technology and infrastructure;
- Promoting commercial opportunities in transport fuel and chemical production from coal as a means of developing CCS technology and infrastructure;
- Supporting market-based responses, such as GHG cap-and-trade systems, to speed the ultimate commercialisation of CCS;
- Encouraging mandatory price supports and feed-in tariffs based on the avoided emissions from systems with CCS; and
- Promoting participation of emerging economies in CCS development and deployment.

In addition to these findings, at a plenary meeting in November 2007, CIAB members:

- Emphasised the need for government support on the early stages of the process;
- Reinforced the need for capital support, and for governments to assist in funding, particularly against the current backdrop of escalating capital costs; and
- Saw participation of the emerging economies as crucial, with loan subsidies through the World Bank being a possible means of encouraging their involvement.

The challenges to commercialising CCS technology in Australia are well articulated by the Commonwealth Government[23]. These include:

- High development capital costs;
- Risks of public perceptions concerning CO_2 leakage;
- Legislative and regulatory frameworks, particularly over the issue of long-term CO_2 liability and inconsistency between the Commonwealth, States and Territories; and
- Skills shortages.

[23] Commonwealth of Australia (2007) "Between a Rock and a Hard Place: The Science of Geosequestration." House of Representatives Standing Committee on Science and Innovation

To this, ZeroGen gratefully acknowledges the significant work being undertaken by the Queensland Government to provide the appropriate legislative and regulatory framework to enable the safe storage of CO_2.

3.6 Role of Emissions Trading Scheme (ETS) in driving innovation

An assignment of an economic value of CO_2 through an ETS is fundamental in driving innovation in low emissions energy technologies. However, a price on CO_2 in itself is insufficient to facilitate radical innovations in low emission energy technologies such as IGCC with CCS.

At present no low emission technology is competitive against conventional coal-fired power plants that do not capture, transport and safely store CO_2. A price signal for CO_2 is a fundamental pre-requisite to incentivize innovation in developing low emission coal power plants that bear the additional regulatory, technical, commercial and stakeholder risks of capturing, transporting and safely storing CO_2.

While several existing CCS projects use the injection of CO_2 to enhance oil or gas recovery where the rents extracted from the oil or gas offset the capture and storage costs, given that many CCS opportunities are not associated with enhanced oil or gas recovery operations, it is difficult to foresee widespread deployment of CCS without assigning an appropriate price signal for CO_2.

Furthermore, the development of large-scale low emission coal power plants that have an economic life in excess of decades need long-term price signals to give confidence in project financial planning. In Australia's deregulated electricity market, the absence of both a price for CO_2 and long-term price trends currently provides a strong disincentive to individual firms to invest in clean coal innovations. Consequently, the planned introduction of an ETS by the Commonwealth Government is welcomed by ZeroGen.

However, energy innovation experts such as Grubb[24] and Foxon[25] note that the energy innovation process is complex, dynamic and non-linear. The introduction of an ETS alone is insufficient to stimulate the widespread commercialisation of low emission technology. Indeed, Grubb[26] states that *"Neither public R&D nor prime reliance on carbon pricing/ cap and trade will achieve the far reaching, long-term innovations required to address climate change."*

3.7 An alternative model for considering policy options for strategic intervention

The Review is seeking comment on alternative frameworks that may be useful to consider the processes of policy analysis and development. As seen in previous sections the new systems thinking on innovation suggests that it is a dynamic, non-linear process open to the actions of many actors, networks and institutions influenced by a myriad of feedback loops. These characteristics would suggest that a policy analysis framework would need to take these dynamic interactions into account.

In addition, ZeroGen would add that one of the core objectives of policy intervention in low emissions energy technology innovation is to facilitate the development of competitive firms domestically and internationally. Given these variables ZeroGen submits that the work of Professor Michael Porter[27] at Harvard Business School on business strategy, competitiveness of industries and the impact of regions/locations on competitive advantage could be useful. The following section draws heavily on Porter's work.

