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Informing proposed International UNFCCC Technology Mechanisms from the Ground up

Using biogas technology in South Africa as a case study to evaluate the usefulness of potential elements of an international technology agreement in the UNFCCC negotiations process.

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With thanks to

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I know the meaning of plagiarism and declare that all the work in this document, save for that which is properly acknowledged, is my own.

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Clarifications and Definitions

Below are clarifications of terminology and acronyms used regularly throughout this dissertation:

Low Carbon Technology: This term applies to technologies that use less carbon than traditional means of power generation - primarily renewable energy technologies. Sometimes the term Energy Saving Technologies (EST) is used. For the purpose of this study, nuclear power is not included in this category.

Technology Transfer: This thesis focuses on the implementation of an existing technology (biogas) and therefore the deployment, diffusion and implementation of technology are of particular interest when considering the technology transfer process. Definitions for technology transfer are discussed briefly in Section 2.1.2, but for the purpose of this study the definition from the IPCC has been applied:
"a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, nongovernmental organisations and research/education institutions".

Biogas Technology: Biogas is a gas composed principally of methane and carbon dioxide produced by the anaerobic digestion of organic waste from landfill sites or waste transfer stations, sewage sludge from sewage works, fermentation of animal slurries and waste from abattoirs, breweries and other agro-food industries (Global Bioenergy Partnership, 2009). There are various conversion technologies which can be used to turn biogas into useful gas or electricity. The scale of biogas units can range from providing cooking gas for 1 household or 10,000 households per year. For this study information was gathered relating to biogas from anaerobic digestion in the industrial, agricultural and domestic sectors.

Acronyms

AWG-LCA – Ad-Hoc Working Group on Long-term Cooperative Action under the Convention

BAP – Bali Action Plan

CDM – Clean Development Mechanism under the Kyoto Protocol

CO_2 – Carbon dioxide

CO_2eq – Carbon dioxide equivalent

COP – Conference of the Parties

DME – Department of Minerals and Energy, Republic of South Africa

DST – Department of Science and Technology, Republic of South Africa

EGTT – Expert Group on Technology Transfer

EST- Environmentally Sound Technology

GHG – Greenhouse Gas Emissions

GW - Gigawatt

GWP – Global Warming Potential

IEA – International Energy Agency

IPR – Intellectual Property Rights

MMTCO_2e - Million metric tonnes carbon dioxide equivalent

NGO's –Non Governmental Organisations

ppm – Parts per million

TNA – Technology Needs Assessment

UNFCCC – United Nations Framework on Climate Change Convention

Abstract

One approach to tackling the issue of the increasing contribution of developing countries to global emissions is through the large scale transfer of low carbon technologies. A draft technology transfer mechanism has been proposed under the UNFCCC (e,2009), but is not yet operational. This thesis uses biogas technology in South Africa as a case study to evaluate the usefulness of potential elements of an international technology agreement in the UNFCCC negotiations process to support national implementation of biogas in South Africa.

Biogas technology can contribute towards South Africas sustainable development goals. Based on estimated figures, the initial indications are that biogas could be a significant contributor to mitigation in the context of the Long Term Mitigation Scenarios analysis. Yet beyond minor activity, implementation of biogas technology has been limited.

Site visits to biogas sites in South Africa, Sweden, Germany and the UK provided practical insights into domestic, agricultural and industrial applications in rural and urban settings. These findings are used to generate a Strength Weaknesses Opportunities and Threats (SWOT) analysis for the biogas sector in South Africa. To synthesise the link between top-down technology transfer decisions and bottom-up implementation of biogas a set of issues which feature in technology transfer literature are identified and used to organise the analysis.

The empirical results from South Africa demonstrate that at a national level there is an apparent lack of information sharing and an enabling environment which lacks appropriate support for biogas. Furthermore innovation has varying interpretations at project level and intellectual property rights proved not to be a significant barrier. These findings should be taken into account when designing an international technology mechanism. The South African biogas sector would therefore benefit from an international mechanism that promotes information sharing networks, technology collaborations and appropriate financial incentives, and that also informs domestic enabling environment and skills training programmes.

The research findings suggest that although an international technology mechanism may not be best placed to ascertain the intricacies within individual technologies at a national level, it could be used to support national level technology transfer bodies which are able to take national and local needs into account.

Chapter 1: Background

1. Background

1.1. Context

The International Energy Agency (IEA) has estimated that the global share of CO_2 emissions of Asia (including China), Africa and Latin America has risen from 13.3% in 1973 to about 37.6% in 2007 (IEA, 2009). Transferring appropriate environmentally sound technologies (EST's) and ensuring their effective implementation can help arrest the sharp growth in greenhouse gas emissions from developing countries as their economies grow (Ramanathan, 2002).

The reality of the global impacts of climate change has led the international community to explore practical solutions to increase mitigation levels in order to stabilise greenhouse gas emissions at 450ppm[1]. This requires, amongst other things, innovative approaches to the large scale deployment and diffusion and transfer of low carbon technologies. Under the UN Framework Climate Change Convention and its Kyoto Protocol, the responsibility to speed up this process – particularly in developing countries-has been put on Annex 1[2] Parties and was re-iterated in 2007 in the Bali Action Plan (BAP). A conference in Delhi (October 2009) was held specifically around the technology transfer mechanism with regards to developing country needs. Leading up to the 15th Conference of the Parties (COP 15) in Copenhagen in December 2009 there was added pressure to come up with an international technology mechanism which would, as far as possible, cater for all Parties' needs and, more importantly, be mutually agreed upon. The outcome of the COP15 was draft decision CP.15 'Enhanced action on technology development' and transfer (UNFCCC(e), 2009), which is currently not legally binding, but discusses activities related to institutional arrangements, technology cooperation, capacity building and a technology mechanism. The key role that technology will play in meeting climate

[1] 450ppm of CO_2 equivalent gases which is required for keeping temperature rise below a 2 degree C, The IPCC's Fourth Assessment Report (2007),
[2] Annex 1 = Are those industrialised countries who have accepted emissions targets under the UNFCCC which includes the 24 original OECD members, the European Union, and 14 countries with economies in transition
(unfccc.int)

change targets and aspirations is clear but the exact mechanisms to ensure delivery are not (Bazillian and DeConinck, November 2008). The technologies should be relevant to the local needs of the developing country, and sufficient expertise should be made available in the local market to maintain the technology (Ramanathan, 2002). The technology-related UNFCCC processes are not that transparent to many in the energy sector (Bazillian and DeConinck, November 2008). Discussions with biogas stakeholders across academia, the private sector and the public sector have all led to the same conclusion that there is a gap in knowledge of international technology interventions and their own work on implementation.

1.2. Motivation for thesis: Why link international technology transfer and biogas in South Africa?

There is recognition in the literature that there is a gap between the high level discussions around technology transfer and the local implementation of low carbon technologies. Ockwell (2008) of the Sussex Energy Group believes that a key contributor to disagreements [on technology transfer] within international negotiations is the current lack of empirical evidence on how low carbon technology transfer might effectively be achieved and that empirical evidence on which to base policy design is lacking on many other aspects of technology transfer. Furthermore much of the work on technology transfer to date, such as the Intergovernmental Panel on Climate Change special report on technology transfer (IPCC, 2000), has focussed more at the theoretical level of technology transfer (Ockwell et al, 2008).

Bazilian et al (2008) re-iterate the value of having more country-led data and empirical project data as many climate models are currently based on assumptions about the technical status and potential scale and rate of deployment, costs and social acceptability. To date there is much literature about technology and investments but little about how technology can be embedded and enabled in the international climate regime.

International technology transfer discussions have intensified since the Bali Action Plan (UNFCCC(b), 2008) and again more recently leading up to the COP15 in Copenhagen in December 2009. Parties have submitted a variety of proposals to the UNFCCC for an international Technology Mechanism which covers issues such as financing packages, intellectual property rights (IPR) and institutional frameworks to enhance the diffusion and deployment of low carbon technologies (see section 3.1.3). Meanwhile, the local facilitation of on the ground implementation of individual technologies is happening at the other end of the spectrum by nongovernmental organisations (NGOs), private or public sector institutions.

Regardless of the final format of any international technology agreement under the UNFCCC, it is likely to stipulate the institutional, financial and organisational arrangements of the mechanism. In the recent conference on technology transfer in New Delhi (2009) the chair concluded by saying "we need to move towards specificity in the global mechanisms for technology development, deployment, and transfer. What I have said up to now is of the nature of a bottom up approach, and this needs to be combined with a top-down approach" (Chairs Summary High-level Conference on Climate Change: Technology Development and Transfer, 2009). International support is able to support the domestic policies and regulatory support required to encourage growing use of low carbon technology at national level by providing resources and creating confidence to encourage domestic and international investment (Cust et al., 2008); however how this interface between international and national support will actually translate into practical implementation of technologies on the ground is still unclear.

In order to gain some insight from the bottom up approach and gain some empirical data, one technology in one country has been selected – biogas technology in South Africa. Biogas technology is considered by many experts to be an excellent tool for improving energy access, livelihoods, and health in the developing world and also offering climate change benefits. Biogas generated from the decomposition of organic waste and used as an energy source has been proven to be technically and financially viable in other parts of both the developed and developing world. It is a technology that can be installed at a small scale in remote rural settings or as a larger scale technology in an urban setting. The useful output from Biogas digesters includes energy (electricity and/or heat) and a high quality fertiliser. Furthermore the process reduces the amount of waste sent to landfill, transport emissions and methane emissions. Beyond the environmental benefits, there is also potential for improved social conditions offering a cleaner supply of household energy and energy independence, potential job creation (YES, 2002), and increased agricultural yield from the high quality fertiliser. Worldwide, about 16 million households use small-scale biogas digesters (Brown, 2006) for heating or lighting their homes. South Africa holds immense potential for prospective projects as biogas production from South Africa's agricultural and industrial sectors, is currently largely unharnessed (Talbot, 2010). Biogas technology also has the potential to contribute towards South Africa's sustainable development agenda as it has environmental, social and economic benefits.

Biogas technology has been a standard technology for years in places like Denmark, Mexico and India. Yet in South Africa, despite the country having strong agricultural and industrial sectors, as well as the construction capacity and the energy demand to make biogas technology an obvious selection, biogas has not yet become a prominent technology. For this reason biogas is an interesting case study to explore technology transfer of a relatively mature technology and identify interventions to increase its diffusion across South Africa.

Due to the complexity of the technology transfer debate, it is inevitable that there have been many reports generated addressing the 'barriers' to technology implementation, such as institutional inconsistency, and lack of financing, patenting laws and knowledge to name but a few. This thesis aims to explore some of these barriers and to gather some empirical evidence of practical obstacles to technology implementation in South Africa by focusing on one technology – biogas from organic waste. Furthermore it aims to understand to what extent the perceived technology transfer barriers presented in literature apply to local contexts.

In order to ascertain this link between perceived barriers and practical case studies, the following research approach has been taken.

1.3. Research approach and conceptual framework

The research approach needs to accommodate literature reviews and stakeholder engagement at national and international levels and ultimately demonstrate a synthesis between two different ideas: top down international technology transfer and bottom up implementation of biogas in South Africa. Rather than being restricted by a prescribed research methodology a tailored approach was developed, the process of which is discussed in section (1.3.2) and is described in greater detail in the contextual framework (Section 1.3.3) and the research activities (section 1.3.4).

1.3.1. Research question

This thesis will use biogas technology in South Africa to explore whether practical insight into the implementation of low carbon technologies in developing countries can be used to inform the proposed technology mechanisms under the UNFCCC.

The question guiding this piece of research is: "How can empirical information from practical implementation of low carbon technologies in developing countries be used to inform an international technology mechanism?"

1.3.2. Research background and activities

There are two tracks that the research approach must cover-firstly an understanding of the high level discussions on technology transfer under the international climate change negotiations and secondly an insight into the current status of biogas technology in South Africa and what is required for its large scale diffusion to contribute to South Africa's energy supply and low emissions development path.

The first part relating to information gathering around technology transfer under the international climate change negotiations, can be achieved through a literature review and a desktop study of publicly available information. Attendance at the COP14 and COP15 events as an observer in Poznan and Copenhagen respectively, provided essential insight into the UNFCCC negotiation process.

There is also a need to learn from past experiences in order to adapt biogas technology from Europe and Asia for local [African] circumstances through research (Mshandetel and Parawira, 2009). Furthermore, even though biogas is not a well established technology in South Africa, it is important to look at the limited installations that exist in order to identify the key players and policies and obtain practical insight.

The data is primarily qualitative data from feedback and opinions gathered during site visits and extensive phone or email liaison with stakeholders. The aim is to present the findings in a concise manner and in such a way that they can be used for further decision-making. As this study focuses only on one technology in one country, it is helpful to align the results in a way that they could be compared to other technologies and countries.

A Strengths Weaknesses Opportunities and Threats (SWOT) analysis has proved to be an effective tool for identifying current problems and to sketch future action lines (Terrados, 2007). The SWOT analysis has been a popular method for identifying suitable renewable energy technologies and renewable energy strategies as it provides a good basis for objectives and strategies and encourages the discussion and criteria amongst stakeholders. A SWOT analysis will be prepared for the generic application of biogas technology in South Africa.

The individual research activities (shown in Figure 1) can be summarised as follows;

- A **review** of existing climate change technology transfer literature in order to extract the main topics that can be applied to biogas in South Africa
- A **review** of the latest UNFCCC position on technology transfer and country submissions and other existing international technology interventions.
- An **investigation of** South African technology transfer activities
- An **exploration** the benefits of biogas technology through international case studies
- An **investigation into** the status of biogas in South Africa: installed units, policy review and identify key players
- **Site visits** and **stakeholder discussions** to understand the intricacies within one technology in one country
- A **SWOT** analysis for biogas technology in South Africa
- The **application of** technology transfer issues (identified in 2.1) to guide the information relating to biogas and the **synthesis of** the main findings on how practical insights could inform international mechanism
- Use findings to **inform activities** in an international mechanism which would support the transfer of biogas technology into and within South Africa.

1.3.3. Conceptual framework: Overview of thesis structure

This **first chapter** introduces international technology transfer and the concept of biogas and its applicability in South Africa. A brief research motivation for linking these two themes aims to justify the stimulus for the overarching research question.

The international debate around the technology transfer process has to an extent been consolidated into a generic set of terms such as 'enabling environment' or 'intellectual property rights' in an attempt to capture the main issues and formulate an international agreement which can be applied broadly to any stage of the technology transfer process. **Chapter two** provides a literature review of the broad technology transfer debate and extracts the main topics (see section 2.1) that are appropriate for, and can be applied to, an assessment of biogas technology in South Africa. Identifying particular topics gears the focus throughout the research and provides a framework for how the information gathered from practical case studies responds to, and could eventually feed-into, the international mechanism.

Chapter three outlines a brief history of technology transfer under the international UNFCCC climate change negotiations and goes on to explore a cross-section of international technology interventions outside of the UNFCCC framework. The history around technology within the UN process is lengthy and complex and therefore only recent activities related to the development of an international technology transfer agreement are touched upon. As a specific international agreement on enhanced technology transfer is not yet operational under the UNFCCC process, a review of existing international technology interventions outside of this process provides an insight into the participation in, and implementation of, active interventions. A selection of initiatives are presented: those that focus primarily on low carbon technologies; those that specifically promote bioenergy (bioenergy incorporates biogas) and those based on building information sharing networks and research collaborations. Measuring the success of their work is a complex matter in its own right a proper consideration of which is outside the scope of this paper. However,

a look at existing interventions assists in understanding what format and activities within an international technology transfer mechanism would be most useful to incorporate in a UNFCCC mechanism to increase the uptake of biogas in South Africa.
An important aspect of this thesis is to appreciate how domestic technology needs or activities would relate to an international agreement – i.e. how an international technology transfer mechanism, should it be agreed upon, would play out at a domestic level in South Africa and vice versa. Therefore Chapter three concludes with a brief review of the technology and innovation environment in South Africa and the technology initiatives that have emerged at a domestic level in response to international programmes.

The concept and benefits behind biogas technology are presented in **Chapter four** alongside international case studies of biogas programmes. International case studies from developed and developing countries provide insight into successful and less successful biogas projects and generate useful lessons to consider for increasing the uptake of biogas technology in South Africa.

Chapter five presents empirical information on the status of biogas technology in South Africa. This chapter is split into two parts. The first considers South Africa's overall biogas portfolio in terms of policy and institutional support, installed biogas units and key players. This is necessary to not only determine the technological maturity of biogas in South Africa but also to identify where barriers to the transfer of biogas technology lie, and how they could eventually be addressed. The second part of the chapter focuses on stakeholder engagement and site visits. These are vital to establish the practical barriers to implementation in the South African biogas sector. A cross section of international and national biogas case studies across the agricultural, industrial and domestic sectors will be used in order to emphasise the intricacies *within* one technology, moving beyond a simple one country, one technology analysis. The results from the multiple stakeholder engagement have been used to populate a SWOT analysis. This information is analysed against technology transfer issues identified in Chapter two in order to understand the degree of significance and relevance of those issues identified in literature to the case study of biogas in South Africa.

Chapter six analyses the main findings and aims to synthesise the two themes of international technology transfer and biogas in South Africa by demonstrating how using practical information from one technology in one country, guided by technology transfer principals, assists in informing decision makers from the ground up. Furthermore this final chapter summarises how these practical findings can be used to inform knowledge of which aspects of the proposed international technology mechanisms are the most effective in increasing implementation of biogas technology in South Africa.

The following Figure 1 presents the conceptual framework and research process in a graphical form. It aims purely to help the reader understand the flow of this thesis and acknowledges that the suggested flow of activities, from the international to the local level, are hypothetical. However they are geared to provide context for the research activities throughout the chapters.

Figure 1 Conceptual framework for thesis structure

Conceptual Framework

Overarching Theme:
Technology Transfer of low carbon technologies

↓

Proposed International Framework:
UNFCCC Technology Transfer Mechanism

↓

National Implementation;
National body implementing international mechanism activities

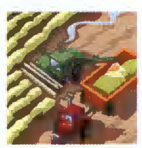
↓

Technology Task Forces:
Identifying potential barriers and implementation activities within technology sectors

e.g: Biogas | Wind | Solar | Hydro

Industrial | Agricultural | Domestic

Biogas Case Studies

This feedback of practical insight is crucial for a national or international mechanism to understand what interventions are required on the ground

Research Activities	Chapter Reference
Review existing technology transfer literature and extract the main topics that can steer analysis of biogas in South Africa	2
Review latest UNFCCC position on technology transfer and country submissions, latest CP15 draft and CA	3
Consider other existing international technology interventions	
Investigate South African technology transfer activities	
Explore the benefits of biogas technology through international case studies	4
Investigate South African biogas status: installed units, policy review, identify key players	5
Site visits and stakeholder discussions to understand the intricacies within one technology in one country	
Prepare SWOT analysis for biogas in South Africa	
Present findings on South African biogas in relation to technology transfer topics identified in 2.1	
Synthesize main findings on how practical insights could inform international mechanism	6

This first chapter has briefly introduced the two themes of technology transfer in the climate change debate and biogas in South Africa and set out the research approach and conceptual framework for how this thesis will tackle the research question outlined in section 1.2.1.

The next chapter introduces the key themes in the international climate change technology transfer debate and identifies those issues that can be applied to guide the biogas data presented in chapters 4 and 5.

Chapter 2: Technology Transfer in the Context of Climate Change

2. Technology Transfer in the Context of Climate Change

The aim of this chapter is to introduce the different aspects that are believed to contribute to the technology transfer process in the context of climate change as these will be drawn on throughout the thesis, with particular reference to biogas technology in South Africa.

There is definitional complexity around the term 'technology transfer' as well the components believed to contribute to successful technology transfer, such as 'enabling environment' or 'absorptive capacity'. This chapter does not seek to clarify these complexities. Rather it seeks to firstly identify and explore the components relevant to biogas technology in South Africa and secondly to understand what those components entail in the context of this thesis. This provides a focus for gathering the empirical data and forms the basis for an analysis of the practical barriers to biogas technology in South Africa later in the thesis.

This chapter aims to provide a framework for assessing information gathered from biogas site visits and stakeholder feedback in relation to technology transfer (see chapter 5). The following issues that reoccur across the literature on international low carbon technology transfer have been selected for discussion in the remainder of this chapter:

- Defining and disaggregating technology transfer
- Enabling Environments
- Technical and Absorptive capacity
- Innovation
- Intellectual Property Rights (IPR)
- Nationally appropriate technologies and country led approaches
- Financing

The above themes will be introduced in this chapter and discussed with more relevance to the South African context in Chapter 3. These themes also form the basis for the analysis in Chapter 5, with particular focus on: enabling environment; technical and absorptive capacity; innovation and intellectual property rights. Although these themes are very closely linked in literature, for the purpose of this thesis they have been discussed individually.

2.1. Introducing technology transfer: The main issues and debates

The topic of international technology transfer has generated research material for over 25 years (Reddy and Zhao, 1989). Specific references to technology transfer in relation to the international climate change negotiations were first made in the original United Nations Framework on Climate Change Convention document in 1992 (UN, 2002).

Beyond contributing to global emission targets, the transfer of low carbon technologies to developing countries also has many developmental benefits such as contributing towards economic growth and job creation. Meeting the climate and developmental challenges simultaneously will require a significant shift in the technological trajectory of developing countries (statement by Ambuj Sagar of the Indian Institute of Technology Delhi, in Padma, 2009). The economic and social benefits of investing in climate change technologies such as reduced costs of mitigation and adaptation, reduced pollution and health costs, greater productivity, energy security, economic development and job opportunities are likely to be greater than the cost of making those technology investments (UNFCCC(g), 2009).

The traditional assumption that technology transfer flows from North to South and that developing countries are dependent on developed countries' technological innovations is also broadening; it was the Bali Action Plan of 2007 which under the UNFCCC process shifted the mindset from the conventional North-South technology transfer towards international technology cooperation (Bazilian, 2009) and South-South transfer. Ockwell et al (2008) further distinguish between vertical technology transfer – along the technology cycle from R&D to commercialisation, and horizontal technology transfer – from one geographical location to another. The relevance of these concepts will vary depending on the maturity of the technology.

Technology is a cross cutting theme across mitigation, adaptation and financing issues. The 2007 IPCC report acknowledged that although technologies have significantly contributed to GHG emissions it is technology and technological change that offer the main possibilities for reducing future emissions and achieving the eventual stabilisation of atmospheric concentrations of GHGs to 450ppmv CO_2 equivalent (Fisher, et al., 2007). Yet the slow pace in climate policy and the steady increase in global emissions make it an enormous challenge to reach the relatively low global emission levels needed to meet 450 ppm CO2-eq in 2020 (Elzen M, 2008).

The volume and disciplinary diversity of literature across science, engineering, economics that is potentially relevant to understanding technology and climate changes is vast and often not in a format accessible and usable for researchers and practitioners investigating a particular country (Martinot, Sinton, and Haddad, 1997).

The technology transfer definition adopted for the purpose of this thesis has been given in the introduction (see clarifications and abbreviations) however the following section introduces some of the other definitions from literature.

2.1.1. Defining and disaggregating 'Technology Transfer

There have been various approaches to defining 'technology transfer', which in itself is a reflection of the complexity of the issue. None are necessarily right or wrong; in fact there is a consensus amongst the literature that the technology transfer process incorporates physical objects, tacit knowledge and the capacity to implement.

The International Energy Agency (2001) suggests technology transfer involves not only the supply and shipment of hardware but also the complex process of sharing knowledge and adapting technology to meet local conditions. It strengthens human and technological capacity in developing countries. A report by the IPCC (2000) defined technology transfer as: a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, NGOs and research/education institutions. This report observes that transfer encompasses the process of learning to understand, utilise and replicate the technology, including the capacity to choose it and adapt it to local conditions.

Karani (2001) proposes that the transfer of technology integrates skills from human beings, know-how, physical objects and techniques. In this regard it should cover the entire technology innovation cycle from research and development (R&D), demonstration, deployment and diffusion whilst also addressing human resources, capacity building, improving enabling environments and accessing adequate financing.

Bazilian et al (2008) discuss the various definitions of technology transfer and draw on the International Institute for Applied Systems Analysis (IIASA, 2006) definition where technology transfer is broken down into:

- Hardware: Manufactured objects;
- Software: Knowledge required to design, manufacture, and use technology hardware and
- Orgware: institutional settings and rules for the generation of technological knowledge and for the use of technologies.

The flow of hardware is effectively the transfer of 'kit' or equipment, such as a photovoltaic panel or solar hot water collector tubes. Transferring the hardware is usually the most straightforward aspect of technology transfer in terms of generating financial and technical models. Many of the outputs from this modelling are difficult to translate into orgware or software dimensions (Bazilian et al., 2008). What becomes even more complex is ensuring successful implementation of the 'software' and knowledge in order to maintain and benefit from the technology.

Exploring the concept that technology transfer covers every relevant flow of hardware, software, information and knowledge between and within countries, from developed to developing countries, there are many levels of intervention. Technology transfer interventions can occur at different levels through for example the sale of technology by private entities, government programmes, non-profit arrangements, or other means. Thorne (2008) outlines the five basic stages of technology transfer to be:

assessment; agreement; implementation; evaluation; adjustment. He goes on to recommend some of the interventions required for technology transfer such as; turnkey factories, license agreements with technical assistance, joint ventures, training, transfer of patent rights, commercial literature, published trade and scientific literature and international co-operative research efforts.

The purpose of briefly disaggregating the technology transfer concept was to demonstrate the main components behind the technology transfer term.

To summarise the main components of technology transfer: Firstly, that the process applies to the entire technology cycle from R&D, through demonstration, commercialisation and eventually down to the end user uptake and therefore different interventions may be required to address these stages depending on the maturity of the technology. Secondly it goes beyond simply a transfer of equipment or new technology, but requires sharing of knowledge as well as sensitivity towards local needs and capacity. Thirdly that technology transfer is shifting from purely a north-south action, the importance of South-South transfer, and ultimately technology collaborations, being acknowledged. Finally the traditional notion of technology transfer being motivated by developed countries needs to meet their mitigation targets is shifting as there is recognition of the potential contribution of technology transfer to the economic and development goals of developing countries.

The remainder of this chapter discusses concepts identified in section 2.1 that are deemed necessary for technology transfer to occur. This chapter primarily introduces the main aspects of these concepts where their relevance to biogas technology in South Africa is addressed in Chapters 3, 5 and 6.

2.1.2. Establishing enabling environments

Definitions for the term 'enabling environment' are numerous, and range from all-encompassing to narrow (Brinkerhoff, 2004). In literature the term 'enabling environment' is often closely linked with absorptive and technical capacity. It is recognised that a successful enabling environment works together with technical and human capacity (Bazilian, et al., November 2008) where national enabling environments can facilitate absorptive and technical capacity through training programmes and human capacity development, and vice versa absorptive capacity contributes to the enabling environment. However in this thesis 'technical and absorptive capacity' are referring to a more local level receptivity and social acceptance of biogas technology where 'enabling environment' focuses rather on national government level actions which create an environment conducive to private and public sector technology transfer (UNFCCC(h), 2010); such as national institutions for innovation and IPR, national legal institutions that introduce best practice standards and codes, and financial incentives such as a feed-in tariff. The following section focuses on the enabling environment where the technical and absorptive capacity will be dealt with in the subsequent section 2.1.3.

Governments have a role to play in improving the enabling environments for new technologies by removing technical, legal and administrative barriers to technology transfer, implementing sound economic policy, regulatory frameworks and transparency, which create an environment conducive to private and public sector technology transfer (UNFCCC(h), 2010). For technological change to be effectively captured and managed in a way that is consistent with tackling climate change, the role of governments must be to create conducive institutional contexts (enabling environments). This will require setting and enforcing appropriate policies and regulations at the national level, and, through the UNFCCC and other international bodies (e.g. WTO) establishing a conducive institutional context at the international level' (Bazilian, et al., November 2008). The process of strengthening enabling environments is inherently tied to economic development, and basic issues of governance facing developing countries (Bazilian, November 2008). Due to the current market-based economy, it is usually left up to the market to decide the most efficient technology to reach the required emission targets (Bazilian, et al., November 2008). Although the private sector should provide the bulk of technology-related investment, significant public financing will also be required (Tomlinson et al, 2008).

Bazilian (2008) believes that in regards to a UNFCCC technology framework, the provision of an appropriate enabling environment is perhaps the most cost-effective intervention that can be made under the UNFCCC. It is one where the need for public sector intervention is clear.

Lack of appropriate enabling policies and institutional support were two barriers to technology transfer experienced under the Montreal Protocol (Andersen and Sarma, 2008).

There are different interpretations to what constitutes an enabling environment with regards to technology transfer. In the UNFCCC process the term generally refers to the appropriate conditions for the uptake and deployment of low carbon technologies such as policy, market and regulatory conditions as well as people and institutions (UNFCCC(h), 2010). Activities that have been proposed to contribute towards a suitable enabling environment for host countries include vocational training of technical staff, improving relationships between research centres and consultancy firms and encouraging joint efforts between enterprises and Governments. Bazilian et al (2008) propose an enabling environment for successful transfer of technologies should include national institutions for technology innovation, national legal institutions that introduce codes and standards, risk reduction and intellectual property right protection. Setting up national institutions for technology innovation or technology transfer offices may not alone be sufficient to create broad technology transfer.

The importance of a suitable enabling environment towards successful transfer and deployment of a technoloy has been recognised in literature and learnt from experiences with the Montreal Protocol. Strengthening an enabling environment requires capacity building to identify needs and learn to implement technologies, as well as institutional support for technology innovation.

Chapter 3 explores South Africa's innovation instititutions, while Chapter 5 considers the enabling environment specific to the biogas sector.

Following on from the idea that a sound enabling environment is influential in a country's human absorptive and technical capacity, it must also be recognised that a good enabling environment alone is not sufficient to ensure technology transfer. The following section explores some of the issues around technical and absorptive capacity at a more local level.

2.1.3. The need for technical and absorptive capacity

Beyond support from a national enabling environment, increasing the uptake of low carbon technologies, the ability to absorb and adapt technologies at a local level is also required. It is recognised that a technology mechanism cannot encompass all aspects of technology for mitigation and adaptation and that an approach based on adaptive learning and adjustment is more pragmatic (Bazilian, et al., 2008). The importance of technical and absorptive capacity in the technology transfer process will vary for different applications of technology. For example Neuhoff (2009) suggests that as biogas is a technology is not a particularly complex technology, its successful uptake relies primarily on strong absorptive capacity.

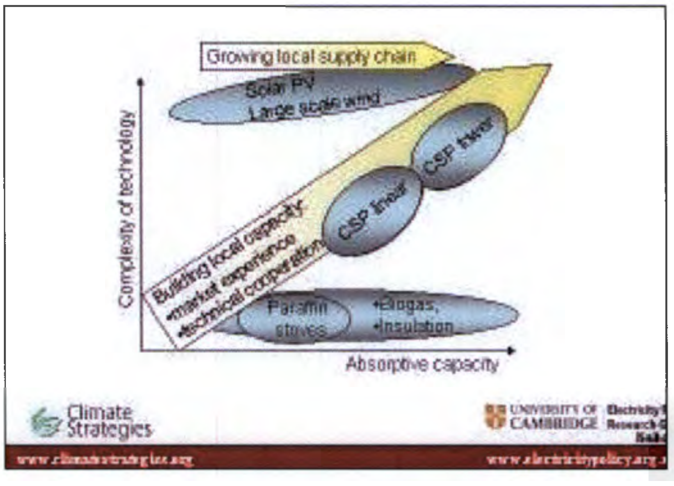


Figure 2 Absorptive capacity required for biogas, (Neuhoff, 2009)

The adoption of a technology comes about by a decision making process which starts with knowledge and moves through persuasion, implementation, and confirmation (Mallett, 2007). Social acceptance and technology cooperation are key to the successful adoption and integration of a technology (Mallett, 2007); whether it is a new or existing technology on a national or international level, any technology must be introduced appropriately at a local level. Although there is agreement on the importance of the social acceptance of technologies to increase their adoption, there has been little discussion of social acceptance in technology transfer debates (Mallett, 2007).

The technology gap between developed and developing countries remains wide. In order to increase technology transfer, Thorne (2008) believes developing countries require assistance with developing human capacity (knowledge, techniques and management skills), developing appropriate institutions and networks, and with acquiring and adapting specific hardware. Furthermore, for assessing, adopting, managing and applying technologies, the required capacity building can be achieved through human resource development, strengthening institutional capacities for R&D and programme implementation, assessment of technology needs and long term technological partnerships between holders of technologies and potential local users (UNCTAD, 2001). Training and education is the key as it is required at all levels of technology transfer from research and development to manufacturing. This may be through formal education of vocational college degrees or at an informal level, i.e. the training of artisans to manufacture the required components. These skills will be required in the manufacturing as well as operation and maintenance strategies for any energy technology. Skill development can best be learnt in practice therefore having the relevant research or manufacturing facilities provides opportunities on-the-job training. The ability to construct and repair a biogas digester provides a long term skill such as welding or plumbing, which are can be applied in other areas of work (YES, 2002).

It is likely that most projects in developing countries will require subsidies or cash injections initially, but financial self sufficiency is the ultimate aim, therefore introducing sound financial skills are essential. Suitable retailing and distribution networks as well as a feedstock of replacement parts are also essential in the ultimate transfer of an energy technology.

It is important to consider social acceptance as well as develop human capacity to ensure the absorptive capacity for a technology at a local level. Demonstration projects, educating relevant stakeholders and training would contribute to this. Suitable technical and financial training are also important for absorptive and technical capacity for a transferred technology to be sustained in terms of operation, maintenance and financial sustainability.

2.1.4. The role of innovation

Technology innovation that is shaped by local needs and rooted in local context is needed to meet developmental *and* climate challenges (Sagar 2009).

Innovation is key at all stages of a technology's lifecycle in order to speed up rapid diffusion of low carbon technologies. This may be technological innovation for new cutting edge technologies, innovative support mechanisms for the diffusion of existing technologies or innovative approaches to financing technology deployment programmes. The already large range of low carbon technologies that exist to address energy security and emissions reduction require different levels of innovative thinking and interventions. This also calls on institutional innovation either within existing institutions or the formation of new institutions specifically focusing on low carbon technology innovation.

A 2008 World Bank report highlighted that innovation and invention of technologies remains almost exclusively in high income countries. Although research and development predominantly occurs in high income countries this is slowly changing with emerging economies such as India and China challenging the notion of technology transfer as a north-south paradigm; the New Energy Finance 2007 data shows that India and China are now key players in many of the renewable energy markets (Bazilian, et al., 2008). By incorporating more R&D facilities in developing countries there is greater potential for innovation and ownership. This in turn enables specialisation and knowledge in more than one particular energy technology, and encourages a choice and flexibility to develop the most suitable technologies for certain areas.

The idea of a country's capacity to innovate has been explored by the Energy Policy Centre at the University of Cambridge and Climate Strategies. Depending on the stage of a technology's innovation cycle, different barriers arise and remedies must be specifically tailored to these barriers.

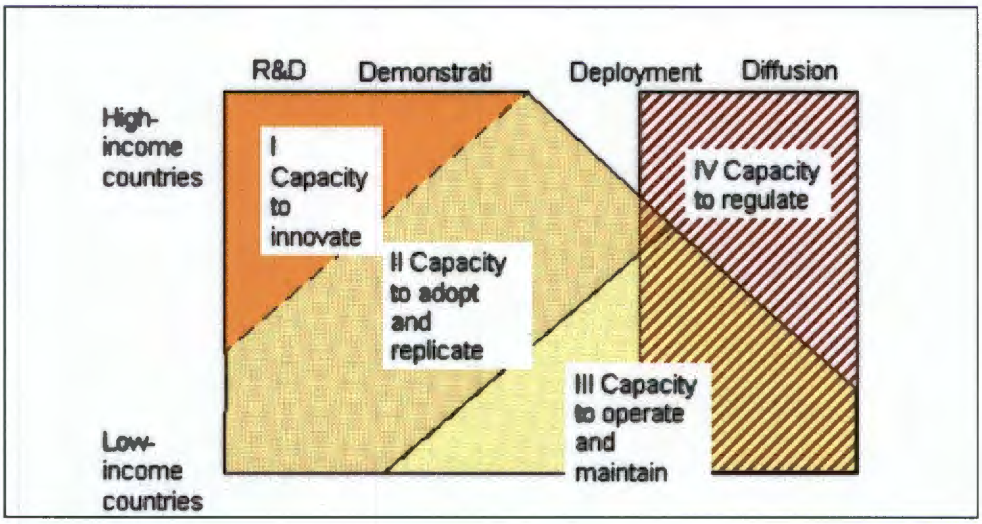


Figure 3 Innovation capacity (Neuhoff, 2009)

The above figure suggests that whereas middle income countries may have the capacity to regulate or operate and maintain existing technologies and lower income countries the capacity to adopt and replicate them, higher income countries will have larger budgets for R&D and be able to carry the risk if a technology falls into the 'valley of death' – the stage between demonstration and pre-commercial financing where many technologies go underfunded and never reach the market (see below diagramme):

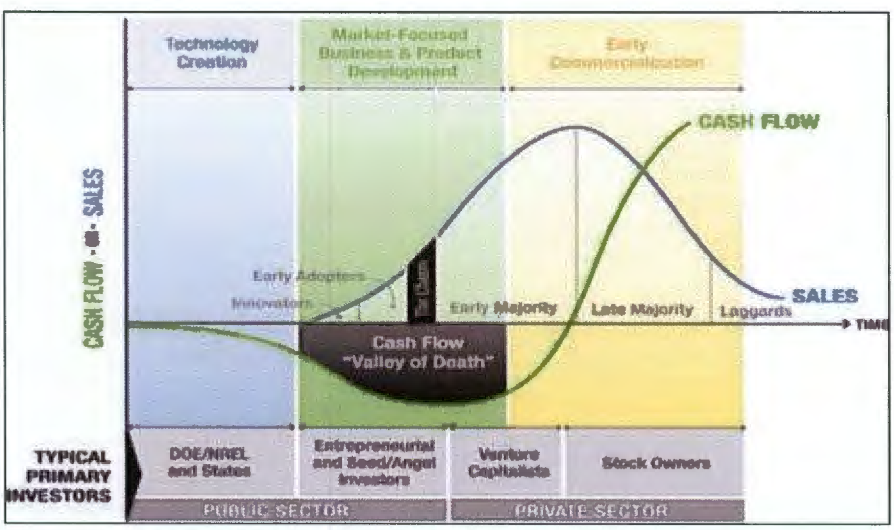


Figure 4 Technology valley of death, (Source: EERE)

A country's capacity to innovate is often measured by the number of patents filed to the World Intellectual Property Organisation. But in terms of demonstrating a country's innovative capacity, this data may favour countries with good understanding of patenting laws and who patent large-scale technologies such as clean coal technologies. However, smaller technologies that may be more relevant in developing countries are less likely to have patents filed.
It may be the case that less developed countries have less capacity to innovate as they simply do not have the funding or markets to support early stage R&D activities.

Bazilian et al (2008) draw attention to the fact that innovation is no longer simply a linear process but rather a complex and unpredictable one where policy and finance institutions interact with technology developers and where R&D continues to evolve even for the more mature technologies where incremental improvements are still valuable. In order to design incentives for deploying technologies it is critical to understand the different stages of the innovation cycle for specific countries and technologies. To accommodate this variability new innovative technology cooperation mechanisms will be required to both deploy existing technologies in emerging economies and develop and share new low carbon technologies (Bazilian et al, 2008). Sagar (2009) calls for cooperative innovation programmes that are informed and driven by technology needs of developing countries rather than the technology agenda of industrialized countries.

Bergek et al (2008) propose that technological innovation systems require fulfilment of different functions such as development and diffusion of scientific, technological, production, market and logistics knowledge. The Carbon Trust in the UK has been promoting the idea of low carbon innovation centres focused on accelerating innovation and removing barriers to low carbon developments. The Climate Technology Programme, a joint initiative between infoDev[3] and DFID[4], builds on the Carbon Trust's work and aims to accelerate the development and commercialisation of low carbon technologies. Pilot programmes in India and Kenya are underway.

[3] infoDev – a global grant programme funded by the World Bank, www.infodev.org/
[4] DFID- UK department for international development

Innovation systems for different technologies will ultimately look very different within the same country or region. Thus there is a need for technological as well as geographical differentiation when designing policies to stimulate technological innovation (Bazilian, et al., 2008). In order to understand the role of innovation in South Africa it will be necessary to look at the institutional support of innovation and also to consider South Africa's capacity to innovate. This will be further considered in chapter 3.

2.1.5. The contention around Intellectual Property Rights

Intellectual Property Rights (IPRs) have become a main discussion point in the climate change technology debate. There appears to be a split in opinions as to whether IPR is a barrier or an opportunity – if either. The intricacies of IPR law are far too complex to discuss at length within this thesis.

In short IPRs can be seen as management of intellectual assets in the forms of licenses, patents, copyrights, trademarks etc., where licenses and patents are potentially the most relevant to technology transfer issues. Ramprecht (2009) describes intellectual property as an 'intangible asset' where without IPRs an idea effectively does not exist. As stated in the UK Climate Group's report: without IPRs there is no choice: there is nothing to give, nor can you transfer (or sell/license) rights so that others can invest in its further development. The benefit of patenting is that once a patent is filed, the information becomes publicly available. If you patent early, then you have to make information publicly available. If you do not, someone else may develop it further and block you from using it at a later stage or charge you a lot of money - i.e. there is an incentive to patent (UK Climate Group, 2009).

Yet, in the technology transfer debate, IPRs are also often regarded as a 'barrier' to technology transfer and deployment and not presented as a tool for establishing constructive IPR agreements where in fact the creation and ownership of IPRs are quite separate from the decision of how those IPRs are to be used. Developed countries may be deterred if there are weak IPR laws in the recipient country that they are transferring a technology to. Conversely if patents are highly priced, access to protected technologies may be unaffordable to many developing countries (Correa, 2009).

Tomlinson et al (2008) propose a 'protect and share' framework which would provide financing for developing countries to strengthen their domestic IPR protection systems in return for government-to-government guarantees that investors' rights will be protected. An agreement of this type should provide templates to help structure public–private joint ventures to ensure that public returns are generated for public investment. An Eco-Patent Pool has been introduced by the World Business Council on Sustainable Development. This builds on the Open Software scheme with a structure where companies join by placing at least one patent into the commons database, which they continue to maintain, paying fees on the patent as necessary. Eco-Patent Commons is non-profit and voluntary (Srinivas, 2008).

There was no evidence in empirical data or published literature of examples of technology projects that were prevented due to financial or other constraints related to IPRs and its associated issues. This is not to say that it has not been an issue however there is not enough literature to conclude that IPR currently poses a significant barrier to the transfer of climate change technologies (Bazilian, et. al, 2008). One of the main findings from Gerstetter and Marcellino's (Gerstetter et al., 2009) review of the proposed UNFCCC technology mechanisms is that intellectual property is not currently a barrier to North-South technology transfer and should not be treated as a major concern in the negotiations.

To date, the evidence related to IPR does not seem to match the prominence this issue has received in the negotiations, but rather focus on building up capacity like R&D, innovation centres in developing countries and creation of enabling environments. (Gerstetter et al, 2009). A report by the UK Climate Group (2009) highlights that any theoretical "IP constraints" are very minor when compared with the failure to address the carbon pricing externalities. During the passing of the Bayh-Dole IP Act in the US little evidence was summoned to show that difficulties in patenting and licensing were hindering U.S. university-to-industry technology transfer (Mowery et al. 2004), and no such evidence has been produced since (Sampat, 2009). Also IPRs are the least frequently referred to barrier in developing countries Technology Needs Assessments [5] (Bazilian, et al., 2008).

[5] Technology Needs Assessments are assessments of country-specific technology needs, which developing countries are encouraged to report to the UNFCCC

Introducing good IPR practice in a country enables good management of intellectual assets and can be tailored advantageously. To support good IPR practice, South Africa introduced an IP Bill (RSA(b)) in 2008. The bill aims to stimulate technology innovation and diffusion in South Africa, particularly from research to industry. This bill is similar to the US Bayh-Dole bill which specifically focuses on taking the results of publicly or government-funded research through to commercialisation. India has also recently passed a similar bill where the motivation is also to encourage the commercialisation of research.

This was only a brief introduction to the volumes of literature and debates that exist around IPR. There is an evident split in opinion as to whether IPR is an opportunity or a threat to technology transfer, and if so how to deal with it. The latest draft text on enhancing technology transfer under the UNFCCC also demonstrates a lack of clarity on how, if it all, to deal with IPR under an international mechanism. Chapter 3 of this thesis looks at IPR in the context of South Africa and Chapter 5 considers whether IPR is an important consideration for biogas technology in South Africa.

2.1.6. The relevance of nationally appropriate technologies and stakeholder engagement

There is much discussion around the format of an international technology mechanism, one being country-led approaches which focus on technology needs at a national level. Bazilian et al (2008) support the idea that the approaches to technology need to be differentiated on a national and regional basis and that technology deployment will require different approaches linked to specific national and regional circumstances, as well as stage of technology developments. Any enhanced treatment of technology in the UNFCCC needs to be closely aligned not only with sources of funding but as well with the needs of recipients and specific technology focused financial tools. Bazilian et al (2008) suggest a technology framework that can be applied at national and regional levels and includes (amongst other things) alignment of sources of financing with technology and country needs, which is demand driven, recognises the national enabling environment, and can be easy to implement, monitor and verify.

Ramanathan also raises the importance of identifying key stakeholders in the decision making process and chooses government, entrepreneurs; end users and experts as key decision makers in the technology transfer process. Governments of the recipient country are an important stakeholder as they are responsible for influencing favourable policies and incentives. As the development agenda is a priority to governments, they will give preference to technologies that give additional development benefits. The entrepreneurs are essential in providing innovative approaches to diffusing a technology and generating local markets. End users' role in the success of technology transfer must not be underestimated as it is social acceptance and satisfied end users that increase the uptake of a technology. Experts are those that may be at a research institution who understand the positive and negative aspects of a particular technology.

Mallet (2007) also agrees that those forms of technology cooperation in which active participants are from various sectors and interact continuously throughout the process are most effective in eliciting social acceptance of renewable energy innovations. The above has highlighted the benefits of considering end user demands and engaging with relevant stakeholders when designing a technology framework. It is also necessary to take into account country needs and development objectives driven from a national level. Ultimately each country and each technology has different needs which are hard to accommodate within one framework. This re-iterates the complexity of designing a one-fits-all technology mechanism.

These concepts substantiate the motivation for selecting one technology in one country (biogas in South Africa) as a case study for this thesis in terms of engaging with stakeholders and understanding end user needs – this will be explored further in Chapter 5 section 5.2 where discussions with end users and stakeholders were undertaken.

2.1.7. Financing

When considering technology transfer within the international climate change debate, it is difficult not to touch upon the issue of financing. Technology and finance are very closely related under the UNFCCC discussions. A technology transfer agreement would ultimately provide some form of financing; however the success of a technology transfer agreement may rest on the finance provisions that will depend on other finance-related arrangements in the UNFCCC process.

Many figures have been put on the table regarding the quantity of money required for covering technology transfer in developing countries. A UNFCCC ((g),2009) report states that current financing support for technology transfer is likely to amount to less than US$2 billion per year. This is only one partial estimate of the additional financing resources that are needed for technology transfer, which has been estimated at US$1.9 billion over five years. The UNFCCC former general secretary Yvo de Boer estimates in the longer-term around US$200 billion is needed for technology to reduce emissions (Padma, 2009). The final figure for, or form of, providing significant levels of finance for technology transfer have not yet been decided.

Finance for technology transfer is one of the issues discussed within the proposed finance proposals under the UNFCCC, but it is beyond the scope of this thesis to look at development of a finance proposal. Regardless of the form of a UNFCCC financing mechanism for technology transfer, any international funds will most likely be channelled through a national body that is responsible for distribution. At this stage it is still unclear how this will be achieved and it is likely that different technologies will require different streams of financing.

Some of the activities that support technology deployment that require financing are outlined in decision 4/CP13(UNFCCC(b), 2008) include:

- Implementation of Technology Needs Assessments
- Joint research and development programmes
- Demonstration projects
- Enabling environments for technology transfer
- Incentives for the private sector
- North-South and South-South cooperation
- Endogenous capacities and technologies
- Licenses to support the access to and transfer of low carbon technologies and know-how

Meeting the full potential cost of deploying low carbon technologies is likely to require a combination of international funds and both public and private sector involvement. Finance could come from domestic, private and public, investments, foreign direct investment or official development assistance (ODA) funding (GEF, 2008) and could be delivered to developing countries by way of both market-based mechanisms such as the Clean Development Mechanism (or AAU's[6]) or by multilateral and bilateral financing such as the World Bank Climate Investment Funds or national development agency support (Tomlinson et al., 2009). Multilateral development banks are also in a position to assist developing countries to improve their enabling environments and provide technical resources to assist access to clean energy (Bazilian, et al., 2008).

Ultimately, the technology transfer agreement will to a certain extent depend on the final format of the finance mechanism for its success, which is why this topic has been introduced. Also, although finance is not a particular focus point of this study, there will be references to financing needs made at various points in the thesis as needed.

2.1.8. Summary

This chapter has introduced some of the issues that are under discussion in regards to international transfer of climate change technologies, which will be explored with relevance to biogas technology in South Africa.

Although there is a range of definitions for technology transfer, they all recognise that the process encompasses the entire technology cycle from R&D to end user uptake as well as from one geographical location to another.

To ensure a suitable **enabling environment** for the transfer of low carbon technologies, governments have a role in creating the right environment for international investment in and national implementation of technologies. This can be addressed by removing regulatory barriers and implementing sound economic policies

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[6] AAU's – Assigned Amount Units, A Kyoto Protocol unit equal to 1 metric tonne of CO2 equivalent. Each Annex I Party issues AAUs up to the level of its assigned amount, www.unfccc.int

and regulatory frameworks. Institutional support at a national and international level along with capacity building are contributing factors.

Local **absorptive and technical capacity** are crucial in ensuring the uptake of a technology once it has been transferred; this relies on education and training to ensure social acceptance and the necessary skills for implementation, operation and maintenance.

Innovation has been recognised as an important factor at all stages of the technology cycle from R&D to large-scale commercialisation. However, the level of innovation depends on a country's capacity to innovate and is also specific to national and local circumstances. Institutional support for innovation also forms part of a suitable enabling environment required for increasing the deployment of low carbon technologies. Appropriate **financing** and well-designed financial incentives will also be important for increasing technology transfer. Regardless of the final format of a finance mechanism, it will have to be flexible to accommodate the needs of technologies at different stages of the technology cycle. The role and significance of **IPR** is a contentious issue, however if used in an appropriate manner they can be used to support technology transfer.

The broad range of potential opportunities for intervention for low carbon technologies varies depending on their stage of maturity, which demonstrates the complexity of designing a one-fits-all technology mechanism.

This was a brief introduction to topics that generate significant amounts of literature in their own right; however the aim of this chapter was to introduce the themes which will be referred to throughout the thesis in relation to biogas technology in South Africa. These issues will be explored further in the next chapter (in relation to technology in South Africa) and in Chapter 5 (in relation to biogas in South Africa) and guide the process of gathering empirical data.

Chapter 3:

3. Current Status: International Technology Collaborations, Technology Under the UNFCCC and Technology Support in South Africa

The previous chapter provided an outline of the main issues surrounding the topic of technology transfer in the context of climate change. This chapter aims to present the current status of technology interventions internationally and nationally (in South Africa) to increase the deployment of low carbon technologies and provides details on the activities happening inside and outside of the UNFCCC process.

Until a decision on an approach for the large scale deployment of technologies has been made, technology under the UNFCCC remains predominantly at discussion status. However, organisations such as the International Energy Agency have for 30 years been involved in technology collaborations. Although originally focused on energy security, they have now developed experience in technology collaborations for low carbon development paths and energy efficiency (IEA, 2010). The only substantial deployment of technologies thus far under the UNFCCC process has occurred as part of CDM projects. Many of the interventions occurring outside of the UNFCCC process follow different formats which could provide useful lessons for the proposed UNFCCC technology mechanism – in fact some of these interventions have been referred to in the country submissions on technology transfer to the UNFCCC. Technology transfer agreements could follow different frameworks for example negotiated bilaterally between particular developed and developing countries within a multilateral framework. This topic is discussed in greater detail in the paper by De Coninck et al (2008): *International Technology-Oriented Agreements to address climate change.*

Although it has been recognised in literature that much of the ongoing and future implementation of low carbon technology will happen at the national level (Bazilian, 2009), there is little literature about the interface between national and international in terms of implementing an international technology agreement.

Bazilian (2009) acknowledges that the aspiration for the UNFCCC to unleash the full potential of technology is likely to be over-ambitious and rather this will require input from national governments, international cooperation inside and outside of the UNFCCC, and private sector companies and entrepreneurs. There will be tools and instruments that can be considered by the international community and those to be implemented (and supported) as a sub-set of national policy (Bazilian, 2009).

The role of the national and international interface is still relatively under researched however there is recognition that a successful tech transfer process will incorporate national level and international cooperation inside and outside of the UNFCCC. This chapter touches on the international cooperation happening inside and outside of UNFCCC, as well as a look at national level technology activities in South Africa. Chapters 5 and 6 explore these themes further in relation to biogas technology in South Africa, and conclusions drawn in chapter 6 incorporate findings from the international and national context.

First a brief review of the interventions aimed at increasing the transfer and deployment of technology outside the UNFCCC process will be provided followed by a summary of recent technology activities and proposals within the UNFCC. Subsequently an outline of the support for technology innovation in the South African context will be presented.

3.1. International context for technology transfer

3.1.1. International technology collaborations

The international discussions around technology transfer have heightened since it gained focus under the UNFCCC negotiations. However international technology initiatives outside the UNFCCC framework already exist. Some of the submissions on a proposed technology mechanisms submitted to the UNFCCC from different countries refer specifically to some of these existing international initiatives (such as the Japanese submission, which refers to the International Energy Agency and the Asia Pacific Partnership on Clean development and Climate).

The following section outlines some (but not all) of the different formats of agreements and collaborations that exist around technology, biogas and experiences from best practice research dissemination. The following section has been divided up into these three areas of interest and general observations will be summarised towards the end of the section. Investigating initiatives in these three areas is particularly relevant for this thesis.

Low carbon technology transfer

International low carbon technology initiatives from the International Energy Agency and Asia Pacific Partnership have been selected as examples as they are specifically referred to in party submissions to the UNFCCC.

The **International Energy Agency** (IEA) works actively on **IEA Technology Road Maps** and also **Energy Technology Implementing Agreements**. The Implementing agreements rely on a system of standard rules and regulations that allow interested member and non-member governments to pool resources and research the development and deployment of particular technologies (IEA, 2010). International Energy Agency Implementing Agreements use two primary mechanisms: task-sharing and cost-sharing. Cost-sharing is where one contractor performs a research task with funding from the collective of the countries participating in the IEA-IA. Task-sharing is where a joint program is pursued with the participating countries but where each country funds and implements its own contribution to the project. Most of the tasks have been funded through domestic R&D budgets and administration tends to be housed at a sponsoring domestic energy agency which keeps costs low (de Coninck et al, 2008).

In 2003 the IEA Framework for International Technology Cooperation was adopted to manage the participation and reporting process. Any programme of work must fit in with the IEA goals of energy security, environmental protection and economic growth and usually encompasses technology assessments, research projects and information exchange.

Following the G8 Ministers meeting 2008 in Aomori, it was decided that the IEA prepare roadmaps to speed up the implementation of innovative energy technologies to advance global development and uptake of key technologies to reach a 50% reduction in energy-related CO_2 emissions by 2050 (IEA 2010). **IEA Technology**

Road Maps exist for the following technologies; CCS for Power Generation and Industry; Efficient Industry Processes; Electric and Plug-in Hybrid Vehicles; Wind Energy. Roadmaps are currently underway for; Biofuels; Concentrating Solar Power; Energy Efficient/Low-Carbon Buildings (heating and cooling equipment); Nuclear Power; Smart Grids; Solar Photovoltaic Power. They prioritise actions for governments, industry, financial partners and civil society. The idea is that the roadmaps represent international agreement on regulatory and financial needs for the deployment of different technologies. The IEA lead this collaborative process under international guidance. The roadmaps are developed through collaboration with international experts and predominantly rely on data available at a national level – which is not always comprehensive particularly in developing countries. The engagement is usually at national policy maker level and although it recognises the importance of social acceptance, does not go down to the level of detail to incorporate end user needs.