At base, Porter suggests that companies achieve competitive advantage through acts of innovation and with a few exceptions, this arises because of unusual efforts in the face of pressure, necessity and even adversity. The level of innovation, their barriers and the state of competition in an industry (in this case the electricity generation industry) could be analysed by considering five forces as shown below in Figure Two:

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[24] Ibid

[25] Ibid

[26] Ibid

[27] Porter, M.E. (1998) On Competition. The Harvard Business Review Book Series

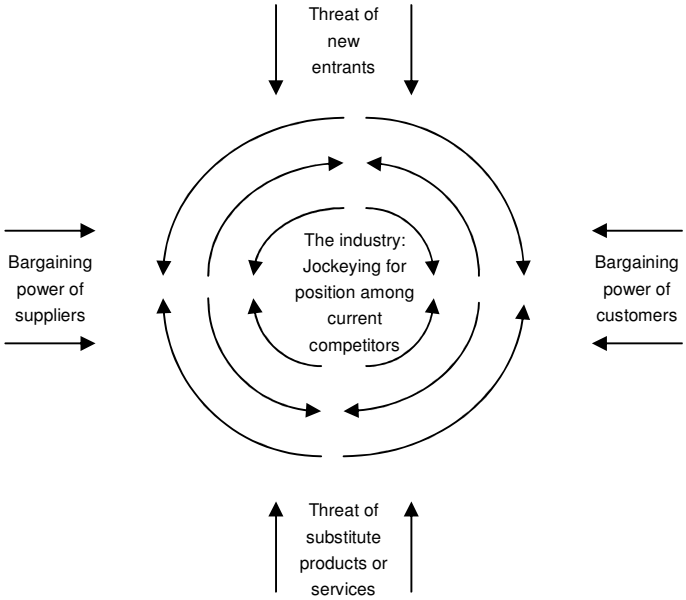

Figure Two: Forces Governing Competition in an Industry

In considering the emergence of early movers in the development of low emissions energy technologies in the existing electricity industry, the five forces model suggests decision makers could consider:

- The bargaining power of customers (What is the level of electricity demand? What is the demand for low emission baseload electricity? If the product is undifferentiated consumers are more price sensitive);
- The threat of substitute products or services (Are their substitutes to more expensive low emissions electricity generation? Is there an ability to differentiate?)
- Bargaining power of suppliers (What is the technology supply chain? Are their any critical gaps? Are their any reputable suppliers? Are they powerful enough to reduce quality or charge higher prices (say for licenses for components used to make the low emission technology)?

- The threat of new entrants and barriers to entry (for example, economies of scale, product differentiation, capital requirements, access to distribution channels and government policy); and
- Jockeying for position and the intensity of rivalry among firms (e.g., industry players, existence of exit barriers, are they high?)

It is the collective strength and the dynamic interaction of these forces which determines the profit potential of a new low emission energy technology. The relative strengths and weakness of these five forces could also be analysed to consider barriers to commercialisation, the viability of early mover firms to be commercial and what, if any policy intervention could be warranted and how they could be targeted.

Porter also considers the attributes of competitive advantage on the capacity to innovate in the context of nations or locations to create and sustain superior performance. Porter's diamond of national advantage suggests that there are four broad attributes of a nation in which companies compete; factor conditions, demand conditions, related and supporting industries and firm strategy, rivalry and structure. This framework could also be useful in considering low emissions energy technology development. Porter's diamond is shown below in Figure Three.

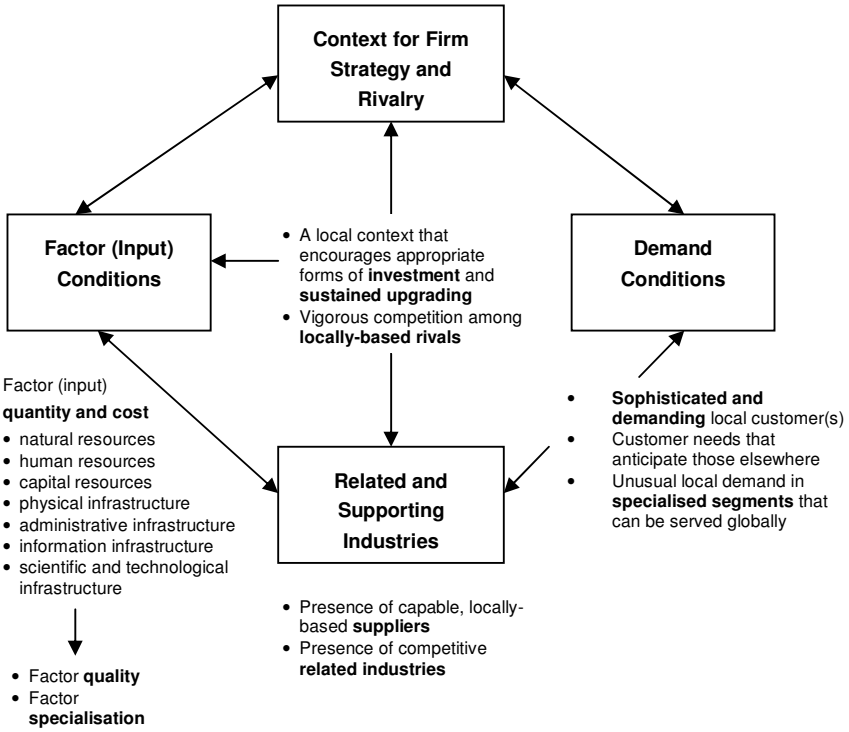

Figure Three: Sources of Locational Competitive Advantage

Each point of the diamond individually and the diamond as a system affects the ability to achieve internationally competitive success for a low emission energy technology developer. It provides a framework to assess the key strengths and weaknesses of an early mover low emission technology. For example, the presence of related and supporting industries can often be critical to commercialisation. Is the presence strong? Are their competitive related industries? Demand conditions are critical to ensuring the viability of the innovation. Is demand sophisticated and strong among local customers? Could these drive innovations to capture a strategic market niche that could be later used to capture international market opportunities?

This analysis of Porter's framework is extremely cursory and by no means exhaustive. ZeroGen submits that it could be a useful framework for policy makers to understand the key attributes and the dynamic actions across the system that drive innovation as a source of competitive advantage. It could also be used to formulate criteria to develop policy.

4.0 Policy Recommendations

Having regard for the complex issues inherent in the innovation of low emission technologies, particularly IGCC with CCS in an Australian context, ZeroGen suggests the following policies be considered:

4.1 Role of Emissions Trading Scheme (ETS)

ZeroGen welcomes the introduction of and ETS as a method to assign a value for CO_2. However, this policy in isolation will be insufficient to facilitate radical innovations in low emission energy technologies.

4.2 Economic incentives for early movers

ZeroGen submits that early movers who develop demonstration projects generate widespread and large positive spillovers which are available to late movers. Development of IGCC with CCS low emission energy technologies at this stage of the innovation continuum will also incur relatively large up-front costs. As a result, significant economic incentives to accommodate for the high, up-front development costs will be required to commercialise this technology.

ZeroGen also acknowledges the significant contribution made by the Australian Coal Association's Coal21 Fund and the Queensland Government to support CCT development to date. These investments are world leading. In addition, the Garnaut Review's ETS Discussion Paper[28] states that the "auctioning of all permits will be the source of a substantial amount of government revenue." Accordingly, ZeroGen recommends that a large proportion of this revenue be invested to develop CCTs such as IGCC with CCS.

What is the scale of investment required to commercialise the technologies? The cost of ZeroGen's Stage One demonstration of IGCC with CCS has a capital cost of $AUD1.7 billion. The

[28] Garnaut, R. 2008, Emission Trading Scheme Discussion Paper. Garnaut Climate Change Review, Canberra, viewed 6 April 2008

< http://www.garnautreview.org.au/CA25734E0016A131/WebObj/ETSdiscussionpaper-March2008/$File/ETS%20discussion%20paper%20-%20March%202008.pdf>

Pew Centre on Global Climate Change[29] recommends 10 to 30 commercial-scale demonstrations of CCS at coal-powered plants over a 10 to 15 year period, plus five to 10 large-scale demonstrations of CO_2 storage (primarily in saline formations) could between US$8–10 billion. Note, these cost estimates are for CCS only which is not as capital intensive as IGCC technology.