The **Asia Pacific Partnership on Clean Development and Climate** is a collaboration of private sector partners across Australia, Canada, China, India, Japan, Korea, and the United States. Individual task forces have been set up which focus on the following sectors: Aluminium, Buildings and Appliances, Cement, Cleaner Fossil Energy, Coal Mining, Power Generation and Transmission, Renewable Energy and Distributed Generation, and Steel. The task forces comprise of government and industry and the chairs to these task forces are shared out among the member countries. Each task force develops an action plan to identify projects and activity priorities. The Policy and Implementation Committee then met and endorsed these Action Plans and the nearly 100 associated projects in October 2006, which are now progressing to implementation phase (APP, 2010). It is a non-treaty agreement without legally binding targets in reducing emission which was established in 2005 and launched in 2006. At this time, the environmental effectiveness and the impact on technological change of the APP are likely to be limited. Economic cost-effectiveness cannot be evaluated at this point; costs are low but so are effects[7].

Lessons from best practice

As well as the IEA and the APP, other initiatives that have been referred to in literature relating to the design of an international technology mechanism are the CGIAR and the Montreal Protocol.

The **Consultative Group on International Agricultural Research** (CGIAR) was set up as a strategic partnership that provides cutting edge scientific research in agricultural growth, food security, and improved management of natural resources to support the livelihood of the poor. Established in 1971 the CGIAR hosts 64 members across the public and private sectors in developed and developing countries. The CGIAR model has often been referred to by the international community as a useful demonstration model for the deployment of low carbon technology (Correa, 2009). At the High Level Conference on Technology Transfer in Delhi in 2009, the CGIAR model was suggested to inspire a network of international research institutes on technology transfer. The CGIAR is a collaboration of independent research centres across nearly 50 countries (developed and developing) where each centre is managed by its own board, has an independent budget, and can seek funding for its own activities. The CGIAR has an independent Technical Advisory panel (now Science Council) which subjects the different centres to regular and thorough evaluations which are conducted by external teams of scientists and other experts (Correa, 2009). Based on the CGIAR model a few issues to consider for a technology mechanism would be: governance of collaborating institutions and capacity to engage in joint research; mechanisms to determine research priorities, distribute tasks, monitor progress, and evaluate the achievement of the defined objectives; conditions for cooperation with and use of technologies held by the private sector; establishment of common policies on diffusion of research outputs and use of the IPRs system (Correa, 2009). However issues around IPR are proving complex under the CGIAR furthermore Correa also advises that science is normally more amenable to cooperative work and dissemination as a public good than is technology,which generally requires adaptation to particular needs and circumstances.

The **Montreal Protocol** on *Substances That Deplete the Ozone Layer* is an international treaty that came into force in 1989. It is often used as an example of a protocol, which demonstrated successful technology transfer mechanisms under its

Multilateral Fund (MLF). Already back in 1999 enterprises and government officials met to discuss lessons learned in technology transfer under the Multilateral Fund for the Implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer (Grida, 1999) and how it could be integrated into the Climate Change convention. The MLF is regarded positively particularly because of the governance framework including project guidelines, preparation of periodic progress reports, tracking of project delays (Bazilian et al., 2008).

Two particular problems in regard to the UNFCCC process noted by these negotiators is the lack of dialogue between climate negotiators and ozone negotiators to build on lessons learnt and also that the Kyoto Protocol does not currently demand anything of developing countries (COWI, 2008). The success to getting developing countries to commit would be assured technology transfer (50% of existing and 50% of new technologies) and independent dedicated global funds that can finance the costs of complying with the treaty the treaty 'help is more useful than punishment' (COWI, 2008). Negotiators from the Montreal Protocol make recommendations to the UNFCCC negotiators which include identifying and involving stakeholders to develop local and national partnerships, and to implement training programmes for stakeholders on technologies and techniques for a green growth path (Andersen and Sarma, 2008).

Promoting Biogas technology

Following on from the IEA frameworks on technology, the IEA has a specific bioenergy programme with activities related to increasing the uptake of biogas technology. Other international initiatives aimed at promoting biogas is the Global Bioenergy Partnership and the Methane to Markets partnerships.

IEA Bioenergy was set up in 1978 and operates within the IEA energy technology and R&D collaboration programme (IEA Bioenergy, 2009). Activities are set up under Implementing Agreements which provide the legal mechanisms for establishing the commitments of the Contracting Parties (which can be government organisations or private entities designated by their governments). The aim of the **Implementing Agreement on Bioenergy** is to increase research, information exchange and technology transfer by collaborating with international partners such as the FAO, the

World Bank, the IPCC, the Global Bioenergy Partnership and IRENA (International Renewable Energy Agency). The particular agreement focuses on 13 tasks two of which are specifically geared towards biogas uptake - Task 36: Integrating Energy Recovery into Solid Waste Management and Task 37: Energy from Biogas and Landfill Gas. In South Africa, the University of Stellenbosch is currently involved with Task 39 under this implementing agreement which focuses on the commercialisation of 1^{st} and 2^{nd} generation biofuels.

At the G7 Gleneagles summit in 2005 it was agreed to "promote the continued development and commercialisation of renewable energy by launching a Global Bioenergy Partnership to support wider, cost effective, biomass and biofuels deployment, particularly in developing countries where biomass use is prevalent".

The Global Bionergy Partnership was launched in 2006 at the 14th session of the Commission on Sustainable Development (CSD14) and its secretariat is hosted at the Food and Agriculture Organization of the United Nations (FAO) headquarters in Rome, Italy. It aims to support national and regional bioenergy policymaking through a partnership of public, private and civil society stakeholders. One of the current programmes of work focuses on areas including technology cooperation frameworks for the deployment of technologies for sustainable bioenergy by raising awareness and facilitates information exchange, improving enabling environments and eventually piloting collaborative field projects. The GBEP published a White Paper in 2005 (Clini et al, 2005) which presented the status of global bio energy, barriers to implementation, international initiatives, roles of technology partnerships, as well as a draft report "Deployment of Technologies for Sustainable Bio energy: Towards an Agenda for International Cooperation".

The **Methane to Markets** partnership began in 2004 and aims to deliver an estimated annual reductions in methane emissions of more than 180 $MMTCO_2e$ [8] (Methane to Markets, 2010) by 2015, although no specific target is set (de Coninck et al, 2008). The US Environmental Protection Agency acts as the Secretariat to the technical sub committees and the Project Network members. The Partnership has four technical subcommittees, consisting of experts from government or the private sector, in

[8] $MMTCO_2e$ = Million metric tonnes carbon dioxide equivalent

Agriculture, Landfill Gas, Coal, and Oil and Gas. Each committee has developed sector-specific Action Plans which identify needs, opportunities and priorities for project development globally as well as key barriers and strategies to overcome them (Methane to Markets, 2010). The Project Network members are from industry, the research community, financial institutions, state and local governments and other expert stakeholders that are interested in supporting methane capture projects. The aim is for them to participate in developing the action plans by sharing their technical expertise, experience, and financial resources and become involved in technology transfer, capacity building and outreach. According to the M2M data, membership has increased tenfold in the last 5 years. To date it has supported the development of more than 170 methane emission reduction projects which are already delivering reductions of approximately 27 $MMTCO_{2e}$ per year and, when fully implemented, will yield more than 63 $MMTCO_{2e}$ annually (Methane to Markets, 2009). The partnership seems unlikely to develop new technologies, although it could encourage diffusion and modification of existing approaches (de Coninck et al, 2008).

When looking at the IEA and the APP collaborations the predominant focus is around large technologies with higher generation capacities and greater emission reduction potential – the ultimate aim of the Kyoto protocol. The focus on the deployment of smaller scale and rural technologies is being addressed technology networking organisations such as the Global Bioenergy Partnership.

Many of these partnerships have evolved out of a top down approach as outcomes of high level meetings and conferences (G8 Gleneagles 2005 was an outcome from the IEA agreements, and the APP was agreed at the 2005 ASEAN meeting etc.). That is not to say they are not allowing for national level inputs as in many cases these initiatives are operating through input from national partners is the chosen option. However it is still not clear how, for the smaller scale technologies, end user stakeholders which actually be incorporated, and to what level of detail such international networks or frameworks are able to be sensitive towards end user requirements.

Useful aspects from international initiatives

Taking this broad and selective sample of existing international interventions outside of the UNFCCC process discussed in this section, certain observations can be made in regards to the actitvities and structure of these initiatives.

Table 1 General observations of similarities of international initiatives outside of the UNFCCC

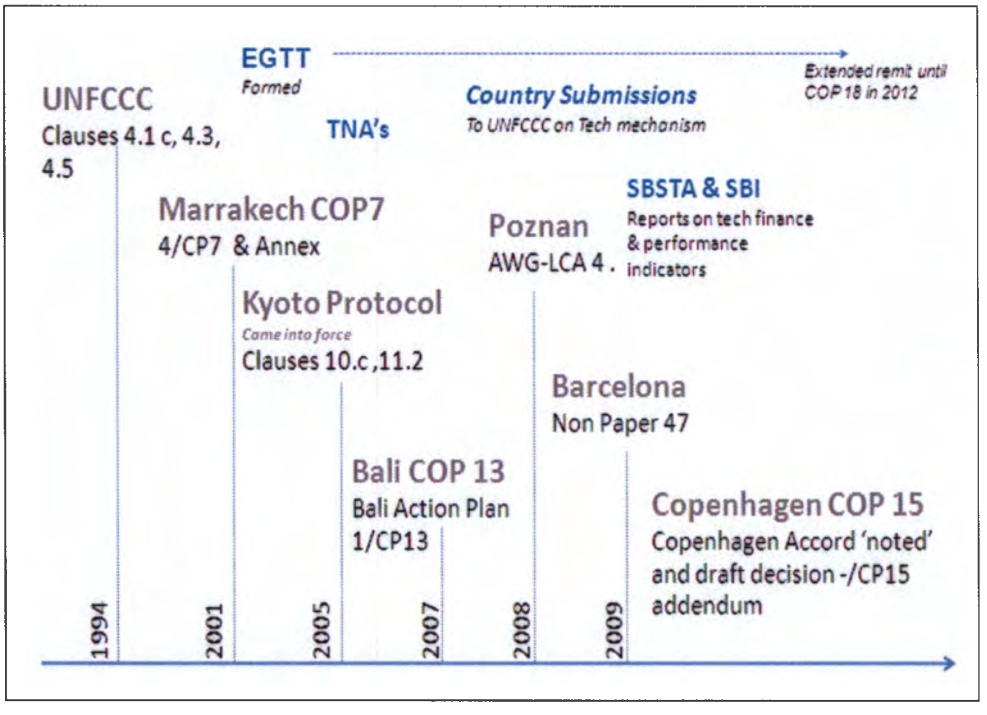
	IEA Technology	APP	CGIAR	Montreal Protocol	IEA Bioenergy	GBEP	M2M
Technology/sector specific task forces	X	X					X
Collaboration of industry, private, public sectors					X		X
Sector/technology specific action plans	X	X	X				X
Information exchange			X		X		
Governance/monitoring framework			X	X			
Technical subcommittee			X				X
Policy support	X				X	X	

Some of the ideas featuring in these initiatives are evident in the proposed country submissions (section 3.1.3) and the latest proposed draft technology mechanism under the UNFCCC ((e), 2009) such as technology action plans, technology collaborations and increasing information exchange. This is a valuable exercise for identifying which types of structures or activities within an international technology mechanism would be most useful for addressing the transfer of biogas technology into South Africa. These ideas will be explored further in Chapter 6. The next section will now briefly look at the evolution of technology discussions under the UNFCCC.

3.1.2. The history of technology activities within the UNFCCC process and recent activities

Technology was allocated its own articles under the UNFCCC back in 1992 and has continued to feature as a key focus area as the climate change negotiations evolve. Some meetings have generated particular action plans, articles or bodies with the specific remit to enhance the diffusion of low carbon technologies. Below is a simplified graphic of the evolution of the technology debate within the UNFCCC process – these are not the only events, but provide some milestones for reference.

Figure 5 Activities under the UNFCCC which featured significant references to technology



The original technology articles included at the inception of the United Nations Framework on Climate Change Convention (UN, 1992) are articles 4.1c which states all Parties shall "Promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases"; Articles 4.3 which stipulates that "developed country Parties …shall also provide such financial resources, including for the transfer of technology, needed by the developing country

Parties to meet the agreed full incremental costs of implementing measures" and 4.5 which requires developed country parties and all other developed country parties to "take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties and….. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties." Also article 11.1 prescribes "financial resources shall be provided for the transfer of technology on a grant or concessional basis".

SBSTA and SBI

Two subsidiary bodies were formed under the Convention to assist the Conference of the Parties (COP): the Subsidiary Body for Implementation (SBI) and the Subsidiary Body for Scientific and Technological Advice (SBSTA). The former makes recommendations on policy and implementation and the later acts as a link between scientific experts and the COP (UNFCCC(h), 2010) as well as providing advice to the COP on matters of science, technology, and methodologies.

Following the COP 7 decision 4/CP.7 (UNFCCC(a), 2002) under the Marrakesh Accord in 2001 called for a framework for meaningful and effective actions to enhance the implementation of Article 4.5 of the convention. The annex to this decision contains 5 main themes; Technology Needs and Needs Assessments; Technology Information; Enabling Environments; Capacity Building; and mechanisms for technology transfer.

At the COP 7 the Expert Group on Technology Transfer (EGTT) was established in order to enhance the technology related aspects of the convention as well as to advise the Subsidiary Body for Scientific and Technological Advice (SBSTA). At COP 13 it was agreed to extend its remit until the COP18 (2012). The most recent reports conducted by the EGTT together with the SBI and the SBSTA in 2009 are around developing performance indicators to monitor and evaluate the effectiveness of the implementation of the technology transfer framework (UNFCCC(f), 2009) and financing options for technology transfer (UNFCCC(g), 2009).

The Kyoto Protocol (UN, 1998) which is an instrument of the UNFCCC which makes specific references to technology including the following; Article 10(c), reiterates the requirement of all Parties to cooperate in the development, application, diffusion and transfer of environmentally sound technologies that are in the public domain and 11.2(b) repeats the commitment of developed country Parties to provide financial resources for technology transfer.

The Clean Development Mechanism (CDM) is a tool under the Kyoto Protocol which allows for technology transfer to occur as it ultimately requires developed countries to invest in carbon mitigation projects in developing countries, thereby potentially transferring some aspect of the technology transfer process. Of a review of 3296 CDM projects, roughly 36% of the projects accounting for 59% of the annual emission reductions claimed to involve technology transfer (Haites et al, 2009).

At COP13 in Bali 2007 technology was taken from a marginal issue to one of the main four pillars of action featuring in the Bali Action Plan (UNFCCC(b), 2008). The plan calls for technology cooperation on research and development of new and innovative technologies as well as accelerating deployment, diffusion and transfer of affordable environmentally sound technologies. Furthermore it requests effective mechanisms for access to financing to assist the transfer of affordable technologies to developing countries.

The latest technology related negotiations fall under the remit of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA). Over 2008 and 2009 they have met to discuss and refine the draft negotiation text proposed in decision Bali (1/CP13). During the course of 2009, Parties submitted proposals for a technology mechanism to the UNFCCC outlining issues around institutional formats, activities, financing (more details are given in section 3.1.3). The Contact group on Enhanced action on development and transfer of technology prepared a document Non Paper 47 (UNFCCC(c), 2009) which outlinec options for a proposed action on technology. This document reiterated the importance of promoting research, development, demonstration and deployment of existing and new technologies for mitigation and adaptation. Furthermore it recognised the need for an effective mechanism to assist rapid diffusion and deployment of technology to developing countries. The format of the draft text remained inconclusive but covered areas on: financing, capacity building, country driven approaches, the format of a technology mechanism, international technology collaboration networks, a new technology body, IPRs and Enabling Environments.

Copenhagen COP15, Copenhagen 2009

Leading up to the COP 15 meeting, the UNFCCC former Executive Secretary Yvo de Boer (2008) said "There is an urgent need to discover what effective language a Copenhagen agreement needs to entail in order to unleash the full potential of technology". Reaching an agreement on technology transfer was only one of the many issues that were up for discussion at the COP15 meeting. As with many decisions that were meant to be agreed, the proposed technology deployment framework remains in draft form.

The Copenhagen Accord (UNFCCC(d), 2009) was the outcome of a political agreement at the COP 15 meeting in Copenhagen which was noted by the COP and to which nations can choose to associate themselves with as well as list mitigation targets. A number of countries - over a hundred (US-CAN, 2010) - including South Africa have associated with the accord. South Africa has also listed actions to reduce emissions – conditional to necessary financing, technology and capacity building. It is a 'non-binding accord' which has not been adopted however political agreement was reached on some major issue one of which was a technology development and transfer mechanism guided by a country driven approach.

The references made to technology, are firstly around scaling up new, additional, predictable and adequate funding as well as provide funding to developing countries to enable and support enhance action on technology development and transfer; with a proposed Copenhagen Green Climate Fund which would be established as an operating entity of the financial mechanism of the Convention to support projects, programme, policies and other activities in developing countries related to.... technology development and transfer.

Secondly a technology mechanism is proposed to accelerate technology development and transfer in support of action on adaptation and mitigation that will be guided by a country-driven approach and be based on national circumstances and priorities." More details relating to technology are provided in the addendum 3 -/CP15 (UNFCCC(e), 2009) accompanying the draft negotiation text which was negotiated, but not agreed upon during COP 15. This addendum focuses specifically on the activities proposed for enhancing technology transfer. Much of the text remained bracketed particularly around the Intellectual Property issue, and the financing arrangement was also not clear (Climatico, 2009). Technology innovation centres and technology networks are proposed to support and advise developing countries and encourage information sharing.

As much of the addendum is bracketed, and the negotiation text itself has not been agreed upon, this addendum is not an official COP document. However references to potentially relevant activities proposed in this addendum have been extracted as part of the analysis in Chapter 6 in order to assess the alignment between the proposed international technology mechanism and the empirical data from biogas in South Africa.

3.1.3. Useful aspects of country submissions on technology to the UNFCCC

Proposals for technology mechanisms were being put on the table by Parties leading up to the COP14 in Poznan in 2008 and subsequently in 2009. These propose issues relating to financing, institutional arrangements, monitoring and implementation of low carbon technologies. Morgan Bazilian (2009) undertook a comprehensive review of the proposed country submissions as they stood in 2009. There are some areas of convergence on issues such as the need for improving cooperation, creating better enabling environments and improving strategic planning on technology. There is also consent on the need for public action to harness private investment, using public money for the R&D phases to jumpstart the markets. There are still mixed views towards the Intellectual Property regime and the proposed level of financing.

The G77 + China proposal was one of the most significant submissions to the UNFCCC and triggered responses from other parties. The G77 proposal was pushing for building stronger enabling environments and creating jointly developed technology and IPR rights and improving accessibility, affordability, appropriateness and adaptability of technologies required by developing countries for enhanced action on mitigation and adaptation.

Technology Action Plans (TAPs) were proposed that would reflect the maturity of a technology along the technology cycle. Japans proposal emphasised the need to draw on the experience from existing technology interventions such as the IEA Technology Roadmaps and the APP to become involved in evaluating and reviewing the progress of technology deployment. The USA's proposal also supports a system similar to the APP where each country pays its own way. Australia recommends improved technology related information exchange to facilitate better R&D collaboration depending on countries expertise technologies and sector-specific expertise between countries and regions. It calls for mechanisms to be technology neutral and the need to avoid smaller technologies getting lost in the current Technology Needs Assessment (TNA) process by introducing a "technology leveraging facility" which could assist matching host country driven technologies with available funds.

The EU proposed technology orientated arrangements and suggests establishing and strengthening national and regional centres of technological innovation networks and R&D between developed and developing countries and actors within and outside of the UN process. The issue of improving domestic enabling environments is mentioned throughout. One noticeable issue which most party submissions commented on , was the IPR issue. It became clear that there is a split in opinion towards the IPR issue between developing and developed country parties. Many NGO proposals, though not all, agree that intellectual property could be an obstacle to technology transfer and therefore some form of action needs to be taken concerning intellectual property (Gerstetter et al., 2009). The concern is that restrictive IPRs will stifle innovation in developing countries, raise the cost of knowledge acquisition and learning, and impede climate change technology transfer but the argument is that without strong IPR protection there is little incentive for the private sector to make clean technologies available for developing countries (Bazilian, et al., 2008). Amongst the developed country submissions, intellectual property is usually considered an incentive for further technology development, rather than a potential barrier to technology transfer (Gerstetter et al, 2009).

Similar to section 3.1, reviewing some of the country submissions to the UNFCCC introduces recommendations and activities that are considered the role of an international mechanism. This is useful for considering which activities are most favourable to the uptake of biogas in South Africa.

Table 2 Activities proposed in a selection of country submissions to the UNFCCC which could be useful for increasing biogas technology in South Africa

	G77	Japan	Australia	EU
Information sharing	X		X	
Improve domestic enabling environment	X	X	X	X
Technology Action Plans	X			
Use experts and draw on existing tech interventions		X		
Sector specific expertise between countries and regions			X	
R&D collaboration			X	X
Consider smaller technologies			X	
Tech orientated agreements		X		X
Technology innovation networks				X

3.2. South African technology implementation

Following on from considering technology transfer at an international level, this section considers some of the national level engagement relating to technology transfer in South Africa such as the innovation and IPR arrangements. These themes also follow on from Chapter 2 which considered the different aspects which contribute to a successful enabling environment for technology transfer at a national level.

This is followed by a brief insight into some of the initiatives which to some extent tackle the interface between the international and national engagement such as the TNA and a brief investigation into whether, if at all, international initiatives are reaching technology implementers in South Africa.

Policies and initiatives relevant to the biogas enabling environment and the technical and absorptive capacity in South Africa, feature in Chapter 5.

3.2.1. Technology innovation and IPR in South Africa

South Africa has not to date been at the forefront of technological innovation, but there is a conscious effort being made in policy decisions to grow South Africa from a manufacturing and processing economy to a knowledge economy with greater focus on research and development.

In 1996 a White Paper on Science and Technology Preparing for the 21st Century was produced for the Department of Arts, Culture, Science and Technology. In 1997 the National Advisory Council on Innovation (NACI) was created by national legislation (NACI Act, No. 55 or 1997*)*. The statutory mandate of the National Advisory Council on Innovation (NACI) is to provide Minister of Science and Technology with advice pertaining to the National System of Innovation (NACI, 2010). In August 2002 South Africa's National Research and Development strategy was produced.

The NACI were involved in approving the **Technology Innovation Agency Act 2008** (RSA (d), 2008) was passed following a stakeholder process with science councils, other Government departments, higher education institutions and state owned enterprises. This Act begins with the statement that "innovation" means the application in practice of creative new ideas, which includes the processes by which new products and services enter the market and the creation of new businesses; i.e. this could apply to South African institutions and organisations becoming more innovative in their approach to instigate technology deployment, stimulating new innovation within industrial sectors by focusing on R&D, or by becoming more innovative with systems to deploy existing technologies (as in the case of biogas technology).

The **Technology Innovation Agency (TIA)** was an outcome of the 2008 Technology Innovation Agency Act and is a new public entity aimed at stimulating and intensifying innovation to improve economic growth and quality of life by developing and exploiting innovations and inventions as well as creating an enabling environment for commercialisation. The TIA's broad objectives are to; act as a technological agency that will provide funding and complementary services to bridge the gap between the formal knowledge base and the real economy; stimulate development of technology-based services and products; support development of technology-based enterprises – both public and private; provide an intellectual property support platform; stimulate investment (venture capital, foreign direct investment, etc.) and facilitate the development of human capital for innovation (DST, 2008). The TIA's budget for 2009 exceeded R720-million (Campbell, 2009) which includes the budgets of already-existing entities migrating into the new agency which are; the Biotechnology Regional Innovation Centres (BRICs); the Innovation Fund; Advanced Manufacturing Technology Strategy (AMTS), and the Tshumisano Trust. It is still however unclear how the TIA is taking shape, or whether any innovative projects have benefitted from it since its inception in 2008. Innovation in the form of research or demonstration is often funded through industry or specific funds such as the Innovation Fund or the Industrial Development Corporation through the Support Programme for Industrial Innovation. Who has funded research becomes important on the IP arrangement in terms of ownership.

In 2008 the Department of Science and Technology also published a document titled *Innovation Towards a Knowledge Based Economy: Ten-Year Plan for South Africa 2008-2018* (DST, 2008). This calls for government to address the *"innovation* *chasm",* in South Africa by improving access to finance, creating an innovation-friendly environment and strengthening the national system of innovation. One of the main drivers is to address the gap between research results and socio economic outcomes (DST, 2008). A shift towards a knowledge based economy could have potential advantages as it would be less emitting than the current industry based economy. In regards to renewable energy technology the plan acknowledges that South Africa possesses known technologies, but that the challenge is in commercialisation and coherent policy interventions for easy adoption. Furthermore increasing public engagement, strengthening human capital, and building up international partnerships increases South Africa's progress to becoming an innovative and knowledge based society.

The **Intellectual Property Rights from Publicly Financed R&D Act** was passed in 2008, but is not yet in force, pending the finalisation of Regulations required for its operation, and the establishment of a national agency to administer it (Wolson, 2009). The 10 year Innovation plan for South Africa also stresses the need to establish an Intellectual Property Management Office to enhance protection of intellectual property rights and ensure synergy with other policies. It will also develop national capacity to manage technology licensing and commercialisation (DST 2008).

Wolson (2009) suggests that there is perhaps more focus on IPR as a barrier to technology deployment than can realistically be justified. However as it provides a concise and definable subject area for debate a significant amount of literature has been produced. Finding case studies of energy projects which were halted due to IP constraints proved difficult to find. From discussions held with stakeholders from the Biogas sector in South Africa, it emanated that few of them knew what 'IPR' actually was and none were able to provide real life examples where it was a barrier to implementation. South Africa has an unfavourable technology balance of payments [9] as there is little alignment in the domestic market for medium-high technology products and local research (DST, 2008). Yet South Africa has a fairly progressive IPR regime (Ramprecht, 2009) and has demonstrated its capacity to use them for competitive advantage in the low carbon technology domain. An example is the thin

[9] The technology balance of payments measures international transfers of technology: licences, patents, know-how and research, technical assistance. Unlike R&D expenditure, these are payments for production-ready technologies (Ref: http://www.oecd.org/dataoecd/42/53/2087228.pdf)

filmed solar panel that was designed at University of Johannesburg, and funded by the South African Innovation Fund required the University and inventor to set up a company in South Africa and then to license the product to a company in Germany for manufacturing. However the IPR agreement was such that the local South African partners had cross partner shareholding which has now enabled a South African manufacturing facility to be set up. Originally this was done as it was proving difficult to attract the investment required for commercialisation in South Africa but ultimately this arrangement has enabled access to expertise, suppliers and finance and overcame some of the initial development and demonstration costs – and may actually have been more efficient than having set up the initial commercialisation facility in South Africa.

3.2.2. South Africa's Technology Needs Assessment (TNA): Example biogas

The UNFCCC process has recognised the need to incorporate country-led needs assessments. The TNA are a set of country-driven activities that identify and determine the mitigation and adaptation technology priorities of Parties (UNFCCC, 2010). By June 2009 69 TNAs by non-Annex I Parties had been submitted, and one from a developed country (UNFCCC(i), 2009).

The Department of Science and Technology (DST) in South Africa produced it's TNA in 2007 which provided a useful step to identifying the national technology status (and in theory feed into international negotiations). For the purpose of analysis the TNA was divided into technologies to be prioritised for mitigation and adaptation. Mitigation technologies were disaggregated into the following sectors: energy (electrical energy generation, industry/mining and waste management); agriculture; land use and forestry; Transport; where adaptation technologies focused on; human health; agriculture, land use and forestry; water resources; built environment and infrastructure

Section 4.2.2 of the TNA provides a list under the category 'Prioritisation of Energy Sector technologies' which include larger high tech technologies such as solar or clean coal technologies. Focusing on the larger technologies is of course not conducive for supporting smaller scale technologies such as biogas technology. A brief example has been provided in Table 3 to demonstrate that although biogas technology has not been specifically mentioned, it does in fact address issues across many of the focus sectors including energy generation, waste management, water and agricultural sectors and furthermore human health. From the extended list of technologies identified in the TNA Resource Document Section (Appendix 3: *List of technologies identified in the TNA Resource Document*) there are at least 8 sectors for prioritisation that are addressed by biogas technology as outlined in the below table:

Table 3 Extracts from TNA Resource Document 2007 that could be addressed by biogas technology.