The Garnaut Review also suggests that a number of more traditional mechanisms to provide assistance for early movers include immediate and delayed tax write-offs; accelerated tax deductions for depreciation and matched funding. ZeroGen suggests that all of these mechanisms need to be available to support early movers particularly given the capital-intensive nature of CCTs.

The application of mandatory feed-in tariffs to support low emission technologies such as wind and solar energy could also be applied to power generated by CCTs. ZeroGen argues that the introduction of a feed-in tariff or differentiated price for CCTs increases their ability to be commercialised. An alternative version of this policy is the renewable obligations or portfolio standards of North America which require utilities to source a percentage of energy through renewable sources through tradeable certificates.

4.3 Establish clear regulatory frameworks

Regulatory uncertainty is a key barrier to the development of CCTs. Much of the discussion has correctly been focussed on resolving uncertainty on CCS because this is the fundamental technology for clean coal. However, IGCC with CCS innovators also face uncertainty on how IGCC technology, which has traditionally been utilised in petro-chemical plants, will be permitted for power generation.

The efforts of the Queensland Government to develop a policy for CCS is gratefully acknowledged by ZeroGen. ZeroGen submits that regulators need to develop institutional capacity to understand the technology and ZeroGen has been working with agencies to facilitate this outcome. At this

29 Kuuskraa, Vello. 2006, A Program to Accelerate the Deployment of CO2 Capture and Storage: Rationale, Objectives, and Costs. Pew Centre on Global Climate Change, Arlington, Virginia.

stage of innovationb it also suggests that the knowledge gained from Stage One could be important for policy makers to understand and be better inform about the issues in setting policies going forward.

4.4 Increased collaboration between government and industry

Given the importance of information flows between various actors and institutions in the process of innovation ZeroGen recommends support for mechanisms that enhance collaboration. This could take the form of cooperative research centres and other institutions such as the Clean Coal Council in Queensland. These types of forums enable executives from the coal and power industry and government to share information and to set priorities for the RD&D, for example.

4.5 Enhancing international collaboration

Deep cuts to CO_2 emissions will require not only unilateral action by Australia but also the cooperation and support of other nations such as China and India. The opportunity exists through CCTs for these nations to maintain their economic development targets while at the same time reducing CO_2 emissions. The development of CCT in Australia through activities such as the ZeroGen program could facilitate technology transfer opportunities internationally. Institutions such as the Asia Pacific Partnership could be vital to the rapid and widespread deployment of CCTs at large-scale.

4.6 Addressing the skills shortage

ZeroGen, like many other energy and infrastructure projects, has been affected by the global skills shortage. The shortage of qualified professionals essential to planning, designing, constructing and operating large infrastructure projects in this tight marketplace is a challenge. In future, the demand for CCS and gasification experts, as an example, may delay the commercialisation of CCTs. ZeroGen submits that government support to enhance skills development will be vital.

4.7 Social acceptance (particularly of CCS)

Various national and international experts and leading agencies cite the social acceptance of CCTs, particularly CCS, as a key challenge to commercialisation. ZeroGen's early mover efforts to build social acceptance have been effective to date but is constrained by budget and geographic limitations. Government needs to play an active role in educating stakeholders about the merits, risks and benefits of the technologies. Government led education campaigns would also enable an "independent" flow of information that could have more legitimacy than project developers.

5.0 Conclusion

ZeroGen welcomes the initiative taken by the Commonwealth Government to undertake the Garnaut Review. To achieve the Government's emission reduction target of a 60% cut of 2000 levels by 2050 will require significant cooperation and will between government, industry and the community.

ZeroGen is undertaking an intensive programme sponsored by industry and government to accelerate the deployment of CCTs, specifically IGCC with CCS, in an Australian context. ZeroGen will achieve this through developing an 80MW IGCC with CCS demonstration plant with up to 75% carbon capture and partial sequestration. Concurrently, a 300MW low emissions coal-fired power plant that can capture up to 90% of CO_2 emissions will be developed.