Sector	Measure	Opportunities for Biogas
Human Health	Provision of water supply and sanitation	Provides a sanitation system and reuses water
	Control of the spread of vector borne disease	Reduces the risk of waterborne diseases
Waste Management	Avoidance, minimisation and reuse	Uses an existing waste stream and reduces quantity of waste sent to landfill
Agriculture and forestry	Macro-economic diversification and livelihood diversification in rural areas	Generating energy and fertiliser onsite offers potential small business potential and job creation.
Water resources	Technologies that promote water efficiency	Processes waste water to a safe level for use in irrigation (and reduces contaminated water sent to sewage/land)
Electric energy generation	Biomass	Uses biomass in the form of organic waste to generate electricity
Agriculture	Manufacture and application of fertilisers	The end product from a biogas digester is a high quality fertiliser and reduces need for purchasing fertiliser
Waste Management	Adopt aerobic digestion in manure management	Aerobic digestion of manure is a potential biogas generating process

The stakeholders involved in preparing this TNA predominantly work in South Africa and offer a cross section of professional and scientific insight into what technologies are appropriate domestically as well as international exposure to appreciate what is realistic in the international framework. Therefore theoretically this TNA process offers a good link from domestic technology gaps to the international negotiations. But to date there do not appear to have been any projects implemented subsequent to this assessment, and under the UNFCCC process the 'next step' after the TNA has not been finalised.

3.2.1. Are international initiatives reaching those on the ground in South Africa?

To try and discover how, if at all, international technology initiatives – particularly those that support biogas, actually support work being done by those implementing biogas technology on the ground, discussions were had with stakeholders in the biogas sector and contact was made with the administrative centres of some of the technology initiatives listed below.

Stakeholder Feedback

To obtain an indication of the level of awareness around international technology mechanisms and collaborations that existed amongst stakeholders in the South African biogas sector, key informants that were engaged with for this thesis research, were asked about their knowledge or involvement in the below initiatives. These stakeholders were drawn from academia, public sector, carbon developers and a rural biogas installer

- International Energy Agency (IEA) Implementing Agreement on Bio energy
- International Energy Agency (IEA) Technology Road Maps
- Global Bioenergy Partnership (GBEP)
- Asia - Pacific Partnership on Cleaner Climate (APP)
- South Africa's Technology Needs Assessment (TNA)
- UNFCCC Technology activities and a proposed technology mechanism

Of the two IEA initiatives, the academic representative had heard of the IEA Bioenergy agreement as they had briefly been involved in the Task 39 work (mentioned in 3.2.3) but was not up to date with its activities. One carbon developer was aware of the IEA Technology Roadmap for wind, but was not aware that there were roadmaps for different technologies. The TNAs were only familiar to the academic actor although they were not aware of what it entailed. None of the sample representatives had heard of the GBEP or the APP initiative or that there were technology activities being proposed under the UNFCCC or Kyoto Protocol. Both the public sector and academic representatives agreed that this gap in knowledge between international interventions and national actors was an important issue that needed to be addressed. The carbon developers and biogas implementer were immediately interested to find out whether any of these initiatives could assist them in accessing financial support for proposed projects.

South Africa's engagement with international biogas technology

Two examples of South Africa's engagement with international biogas technology mechanisms are the GBEP and IEA Bioenergy Implementing agreement.

South Africa was present at the original meetings of the Global Bioenergy Partnership, and is currently considered an observer in the GBEP. However although contacts have been forged between **GBEP** and the Government of South Africa, the Department of Minerals and Energy (who is the GBEP official focal point for South Africa) has not yet signed the Terms of Reference or had representation at recent GBEP meetings. Therefore the GBEP is currently welcoming new partnership opportunities for an organisation to represent South Africa at international GBEP forum (Ianna, 2010).

Task 39 of the **International Energy Agency's Bioenergy Implementing Agreement** is 'Commercialising 1st- and 2nd-Generation Liquid Bio fuels from Biomass' which is a global network dedicated to the development and deployment of biofuels for transportation fuel use (IEA Bio energy, 2010 http://www.task39.org/). South African participation in Task 39 has allowed interaction with other international experts in their field (bioconversion of lignocelluloses to bioethanol), active collaboration through exchange of scientists and students and access to latest information on the developments in the field. Furthermore this information has been used to inform interested scientists in South Africa about these developments as well as involving officials from various government departments and institutes that are involved in the development of a biofuels strategy for South Africa (Prior, 2010).

Agama Biogas is also a project network member of the **Methane to Markets** programme.

The above results demonstrate that firstly there is a disjuncture between knowledge of active international initiatives and project implementers on the ground. This raises an interesting point about the role of an international mechanism stimulating local technology transfer. Secondly that there are opportunities, as in the case of GBEP, for South Africa to become involved and benefit from international collaborations, yet this has not been followed up - maybe due to a lack of resources or awareness at a national level.

3.3. Summary

Exploring some of the international initiatives in the technology and biogas sector, as well the country proposals to the UNFCCC, has provided a useful insight into the types of activities and structures for international mechanisms which could be suggested to be incorporated within a technology mechanism under the UNFCCC. These will be considered in the analysis within Chapter 6 as to which types of actions and activities would contribute to the transfer of biogas technology in South Africa.

A brief history of the UNFCCC has shown the progression of technology discussions and shown that as a legally binding technology mechanism under the UNFCCC does not yet exist, any analysis of a UNFCCC technology mechanism can at this stage only be based on Draft Decision CP15.

Following on from chapter 2, South African innovation and IPR laws are considered to try and establish the national level engagement in aspects contributing to technology transfer. Although the current IPR framework may not specifically promote low carbon technologies, cases where IPR has been a barrier to technology transfer in South Africa could not be found. In regards to innovation, although South Africa may not be at the forefront of R&D innovation, particularly in low carbon technologies, this is still where the innovation framework focuses.

There is South African participation in international interventions but this is minimal, which will is partly due to the disjuncture between knowledge of available international mechanisms from the biogas technology implementers.

South Africa has produced a Technology Needs Assessment (TNA) in response to UNFCCC requirements to identify country driven technology needs. Although biogas technology does not feature as a priority technology, it is evident that it could address some of the TNA criteria.

Many of the above themes will be picked up again in Chapters 5 and 6 with relevance to the biogas sector in South Africa. The next chapter moves on to introduce the concept behind energy from biogas.

Chapter 4: Analytical Background: Energy from Biogas

4. Analytical background: Energy from biogas

The process of using biogas from the decomposition of organic waste has been around a long time – in China, India and Nepal, biogas has been used widely since the 1950's as a source of energy and waste treatment, and as liquid fertiliser for soil enhancement (Agama, 2008). Therefore extensive literature, case studies and data are available for different examples of the application of biogas for energy generation.

The following section will briefly touch upon the concept behind biogas generation and provide case studies to outline some of the benefits, opportunities and incentives around biogas technology internationally. Chapter 5 will then take a more in depth look into the biogas sector in South Africa. Gathering information on Biogas programmes in South Africa may veer away from a traditional literature review in the sense that it is based on very recently published reports, site visits and informed discussions.

4.1. The benefits of Biogas for energy generation

Global experience shows that biogas technology is a simple and readily usable technology that does not require particularly sophisticated capacity to construct and manage. It has also been recognised as a simple, adaptable and locally acceptable technology for Africa (Amigun, 2008). Biogas technology has many social and environmental benefits such as improving human well-being through better sanitation, reduced indoor smoke, and employment generation as well as conservation of resources particularly trees, reduced greenhouse gas emissions (Amigun, August 2008). Biogas initiatives in Africa could benefit from the success story of biogas technology in countries like Nepal, India and Vietnam. In South Africa, there are very few documented reports on technologies being used for effective energy recovery from wastewater (Burton et al, 2009) let alone many on installed biogas units from other organic waste streams.

Biogas is a technology can be applied at various scales with low tech and high tech applications; therefore it is suited to small rural household units or larger urban facilities. The process makes use of existing waste streams and as well as generating useful clean energy it simultaneously reduces waste sent to landfill, provides cleaner water and the output is a high quality fertiliser that can be distributed to improve agricultural yields.

In South Africa where only 21.8% (Statistics South Africa, 2008) of households receive solid waste collection from the municipalities, rural energy supply is a problem and biogas technology would offer a good closed loop solution to act as waste management system. Biogas technology would also contribute to reducing South Africa's increasing CO_2 emissions as it offsets emissions from electricity generated from coal and methane emissions from waste. Also it can stimulate energy independence, reduce annual fuel costs and can generate job creation through selling of fertiliser or improved localised construction skills. Yet biogas technology has not made an impact in South Africa. It is estimated that in South Africa there are approximately 300,000 households with two or more cows and no electricity that could make use of biogas digesters (Agama, 2007). Furthermore it is estimated that 45% of schools in South Africa have no electricity, 66% have poor sanitation facilities, 27% have no clean water, and 12% have no sanitation at all. Biogas installations could help mitigate all of these problems (Brown, 2006).

With many projects operational internationally biogas technology has progressed through the R&D and demonstration phases of the technology innovation cycle and is rather at the commercialisation and deployment phase. For these reasons biogas makes an interesting case study for exploring the barriers of technology transfer into South Africa.

4.2. How does biogas technology work?

Biogas is generated from the decomposition of organic waste and consists of primarily methane (~50-70%), CO_2 and water. It is the methane in the biogas that can be used as a useful energy source – either as a heating gas or converted into electricity. From a climate change perspective, the primary benefit of using Biogas as an energy source is that methane has a Global Warming Potential (GWP) of 25 (Table

2.14, Forster et al, 2007), therefore capturing and using it as useful energy prevents it escaping into the atmosphere. Currently methane from biogas, particularly in an industrial context, is burnt of vented – the former is better from GHG perspective than the latter. By capturing the methane from the decomposition of waste and using it as energy, reduces methane emissions as well as displacing emissions from other energy sources.

Beyond the energy benefits, biogas makes use of an existing waste stream for fuel and the generated outputs are a nutrient rich fertiliser and nutrient rich water for irrigation. Energy from organic waste therefore facilitates the integration of water, waste and energy management within a model of sustainable development. It is effectively a closed loop system as what goes in i.e. organic waste, comes out as a useful output i.e. biogas energy or fertiliser:

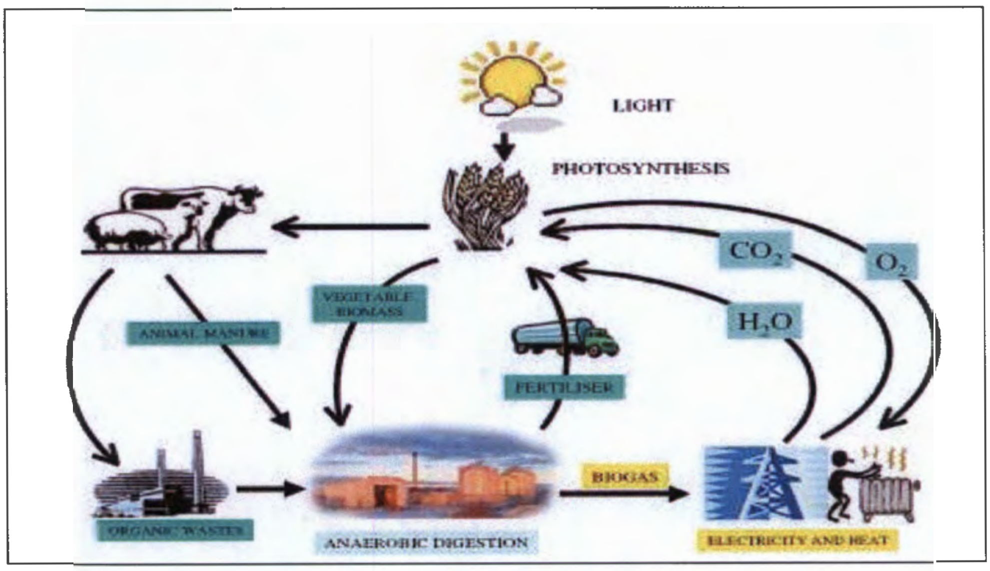


Figure 6 Biogas cycle (Al Seadi, 2002)

There are various ways of generating Biogas depending on the waste stream and the applications range from sewage in waste water treatment facilities, small scale pig farms in rural locations or trapping gas from landfill gas.

Below is a table showing options for inputs from a variety of organic waste streams, different conversion technologies, and potential outputs.

Table 4 Examples of different waste streams, conversion processes and outputs involved in biogas generation (compiled by author)

Input – Organic waste streams from:	**Conversion Technologies**	**Output**
Waste water Sewage Agricultural processes Food/crop waste Animal Dung Organic Fraction of Municipal Solid Waste	Anaerobic Digestion Combustion and gasification, Fermentation Waste heat	Heat energy Electricity Fertiliser High nutrient water Vehicle Fuel

The basic process of the biogas cycle involves waste being fed into a digester through an inlet, and the waste ferments in the digester over a period of time. In order to ensure the correct consistency of the slurry liquid may be added. In some cases the digester is also heated to optimise the efficiency of the biogas generation. For some larger digesters a mixing device such as a mechanical paddle or the injection of air may be used to optimise efficiency. At a household level the digesters are usually just kept at ambient temperature and don't have mixing devices. The below diagramme depicts a simplified version of the biogas process:

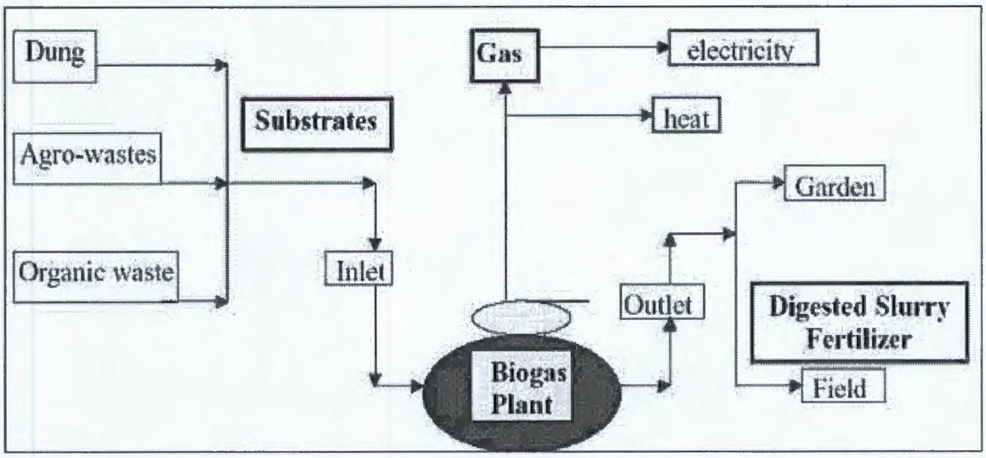


Figure 7 Flow diagramme of biogas process (taken from Amigun, 2008)

This thesis focuses primarily on the generation of biogas from anaerobic digestion. Anaerobic digestion refers to the decomposition of organic matter in the absence of oxygen i.e. fermentation in an enclosed container. This container could be a large concrete digester tank or a sealed off lagoon pond. Anaerobic digestion is a process of decay of organic biomass through the activity of anaerobic bacteria in the absence of oxygen. There are 3 micro-organisms (Hydrolytic, Acetogenic and Methanogenic) that break the complex chains to short chain fatty acids and gases then converted to acetic acid with further gases and finally biogas (Agama Biogas, July 2009). The energy output depends on the volume of the biogas produced and the percentage of methane. Anaerobic digesters can be used in rural or large scale industrial applications as can be seen in the images below:

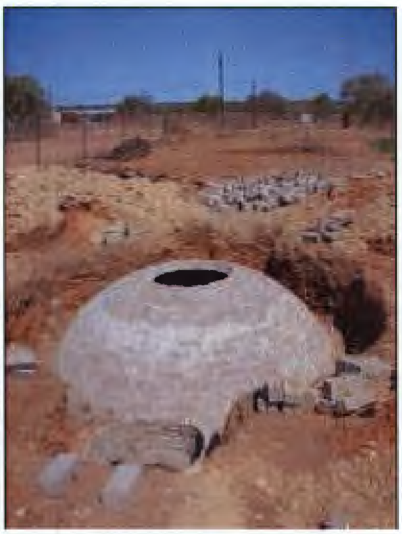


Figure 8 (above) Photo:Bran Sands Biogas, UK, 4.2Mwe feedstock: sewage (Source:Cambi)

Figure 9 Photo: Rural digester Giyani, Limpopo, 15m^3 feedstock: cow manure (Authors own photo)

In terms of mitigation potential, methane has a GWP of 25 therefore by using biogas technology to capture the methane otherwise released from the natural breakdown of organic waste Greenhouse gas emissions reductions can be realised. Added to this is the offset of grid electricity emissions.

In Nepal for example, biogas has turned into an indispensable part of Nepal's efforts to mitigate global warming, according to WWF-Nepal (IRIN, 2007). Over six million tonnes of carbon emissions could be avoided in the next five years by Nepal through large-scale use of biogas, according to climate change experts (IRIN, 2007). Nepal has had a very successful biogas programme due to the Biogas Sector Partnership (BSP Nepal, 2010). BSP estimate a net reduction of 4.7 tonnes/year of CO_2 equivalent per plant, or 660 thousand tonnes/year for the plants installed to date (this was for a figure of 124,000 units and offsetting the unsustainable use firewood for cooking and kerosene for lighting and cooking) (Ashden Awards, March 2006).

Other environmental benefits include the reuse of water as the fermentation process reduces any pathogens present in waste water and the result is high nutrient water ideal for irrigation. The waste slurry also generates a fertiliser which improves quality of agricultural land. Under the BSP programme, 74% of bio-slurry is utilized as an organic compost fertilizer (BSP Nepal, 2010).

There are also many social benefits associated with biogas including job creation, improved sanitation, reduced localised waste, cheaper and cleaner fuel and energy security and supply. In Nepal 11,000 have gained employment from the national biogas programme, and 1,080,000 persons are directly benefited by biogas plant (BSP Nepal, 2010). In India a proposed system has been suggested which would train informal waste pickers to set up and manage composting and biogas plants. In order for this to happen the government should invest in and upgrade the informal recycling sector, so that collectors can take up trade and processing of organic and inorganic waste, so that they are no longer at the bottom of the pyramid (Sawant, 2010). A 5 tonne wet waste project has been proposed in Pune, India for electricity for street lights. The dry waste will be used by the waste pickers in that area (The Punekar, 2009). Amigun (2008) and Sagar (2009) also draw attention to the fact that of the eight millennium goals, domestic biogas has a very direct relation with four: MDG 1 *Eradicate extreme poverty and hunger*, MDG 3 *Promote gender equality and empower women*, MDG 6 *Combat HIV/AIDS, malaria and other diseases* and MDG 7 *Ensure environmental sustainability.*

4.3. International examples of biogas initiatives

There have been many examples of successful installed biogas units internationally from those that supply cooking gas for one household to industrial units that provide 10,000 households with cooking gas. Worldwide, about 16 million households use small-scale biogas digesters to cook and light their homes, according to Renewables 2005: Global Status Report, a study by the Worldwatch Institute (Worldwatch Institute, 2005).

Many developed and developing countries have also introduced incentives to increase the uptake of biogas. This section has selected a small sample of case studies (there are many) including India, Nepal, Kenya, Nigeria, Poland, Austria, Germany and the USA.

In **India** over 4 million small biogas plants (1 m^3 onwards) that run on cattle manure are installed as well as 2000 medium sized plants which use cattle manure for heat, electricity or motive power (5-25kw) (Dhussa, 2004).

One of the bigger conventional biogas projects in India a 1 MW Cattle manure based biogas project at a dairy farm in Ludhiana, Punjab. The Ludhiana plant has been running since 2004 and processes 235 tonnes of cattle manure per day. It generates 21000 kWh and 70 tonnes per day of organic manure (Dhussa, A. 2004). It is based on technology from Austria. Imported components included the gas engine, macerator, screw presses, gas holder, some of the spare components for the imported components have been indigenised such as the macerator shaft, mechanical seals, and the sieve cylinders of screw press.

Figure 10 Photo of 1.0 MW power project based on cattle dung at Haebowal Dairy Complex Ludhiana, Punjab (Dhussa, 2004)

India has introduced instruments such as the National Biogas and Manure Management programme (NBMMP) which started in 1981. This provides capital subsidies based on the size and location of the plant. There are now still subsidies for installation of up to 20-40% of the capital cost and a preferential tariff for sale of power. The government also provides capacity building for officials and constructors assists in information dissemination and provides sponsorship for further research. Policy support from the Electricity Act 2003 includes targets for renewable energy, open access to the grid for renewable energy as well as other fiscal incentives from government.

The Biogas Sector Partnership (BSP) in **Nepal** started in 1992 and won an Ashden award in 2005 for its successful roll out of biogas plants. The funding comes from Holland (SNV and DGIS), Germany and the Nepalese Government (through AEPC). By December 2007 BSP had installed 172,858 biogas plants (mainly domestic scale units) of which 95% are operational. It also provided support to over 70 private biogas companies and helped develop 16 biogas appliance manufacturing workshops. The standard 6m^3 plant costs between £170(ZAR 1900) and £220(R2400) depending on the location of the plant. The BSP subsidy system operates in such a way that wherever you live, you pay £120 (approximately ZAR1400) for your digester. One third is paid off in manual labour from the owners of the plant and the remaining £80 is taken out in the form of a loan (and usually paid back within 18months). Up to 6000 people have been trained to construct digesters. The combination of good installations, affordable finance, support and quality checking has led to very high success rates for biogas plants in Nepal (Ashden Awards, March 2006).

In **Kenya** many small biogas digesters have been installed however there have been problems with keeping these plants operational. It is estimated that only 25% of 300 units installed between 1980 and 1990 in Kenya are operational today. Njoroge (2002) suggests the high failure rate is due to poor design and construction of digesters as well as incorrect operation and maintenance caused by poor ownership responsibility by the end users. Furthermore project developers have had weak project monitoring and follow-up strategies whilst failing to disseminate information. There is also failure by government to support biogas technology through a focused energy policy.

The Ibadan Plant, **Nigeria** uses wastewater from an abattoir to provide cooking gas for local households. The project is expected to generate 1,500 m^3 of biogas per day and to capture 900 m^3 of pure methane per day. This is equivalent to a reduction of greenhouse gas emissions from the slaughterhouse of over 22,300 tonnes of carbon dioxide per year. In addition, the sludge from the plant will be used as organic fertiliser (Steets, 2008). The Ibadan plant will be one of the larger biogas installations in Africa, providing gas to 5,400 families a month at around a quarter the cost of liquefied natural gas (Brown, 2006).

Interesting case studies of installed biogas units as well as innovative biogas incentives can also be found in developed countries. In **Poland** the Ministry of Economy has recently unveiled a program entitled Innovative Power-Energy Agriculture (The Bioenergy Site, 2009). The aim of this programme is to create an enabling environment that encourages the increase of agricultural biogas plants for heat and electricity. Currently the legalities are being finalised so that the biogas from agriculture can be fed into low pressure gas lines, to increase distribution to rural areas. The biogas would also be eligible for certificates of origin (green electricity certificates). To speed up construction, changes have also been made to planning regulations so that agricultural biogas plants can be classified as public purpose investment projects. The Power Energy Agriculture Programme initiative comes out of the EU Directive 2009/28/EC which requires Poland to achieve 15 percent of energy from renewable sources by 2020 and a 10 percent share of renewable energy specifically in the transport sector.

Austria has seen a large increase in agricultural biogas plants due to the introduction of feed-in tariffs between 10.3 and 16.5 Cents€/kWhel into the grid, which are guaranteed for a period of 13 years (Green Electricity Act, 2002). As a consequence, the number of plants rose from 119 at the end of 2003 to 231 by the end of year 2005 (Braun et al., 2007). These plants use mainly energy crops (silage) for digestion. However as the focus has been on electricity feed-in tariffs rather than efficient conversion of biomass or gas for heating, there is often wasted heat energy produced in the cogeneration units. Therefore, in many cases up to two thirds of the available technical energy potential remains unused (Madlener et al, 2009).

In **Germany** by 2007 there were 1280 MW of installed biogas capacity and approximately 3,750 installed biogas plants (Burgermeister, 2008). As much as 20 percent of Germany's natural gas needs could be supplied from biogas by 2020 (Burgermeister, 2008). Germany has favourable feed-in tariffs for electricity and more recently for the national gas grid. Könnern, East Germany, claimed to be the world's largest biogas plant installed in September 2009. It processes 120,000 metric tons of substrate (renewable raw materials and manure) every year from 30 different farms, to produce more than 500 million cubic feet of biomethane. This amount is sufficient to supply about 10,000 homes with heat and electricity or about 9,000 cars with an annual mileage of 18,600 miles (Weltec Biopower, 2009). Biogas contains about 60 % methane and 40 % CO_2 while natural gas contains about 97 % methane. At Könnern a new technology has been introduced which filters out the CO_2 and increases the proportion of methane in the biogas. At the end of the process, the biogas is 99 % biomethane and can therefore be fed into the grid.

Previously biogas had to either be converted into electricity for national distribution or the gas used locally as a heating gas i.e. for local swimming pools, buildings etc. Since the Gas Network Access Ordinance (GasNZV) was amended by the German Federal Government in 2008 and in line with the Renewable Energies Act (EEG), biogas suppliers have the privilege of connection and feed-in to the national gas grid (Weltec Biopower, 2009). In contrast to wind and solar energy, this utilisation manner also ensures seamless, permanent energy supply to end consumers (The Bioenergy Site, 2008).

One of the world's biggest biogas plants is the Huckabay Ridge Renewable Natural Gas facility in Texas, **USA**, where 635,000 MMBtu (186.05309 GWh[10]) of biomethane is generated from cow manure and other organic waste and has been fed into the Enterprise natural gas pipeline since January 2008 (Burgermeister, 2008). It consists of eight anaerobic digester units and produces pipeline-quality renewable natural gas (RNG(R)). The company is delivering RNG(R) to Pacific Gas and Electric Company (PGandE) under the previously announced long-term purchase agreement that will run through December 2018 (PR Newswire, 2008).

Looking at these international case studies has provided some insight into the different national approaches to increasing biogas programmes – some large, some small, some successful, some not so successful. The success of biogas projects in India is due to the support from domestic policy which provides financial incentives and capacity building opportunities. The larger projects such as that Ludhiana, Punjab, still rely on hardware to be imported from Austria - a conventional North-South transfer of technology. However without the domestic government support this may not have been enough to succeed in implementation and scaling up. The Nepalese Government was also significant in collaboration with foreign funding bodies to provide financial subsidies on the capital cost of the units. As well as incentives the construction of the units required participation from the end users which provides stronger ownership once the unit is operational. Good workmanship coupled with effective quality control practices have also contributed to the Nepalese biogas sector partnership (BSP) winning international recognition for its success. The uptake of biogas in Kenya was not as successful, primarily for the lack of those

[10] http://www.hessenergy.com/dashboard/conversionCalculator.aspx

interventions present in Nepal. Rather it suffered from bad construction techniques, poor engagement from the project developers and lack of government support.

Looking at the developed country examples, much of the support for biogas comes from policy decisions and in particular effective renewable energy feed-in tariffs. Germany aligned its policy framework to allow both electricity and gas to be fed into their respective national grids. The refining of already advanced technology to increase the quality of the biogas is incentivised by such feed-in tariffs. The incentive for Poland's interest in biogas is also stimulated by the national renewable energy target, and the necessary legislation in the planning sector has also been tailored to accommodate a faster paced construction programme of biogas units. In Poland there are also efforts being made to allow gains from biogas as electricity or gas to be made, either with feed-in tariffs or renewable energy certificates. The USA case study in Texas also relies on feeding biogas into the natural gas grid, whereas in Austria although the electricity feed-in tariff has had a positive effect on the uptake of biogas technology, it does not include the feed-in of gas therefore the efficiency of the end use biogas is not maximised. The only African case study presented is that in Nigeria, which demonstrates the potential for revenue generation and emissions reduction from integrating large industrial waste streams to meet local energy needs

4.4. International biogas CDM projects

The CDM market has in some countries been a useful tool in some countries to increase the installation of biogas projects, particularly due to the high methane content in biogas which has a GWP of 25. Methane emissions resulting from a variety of human activities account for 14 percent of global GHG emissions and make methane the second most important GHG after CO_2 (Methane to Markets, 2010) see figure below.

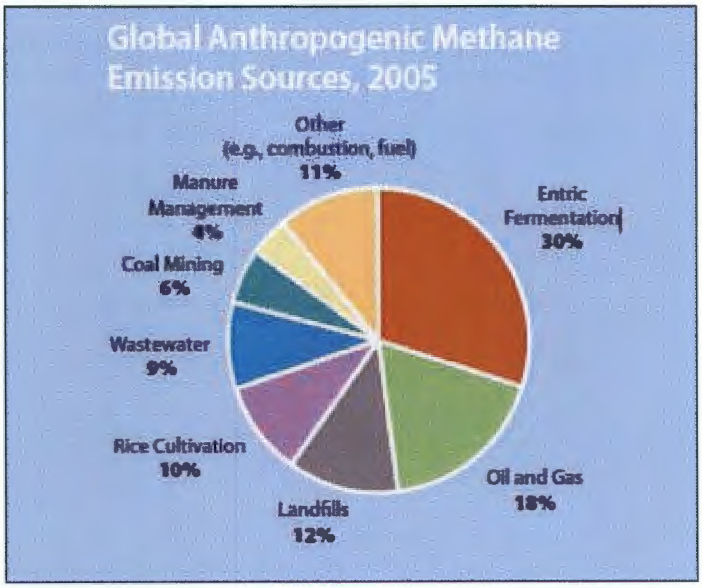


Figure 11 Global Anthropogenic Methane emissions, 2005
(source: Methane to Markets)

In Mexico, biogas is the most popular project type for CDM projects with 69 biogas recovery from agriculture projects existing. The average project size is 31 $ktCO_2eq$ totalling 2146 $ktCO_2eq$ per year (Dechezlepetre et al, 2008). Brazil has 20 registered CDM biogas (from agriculture) projects with the average project size being much bigger at 74 $ktCO_2eq$ and an annual reduction of 1477 $ktCO_2eq$. In India agricultural biogas projects contribute 7 to the national CDM portfolio – an average project size of 32 $ktCO_2eq$ with annual total reductions of 224 $ktCO_2eq$. There are also efforts being made in Nepal and India to generate CDM credits from programmatic roll out of smaller units.

As for most project types, a minimum project scale is required to make CDM projects economically attractive. The viability of a biogas CDM project depends on the baseline emissions calculation (which has changed over the last few years), the onsite energy demand of the plant, the energy mix of the country, the transaction costs and the price of the carbon credits. In South Africa it is assumed that the minimum size for an agricultural biogas CDM project to be viable is a farm with 1000 cows (Wright, 2009).

4.5. Summary

Generating energy from biogas combines environmental, social and economic benefits with the potential to be applied at a variety of scales and is suitable for agricultural, domestic or industrial locations whether in a rural or urban setting. This offers potential in South Africa to address some of the environmental needs around waste management, reusing water and providing good quality agricultural fertiliser to improve farming techniques. Smaller and medium scale projects offer small business opportunities around the collection and distribution of input and output resources respectively. Incorporating biogas in larger scale projects at an industrial scale provides an opportunity for reduced expenses incurred from landfill tipping fees and onsite energy costs. Emissions could also be significantly reduced which would make projects eligible for carbon revenue.

From the international case studies it has been possible to draw useful lessons to consider when developing the transfer and uptake of biogas technology in South Africa.

Building on the topics from Chapter 2, in terms of **enabling environments** one of the most noticeable aspects in the cases of successful biogas programmes is the importance of good government engagement and policy support. This includes providing financial incentives such as feed-in tariffs and providing capacity building and training.

From a technical capacity perspective good workmanship and quality control in construction is also important – particularly in developing countries where quality control is not standard practice. If the necessary skills or equipment are not available locally, international experts should be brought on board as necessary. By involving the end user in the design and construction process and the design of financial arrangements increases social awareness and long term ownership and thereby increases the local **absorptive capacity of the technology.** Furthermore good end user engagement practices increase successful operation and maintenance of the plant.

The different case studies also show the **innovative** approaches to using existing waste streams to meet local energy needs as well as the potential exploitation of carbon revenue as methane is such a high emitting greenhouse gas.
It also demonstrates the innovative approaches used internationally towards mitigation efforts by using an existing waste stream as a fuel source and thereby reducing emissions from methane released into the atmosphere. These approaches have however not been evident in South Africa to date. There have been feasibility reports and studies done into the potential of biogas in South Africa (see Chapter 5) for industrial, agricultural and domestic applications, however the number of biogas plants operational is still limited. It is not obvious exactly what the reasons are for this discrepancy between potential and installed units in South Africa, which is why these issues will be explored further in the following Chapter.

The points identified in this chapter rely on a literature review of existing projects across the world. This provides context for how biogas technology can be applied and supported from a national and international level and establishes activities which have contributed to the successful implementation of biogas technology. It will also contribute to assess how practical experiences compare to the proposed supportive activities from an international mechanism.

The next chapter considers further case studies overseas and in South Africa, but this time the data is based on site visitors with stakeholder discussions with those involved in biogas projects. The aim of this is build on information gathered in this chapter but to add empirical information of practical barriers as to why biogas may not have been deployed into South Africa.

Chapter 5: Setting the Scene: Empirical Data From a National and Local Level in South Africa.

5. Setting the Scene: Empirical Data from a National and Local Level in South Africa.

Chapter 4 introduced the concept of energy from biogas and presented case studies of existing biogas projects presented in literature to provide an international overview of aspects that could be useful to guide the biogas sector in South Africa. However, the underlying approach of this research is to use empirical information from a national and local level in South Africa and relate it back to the decisions being taken at an international level. The first part of this chapter focuses on ascertaining the national status of biogas in South Africa. The second part focuses on obtaining an insight at a local level.

There is some activity in the South African biogas sector, yet the level of implementation to date has been low. Understanding the national status of biogas in South Africa requires an assessment of existing policies and initiatives, industry reports, identifying key players in the biogas sector and an overview of the installed biogas portfolio in South Africa. Data from a local level was based on discussions with relevant stakeholders and site visits. The data analysis is presented in relation to the main aspects of the technology transfer debate as identified in Chapter 2 in order to start the process of aligning the practical information and the more abstract debates around technology transfer.

5.1. Status of biogas in South Africa: A national perspective

As urbanisation increases in South Africa, the quantity of waste water and municipal solid waste is growing. This puts pressure on the landfill site capacity and increases methane emissions as well as causes ground and water pollution (Agama Biogas, 2009). Furthermore it was estimated a report by Agama Energy (2007), that potentially for biogas could supply more than 300 000 rural South African households with waste-to-energy production to meet their cooking needs whilst eliminating long journeys to collect firewood for cooking.

Yet, although the potential for biogas in South Africa has been identified (as will be further explored within this chapter), the biogas sector in South Africa has yet to make its mark on national or rural energy supply. There have been feasibility reports undertaken by NGO's and academic research centres, interest shown from carbon developers as well as attempts at implementing initiatives to promote the uptake of biogas in South Africa. There is a lot of research, literature, design and demonstration of successful biogas projects exist internationally. Biogas technologies offers the potential to contribute towards South Africas sustainable development agenda, beyong minor activity, project implementation has been limited. The following section aims to investigate for what reason biogas has not become a significant technology in the country.

In order to build a profile of the status of biogas from anaerobic digestion in South Africa, a review was undertaken of installed biogas units and biogas sector actors involved in current biogas activities. A brief review of incentives from institutional or policy that could support the roll out of biogas technology was undertaken. The scope of this paper however, does not permit an exhaustive review.

5.1.1. Feasibility studies on South Africa's biogas potential

Beyond the physical installations, feasibility studies into the potential of biogas from waste in South Africa have also been prepared by a variety of organisations. Some of the most prominent and publicly available reports have been summarised below to provide useful information relating to the barriers to implementation.

A study titled **Energy from Wastewater – A feasibility study** (Burton, et al, 2009) prepared by the University of Cape Town for the Water Research Commission, provided an assessment of the potential of energy generated from wastewater in South Africa. The report concluded that an estimated 10 000 MWth [11] can be recovered from the wastewaters of the whole of South Africa, representing 7% of the current Eskom

[11] Megawatts of thermal energy

electrical power supply (approximately 140 000 MWth or 42 000 MWe)*, *however*, since most of the waste streams are widely distributed, the energy from wastewater is best viewed as on-site power.

Many wastewater treatment plants in South Africa already having anaerobic digesters installed as part of the treatment plant as it is part of the effluent cleaning process, however, the biogas generated as part of this process is often vented or flared as the focus is not on energy generation but on ensuring the quality of the discharged effluent, thereby missing an opportunity to reduce GHG emissions. At the Cape Flats wastewater treatment facility, the biogas generated on site is used to help dry and pelletize the wastewater sludge in order to reduce disposal costs. These pellets have a very high energy content (16.6 MJ/kg) and are currently used by the Pretoria Portland Cement Company Ltd. (PPC) factory as a fuel source in their combustion kilns. This highlights that there is not a focus on onsite energy generation – the biogas and the wastewater pellets are merely side product. The feasibility study has shown that the Cape Flats WWTP generates enough biogas to meet its basic onsite energy requirements. It is also interesting to note that this study discusses the *energy* potential of biogas, yet it was commissioned by the Water Research Commission, demonstrating the multiple sector interest in biogas.

This study identifies general barriers to implementation of biogas projects in South Africa which include the perception that biogas technology is highly complex, and although the technology is well established internationally, the lack of demonstration projects in South Africa hinders large scale implementation. Additionally the technologies operational overseas may need to be adapted to local conditions in terms of maintenance and operational requirements for distributed systems. Furthermore the skills base to build, operate and maintain larger biogas plants does not exist in South Africa. Even at a Government level capacity building is essential so as convey the importance of designing legislation to be less prohibitive of public private ventures and also to speed up the time it takes to approve Environmental Impact Assessments. Access to third party funding from sources such as the DME, the Eskom Demand Side Management fund or the CDM mechanisms, is also highlighted as a problem to realising the implementation of these projects. The lack of an operational feed-in tariff was also given as a limit to viability of biogas projects.

Agama Energy prepared a report titled **Biofuels in the City of Cape Town** (Agama Energy Pty, 2007) along with the UNDP, City of Cape Town and Stellenbosch Sustainability Institute. It focuses on energy from waste opportunities in the city of Cape Town in particular at the Athlone Refuse Transfer Station (ARTS) and the nearby wastewater treatment facilities (AWWTW). From just the Organic Fraction of Municipal Solid Waste (OFMSW) coming through the ARTS, 25,000m^3/day of biogas (with a 55% methane content) could be generated. Each m^3 of biogas is assumed to be sufficient to generate 1.7KWh_e this equates to 14.3GWh_e/year. Including additional biomass from invasive weed programmes in Cape Town, a plant size of 2.1MW_e generating 17.5GWh_e/year could be feasible. The AWWTW (across the road from the ARTS) already has existing anaerobic digesters, but need significant upgrading if the biogas potential is to be realised. Each day 10,000m^3/day of biogas with a methane content of 65% will be produced – enough for a 830kwe generator to supply 6.9GWh/year. This study recommends that the projects would be financially viable providing the necessary legal framework within the City of Cape Town is set up, particularly in allowing for private and public partnerships

Another Agama report is '**Sustainable Cities: Biogas Energy from Waste: Guidelines Report**' (Agama Biogas, July 2009). This was geared towards municipalities and provided a toolkit for Municipal officials to assess the opportunities from liquid and sewage waste. The report focus is on-site waste management and optimising co-treatment of OFMSW and wastewater facilities. It presents a summary of the cross cutting policy areas related to biogas including waste management, municipal by laws and renewable energy policies (briefly introduced in 5.1.5).

Under the **Biogas for a Better Life** programme, feasibility studies were undertaken for 13 African countries including South Africa. The South African feasibility report was completed in 2008 by Agama along with Julio Castro and Suresh Hurry (Biogas for a Better Life, 2008). The lessons learned from biogas experiences in Africa suggest that having a realistic and modest initial introductory phase for Biogas interventions, taking into account the convenience factors in terms of plant operation and functionality, identifying the optimum plant size and subsidy level and having provision for design adaptation are key factors for successful biogas implementation in Africa (Biogas for a Better Life, 2008). The feasibility study stated there is the potential for 310,000 rural households to benefit from biogas units.

The CSIR recently published a paper **Unlocking the resource potential of organic waste: a South African perspective**. The barriers to implementation are suggested to range from budget restrictions to lack of effective bylaws and insufficient skills development (Greben and Oelofse, 2009). According to this study the real incentive for using the anaerobic digestion technology to digest organic waste and generate energy will no doubt arise with the present and future predicted increases of electricity costs as well as with the increase of the world oil/energy prices and more importantly, due to the forecast shortage of national electricity supplied by Eskom (Greben and Oelofse, 2009).

According to the above reports there are opportunities for biogas in South Africa, particularly on a large scale at waste transfer and wastewater facilities. Below is a summary of the quoted potential energy capacity from various biogas sources.

Figure 12 Quoted potential for biogas capacity

Feedstock	Quoted potential capacity	Reference	Notes
Wastewater to WWTP	850 MWth	Energy from Wastewater – A Feasibility Study	Municipal WWTP load consists of captured domestic backwater, domestic greywater and industrial wastewaters.
Households (rural)	310,000 households Estimate: Approximately 680GWh/yr of thermal energy	Biogas for a Better Life	i.e. rural cattle Assume 6m3 digesters, produce 1m3 biogas/day, 1m3 biogas = 6kWh thermal energy
Agricultural Cattle in feedlots Piggeries Poultry farm	3906MW th 79 – 215 18 – 715 940 – 2976	Energy from Wastewater – A Feasibility Study	Excluding rural cattle Use high range

The data above are figures stated in the literature. It can be seen that there is a range in the estimates – particularly in the agriculture sector. In order to obtain a rough estimate in terms of primary energy potential and the potentially avoided CO_2 emissions, the following assumptions have been made:

- Rural cattle have been omitted from the 'agricultural' category as these are assumed to roam freely and some will be included in the household digesters.
- The energy content of methane is 55.6MJ/kg (Burton et al, 2009)
- The biogas plants run at approximately 75% of the time
- To calculate the avoided emissions from burning methane a GWP of 25 has been assumed as it is from a renewable energy source
- It is assumed 25% of the energy is used for electricity generation with a conversion efficiency of 30%

- A grid emissions factor for electricity of 1kg/kWh has been used
- There is potential for more mitigation from displacement of other thermal energy sources, but this has not been assessed.

Table 5 Estimated energy potential and emissions avoided from biogas

	MWth	MWHth/yr	MJ	PJ/yr	t methane	t CO_2/yr	Mt Co_2/yr avoided from burning biogas	Mt Co_2/yr avoided displacing grid elect	Mt Co_2/yr avoided total
Wastewater	850	5584500	2.01E+10	20.1042	361586.3	9039658	9.0		
Rural household		680	2448000	0.002448	44.02878	1100.719	0.0		
Agricultural(high)	3906	3.4E+07	1.23E+11	123.1796	2215461	55386518	55.4		
Agricultural (low)	1037	9084120	3.27E+10	32.70283	588180.4	14704511	14.7		
				High	Total (High)		64.4	3.0	67.4
				Low	Total (Low)		23.7	1.1	24.8

The above figures are only indicative, given the poor availability of accurate data, but these do indicate that there is potential for energy from biogas to contribute to avoiding 24.8 – 67.4 Mt CO_2 /yr, towards South Africa's mitigation efforts. In terms of the Long Term Mitigation Scenarios (LTMS) (SBT, 2007), there is an opportunity to re-adjust certain wedges to incorporate biogas in the modelling. However as this rough estimate has been modelled on an annual basis, further extensive modelling would be required to obtain accurate data over the LTMS modelling period. Initial indications are that in terms of the LTMS analysis, biogas would be a significant contributor to mitigation in South Africa if measures outlined in the above reports were fully implemented.

This short review of feasibility studies and proposed figures for energy from biogas, has highlighted that there is significant potential for biogas in South Africa; however, much further assessment will need to be done to verify these estimates to accurately assess the actual potential. The following section considers the actual installed units currently to consider how much of this potential has been realised.

5.1.2. Installed portfolio

It is difficult to obtain accurate data on the number of installed biogas units in South Africa given the number of small private installations that may not be recorded, the lack of regulation and the lack of centralised data on the numbers of operational biogas units. However, based on data provided by Agama Biogas, personal site visits and other publicly available data, the table below gives an overview of installed units to date.

Table 6 Installed anaerobic digester biogas units South Africa (courtesy of Agama Biogas 2010 and own data)

Scale	Location	Digester size (unless otherwise stated)	Substrate	End use	Year
Household	eThekweni	$10m^3$	Toilet sewage, manure from 3 cows	Cooking for family of 8	2000
	Lynedoch Ecovillage Stellenbosch	$11m^3$	Toilet sewage, organic household waste and institute waste	Cooking in 1 home	2004
	De Goode Hoop Estate, Nordhoek,	$8m^3$ and $6m^3$	Toilet sewage from 2 homes and manure from 3 horses	Cooking in home and potentially electricity	2007
	Stanford Valley Farm Conference Centre,	$11m^3$	Toilet connections from 30 people, restaurant waste, manure	Cooking in restaurant	2006
	Stanford Household	$6m^3$	Sewage and Food wastes	Household sewage and food waste	2007
	Stanford Bodhi Khavi	$8m^3$	Sewage	Cooking gas	2008
	Giyani, Limpopo	In use: (1x)4,6,$8m^3$ Commissioned: (1x) 8, $15m^3$ Under construction: 6,8,8,$15m^3$ Total= $68m^3$	Cow manure	Cooking gas for 12 households, a church & a school	2009
Wastewater and Sanitation	Goedgedacht Farm, Riebeck Valley	$20m^3$	Toilet connections 100 people, restaurant and food waste	Cooking in restaurant and lighting	2007

	Cape Nature conservation: sewerage upgrade at Groot Winterhoek	11m³	Sewage from 56 people, food waste from houses	Cooking in communal kitchen	2005
	Cape Nature conservation: sewerage upgrade at Vrolikheid nature reserve	8m³	Sewage and food waste	Cooking in communal kitchen	2007
	JoJo Senior Secondary school	Sanitation digester; 15m³, energy digester 30m³	Sewage from toilet block, food waste, cattle manure from community	Cooking gas in kitchen/bakery	
Small to medium agricultural	Dundee Research Farm	16m³	2400 litres water from washing 11 dairy cows	Cooking gas in kitchen	2004
	Ecabazini, KZN	20m³	Manure from 25 cows in a kraal & additional organic waste	Replaces LPG for fridge & cooking and supplement the driving of the diesel powered pump	2006
	Backsberg Wine Estate, Paarl	20m³	Chicken manure	Potentially vehicle fuel	
	Pateni residents (x 10 HHs)	6m³	Cow manure	Gas: cooking. Slurry: food production	2009
	Zakhe Agricultural College	6m³	Sewage	Gas cooking	2009
Pre Fab 6m3	Winford Farm	6m³	Sewage and food waste	Gas: cooking. Water: food production	2009
	Goedgedacht Estate	6m³	Sewage and food waste	Gas: cooking. Water: food production	2009
	Stellenbosch	6m³	Sewage and food waste	Gas: cooking. Water: food production	2009
	Somerset West	6m³	Sewage and food waste	Gas: cooking. Water: food	2009
Industrial	Petro SA (CDM)	4.2Mwe Capacity (approx 25,700 MWh/yr)	Refinery process waste	Electricity	2007

	SABrewery Alrode	9200 m3 produced each day	Process Wastewater and organic waste	Used to power large onsite boilers	2009
	SA Brewery Rosslyn (CDM)		Onsite wastewater digester	substitute part of the coal consumption at the boiler room,	
	Cato Manor	$280m^3$	Sewage, OFMSW, Chicken litter	Not yet commissioned	
	Humphries Pig Farm, Limpopo	Small amount of onsite electrical generation	Waste from piggery	Partly operational & under CDM registration process	2009
		Total;	*Approx 35 installed units*		

The above table shows the location, application, size, substrate and end use of the biogas units. The majority of projects are relatively small scale and rely on onsite waste collection and generate a cooking gas for onsite use. According to this review less than 40 biogas units (using anaerobic digestion) are installed in South Africa. This is by no means a comprehensive list, but the difficulties in compiling this information highlighted the need for a central database of biogas projects in South Africa. It is however evident that the number of installed units is very low relative to some of the international country examples also well below the identified potential in the previous section (5.1.1).

The last few years has seen some larger scale units being installed across South Africa. SA Breweries now has anaerobic digesters installed at their Rosslyn and Alrode Breweries in Gauteng. The Alrode brewery currently produces five-million litres of effluent a day, with an organic load of 25 t/d., to generate 9200 m^3 of biogas per day. A two-stage anaerobic digester was installed on site which converted 90% of the organic matter into biogas with a methane content of 85% (SA Good News, 2009) which then feeds into biogas powered boilers. SAB Miller claims to now burn 10.4 fewer tons of coal per day and therefore saves approximately R7000/day on fuel costs.

Biogas Clean Development Mechanism projects in South Africa

In 2006 two biogas projects gained CDM registration –the Rosslyn Brewery fuel-switching project and the PetroSA biogas to-energy project (25 Degrees Net, 2006).

The Rosslyn fuel switch project aims to replace the use of coal with natural gas and biogas that is currently flared (DME, 2005), which requires an upgrade to plant in the existing boiler room. Currently there is an anaerobic digester generating biogas from the wastewater, which is being flared. Carbon credits are generated by using the biogas and the waste heat from previously flaring the biogas for replacement fuel in new boilers thereby offsetting the emissions from of coal boilers.

The PetroSA project was launched at the state-owned PetroSA's gas-to-liquids refinery near Mossel Bay. This is South Africa's first independent power project funded by carbon credits. The biogas produced from the wastewater treatment is burned in the reciprocating engines displacing coal based electricity therefore reducing CO_2 emissions by 33,000 tonnes per annum for the life of the project.

The 4.2 MW biogas-to-electricity plant was developed and financed by MethCap, the Central Energy Fund, and NRG, a group of empowerment investors (van der Merwe, 2007).

Humphries project has applied for CDM status but it is not yet crediting as a CDM project.

Biogas CDM projects from livestock have been successful in Brazil and Mexico but agricultural biogas CDM projects have not yet proved viable in South Africa. Kerry Wright of Cleaner Climate South Africa suggests the lack of agricultural CDM biogas projects in South Africa is due to open kraal farming practices (which are inappropriate for collecting manure) as well as smaller commercial farm sizes. Farms with dairy herds numbering at least 1 000 cows or livestock farms with more than 8 000 pigs and 80 000 poultry begin to create a viable CDM (Wright, 2009). Coupled with complicated project registration processes and high transaction costs for methane-capturing projects this makes many projects financially unviable. Many of the farmers contacting carbon developers are too small to warrant CDM projects.

Investors are risk averse at the moment due to the recession; the perceived unpredictability of biogas makes it a risky investment from an investor's perspective. Therefore, there is currently little demand for carbon credits from agricultural biogas in South Africa (Wright, 2009).

5.1.3. Biogas sector players in South Africa

A significant part of this thesis research was trying to identify the key players in the South African biogas sector so as to establish a group of informants and stakeholders. Determining who these were was not a straightforward exercise as a national biogas body, such as the ones in Germany or Nepal, does not exist in South Africa. The number of informants grew over the course of the research process – this highlighted the lack of awareness and information sharing (in terms of sharing information about who is doing what, what has been done before, who knows about what, sharing designs and experiences) amongst those players. It also demonstrates that more people are recognising, or trying to tap into, the potential benefits of biogas.

To provide an overview of some of the key informants who provided input into this thesis this section briefly introduces some of the actors from research, private sector, and NGO sector who are currently or have recently engaged in biogas projects in South Africa. Again this is not an exhaustive list but it demonstrates the cross section of players showing interest in the South African biogas sector.

Agama Biogas[12] (part of Agama Energy Pty) is one of the most experienced private consultancies in the South African biogas market. They have been responsible for designing and installing the majority of units listed in Table 3 as well as preparing extensive feasibility reports for the biogas opportunities in South Africa for national and international clients. They have amongst other things recently launched the Biogas Pro which is a patented prefabricated household biogas digester unit and have also prepared a design toolkit for municipalities to identify biogas projects in their region.

Bio2Watt [13] is a South African company whose technical partner is Waste Solutions Ltd in New Zealand. Bio2Watt is currently involved in projects across South Africa including the Bronkhorstspruit Biogas Project, Western Cape Biogas Project, and Sol Plaatje municipality Waste Water Treatment Plant. Their aim is to form partnerships with industries, the agricultural sector and local municipalities to consolidate and confirm the viability of developing waste to energy projects in South Africa.

CAE Energy/Organenergy[14] has recently installed a demonstration gas engine generating electricity from the biogas generated from pig manure at the Humphries Piggery in Limpopo. **Talbot and Talbot** [15] **are** an environmental engineering firm based in Pietermaritzburg who have been involved in the installation of four anaerobic digesters in the food and beverage industry.

Ecosecurities [16] and **Agcert** [17] **and Cleaner Climate**[18] are all carbon developers who have looked into the viability of carbon credits from biogas projects in South Africa.
In Limpopo the NGO **Mpfuneko Community Support** [19] is working with local suppliers and training local workers to install community biogas units.

The **Agricultural Research Council in** Pretoria focuses mainly on the engineering aspect of biogas digesters (design, input load etc.) and how to physically construct the digesters. They tested manure from different sources and consequently designed a Biogas Design and Operational Manual from the data. They have also designed and installed digesters for different clients.

It can be seen that there are a variety of stakeholders who are interested in the biogas sector in South Africa, however, what proved particularly interesting from the process of identifying the key players is that many were not aware of eachother's existence within the sector. This highlighted the lack of information sharing between organisations and also the lack of a central body to provide support in the dissemination of information.

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[13] http://bio2watt.com/
[14] http://organergy.co.za/cae_energy/index.html,
[15] http://www.talbot.co.za/
[16] www.ecosecurities.com
[17] www.agcert.com
[18] http://www.cleanerclimate.com/
[19] http://www.idsfoundation.org/mfuneko.html

It also became evident that the motivations amongst the stakeholders for installing biogas in South Africa varied. As a renewable energy source with the potential to increase energy access and reduce deforestation (from fuel wood use), biogas technology has an element of being a public good. Therefore many NGO's and research centres have been interested in increasing its uptake. Carbon developers however are more likely to be interested in larger mitigating biogas projects as this generates larger carbon revenue from the sale of carbon credits. The private sector will be involved in promoting both large and small projects, but will ultimately be concerned with protecting their commercial interests. These factors are important when considering the facilitation of increasing the transfer and uptake of biogas technology into South Africa. The various views from stakeholders and interventions that they would find useful for increasing biogas technology have been summarised in Table 7 in section 5.2.6.

5.1.4. Other biogas initiatives in South Africa

Beyond a review of the feasibility reports, policies and looking at installed units, it is also interesting to look at biogas related initiatives driven from a national or international level.

The **Biogas for a Better Life: an African initiative** was established through the Dutch NGO SNV, and a feasibility study for South Africa was prepared. The initiative has since been superseded by the **Africa Biogas Partnership Programme** which is still run through SNV in partnership with Hivos (SNV, 2010) but now only focuses on supporting national biogas programmes in Ethiopia, Kenya, Tanzania, Uganda, Senegal and Burkina Faso; South Africa is no longer a focus country under this programme. The aim is to provide about half a million people access to a sustainable source of energy by the year 2013.

Following on from the Working for Water and Working on Fire initiatives, the South African **Working for Energy** MTEF (Medium Term Expenditure Framework) budget 2009-12 submission was launched at the end of 2009. The proposed programme would be co-ordinated by the Department of Minerals and Energy, in partnership with the Departments of Public Works, Water Affairs and Forestry; Environmental Affairs and Tourism, and Agriculture (Department of Minerals and Energy, 2009). The aim of the programme is to support labour intensive energy projects on the demand and supply side. Particular focus is given to biogas generated from household and agricultural waste, alien species and wastewater. Technology partners are currently submitting proposals of suitable demonstration projects that would be eligible for funding under the programme. SANERI (South Africa's National Energy Research Institute) [20] are managing the Working for Energy (WfE) initiative however by the end of 2009 the Department of Energy had not yet released the funding for WfE and a Memorandum had not yet been signed, therefore there are no projects that have been approved or are currently being implemented.