ZeroGen submits that a portfolio approach must be undertaken to achieve this target. It supports renewable technology development and demand side management approaches such as efficiency measures. However, given that coal will remain a significant element of Australia's and indeed, the world's electricity generation mix, development of CCTs is vital. ZeroGen's development of IGCC with CCS gives key stakeholders (the Australian and Queensland Governments, the Australian coal industry and power generators) a key early mover advantage in the commercialisation of these technologies in an Australian context. ZeroGen is able to assist develop and expand the technical capacity and ability to support IGCC with CCS development, build social acceptance of CCTs, particularly CCS and critically de-risk the storage of CO_2 in low permeability deep underground reservoirs. IGCC technology is among the alternative types of clean coal power generation technologies the only one that facilitates the development of the hydrogen economy.

The ZeroGen Program can not only enable the Commonwealth Government to meet its emissions target through the widespread deployment of IGCC with CCS low emission coal power plants but it can also facilitate technology transfer to other high emitting nations such as China and India. The transfer of CCTs, specifically IGCC with CCS, can enable these nations to sustain their economic growth which is often underpinned by the burning of coal for power generation, whilst at the same time, reducing their emissions to atmosphere.

ZeroGen submits that there are a host of challenges and barriers to the commercialisation of low emission CCTs. Some of these are market failures in the traditional neo-classical economic sense but others are barriers to entry specific to the electricity generating sector. In Australia, the power generating sector is characterised by a small market, policies targeted at meeting social requirements that reduce the opportunities to increase prices, the high capital cost of generating technologies to produce a commodity which means product differentiation is extremely limited and a very limited presence of original equipment manufacturers.

Conceptually, market failures and barriers in the electricity generating sector include appropriability issues, coordination failures, the presence of spillovers, long development timelines, insufficient capacity of skilled workers, very weak market drivers in the absence of a CO_2 price signal and the potential for multiple political risks arising from stakeholder opposition. Individually, or in concert, these act as major disincentives for energy companies to invest in CCTs. This presents a challenge to policy makers who are seeking to facilitate the commercialisation of low emissions energy technologies to meet socially defined emissions targets (60% cuts of 2000 levels by 2050) against the "real politick" of historically low levels of innovation and indeed, innovation that is incremental. This approach is unlikely to facilitate the step change to low emissions generating technologies that can de-carbonise Australian society in the timeframe required.

ZeroGen submits that as an early mover technology developer it has generated significant and positive spillovers. These include social acceptance, support sector, knowledge, skills and regulatory reform externalities. At this stage of the development path for IGCC with CCS technologies in particular, the efforts of early movers such as ZeroGen generate significant benefits for later movers. Given this, and the fact that ZeroGen Stage One is the world's first integration of the technologies for a demonstration project, and indeed, the objective of demonstration projects is to generate knowledge to reduce commercialisation risks the value of the positive spillovers can be considered in two ways. The first is the value of the feasibility study $AUD125 million (if the project does not proceed to construction). The second is the value of the capital cost of Stage One ($AUD1.7 billion) if it does proceed to construction.

The role of an emissions trading scheme is welcomed by ZeroGen. The failure to assign a value on CO_2 is a major disincentive to low emission technology development. The Review's introduction of a scheme by 2010 will provide a major impetus to developing low emission energy technologies but it alone will not be enough.

New thinking on innovation suggests it is a non-linear, dynamic process involving a range of actors, institutions and networks. Accordingly, ZeroGen submits that the work of Professor Michael Porter at Harvard Business School could be informative in understanding the dynamics of the electricity generating sector and the issues associated with introducing low emission technology to be nationally and internationally competitive.

ZeroGen acknowledges the strong support provided by the Queensland Government and the Australian Coal industry through ACALET Ltd to support the development of CCTs. ZeroGen also acknowledges the challenges faced by the Review in allocating scarce resources across a wide spectrum of technologies. Some additional policies that could be deployed to facilitate the commercialisation of CCTs including IGCC with CCS include capital support to offset the high and upfront development costs, accelerated tax deductions and the application of mandatory feed-in tariffs, for example. ZeroGen Stage One's capital cost is $AUD1.7 billion for developing both IGCC with CCS low emission energy technology. To put this into context, the Pew Centre for Global Climate Change is calling for between $US8-10 billion to be invested in the United States of America only to develop just CCS technology.

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