Originally started in 1998 as **Programme for Biomass Energy Conservation** (now *Programme for Basic energy and conservation)* **ProBEC's** implementing agency is GTZ (GTZ, 2010) and is led through the SADC Secretariat, Infrastructure and Services Directorate. ProBEC promotes a switch to renewable energy sources through the introduction of biogas, solar cookers, and fuels which include crop residues. It aims to increase access to energy for low income rural and urban households, businesses and institutions in an environmentally sustainable manner.

The fact that initiatives have been driven by both foreign funders and at a nation level, demonstrate that there is recognition that biogas in South Africa has potential. Unfortunately although initiatives have been attempted in South Africa, to date they have not been able to get off the ground in the same way that other programmes had (e.g. Nepal (also funded by SNV)). There is little publicly available information as to why these initiatives have not effectively been scaled up, but it is a safe assumption that it is at least partly due to the recurring themes of lack of financing, suitable enabling environment, and technical knowledge.

As touched upon in section 5.1.3, biogas technology cuts across different policy arenas. The following section establishes some of these existing policies.

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[20] The Department of Science and Technology, together with the Department of Minerals and Energy, are joint custodians of SANERI and assist in providing political and strategic focus for the company.

5.1.5. Policies relevant to biogas in South Africa

The process of generating energy from organic waste cuts across legislative and policy-writing capacities from different government divisions including waste, energy, agricultural and wastewater management. The policy drivers vary in different countries- in the UK the landfill tipping fees are very high (waste policy), in Germany the feed-in tariff is well established for electricity and gas (energy policy) whereas in South Africa the main motivation for installing anaerobic digesters which produce biogas is to treat sewage sludge and water to a suitable discharge level. This makes biogas technology very interesting in terms of understanding the importance of policy integration.

Currently a national policy target specifically for biogas in South Africa does not exist. Some of the policies, primarily from the waste and energy sectors, which could allow space for biogas initiatives to evolve, are outlined below.

Energy Policy

The **White Paper on Renewable Energy** (DME, 2003) recognises the benefits of using waste for power generation and refers to electricity from sugar mill bagasse and paper mill waste. It acknowledges the organic components in municipal and industrial wastes streams as useful fuel sources. The energy content of the total domestic and industrial refuse disposed of in 1990 amounted to 40.5 PJ per annum. Furthermore the net realisable energy available from sewage-derived methane in South Africa would be in the order of 36 MWh (1.13 PJ) per annum for electricity generation and 96 MWh (3.0 PJ) for heating purposes (DME, DANCED, 2001). Austin et al (2006, in Greben 2009) suggests that as biogas is a renewable energy, it can contribute to the South African government's 10-year goal of 10 000 GWh of cumulative renewable energy contribution to final energy consumption by 2013.

The South African **National Energy Act 2008** calls for the establishment of a Renewable Energy Division responsible for establishing programmes and initiatives to increase and promote the uptake of renewable energy technologies. Under the Bill the Minister may "institute measures and incentives designed to promote the production, consumption, investment, research and development of renewable energy and may establish a renewable energies subsidy and grant fund". Biological waste is included under its definition of renewable energy (Republic of South Africa, 2008) therefore this bill could support initiatives related to biogas.

The **Free Basic Alternative Energy** (FBAE) policy document defines this to be "any other form of basic energy excluding electricity (including solar home system) deemed necessary to support basic energy needs of an indigent household" (DME, 2004). Biogas aligns with the policy objectives around social, environmental, and basic energy access. The energy carriers mentioned are LPG, Paraffin, Coal, Bioethanol gel, however reference is made to the fact that this list of energy carriers in not exhaustive, therefore biogas could be adopted as an eligible energy carrier.

The first phase of South Africa's **Renewable Energy Feed-in Tariff** (REFIT) was approved in March 2009 and in November 2009 the national energy regulator NERSA issued a media statement confirming that Biogas has been included in Phase two of the REFIT (NERSA, 2009). The agreed tariff is R0.96/kWh.

Waste Policies

The **Polokwane Declaration** (DEAT, 2001) on waste management in South Africa calls on a reduction in waste generation and disposal of 50% and 25% respectively by 2012 and zero waste by 2022 as well as a focus on recycling and growing the recycling industry by 30% by 2012. Incorporating biogas plants into waste strategies can assist in reducing pollution from waste water and waste streams into the environment and reduction in waste disposal sent to landfill.

The **National Waste Management Strategy (DEAT, 1999)** aims to increase integrated waste management planning, waste collection; improve waste treatment and disposal as well as minimising waste and increasing recycling by 2010 whilst building capacity within the waste sector to undertake these activities.

The **Integrated Pollution and Waste Management Policy for South Africa** (DEAT, 2000) promotes a reduction in pollution from waste and encourages cooperation between government and private sector to achieve a common goal.

When considering larger scale biogas projects particularly from waste water or requiring large amounts of water flowing in or out, Water Policies such as the **National Water Act** (DWAF, 1998) and **Water Services Act** (RSA(c), 1997) would have to be taken into consideration.

A more detailed review of national and provincial and municipal by-laws supporting or hindering the implementation of biogas was undertaken in a report by Agama in 2009 (Agama Biogas, 2009). It suggests policy makers should recommend the following with respect to energy from waste at a municipality level:

- Carbon revenue can make large anaerobic digestion possible
- Integration into effective sanitation goals and free basic alternative energy policy
- A standard implementation agency is required as is skills development and capacity building in energy from waste projects
- Demonstration projects would help pave the way
- Better waste data collection is required
- Cumbersome regulatory issues have led to the lack of successful projects
- Municipal Finance Management Act imposes constraints on public-private partnership.

Summary

It can be seen how biogas technology relates to policy decisions in the energy, waste and water sector. The above policy recommendations listed by Agama Biogas are a useful starting point in informing an appropriate policy environment for biogas in South Africa. Although current policies include waste reduction targets and renewable energy targets, it is still apparent that, for example, energy prices and landfill tipping fees remain too low to incentivise efficient use of waste for energy. With the increase in pressure to reduce global greenhouse gasses along with the electricity crisis in South Africa, integrating policy alignment to improve the enabling environment for the uptake of biogas technology would be a useful contribution.

The feasibility reports that have been undertaken show that there are opportunities for biogas projects in South Africa for domestic, agricultural and industrial applications – 10,000MWth available from biogas from wastewater, and the potential for 300,00 rural homes to benefit from domestic digesters. Although based on the number of actual installed biogas units, this potential is still far from being realised. The majority of installed units are small scale; however there has been an increase in larger scale projects such as those at Petro SA, where the CDM mechanism has been a contributing factor.

Not only is there a cross section of policies relevant to the biogas sector but also a cross section of interested stakeholders, with different motivations, which adds to the complexity of understanding how to facilitate better transfer and implementation of biogas technology.

Section 5.1 has touched upon existing activities and initiatives in the South African biogas sector as well as introduced related reports which look into the potential of biogas in South Africa. Some key players have been introduced and an overview of the policy environment has been given. This has provided a useful insight into the current status of the national biogas interventions in South Africa.

Section 5.2 will now move on to explore the localised context of biogas implementers and use discussions with stakeholders and site visits to gather further information on the practical implementation barriers.

5.2. Data: Gathering and analysis

Having undertaken a review of the status of biogas in the South African context this section follows on from section 2.1.5 which introduced the importance of stakeholder engagement and understanding end user needs in successfully transferring technology. Site visits and discussions with stakeholders at various locations across South Africa, Germany, Sweden and the UK were undertaken. Beyond the site visits, phone interviews and email dialogue were also held with representatives from Ecosecurities, Agcert, and Cleaner Climate, which are all carbon developers with experience in CDM Biogas projects at an international scale and have considered trying to expand their biogas portfolio to include South Africa.

The purpose of this is to gain different insights into the practical issues, incentives and barriers from various stakeholders' perspectives in order to identify how relevant the barriers identified in technology transfer literature are to 'real-life' case studies. The set of relevant issues from the technology transfer literature identified in section 2.1 have been used to organise the data. The following section applies these technology transfer issues to biogas case studies and uses them as a framework to organise the main observations from site visits. This assists in synthesising the overall biogas findings with the topic of technology transfer.

Where possible sites in South Africa were visited, however as there are not many installed units in South Africa it was valuable to visit sites in Europe – particularly larger commercial biogas facilities. Despite the limited number of local sites, they provided ample opportunity for observations. The level of information varied depending on the time spent with the stakeholder and the level of access into the facilities.

Table 7 Site visits conducted as part of the research

Application	Location	Comments	Country	Level of access	Date
Industrial	Bran Sands Sewage works	Biogas used to generate onsite electricity	United Kingdom	Short walk around facilities and presentation from project manager	July 2009
	Cape Flats Sewage Works	Anaerobic digester used for treating the sludge, some biogas used to heat the digester	South Africa	Brief meeting with site manager and walk around external buildings	May 2009
	Athlone Sewage Works	Anaerobic digester used for treating the sludge, biogas vented	South Africa	Group visit around the site	2008
	Bromma Sewage Works	Biogas used for transport	Sweden	Discussion onsite with engineer	December 2009
Agricultural	Triesdorf Research Centre and Agrikomp site	Biogas used for electricity generation onsite and feed into national electricity grid	Germany	Meeting with professor and visit to construction site of new unit	June 2009
	George, Private Farm	Potential site with interested client	South Africa	Visit around the dairy farm and discussion with farm owner	September 2009
	Elim (Stanford)	Potential site for biogas from community sewage works and dairy farm	South Africa	Walk around small dairy and sewage works with official	Oct 2009

Domestic	Nordhoek Private home	Private home using horse manure and food waste	South Africa	Home visit with installation engineer	May 2009
	Giyani, Limpopo	Community scale biogas projects being constructed	South Africa	A whole day on various sites with project manager	October 2009

Figure 13 Photo: Dairy farm in George, potential biogas site

Figure 14 Photo: Elim farm, Western Cape, potential biogas site

Figure 15 Photo: Bromma sewage works and biogas pump

Figure 16 Photo: Community scale biogas, Giyani, Limpopo

As outlined above the following analysis is based on the technology issues raised in section 2.1 which were: enabling environment; technical and absorptive capacity; innovation; and IPRs. This is followed by a section on the role of CDM in the South African biogas sector.

5.2.1. Enabling Environment

The projects visited were in countries with individual enabling environments in terms of policy drivers and financial incentives at a national level which support the uptake of biogas technology. The following section draws on observations related specifically to the enabling environment in that particular country.

Biogas has been produced in Sweden since 1932 as a by-product from the stabilisation of municipal sewage sludge. This was originally used for heating as well as for power production although sometimes it was necessary to flare it (Persson et al, 2006). However in 1991 a CO_2 tax was introduced. From 1996 the generated biogas was used as a fuel for transport (Persson et al, 2006). This means that the biogas is actually cheaper to produce than transport fuel from imported fossil fuels. There is an extra 2.34 kronor = R2.40 per litre on a tank of petrol from CO_2 tax (Fouché, 2008). Currently the oil companies in Sweden buy the biogas at a reduced price (i.e. *excluding* the CO_2 tax), upgrade it and then sell it at a price which tracks the oil price (i.e. *including* the CO_2 tax).

For the agricultural biogas sector in Germany, the incentive is very much driven by rising energy prices, the desire for energy security and a very effective feed-in tariff into the national electricity grid. The feed-in tariff enables farmers to generate income from selling off any excess electricity or gas generated. More recently the feed-in tariff has been extended to allow for biogas to be fed into the national natural gas grid. This has not been as straightforward as the biogas has to be refined so it can freely mix in with the natural gas supply. The Koennern case study introduced in Chapter 4 outlines some of these incentives.

In the UK, large scale biogas digesters such as at Bran Sands are eligible for Renewable Energy Obligation certificates (ROCs)[21]. The project is eligible for ROCs worth R21million (Agama, 2009), which contributes to the projects viability. Also as the cost of tipping waste to landfill is also constantly increasing, incorporating an onsite biogas digester significantly reduces operational costs and justifies the upfront capital cost of the biogas technology as a longterm investment.

These enabling environments do not exist in South Africa. In South Africa, many of the sewage works have anaerobic digesters primarily to ensure the discharged effluent attains the necessary environmental standards: the generation of biogas is merely a by-product. However, as there are no penalties for allowing methane to escape into the atmosphere, electricity is cheap, tipping fees to landfill are low and there are no demonstrated feed-in tariffs, there is little incentive to maximise the use of biogas.

The project in Giyani particularly struggled due to the lack of institutional and financial support at both a national and international level. International funding streams for biogas digesters are being directed to Asian countries where labour and material costs are lower, therefore more projects can be realised in Asia than in South Africa for the same amount of money. Also the project is too small to benefit from international CDM or voluntary carbon mechanisms as the transaction costs are too high. At a national level, the lack of feed-in tariff in South Africa as well as end user subsidies for capital costs of the installations are slowing down a larger scale roll out at Giyani. However recently the ICCO [22] in the Netherlands agreed funding for the construction of 60 biogas digesters (15 m^3 digester volume) supplying 180 households, a church and a school with biogas.

At a municipal level it has also been shown the Municipal Finances Act makes it difficult for private sector investment in industrial biogas applications. In November 2009 the REFIT Phase 2 accepted Biogas, however to date there are no projects in operation which are benefiting from it.

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[21] A green certificate issued to an accredited generator for eligible renewable electricity generated within and sole in the UK One ROC is issued for each megawatt hour (MWh) generated. http://www.ofgem.gov.uk/Sustainability/Environment/RenewablObl/Pages/RenewablObl.aspx
[22] www.icco.nl

Cilliers (2009) reports that although numerous enquiries are made for biogas as a replacement fuel. However due to the lack of capital subsidies from Government, farmers particularly in rural areas cannot afford the upfront cost of the equipment, and in areas where the Eskom grid is present, biogas is still more expensive than electricity. However in areas where there is no grid biogas becomes a viable energy source (Cilliers, 2009).

From these site visits, it was evident that national policies or incentives such as a high CO_2 tax, feed-in tariffs or ROC's in the case of the UK, were all important drivers of an enabling environment supportive of biogas technology. South African projects on the other hand were suffering from lack of financial incentives and funding from both a national and international level. Without a feed-in tariff the larger projects in particular become unviable. Furthermore a lack of suitable policy drivers that incentivise using biogas to generate energy limits the demand and motivation to install biogas technology. These issues must be considered when designing a national or international mechanism geared towards increasing biogas technology in South Africa.

5.2.2. Technical and absorptive capacity

The technical and human capacity requirements vary depending on the application of the biogas unit whether in an industrial, agricultural or domestic context.

At the two South African sewage works that were visited- Athlone and the Cape Flats - anaerobic digesters which produce biogas are already installed on site. However the main motivation for anaerobic digestion on both sites was to ensure the discharge sewage was of a necessary environmental standard, not energy generation. At the Cape Flats some of the biogas is used to heat the reactors, however, due to old technology and the fact that capturing the biogas is not the main incentive from having the digesters, the biogas is not being maximised for energy use. At Athlone the biogas from the digesters is not currently being captured at all. In both cases feasibility studies into the viability of using biogas for onsite energy generation, have been undertaken by external parties. Discussions with the site manager at the Cape Flats Works highlighted an evident lack of technical capacity in regards to understanding the necessary steps for upgrading the facilities to include the additional plant required to efficiently convert the biogas into useful onsite energy. Without an in-house champion who fully understands the process of tendering and commissioning for such work and can pioneer the implementation of the necessary biogas technology, no projects are currently being considered. The informant who was said to be the most informed on the potential for onsite biogas was also not clear how they could access finance for the capital costs for the additional plant and furthermore there were no incentives to implement a biogas unit. As a contrast, the sewage works visited in Sweden and the UK has onsite engineers who were specifically appointed to manage and operate the biogas generating plant, and even in one case subcontracted out a full time maintenance engineer directly from the supplier of the biogas technology.

It was not possible to visit existing agricultural biogas plants in South Africa however two sites where farmers were interested in installing biogas digesters were visited in the Western Cape and an operational agricultural biogas plant was visited in Germany. The problems identified by the potential project implementers began with the initial stumbling block of not knowing where to start when wanting to build a biogas digester. At the German site, this is overcome by having turnkey biogas providers who offer everything from initial quotes, designs and construction, to maintenance services and also training programmes for the farmers to manage their own facilities. In South Africa it is a different story, as the biogas sector is not large enough to have generated Turnkey providers. Agama Biogas is one of the most well known biogas companies in South Africa, yet they are not a 'turnkey' operator as such as they would still employ other local construction companies to build the digesters, and then separate maintenance contracts would also be agreed upon.

At a domestic level the technical design and construction of a digester does not require high-tech designs or equipment, or highly skilled construction skills. At the community scale project in Giyani, a dome shaped digester based on the Cambodian model from SNV (van Ierland, 2009) was chosen as this is a low technology solution where all materials can be sourced locally and construction skills can be developed locally – the workforce consisted of diggers, construction workers and one site manager. Finding a competent site manager and reliable work force proved a challenge when trying to use local skills. The digester itself is made from handmade bricks, plaster, PVC inlet and outlet pipe.

The workforce required to build the digesters were a mix of diggers and construction workers with one site manager. At Giyani, managing a consistent and efficient workforce was not straightforward. A conscious effort was made to train the workforce and there were incentives for those that worked well including promotions or bonuses. However often labourers did not turn up for work or did not follow instructions – ignoring the importance of quality of work. It was also difficult to find a reliable local site manager who realised the importance of an efficient and effective workforce.

The three households tapping off one digester have direct pipes from the roof of the digester dome to their kitchen. At this stage only cow dung is being fed into the digester sewage and organic waste is being excluded to avoid confusion to those feeding the digester. Biogas can be used to cook in conventional LPG stoves which are very straightforward and low cost to convert (biogas needs less oxygen introduced than LPG therefore the oxygen inlet in the LPG stove needs to be adapted to make the inlet smaller for using biogas). However finding an appropriate meter to monitor the cooking gas production and consumption has not been successful yet - the tested meters was damaged from the additional level of water in the methane gas.

The equipment or 'kit' required to construct biogas plants can vary depending on the complexity of the actual plant design. A simple dome construction digester requires bricks, cement, concrete and pipe work, whereas a high tech industrial plant may require a high level of electrical components or mechanical paddles which may need to be imported.

It was evident from the case studies that the level of technical capacity varied depending on the application and scale of the project. The skills required for small scale digesters are low and therefore particularly appropriate in rural South Africa where the skills base is not so high. In terms of larger units, there would be benefits in collaborating with international partners.

Issues of **absorptive capacity** were in the ability to operate and understand the biogas units as well as the social acceptance of the technology. In Giyani some of the installations were not running to optimal efficiency as end users were not fully aware of the importance of feeding the digester on a daily basis. This was addressed by education through demonstration and where possible incorporating end users in the local construction process. At the larger potential sites such as sewage works, education and training would also be required to ensure smooth operation of a biogas plant.

Social acceptance varies depending on the country and the end use application of the biogas. As mentioned in chapter 2, social acceptance contributes to the absorptive capacity of a technology at a local level. The site visits provided the opportunity to speak directly to stakeholders and end users and in particular get a greater insight into the social acceptance aspects.

It became evident from the site visit to Triesdorf, Germany, that there is wider accepted socially to have a biogas digester. They have the expression from *'Bauernwirt zum Energiewirt'* i.e. from a farm manager to an energy manager. The concept is sold as a no-brainer for farmers to become energy independent and save on costs, and there is a great demand from farmers wanting to install digesters. There is more resistance however when biogas is considered for domestic use. Domestic biogas applications are very uncommon not only because the cost is still too high but also because users would not be willing to risk the potential intermittency of energy supply. The generation of biogas relies on a constant waste stream being fed in, however even a few days of insufficient input can cause downtime in supply. Unlike South Africa where consumers, particularly in a rural setting, are used to intermittency in household energy supply, this would not be socially acceptable in Europe.

In the case of using biogas as a transport fuel, the onsite engineer at Bromma, when posed the question of 'Are people happy to use Biogas when they know it's from human sewage?' seemed very surprised. This was not a problem that seemed to have featured in their planning. Consumers only seemed concerned with having a fuel supply which is easily accessible through pumping stations, reliably available and comes at a reasonable price. Some end users in South Africa raise the question about the smell of the biogas, however at Bromma the biogas itself does not have any odours; in fact they have to add a smell so that a leak can be detected.

At a household level in Giyani, the social acceptance regarding the use of cow dung to generate cooking gas, was not a barrier in itself, but there was very much a 'sit back and see' attitude where villagers wanted to see the digester work successfully first. Electrification also affected the requests for digesters – some of the villages in that area had only recently been electrified and therefore there was no desire for an alternative energy source at this stage as the novelty of electricity was still too great.

An encouraging component of this research was the interest shown amongst South African stakeholders towards the uptake of biogas digesters. This attitude is due to the recognised benefits – for farmers there was the opportunity of reduced energy costs, energy independence, manure management, improved fertiliser and reusing water. For industrial operations such as municipal sewage works, it was the revenue from onsite power generation thereby reducing operating costs, reduced landfill costs and also revenue from carbon credits. At a household level biogas could provide a good solution to restricted energy access and reducing energy costs.

The observations have confirmed that social acceptance at the end user level is an important dimension of the absorptive capacity and successful uptake of a technology. Furthermore, social acceptance varies depending on the country, the cultural perception and the application of the unit. Acceptance is likely to be higher if biogas offers improved energy supply or reduced energy costs.

5.2.3. Innovation

The overarching observation is that the innovation witnessed in the case studies differs to the concept of innovation stipulated in literature, however there was definitely innovation occurring.

From the German case study two of the most noticeable innovations, were the emergence of the 'turnkey' supplier model, and secondly the collaboration between an agricultural research centre and a series of turnkey suppliers. The agricultural research centre runs specific training courses in the operation of biogas units for the landowners. The founder of the turnkey company (Agrikomp) was originally trained at the Research Centre and maintains a close relationship with them as they are able to fund demonstration and testing laboratories which complement work being done by the research centre. Educational videos for end users are also produced, obviously as part of a marketing strategy but as it includes information on the process of biogas digestion, the benefits, and the process of commissioning a plant, it acts as a useful tool for awareness raising.

The Bran Sands plant in the UK treats up to 40,000 dry tonnes of sludge per year in three 6,300 m³ digesters and generates 4.7MW of electricity from biogas. It uses Thermal Hydrolysis (THP) and applies a high temperature of 165°C combined with high pressure (6 Bar) (Neave, 2009) for less than one hour- this is very fast bearing in mind retention time can take a matter of days under normal temperature conditions. This level of innovation requires high capital investment, and a dedicated maintenance engineer on site.

At the sewage works in Bromma, Sweden, the onsite engineer explained that the motivation for generating biogas to be used as a transport fuel was due to a high national CO_2 tax and also natural resource constraints in Sweden. Most sewage works therefore had to find innovative ways reducing costs and avoiding the CO_2 tax by capturing emissions through the biogas process and maximising an existing fuel source - waste.

In the Giyani region, biogas offered an innovative approach for dealing with the large scale deforestation from fuel wood gathering. Cooking gas from biogas uses cow manure and eliminates the need for fuel wood. A 15 m^3 digester should produce about 10 hours cooking time and be able to boil over 50 litres of water. This project relied on an existing digester design from Cambodia but the innovation lay in the modification of the design to allow for locally available and cheaper materials. The payment framework is also innovative in that it deals with the problem of raising finance for the capital cost as the project was designed to also offer a contract option. Users can either pay the full amount for the installation upfront or pay fixed monthly payments for a biogas supply straight to their homes.

Agama energy has recently developed a prefabricated Biogas Pro unit which allows off the shelf purchasing of a domestic biogas unit in $1m^3$ or $6m^3$ sizes. This cuts out the bespoke design process and prepares them for large scale roll outs as well as single household purchases. These units are also appropriate for different urban or rural contexts.

The outcome of discussions with a regional Department of Agriculture in South Africa, was that they were motivated to install biogas demonstration projects and eventually roll out a regional scale biogas programme as they believed this would be an innovative approach to dealing with climate change issues and diversifying the opportunities of the farming sector. They saw an innovative biogas programme as an opportunity to increase their regional competitiveness through leading by example and increasing regional awareness of climate change issues.

South Africa may not currently be at the leading edge of early stage R&D innovation, such as the projects at Bran Sands in the UK or Koennern in Germany; but there have been signs of innovation. The opportunity and capacity for innovation lies in the application of systems innovation to an existing technology through for example increasing the number of demonstration projects, financing models, disseminating information and raising awareness.

5.2.4. Intellectual Property Rights

In many cases the stakeholders when asked whether they had encountered barriers due to 'IPR' were not actually familiar with the term, which implies that it is not a particularly significant issue. In some cases smaller South African companies aiming to be entrepreneurial in the biogas sector, partnered with foreign companies who had given them exclusive rights to use their technology designs. Agama Biogas who are more established in the South African biogas market, have recently developed the Bio Gas Pro which now has patents filed in a selected few African countries- there were costs associated with filing the patents but this was not a significant obstacle. It was not possible to find an example of a project where IPR laws or patenting proved to be a critical stumbling block to accessing technology for a biogas project.

The most evident issue in terms of IPR was the protection of tacit knowledge; this contributes to the lack of information sharing but in some cases is regarded as necessary for industrial competitiveness. The level of information sharing therefore depended on the position of the organisation, whether it is a small start up or larger private company or an NGO primarily aiming at increasing awareness through sharing information to stimulate the uptake of the biogas technology. In general accessing information across the South African Biogas community was not easy as there was not a platform available to do this. This leads to problems like the Giyani project where rather than using a South African developed design, the digester design used eventually had to be based on a Cambodian design courtesy of a Dutch organisation SNV. Being based in a rural setting in Limpopo, the project manager of Giyani was also not familiar with national initiatives such as the Working for Energy scheme or the phase two of the South African feed-in tariff – which highlights that information about these initiatives struggle to reach those in the field, particularly in a rural setting. Furthermore for most stakeholders international interventions such as the UNFCCC Technology Mechanisms or the IEA agreements were not familiar to them (see section 3.3).

Aside from the site visits, discussions were also held with carbon developers to ascertain how an international CDM mechanism under the UNFCCC, which has successfully supported biogas in other countries (such as Mexico and Brazil), is related to the South African biogas sector.

5.2.5. Experience of biogas CDM in South Africa

Discussions with carbon developers highlighted that there was a clear distinction between CDM projects for biogas from landfill and biogas from commercial agriculture farming – where small scale agriculture was different again. For commercial agricultural projects, which have proved very successful CDM projects in places such as Brazil and Mexico. The inability to maximise CER's stems from South African farming practices. In Brazil and Mexico large scale agricultural farming keep the livestock on concrete surfaces at all times – maximising collection and flushing of the cow dung. In South Africa, however, the practice is to allow cattle to roam freely in the fields and only bring them into kraals for feeding times (approximately 5-6% of the day) thus limiting manure collection potential and thereby reducing the amount of CER's that could be generated, making the project less viable. · Biomass (i.e. manure) is a natural and therefore potentially unpredictable energy source. As soon as the manure stands for some time it loses a lot of its volatility i.e. Methane. Furthermore the CDM methodology has become more stringent which makes the calculation process lengthier and allows fewer CER's to be awarded. Also due to methane corroding the original monitoring equipment stipulated by the CDM there are now more stringent and costly requirements on the monitoring equipment. The CDM registration and transaction costs are also still very high therefore much larger projects are required before it becomes viable. Therefore commercial agriculture in South Africa has not demonstrated significant potential for carbon developers.

For landfill projects there appeared more scope in South Africa as the CDM methodology is less complex and the quantities of methane are much more predictable and larger, therefore more CER's can be claimed. Domestic scale biogas has not been significantly explored by carbon developers as this is unlikely to be viable until the programmatic CDM process has been strengthened. According to one of the carbon development consultants, adoption of the programmatic CDM could potentially provide an opportunity for community biogas projects between agricultural landowners. However by bundling projects for programmatic CDM farms must be within close proximity to avoid duplication of infrastructure.

In South Africa, the lack of feed-in tariff or confidence in Power Purchase Agreements (PPA's) also slows down the uptake of Biogas. Although biogas features in the second phase of the REFIT there are logistical concerns about the actual metering equipment. Carbon developers said that there was also concern amongst consumers that a new government may withdraw the REFIT making the investment risks high. Reliable PPA's would make farmers' projects more viable, as even if the price of carbon credits were low, Eskom or an IPP would give them good money for their additional electricity. Outside investors in carbon projects like low risk, high return projects, and currently Biogas is high risk and low return, and less attractive following the recent financial crisis.

The potential for CDM increasing biogas in South Africa depends on the application. Agricultural CDM projects are partly limited due to the open kraal farming techniques where domestic CDM projects will require the programmatic CDM methodology to be approved. Maybe the biggest potential for CDM biogas in South Africa is in the industrial context – which is slowly being realised as can be seen at the PetroSA and Mossel Bay projects discussed in Table 5.

5.2.6. Findings from overall stakeholder feedback

Below is a tabulated overview of the findings following discussions with stakeholders in the biogas sector in South Africa. It highlights the different motivations and perceived barriers towards a successful biogas programme in South Africa. Recommendations have been made on how to accommodate and support the different requirements. These 'on the ground' insights can be used to assist in formulating appropriate interventions to support a biogas programme. These findings help to demonstrate the varying requirements alone within one technology group, in one country, within a very small sample of stakeholders

Table 8 Feedback from South African biogas stakeholders (compiled by author)

Stakeholder	Motivation for Biogas Programme	Barrier to Biogas Programme (Perceived)	Recommendations for building a nationally appropriate tech mech
Farmer/Landowner	Energy Security Energy Independence Reduce electricity cost Manure Management Water re-use Improved soil quality	Capital cost Lack of knowledge Insufficient demonstration projects No turnkey provider/point of contact/don't know where to start	Assistance with capital cost Guaranteed mentor partner Training Information provision Technical assistance
NGO	Energy poverty Energy provision Waste and water management MDG's Job creation	Lack of technical knowledge Access to financial needs Insufficient construction skills	Technology Partnerships Funding for demonstration projects Training programme for NGO
Carbon Developer	Great CDM potential (Methane GWP 25) Proven CDM methodology International success	High transaction costs Complex CDM methodology Expensive monitoring equipment SA Farming practices (load too low and hard to collect) Lack of PPA's and Feed-in tariff for farmers	Assist with CDM costs - especially transaction and monitoring Accept smaller methodologies/bundled etc. Support PPA's Support enabling environment
Government (Regional)	Diversifies farming practices Meets climate change agenda Job creation Regional development Farmer upliftment	Lack of implementing agency Lack of technical capacity Lack of knowledge Other priorities Too high risk and low return? Lack of demonstration	Offer soft loans or lease equipment (either International Technology Mechanism to Government or Government to farmers) Train staff to facilitate implementation I.e. technical training and procurement contracts Allow collaboration with private partnerships with expertise

Private Consultancy (e.g. Agama, Bio2Watt)	Lots of opportunity for Biogas in SA Have the technical capacity Part of their core business Could be market leaders Sell credits	Lack of policy incentives for clients Therefore lack of demand Low energy costs in SA (No turnkey construction company?) Lack of funding (Patenting?)	Assist change in enabling environment to allow private investors (Assist in patenting costs?) Large scale programme funding (I.e. Working for Energy?)
Foreign Partner (I.e. Agrikomp, PlanET, Waste Solutions	Large opportunities in SA Assisting global climate change agenda Pioneer in SA Knowledge sharing Growing business internationally	Policy environment not conducive/consistent for foreign investment Need SA partners to part fund - not always easy Lack thorough understanding of SA enabling environment Cheap electricity in SA makes alternative less competitive Not confident in consistency of policies yet - i.e. feed-in tariff and PPA's	Bring international experts in on training SA stakeholders Use international expertise to advise a 'Biogas Taskforce'Assist in building technology partnerships I.e. in this case Germany/India/Holland/New Zealand with SA for Biogas

The above results demonstrate the diversity of different stakeholder requirements with regards to why they would be interested in a biogas technology being transferred into South Africa and their perception of why it has not yet become a significant technology.

Beyond the stakeholders listed above the views of other parties that may also have different motivations is also interesting to consider. Eskom, for example, the South African utility provider, could use biogas in circumstances where it is cheaper than extending the national grid and contributes to meeting rural or off grid electricity targets. The Technology Innovation Agency (TIA) do not have a specific biogas remit however they could regard a successful biogas programme as an opportunity to apply an innovative approach to deployment of low carbon technologies. It could strategically position itself to become a technology transfer point of contact from the top-down international mechanism. From a global perspective i.e. the UNFCCC, the mitigation potential may not be as high as other larger technologies such as wind or solar, however it does address both mitigation and adaptation goals and is a low tech existing technology which lends itself to large scale deployment. In terms of other international development priorities it addresses rural and urban energy security, reduces waste and water consumption, offers job creation and improved farming practices.

The above highlighted the different needs of national and international stakeholders across academia, government, private sector. This emphasises the complexity of dealing with needs of different stakeholders within one technology domain. From these multiple stakeholder observations and views it is possible to extract the barriers specific to whether the biogas application is in the agricultural, industrial or domestic sector at a national South African level. These now follow.

Table 9 Barriers in the South African biogas Sector (compiled by author)

Application of Biogas	Implementation Barriers	Incentive options
Agricultural	-No feed-in tariff -No turnkey provider or one-stop-shop for support -Electricity prices still cheap -Current farming techniques not appropriate for CDM, CDM methodology too stringent and transaction costs too high to make CDM viable -Access to finance	-Operationalise Refit Phase 2 -Provide international subsidy for CDM registration and transaction cost -Improve enabling environment to increase demand of biogas units and appropriate financial incentives to increase suppliers. -Encourage international technology collaborations
Industrial	-High capital cost -No incentives: Low tipping fees and no CO_2 tax -Motivation for biogas digesters are for waste management not energy generation -Municipal by law limits private sector involvement -Lack of knowledge and awareness -Lack of feed-in tariff	-Implement environmental policies which increase tipping fees and CO_2 tax. -Adapt municipal bylaws to encourage public-private partnerships -Operationalise Refit Phase 2 Build on international expertise
Domestic	-Lack of social awareness -High capital cost -Lack of technology suppliers -Cheap electricity price -Lack of knowledge and awareness	-Develop innovative financing packages for end users -Educational and information platforms for end users -Provide incentives for

5.2.7. SWOT Analysis

Using information from stakeholder discussions and current literature, a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis for the biogas sector in South Africa was prepared. Where Table 6 took into account the opinions from different stakeholders of the biogas sector and table 7 summarised barriers specific to the application of the biogas unit, this SWOT analysis aims to extrapolate and illustrate the main cross cutting issues surrounding the lack of implementation in the South African biogas sector.

Strengths	**Weaknesses**
• Methane reducing • Improved fertiliser • Urban and rural scale • Industrial, agricultural and domestic application • Social, environmental and economic • Operates on a variety of existing waste streams	• Capital costs still high • Lack of awareness of the technology • Lack of demonstration projects • Sharing of information in SA • Technical logistics of feeding into grid • Farming practices
Opportunities	**Threats**
• Small businesses opportunity • Meets off grid needs • Electricity prices are increasing • Feed-in Tariff • Carbon revenue • Integrated waste management	• Removal of feed-in tariff • Bad maintenance of plants (?) • Social Acceptance • Electricity tariffs remain low

Figure 17 SWOT Analysis of Biogas Opportunities in South Africa (compiled by Author)

Regardless of the scale and application of the project or the stakeholders involved, there are certain aspects that are universal. A particular strength of biogas technology for South Africa is the diversity of its application, whether at an urban or rural setting with project sizes varying from small scale domestic households, through commercial or community agriculture operations, up to large industrial plants. By making use of existing waste streams all of these applications capture methane emissions which otherwise would have been released into the atmosphere. Beyond its environmental benefits, biogas can address both social and economical issues which are critical in South Africa, such as waste management, job creation, reduced fuel costs, and better quality water and fertiliser.

Many of these benefits also offer small business opportunities of selling fertiliser or gathering and selling manure. As fuel prices continue to rise in South Africa this technology offers off-grid fuel independence as well as cost savings – which could be further increased once the REFIT Phase 2 is operational. Carbon revenue through the CDM mechanism also offers a great financial incentive for larger scale projects particularly due to methane having a GWP of 25. Many international and South African based carbon developers have been interested in using the carbon market to instigate biogas projects in South Africa. Unfortunately CDM projects have not yet helped leveraging biogas projects in South Africa. The REFIT has also not yet been operationalised therefore this increases the payback period and risk for any investment. Without such incentives there have been few projects installed, and with lack of demonstration projects it means the level of awareness of the technology remains low. Increasing awareness requires disseminating and sharing information, however currently the information sharing network is weak in South Africa.

Social acceptance is also hindered through lack of awareness and education. Without social acceptance many biogas projects will fail due to poor maintenance and operation of installed biogas units. End users are also still sceptical of the benefits of the feed-in tariff, and if fuel prices remain low this could hinder the incentives to increase the uptake of biogas units.

5.2.8. Summary

The first part of this chapter (5.1) was used to identify the current status of biogas in South Africa in terms of installed units, key players in the sector and a review of the cross cutting policy themes. Stakeholder engagement and site visits were the focus of the second half of the chapter (5.2). This added a localised and practical dimension to the information gathered about the status of the South African biogas sector and therefore added a useful dimension to trying to understand what the potential practical barriers are. Furthermore it brought to light potential interventions that could be useful in supporting a biogas programme in South Africa.

Establishing the installed portfolio proved difficult and demonstrated the lack of biogas data and information sharing platforms. It is by no means an exhaustive list but showed that there are operational units in South Africa – although primarily small scale.

The above figures are only indicative, given the poor availability of accurate data, but these do indicate that there is potential for energy from biogas to contribute to avoiding 24.8 – 67.4 Mt CO_2 /yr, towards South Africa's mitigation efforts. In terms of the Long Term Mitigation Scenarios (LTMS), there is an opportunity to re-adjust certain wedges to incorporate biogas in the modelling. However as this rough estimate has been modelled on an annual basis, further extensive modelling would be required to obtain accurate data over the LTMS modelling period. Initial indications are that in terms of the LTMS analysis, biogas would be a significant contributor to mitigation in South Africa if measures outlined in the above reports were fully implemented.

Feasibility reports have been undertaken for isolated and general cases for South Africa. Using the data in these reports a rough estimate showed potential for energy from biogas to contribute to avoiding 24.8 – 67.4 Mt CO_2 /yr, towards South Africa's mitigation efforts. However there is no evidence that these figures stated in feasibility studies are being progressed into implementation phase.
Some of the suggested barriers to implementation in these reports include: lack of demonstration projects and lack of skills, not appropriately adapting technologies for local conditions and inadequate legislation.

Similarly, although there have been some biogas initiatives driven by international partners and national South African bodies, these have not to date instigated large scale diffusion of biogas technology.

A review of the policy environment highlighted that biogas touches upon different policy sectors, from renewable energy to waste, and water management and that the positioning of suitable policy interventions will vary across sectors. This cross cutting policy integration is particularly interesting for biogas and becomes more relevant as the motivations for GHG mitigation and addressing the electricity crisis become more prominent policy considerations.

Using the recurring topics from the technology transfer topics as indicated in chapter 2 and comparing empirical data provided not only a local technology context but also structure to the research findings – which provided a useful basis for synthesising the high level criteria with on-the-ground experiences.

The current policy environment and incentives in South Africa are not currently contributing to an appropriate **enabling environment** needed to support biogas in South Africa, unlike in the international examples where feed-in tariffs and CO_2 taxes are incentives for the uptake of biogas. The landfill tipping fee and energy costs are still relatively low – although this is due to change soon.

The considerations in regard to **technical and absorptive capacity** depend on the scale and application of the biogas technology. Technical complexity increases for larger projects whereas smaller projects are possible using low skilled construction workers and applying basic technical knowledge. Larger biogas plants in the international case studies had project managers on site specifically responsible for the biogas digesters. In the South African example the site managers at sewage works were interested yet largely uninformed of the potential for biogas. The complexity of operating a biogas plant will also affect the absorptive capacity as end users or plant operators need to be able to ensure the digesters are appropriately fed with substrate. Social acceptance also varies depending on the country and application, but is generally higher when benefits such as energy access or reduced energy costs are realised.

The **innovation** observed at the international case studies varied from innovative research and private sector collaborations in Germany to new technology innovations as at the Bran Sands project in the UK. In the South African examples there was also innovation occurring – the financing models in Giyani, and the new pre-fabricated digesters developed by Agama Energy. What became clear is that **innovation varies** across the case studies and also differs from that stipulated in literature. The success of biogas technology is not so much about technology innovation but rather **systems innovation** and **innovative approaches** towards an existing technology.

The findings pointed to **IPR not being such a significant issue** in the biogas domain. Literature has suggested that patenting and IPR issues can be a barrier to implementation however none of the visited projects or the consulted stakeholders suggested that IPR in the form of patenting had been a barrier. IPR issues around protecting tacit knowledge and commercial design information were more of a problem. This is due to the different motivations and commercial interests of stakeholders.

Chapter 2 introduced the importance of incorporating different stakeholders and also the complexity of conveying their opinions. These varying motivations from the **cross section of players** across private, public and research sector are an important consideration when designing an appropriate technology mechanism. Summary tables of different stakeholder views were also developed into a **SWOT analysis.** This provided a more generic summary of the South African biogas sector which is more useful for comparing to the international level, as the stakeholder level is likely to be too much detail for an international mechanism.

This research process has demonstrated that comparing empirical information to the technology transfer topics extracted from literature in chapter 2, a variety of implementation support is needed at different levels. The requirements will vary depending on factors such as the stakeholders, the end users, waste streams and the end use. Going to this level of detail at a national and individual technology level is not realistic for an international mechanism. To that end it begs the question of whether international mechanisms are in a position to dig down to such a level of involvement or whether such country level technology specifics need to be undertaken at a national level in order to identify proposed appropriate interventions.

Chapter 6: Analysis and Conclusion

6. Chapter 6: Analysis and Conclusions:

This research thesis set out to explore what lessons could be learnt from the practical implementation of low carbon technologies to inform the design of an international technology mechanism.

Biogas technology in South Africa was chosen as a practical case study as it is an existing technology which has potential to contribute to South Africa's energy and sustainable development agenda. Furthermore using estimates for the potential of biogas outlined in Chapter 5, there is the opportunity for energy from biogas to contribute to avoiding 24.8 – 67.4 Mt CO_2 /yr, towards South Africa's mitigation efforts; however due to poor availability of data further assessment and extensive modelling would be required to obtain accurate data over the LTMS modelling period. Yet despite its potential for energy provision and contribution to avoided CO_2 emissions, as well as its suitability as a technology to contribute to sustainable development in South Africa, biogas has not yet become a prominent technology.

The suggested reasons for the lack of installed capacity have been lack of demonstration projects, lack of skills capacity and inappropriate legislation. However the barriers to implementation at a practical level have not been studied in depth, making for an interesting example to determine practical barriers specific to one technology in one country in relation to the high level discussions around international technology transfer.

This chapter aims to synthesise the main findings of the research, and conclude how practical experience can assist in informing an international technology mechanism in ways that would increase the transfer and diffusion of biogas technology to, and within, South Africa.

To understand the relationship between the two key themes – international technology transfer in the context of climate change, and biogas technology in South Africa, literature reviews of both international technology transfer and biogas technology were undertaken. Secondly, empirical data was gathered through stakeholder discussions and a series of site visits to existing and proposed biogas projects in South Africa, Germany, Sweden and the UK. The findings from this empirical data were organised around four main themes arising from the review of international technology transfer literature namely: enabling environment, technical and absorptive capacity, innovation and IPRs. This assisted in understanding the significance of these identified issues and also provided a framework for assessing the relationship between practical and internationally perceived barriers to technology transfer. A review of technology initiatives within and outside of the UNFCCC process as well as an assessment of the national status of biogas technology in South Africa assisted in extracting specific activities that could be included in an international mechanism to increase the dissemination of biogas in South Africa.

6.1.1. Analysis of Main findings

The empirical data revealed a series of findings – some directly related to technology transfer issues from literature, others specific to biogas in South Africa.

In terms of the South African biogas sector, patenting or other **Intellectual Property Rights** issues do not appear to have been a significant problem to date. South Africa has a sound Intellectual Property regime therefore patenting could be used as a positive tool to stimulate innovation.

Currently much of the literature around innovation focuses on early stage R&D whereas **biogas technology needs system innovation** in deploying and delivering biogas units. The proposed focus areas of the Technology Innovation Agency and the content of the DST's 10 year Innovation Strategy does not focus on the deployment of existing technologies. South Africa does not currently have a specific biogas institution nor is the Technology Innovation Agency specifically focusing on low carbon technology – which would encompass biogas. South Africa has the opportunity to be innovative in its delivery of existing technology, such as biogas, by building on lessons learnt in early stage R&D and demonstration innovations already explored in other countries.

South Africa's **enabling environment** lacks clear policy or institutional support specifically geared towards biogas technology. In particular without **specific biogas targets or policies** and without an operational **feed-in tariff** the risk is still very high for investors. Furthermore **inappropriate incentives** such as low landfill tipping fees and low electricity costs do not incentivise innovative uses of waste for energy generation. The current Municipal Finance Management Act imposes constraints on public-private partnership in South Africa – this is a barrier at a municipal level which complicates private sector investors financing larger scale industrial projects such as at sewage works in Cape Town.

Necessary **financial incentives will vary for each application of biogas-** at a domestic level access to capital is of great concern, whereas agricultural and industrial projects have a stronger interest in a feed-in tariff or carbon revenue. There was an evident call for assistance from carbon developers in funding the monitoring equipment that is required for agricultural CDM projects, which contributes to CDM projects remaining unviable in South Africa. This is further complicated by **open-kraal farming techniques not being conducive** to collecting manure at scale, which is currently limiting the potential for biogas projects from commercial agriculture. The **lack of existing and demonstration biogas** units in operation and lack of **turnkey providers** in South Africa contributes to low end user awareness and/or understanding of the technology which **hinders the absorptive capacity.** A successful uptake of biogas technology will require the highlighted end user engagement and incentives, education and demonstration projects.

From a skills perspective the **level of training required depends on the application of the biogas unit**. Domestic and community scale units do not require a high level of technical skills, as they only need primarily basic construction skills and an understanding of the operation and maintenance is required. This is particularly useful for smaller scale units in rural locations where the skills base may be low. However for larger industrial scale units some international support may be required for the construction, operation and maintenance aspects.

Beyond those issues steered by the technology transfer issues in literature, the research process has resulted in further lessons that can be extrapolated from the empirical case studies and used to inform an international mechanism to increase biogas in South Africa. Particularly evident was the **lack of information and knowledge sharing** within the South African biogas sector. Firstly, those stakeholders already involved in some capacity in the biogas sector were often not familiar with other current projects, organisations or initiatives. Secondly, stakeholders interested in installing biogas units were in most cases not aware of where to find advice or information on financing or installing a unit.

Furthermore there is an apparent **disjuncture between international technology interventions** and knowledge amongst biogas project developers of how to access or benefit from them. There are international technology interventions which are reaching South Africa - such as the IEA Bioenergy Implementing Agreement and the Global Bioenergy Partnership; however there needs to be substantially more dissemination of information regarding international collaborations so that project implementers understand how they could benefit.

A significant finding was that **different barriers exist for different biogas applications and different stakeholders** across the agricultural, industrial and domestic sector. In the agricultural sector for instance the lack of a feed-in tariff, open-kraal farming techniques, lack of information and access to finance were the main barriers to implementation. On the domestic front, however, access to finance and a lack of awareness of how the technology works were the main concerns. From an industrial perspective high capital costs, difficulty in attracting private investors and lack of incentives for onsite waste to energy generation are the main barriers. These intricacies will be important to understand and take into account when designing a national or international technology mechanism as they preclude a one-size-fits all policy approach.

6.1.2. Conclusion: How these barriers could be dealt with at a national and International level?

The diversity of the findings- ranging from unsuitable South African farming techniques, to a greater need for international technology collaborations, demonstrates that there is a need for engagement at both a national and international level to increase the uptake of biogas technology in South Africa.

Although there remains little clarity on precisely how the interplay of national and international will be dealt with within the technology framework, the research undertaken has highlighted several practical barriers which could be tackled at a national and international level as outlined below. For example the issue of lack of awareness and information sharing amongst stakeholders within the South African biogas sector is something that needs to be dealt with at a national level rather than necessarily an international intervention.

National level engagement

To address the weaknesses in **information sharing platforms** within the South African biogas sector, the dissemination of information on national biogas activities would benefit from a facilitation network providing a transparent database of 'who's done what', as well as linking up suppliers, funders and project developers. Providing a "one-stop-shop" to establish Biogas partnerships within South Africa would enable the end user to create own linkages with knowledge and potential supplier and partnership information. A central **biogas body and implementing agent** or a **national level technology network** could compile and disseminate information on national biogas activities. This would stimulate domestic collaborations and capacity. **National level technology action plans** and **national technology task forces** as proposed in the introduction Figure 1 would also be a useful tool to obtain a more detailed overview of what is happening within one technology sector in one country and enable project developers and end-users to plan ahead.

A South African **national technology transfer office** specifically focusing on low carbon technologies with an understanding of the UNFCCC process, could assist biogas implementers to access funding or international technical support, as well as provide advice on IPR related issues. This would address the **disjuncture** between international and local initiatives.

To increase social awareness of and demand for biogas, **demonstration projects** and **appropriate incentives** need to be implemented. For example placing demonstration units within regional agricultural departments or educational facilities would significantly raise the profile of the technology. Incentives such as higher gate fees at landfill sites for instance should be considered in order for it to become attractive to install biogas units. In addition to these incentives, ensuring the **REFIT Phase 2** becomes operational would contribute to an appropriate **enabling environment.**

Aspects which would be useful in an international mechanism

Beyond these national interventions, an international mechanism could provide essential resources and support. A review (in Chapter 3) of the UNFCCC draft addendum -/CP15 text (UNFCCC(e), 2009), the country submissions to the UNFCCC, and interventions outside of the UN process, provided several activities that could potentially support biogas implementation in South Africa, and are outlined below.

Firstly with regard to the lack of **information sharing,** draft decision -/CP15 proposes to increase access to publicly available information on existing and emerging technologies. The UNFCCC secretariar would act as a clearing house to facilitate the exchange of information[23]. The Australian submission to the UNFCCC as well as the CGIAR and IEA Bioenergy frameworks also support the notion of increasing information sharing platforms. Furthermore the suggested **technology centres and networks** and **technology innovation centres**[24] in the -/CP 15 draft and also the EU proposal to the UNFCCC could incorporate a particular biogas focus and act as an information sharing platforms. The draft text -/CP15 also suggests promoting collaborative action through North-South, South -South, and triangular technology partnerships. Furthermore it suggests establishing cooperative partnership arrangements with public/private, regional and international technology centres[25] to build up information sharing and capacity within the South African and across the international biogas sector.

As biogas technology is not a new technology the focus on i**ncreasing the deployment of existing technologies and enhancing endogenous capacities** and technologies of developing country parties by promoting cooperative research and demonstration programmes[26], as suggested in draft -/CP15, would be beneficial. From an international level, the biogas industry in South Africa would benefit more from **technology cooperation** geared towards the diffusion of existing technology rather than primary R&D.

International technology collaborations such as those suggested by the draft CP15 text as well as the IEA Bioenergy and M2M initiatives, would also assist in allowing South Africa to build on R&D and demonstration projects which have already been undertaken internationally. The draft -/CP 15 proposal suggests facilitating international partnerships where **technical assistance and training is provided in-country to support identified technology actions** in developing country Parties on request. This would be very beneficial for larger biogas units such as in sewage works which may require support from experienced international companies with the necessary experience who may contract out their staff to train and mentor local technicians and managers on site in South Africa. Increasing the biogas skills base at all levels could be supported through provision of training and workforce development programmes, through the raining of trainers and on-the-job technical training and vocational training[27] as suggested by draft CP 15.

Support for improving domestic enabling environments has been recognised in proposals submitted to the UNFCCC from the G77, Japan, Australia and the EU , policy support also forms part of the remit of the GBEP and the IEA Bioenergy initiatives. The -/CP15 text also proposes support for country driven approaches including customising policies and practices. In this regard an international mechanism which would incorporate strengthening of enabling environments through strengthening policy and institutional interventions at a national level could be very beneficial. For example **international support for developing appropriate domestic policies** and assistance in ensuring the implementation of REFIT Phase 2, or for setting biogas policy targets, would be helpful for improving the South African enabling environment. The lack of clarity on the issues on IPR is evident from the literature and also from the draft -/CP15 text, in which IPR is a bracketed (undecided)

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[27] 12c

issue. The final decision is however less critical for biogas in South Africa at this stage as to date it does not appear to have been a significant barrier.

There are three potential scenarios to be considered for increasing the transfer of biogas technology to South Africa: firstly, technology transfer left purely to national level structures; secondly, only international support without the necessary level of national commitment and thirdly a system relying on a combination of national and international commitment. Based on the latter case, the below table summarises how different practical barriers identified in this research could be addresed at a national and/or international level.

Table 10 How to address barriers to implementation of biogas in South Africa at a national and international level

'Barrier' to implementation	Address at a National level	International Involvement
Information Sharing Lack of knowledge and awareness	Facilitation of biogas network Information for end users i.e.'one-stop-shop'	Funding, capacity building, educating
Incorrect policy incentives	Integration of policies i.e. Tipping fee Electricity price Municipal finance act	International support for developing appropriate domestic policies
Technical Skills	On the job training National level technology task forces	In-country training support Facilitate partnership/task forces with technical experts
Appropriate financial incentives	i.e. Feed-in tariff	Fund national technology initiatives i.e. Working for Energy Clarity on access to available finance
CDM	Identify interventions required depending on agricultural/domestic/industrial	Fund registration and transaction costs/ programmatic CDM
Innovation	Shift innovation focus towards existing technology Technology innovation centres	Technology innovation centres
Technology Collaborations	National low carbon technology transfer office to facilitate collaborations nationally and internationally	Facilitating regional /international tech partnerships Disseminate R&D experiences

Demonstration projects	Place at a regional level or near education centres	Provide funding for demonstration projects in South Africa.
IPR	Sharing of tacit knowledge	Flexible position on IPR - depends on technology & country
Disjuncture between local knowledge of accessing international	National low carbon technology transfer office to educate	Technology networks

What does this mean for informing the international mechanism?

Table 9 above suggests the potential of national level engagement in technology transfer and how it could be supported by an international framework. From this it is possible to extract which aspects of an international mechanism could assist and augment a certain level of national engagement – or could instigate national level engagement in cases where the appropriate structures do not exist. Table ten below delineates activities suggested in the proposed technology mechanism under the UNFCCC, the country submissions, other international technology interventions explored in Chapter 3.

Table 11 Activities from an international mechanism which would support biogas technology in South Africa

Contributes towards (biogas in SA): Action (from international mechanism):	Information Sharing	Enabling Environment	Absorptive Capacity/Social awareness	Technical and skills capacity	Appropriate financing incentives	Innovative transfer of existing tech	Reduce disjuncture between international and local initiatives
Technology Partnerships	X			X			X
Cooperative research R&D and demonstration	X		X				
Yechnology Network Centres	X		X				X
Technology innovation centres						X	
National Technology Transfer office with technology specific task forces	X	X	X			X	X
Training and skills development programme				X		X	
International financial support for national body					X		
International policy making support customising policies and practices		X			X		

It is still unclear in literature what the expected interface between national and international engagement may be. At a national level there may be enough capacity to initiate some of those activities suggested in Table 9; however international support in terms of financial resources or forming international collaborations will still be essential in ensuring successful implementation and operation. It has become apparent during the course of this research, that this specific aspect of the national and international interface - how international mechanisms would play out at a national level,- is an area with warrants further enquiry.

6.1.3. Summary: how can practical insight inform international mechanisms?

The question guiding this piece of research was: "How can empirical information from practical implementation of low carbon technologies in developing countries be useful to inform an international technology mechanism?" This thesis has considered some of the implementation barriers from academic literature regarding technology transfer and implementation challenges identified by stakeholders in the South African biogas sector.

At the outset of this research the assumption was that the needs and priorities of biogas implementers in South Africa would differ from the activities and interventions proposed under the draft UNFCCC technology mechanism. At this stage a UNFCCC technology mechanism exists only as a proposed draft text following the stalling of negotiations at Copenhagen. However there are activities proposed in the draft text which appear to align with some of the interventions suggested to increase the transfer of biogas technology to, and within, South Africa. It may be a case that the international mechanism is responsible for facilitating and supporting national interventions, as outlined in Table 9 as it is would not be realistic for an international mechanism to go to such a level of detail.

The findings outlined in this chapter have demonstrated that practical examples provide context for the potential activities under an international technology mechanism. Applying a real case study to academic, and sometimes abstract, concepts around the technology transfer debate, reveals the importance and relevance of exploring speculative barriers – such as the example of IPR not being a significant problem. However these issues will differ across technologies and it is clear that designing a 'one size fits all' mechanism is a complex exercise.

This case study of biogas in South Africa has shown that the international technology support needed is quite specific – depending not only on the country, but the specific application of the technology in different sectors and contexts. The research process also demonstrates how an international mechanism could be interpreted and applied at a domestic level and therefore emphasises the importance of country and technology driven approaches to steer the needs for the diffusion of particular technologies depending on technical maturity and domestic capacity in that country. Furthermore this process assists in defining actual practical activities that need to occur subsequent to a higher level decision being made.

Until the technology mechanism is agreed upon, there is not yet a clear indication of how the interventions will be managed at a national level. Furthermore at a national level there will still need to be flexibility in any interventions for different technologies depending on their position along the technology development cycle. For an international mechanism to capture such levels of details at each national and technology level would not be the most effective use of an international body. A more effective approach may be to focus the international mechanism on augmenting the national implementation of low carbon technologies. Using a bottom up approach of a country level study which is used to identify activities for increasing deployment of individual technologies at a national and international level may be more appropriate. In this regard gathering empirical information will provide valuable insights in order to formulate such an approach.

7. Bibliography

Agama Biogas. (July 2009). *Sustainable Cities: Biogas Energy from Waste, A Feasibility study and guidelines for implementing biogas from waste projects in Municipalities.* Cape Town.

Agama Energy Pty. (2007) v2(2008) *Agama Energy (Pty), Integrated Biogas Solutions: Compiled to assist the developer, planner, homeowner, and other interested parties in assessing the role that anaerobic digestion can play in addressing waste management, energy needs and sanitation through.* Cape Town.

Agama Energy Pty. (2007). *Biofuels in the City of Cape Town: Energy from Waste,* 11 July 2008, Prepared for UNDP/CCT/SI

Al Seadi, T, (2002) *Quality management of AD residues from biogas production.* IEA Bioenergy, Task 24 – Energy from Biological Conversion of Organic Waste, January 2002, www.IEA-Biogas.net in Holm-Nielsen, J.B, Al Seadi, T. And Oleskowicz-Popiel, P (2009). The future of anaerobic digestion and biogas utilization. *Bioresource Technology 100 pages 5478–5484*

Amigun, B. (August 2008). *Processing Cost Analysis of the African Biofuels Industry with Special Reference to Capital Cost Estimation Techniques.* PhD Thesis, University of Cape Town, Department of Chemical Engineering .

Andersen, S. O., and Sarma, K. M. (2008). Lessons from Montreal to Kyoto – Presentation Retrieved: http://www.cowi.com/menu/news/newsarchive/generalnews/Documents/Montrea_Protocol_Climate_Stephen_Andersen.pdf

Asia Pacific Partnership on Clean Development and Climate, http://www.asiapacificpartnership.org/english/default.aspx

Ashden Awards. (March 2006). *Domestic biogas for cooking and sanitation.* Available: http://www.ashdenawards.org/files/reports/BSP%20Nepal%202005%20Technical%20report.pdf

Austin, G., Gets, L.E., Liphoto, C., Nissing, C. and von Blottnitz, H. (2006) *Energy Recovery from MUNICIPAL SOLID WASTE in South Africa. A pre-feasibility study for the Department of Science and Technology, pp. 206. Department of Science and Technology, Pretoria, South Africa.* In: Greben, H. A., and Oelofse, S. H. (2009). *Unlocking the resource potential of organic waste: a South African perspective.* Pretoria, South Africa: CSIR – Natural Resources and the Environment. Waste Management Research, published on May 26, 2009 as doi:10.1177/0734242X09103817

Bazilian, M. (September 2, 2009). *Technology in the UN Climate Change Negotiations:Moving Beyond Abstraction, Policy Brief.* Harvard Project on International Climate Agreements, Belfer Center for Science and International Affairs, Harvard Kennedy School.

Bazilian, M., DeConinck, H., Radkac, M., Nakhooda, S., Boyd, W., MacGill, I., et al. (November 2008). *Considering Technology within the UN Climate Change Negotiations.* Energy Research Centre of the Netherlands.

Bergek, A. S. (2008). *Analyzing the functional dynamics of technological innovation systems: A scheme of analysis.* Research Policy, Volume 37, Issue 3, April 2008, Pages 407-429

Biogas for a Better Life. (2008). *South Africa: Household Biogas Feasibility Study, January 2008*
Available: www.biogasafrica.org

De Boer, Y. (2008). *Address at: Forum on climate change and science and technology and innovation Beijing* . Forum on climate change and science and technology and innovation Beijing, PR China, Executive Secretary, UNFCCC
Available:
http://unfccc.int/files/press/news_room/statements/application/pdf/080424_speech_be jing.pdf

Brinkerhoff, D. W. (2004), *The Enabling Environment for Implementing the Millennium Development Goals: Government Actions to Support NGOs,* Paper presented at: George Washington University Conference
"The Role of NGOs in Implementing the Millennium Development Goals"
Washington, DC May 12-13, 2004
Available: www.rti.org/pubs/brinkerhoff_pub.pdf\

Braun, R., Madlener, R., and Laaber, M. (2005), *Efficiency evaluation of energy crop digestion plants.* In: Seventh FAO/SREN Workshop on ''The Future of Biogas for Sustainable Energy Production in Europe", Uppsala, Sweden, December 2005.

Brown, J. (2006, May). Biogas: A Bright Idea for Africa. *Environ Health Perspectives* , pp. 114(5): A300–A303.

BSP Nepal. (2010). *Ashden International Award.* Retrieved 2010, from Biogas Sector Partnership Nepal : http://www.bspnepal.org.np/ashden_awards.htm

Burgermeister, J. (2008, July). *Biogas Flows Through Germany's Grid Big Time* . Retrieved January 2010, from Renewable Energy World :
http://www.renewableenergyworld.com/rea/news/article/2008/07/biogas-flows-through-germanys-grid-big-time-53075

Burton, S., Cohen, B., Harrison, S., Pather-Elias, S., and von Blottnitz, H. (2009). *Energy From Wastewater – A Feasibility Study, Technical Report, for Water Research Commission.* University of Cape Town, Department of Chemical Engineering.

Campbell, K. (2009, July). *SA's Technology Innovation Agency board announced and inaugurated* . Retrieved 2010, from Engineering News:

http://www.engineeringnews.co.za/article/sas-technology-innovation-agency-board-announced-and-inaugurated-2009-07-06

Cargill. (2007, August 8). *Cargill to convert pig waste to energy on South African farm*. Retrieved 2010, from Cargill : http://www.cargill.com/news-center/news-releases/2007/NA3007823.jsp

Chairs Summary (2009), *Delhi High Level Conference on 'Climate Change: Technology Development and Transfer* 23rd October 2009
Available:
http://www.un.org/esa/dsd/dsd_aofw_cc/cc_pdfs/conf1009/Chair's_summary-FINAL.pdf

Cilliers, F. (2009). Personal Communication, Agricultural Research Council, Pretoria

Clini, C., Bauen, A., Caserta, G., Franzosi, M., Howes, J., and Prag, A. (October 2005). *Global Bioenergy Partnership White Paper.* Prepared by the Italian Ministry for the Environment and Territory with the participation of Imperial College London, Itabia and E4tech

Climatico, (2009), *Post Copenhagen Report,* Retrieved March 2010: http://www.climaticoanalysis.org/post/copenhagen-de-briefing-an-analysis-of-cop15-for-long-term-cooperation/

Correa, C. M. (December 2009). *Fostering the Development and Diffusion of Technologies for Climate Change: Lessons from the CGIAR Model, Policy Brief Number 6.* University of Buenos Aires.

COWI. (2008). *The road to a Copenhagen Protocol starts in Montreal - Interview with the Montreal negotiators Stephen O. Andersen and K. Madhava Sarma:.* Retrieved from COWI: http://www.cowi.com/menu/news/newsarchive/generalnews/Documents/The%20road%20to%20a%20Copenhagen%20Protocol%20starts%20in%20Montreal.pdf

Cust, J., Grant, K., and Neuhoff, I. (2008.). International Cooperation for Innovation and Use of Low-Carbon Technology.

De Coninck, H., Fischer, C., Newell, R. G., and Uenod, T. (2008). *International technology-oriented agreements to address climate change.* Energy Policy 36 , p. 335–356.

Dechezlepetre, A., Glachant, M., and Meniere, Y. (29 November 2008). Technology Transfer by CDM projects: A comparison of Brazil, China, India and Mexico, Mines ParisTech, Cerna, Paris, France,.

Department of Environmental Affairs and Tourism (DEAT), South Africa, (2001), *The Polokwane Declaration on Waste Management,* September 2001

Department of Environmental Affairs and Tourism (DEAT) (1999) *National Waste Management Strategis and Action Plans South Africa*, 15 October 1999

Department of Environmental Affairs and Tourism (DEAT) (2000) *Integrated Pollution and Waste Management Policy for South Africa*

Department of Minerals and Energy. (2003). *White Paper on Renewable Energy.* Republic of South Africa.

Department of Minerals and Energy (September 2005). *Rosslyn Brewery Fuel-Switching Project, CDM PDD V. 02.* MGM International SRL.
Available: http://www.dme.gov.za/dna/pdfs/pdd_rosslyn.pdf

Department of Minerals and Energy. (2009). *MTEF Submission: 2009-2012, Working for Energy,*

Department of Minerals and Energy (2004). *Free Basic Alternative Energy Policy, Households Energy Support Programme, .* Government Gazette, 2 April 2007,
Available:
http://www.cityenergy.org.za/files/resources/energy%20poverty/DME%202007%20Free%20Basic%20Alternative%20Energy%20Policy%202007%20(DME).pdf

Department of Minerals and Energy , DANCED, (2001) *Bulk Renewable Energy Independent Power Producers in South Africa,* January 2001

Department of Science and Technology (DST), South Africa (2008). *Innovation Towards a Knowledge Based Economy : Ten-Year Plan for South Africa 2008-2018.*

Department of Science and Technology, South Africa. (2007). *South Africas Climate Change Technology Needs Assessment,* September 2007

Department of Water Affairs and Forestry (DWAF) (1998), *National Water Act*, Act No 36 1998, 20th August 1998

Dhussa, A. (April 22, 2004). Biogas in India. *Ministry of New and Renewable Energy Government of India New Delhi, Methane to Markets Partnership .*

EERE (2010), US Dept of Energy, Renewable Energy and Energy efficiency
http://www1.eere.energy.gov/commercialization/images/valleyofdeath_sm.jpg

Elzen M, H. N. (1 December 2008). Climatic Change 2008. *Volume 91, Numbers 3-4:* , 249-274.

Fisher, B., Nakicenovic, N., Alfsen, K., Morlot, J. C., Chesnaye, F. d., Hourcade, J. C., et al. (2007). *Issues related to mitgation in the long term context in Climate Change Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Inter-governmental.* IPCC. Cambridge: Cambridge University Press.

Forster, P., V. Et al (2007) *Changes in Atmospheric Constituents and in Radiative Forcing. In: Climate Change 2007:The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change ,Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf

Fouché, G. (2008, April). *Sweden's carbon-tax solution to climate change puts it top of the green list.* Retrieved from Guardian Environment: http://www.guardian.co.uk/environment/2008/apr/29/climatechange.carbonemissions

Gerstetter, C., and Marcellino, D. (16 November 2009). *The Current Proposals on the Transfer of Climate Technology in the International Climate Negotiations, An Assessment,* Ecologic Institute, Washington tD. C, www.ecologic.eu/washington

Global Bioenergy Partnership. (2009). *Global Bioenergy Partnership.* Retrieved January 2010, from Global Bioenergy Partnership: http://www.globalbioenergy.org/programmeofwork/en/

Global Environment Fund (GEF) (2008) *Elaboration of a Strategic Program to scale up the level of investment in the transfer of Environmentally Sound Technologies.*
GEF Council 13 November, 2008GEF/C.34/5 Rev 1 www.thegef.org

Greben, H. A., and Oelofse, S. H. (2009). *Unlocking the resource potential of organic waste: a South African perspective.* Pretoria, South Africa: CSIR – Natural Resources and the Environment. Waste Management Research, published on May 26, 2009 as doi:10.1177/0734242X09103817

Grida (1999), Press releases Thursday 11 Mar 1999
Applying Montreal Protocol technology Transfer Experience to climate change
Workshop held in Bangkok, Thailand 1-3 March 1999

GTZ. (2010). *Probec.* Retrieved from GTZ: http://www.probec.org/displaysection.php?czacc=andzSelectedSectionID=sec119275 0452

Haites, E., Seres, S., and Murphy, K. (2009). Analysis of technology transfer in CDM projects: An update. *Energy Policy 37* , 4919–4926.

Ianna, R., GBEP (2010) Personal Communication

IIASA. (2006, June 2006). *What is Technology?* Retrieved November 2009, from IIASA - International Institute for Applied Systems Analysis: http://www.iiasa.ac.at/Research/TNT/WEB/Page10120/page10120.html

International Energy Agency (IEA) (2009) Key World Energy Statistics, IEA, Paris, France, www.iea.org

International Energy Agency. (2010). *Energy Technology Agreements (Implementing Agreements.* Retrieved 2010, from International Energy Agency: http://www.iea.org/techno/index.asp

International Energy Agency. (2001). *Technology without borders; Case studies of successful technology transfer,* Available: http://www.iea.org/papers/2001/ctifull.pdf

International Energy Agency Bioenergy. (2009). *Our Work*. Retrieved January 2010, from IEA Bioenergy: http://www.ieabioenergy.com/OurWork.aspx

International Energy Agencey (2010). *Technology Roadmaps* . Retrieved from IEA: http://195.200.115.136/subjectqueries/keyresult.asp?KEYWORD_ID=4156

IPCC. (2000). *Special Report Methodological and Technical Issues in Technology Transfer, Working Group III.* Available: http://www.ipcc.ch/pdf/special-reports/spm/srtt-en.pdf

IRIN. (2007, December). *Biogas Technology Beginning to Make its Mark.* Retrieved January 2010, from IRIN News: http://www.irinnews.org/Report.aspx?ReportId=75719

Karani, P. (2001). *Constraints for activities implemented jointly (AIJ) technology transfer in Africa.* Renewable Energy, Volume 22, Issues 1-3, January-March 2001, Pages 229-234

Madlener, R., Henggeler-Antunes, C., and Dias, L. (2009). *Assessing the performance of biogas plants with multi-criteria and data envelopment analysis.* European Journal of Operational Research 197, Issue 3, 16 September 2009, Pages 1084-1094

Mallett, A. (2007). *Social Acceptance of renewable energy innovations: The role of technology cooperation in urban Mexico*, Energy Policy, Volume 35, Issue 5, May 2007, Pages 2790-2798

Martinot, E., Sinton, J., and Haddad, B. (1997). *International technology transfer for climate change mitigation and the cases for Russia and China.* University of California at Berkeley, Energy and Resources Group, Annual Review of Energy and the Environment. Volume 22, Page 357-401, Nov 1997

Van der Merwe, C. (2007). *Cape biogas-to-electricity project up and running.* Retrieved from Engineering News: http://www.engineeringnews.co.za/article/cape-biogastoelectricity-project-up-and-running-2007-11-02

Methane to Markets. (2010). *About the Partnership* and *Partnership Accomplishments 2004-2009.* Retrieved February 2010: www.methanetomarkets.org

Mowery, D., Nelson, R., Sampat B. S., and Ziedonis., A. (2004). *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer before and after the Bayh-Doyle.* Stanford University Press.

Mshandetel, A. M., and Parawira, W. (2009, January 19). Biogas technology research in selected sub-Saharan African countries – A review. *African Journal of Biotechnology Vol. 8 (2)* , p 116-125,.

National Advisory Council on Innovation (2010), Available: http://www.naci.org.za/

Neave, G, *Advanced Anaerobic Digestion: More Gas from Sewage Sludge,* Renewable Energy World, 27 April 2009, Retrieved March 2010:

http://www.renewableenergyworld.com/rea/news/article/2009/04/advanced-anaerobic-digestion-more-gas-from-sewage-sludge

NERSA. (2009, November 2). *Media Statement, NERSA Decision on Renewable Energy Feed-In Tariffs (REFITS) Phase II.* Retrieved:http://www.nersa.org.za/UploadedFiles/News/Media%20statement%20NERSA%20Decision%20on%20REFIT%20Phase%202%20-021109.pdf

Neuhoff, K. (2009), *International Support for Domestic Climate Policy,* Climate Strategies and University of Cambridge, Presentation given at the University of Cape Town, 2009

Njoroge, D. K. (2002). *Evolution of biogas technology in South Sudan: current and future challenges.* Proceedings from an International Workshop, Research and Development on use of Biodigesters in SE Asia region
Retrieved January 2010: http://www.mekarn.org/procbiod/kuria.htm

Ockwell, D.(a), Watson, J., MacKerron, G., Pal, P., and Yamin, F. (2008). Key policy considerations for facilitating low carbon technology transfer to developing countries. *Energy Policy 36* , p. 4104– 4115.

Ockwell, D.(b)., Haum, R., Mallett, A. and Watson, J. (2008). *Intellectual property rights and low carbon technology transfer: conflicting discourses of diffusion and development,* Draft, 2008
Available:
http://www.sussex.ac.uk/sussexenergygroup/documents/ockwell_et_al_conflicting_discourses_of_dev_diffusion.pdf

Padma, T.V., (2009) *Climate change's tech transfer challenge,* 5th November 2009, SciDev.Net, Retrieved March 2010: http://www.scidev.net/en/features/climate-change-s-tech-transfer-challenge.html

Persson, M., Jonsson, O. and Wellinger, A . (2006), *Biogas Upgrading to Vehicle Fuel Standards and Grid Injection,* A Report for IEA Bioenergy, Task 37, 2006
Available: http://www.iea-biogas.net/Dokumente/upgrading_report_final.pdf

PR Newswire. (2008, December 22). *Environmental Power's Huckabay Ridge Facility Begins Delivery of Renewable Natural Gas to Pacific Gas and Electric Company.* High Beam . Retrieved February 2010: http://www.highbeam.com/doc/1G1-190934247.html

Prior, B.(2010). University of Stellenbosch, Personal Communictation

The Punekar (2009), *Model Colony gets first bio-gas plant,* Retrieved March 2010: http://punekar.in/site/2009/11/16/model-colony-gets-first-bio-gas-plant/

Ramanathan, R. (2002). Successful transfer of environmentally sound technologies for greenhouse fas mitigation: a framework for matching the needs of developing countries. *Ecological Economics 42* , pp. 117-129.

Ramprecht, S. (2009), *Innovation Workshop Stephan Ramprecht,* Presentation at workshop at the University of Cape Town 9 and 10 September 2009

Reddy, N. M., and Zhao, L. (1989). *International Technology Transfer: A Review.* Research Policy, Volume 19, Issue 4, August 1990, Pages 285-307

REEP SA. (2008 , May 30). *Biogas, PetroSA Biogas to Energy Project MethCap SPV1 (Pty) Ltd.* Retrieved January 2010, from REEP SA: http://reeep-sa.org/index.php?option=com_docmanandItemid=32

Republic of South Africa (RSA(a)) (2008). *National Energy Act.* Retrieved January 2010: http://www.info.gov.za/view/DownloadFileAction?id=92826

Republic of South Africa (RSA(b)) (2008). *Intellectual Property Rights from publicy financed research and development Bill,* Available; http://www.info.gov.za/view/DownloadFileAction?id=86995

Republic of South Africa (RSA(c)) (1997), *Water Services Act*, 1997

Republic of South Africa (RSA(d)) (2008). *Technology innovation Agency Act* . Retrieved January 2010:http://www.info.gov.za/view/DownloadFileAction?id=92827

SA Good News. (2009, November 23). *SABMiller turns to biogas.* Retrieved January 2010, from The Good News SA: http://www.sagoodnews.co.za/environment/sabmiller_turns_to_biogas.html

Sagar, A (2009) *Beyond 'Technology Transfer': Innovation Cooperation for Meeting Climate Challenges,* Indian Institute of Technology Delhi
"Delhi High-Level Conference on Climate Change: Technology Development and Transfer", New Delhi, October 23, 2009

Sampat, B. N. (October 2009). *The Bayh-Dole Model in Developing Countries: Reflections on the Indian Bill on Publicly Funded Intellectual Property, UNCTAD-ICTSD, Policy brief Number 5,* Available March 2010: http://www.unctad.org/en/docs/iprs_pb20095_en.pdf

Sawant, S. S. , *Nation-wide rally to demand rights of waste collectors*
TNN, Mar 9, 2010, http://timesofindia.indiatimes.com/city/pune/Nation-wide-rally-to-demand-rights-of-waste-collectors/articleshow/5660719.cms

Scenario Building Team (2007), *Long Term Mitigation Scenarios, Technical Report*, Department of Environmental Affairs and Toursism, October 2007

Sinden, G. (February, 2009). *Low Carbon Technology Innovation and Diffusion Centres.* Cambridge: The Carbon Trust. Publication ID: CTC736

SNV. (2010). *Africa Biogas Partnership Programme* . Retrieved from SNV: http://www.snvworld.org/en/ourwork/Pages/Africa_Biogas_Partnership_Programme.aspx

Srinivas, K. R, (2008) *Sink or swim: Eco-patent commons and the transfer of environmentally sustainable technologies,* ICTSD News and Analysis, Volume 2, Number 2, May 2008, Available: http://ictsd.org/i/news/bioresreview/12098/
Statistics South Africa. (2008). *Non-financial census of municipalities for the year ended 30 June 2008.*

Steets, J. (2008, April). *Climate Change: From Cows to Kilowatts – A Case Study in Successful Technology Transfer* . Retrieved December 2009, from http://www.wipo.int/wipo_magazine/en/2008/02/article_0002.html

Talbot, T. and. (n.d.). *Biogas -A new generation of power supply.* Retrieved from Talbot and Talbot: http://www.talbot.co.za/portal/talbot/UserFiles/SysDocs/bb_content/26/Biogas_power_supply.pdf

Terrados, J., Almonacid, G., and Hontoria, L. (2007). *Regional energy planning through SWOT analysis and strategic planning tools. Impact on Renewables Development.* Renewable and Sustainable Energy Reviews, Volume 11, Issue 6, August 2007, Pages 1275-1287

The Bioenergy Site. (2009, September 16). *Biogas: New Income Opportunities in Rural Areas.* Retrieved January 2010, from The Bioenergy Site: http://www.thebioenergysite.com/news/4539/biogas-new-income-opportunities-in-rural-areas and (2008 , June 9). *World's Largest Biogas Plant Receives Permit.* Retrieved 2010, from The Bioenergy Site: http://www.thebioenergysite.com/news/1673/worlds-largest-biogas-plant-receives-permit

Tomlinson, S. Zorlu, P. and Langley, C.(2008)
Innovation and Technology Transfer Framework for a Global Climate Deal, An E3G report with contributions from Chatham House,November 2008
Available:
http://www.e3g.org/images/uploads/E3G_Innovation_and_Technology_Transfer_Full_Report.pdf

Thorne, S. (2008). Towards a framework of clean energy technology receptivity. *Energy Policy 36* , 2831– 2838.

UK Climate Group. (2009). Intellectual Property Rights – Catalysts to Deliver Low Carbon Technologies.

UN ESCAP and APCAEM. (2008). *Regional Forum on Bioenergy Energy Sector Development: Challenges, Opportunities, and Way Forward.* http://www.unapcaem.org/publication/bioenergy.pdf.

UNCTAD. (2001). *Report of the expert meeting on international arrangements for transfer of technology: Best Practices for access to and measures to encourage transfer of technology with a view to capacity building in developing countries, especially in least developed countries,* TD/B/COM.2/EM.9/3 http://www.unctad.org/en/docs/c2em9d3.en.pdf

United Nations (1992). *United Nations Framework Convention on Climate Change.* FCCC/INFORMAL/84.Available: http://unfccc.int/resource/docs/convkp/conveng.pdf
United Nations (1998), *Kyoto Protocol to the United Nations Framework Convention on Climate Change*, Available: http://unfccc.int/resource/docs/convkp/kpeng.pdf

UNFCCC(a) (2002), *4/CP.7. Development and transfer of technologies*, p.22 Report of the Conference of the Parties on its seventh session, Addendum 1, Part 2, held at Marrakesh 29 October 10 November 2001, 21 January 2002, FCCC/CP/2001/13/Add.1

UNFCCC(b) (2008) *Bali Action Plan 1/CP13 in Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007 Addendum Part Two: Action taken by the Conference of the Parties at its thirteenth session,* Decisions adopted by the Conference of the Parties, 14 March 2008, FCCC/CP/2007/6/Add.1

UNFCCC(c) (2009). *Non-paper No. 47.* Barcelona: Contact Group on Enhanced Action on Development and Transfer of Technology, Draft Text, Ad Hoc Working Group on Long Term Cooperative Action under the Convention, Resumed seventh session. Draft text 6th November 2009, this non-paper supersedes non-paper No. 29 and No. 36

UNFCCC(d) (2009) *The Copenhagen Accord*, Decision -/CP.15 Available: http://unfccc.int/files/meetings/cop_15/application/pdf/cop15_cph_auv.pdf

UNFCCC(e) (2009). *Draft decision -/CP.15, Draft conclusions proposed by the Chair, Addendum, Enhanced action on technology development and transfer.* Ad Hoc Working Group on Long Term Cooperative Action under the Convention , Eighth session, Copenhagen. FCCC/AWGLCA/ 2 009/L.7/Add.3

UNFCCC(f) (2009) *Performance indicators to monitor and evaluate the effectiveness of the implementation of the technology transfer framework* Final report by the Chair of the Expert Group on Technology Transfer, 11 November 2009, FCCC/SB/2009/4

UNFCCC (g) (2009) *Recommendations on future financing options for enhancing the development, deployment, diffusion and transfer of technologies under the Convention*, Report by the Chair of the Expert Group on Technology Transfer, 26 May 2009, FCCC/SB/2009/2
UNFCCC(h) (2010). *TT Clear: Enabling Environments*. Retrieved 2010, from: www.unfccc.int

UNFCCC(i) (2009), *Development and transfer of technologies Draft conclusions proposed by the Chair,* 9 June 2009, FCCC/SBSTA/2009/L.8,

**All UNFCCC documents available at www.unfccc.int*

USA Climate Action Network (CAN) (2010), *Who's on board with the Copenhagen Accord?* Retrieved March 2010: http://www.usclimatenetwork.org/policy/copenhagen-accord-commitments

Van Ierland J. (2009). *Proposal for a pilot project for the application of Biogas for Cooking Purposes in a rural region in South Africa.* Draft
Weltec Biopower. (2009, September). *WELtec-Biogaspark in Könnern now Online.* Retrieved from RE Green: http://www.regreen.co.uk/20090925Koennern.pdf

Wolson, R. (2007). Technology Transfer in South African Public Research Institutions. In R. M. A Krattiger (Ed.), *Intellectual Property Management in Health and Agricultural Innovation: A Handbook of Best Practices.* MIHR: Oxford, U.K and (2009) Personal Communication
http://www.iphandbook.org/handbook/ch17/p07/

World Bank. (2008). *Global Economic Prospects Technology Diffusion in the Developing World 2008.* Available: http://siteresources.worldbank.org/INTGEP2008/Resources/complete-report.pdf

World Resources Insitute (WRI). (2009). *Technology in a Global Climate Agrement; Emerging Consensus.*

Worldwatch Institute. (2005). *Renewables 2005: Global Status Report, a study by the Worldwatch Institute.* Paper prepared for the REN21 Network by The Worldwatch Institute, Lead Author: Eric Martinot
Available http://www.worldwatch.org/brain/media/pdf/pubs/ren21/ren21-2.pdf

Wright, K. (2009). Personal Communication. Cleaner Climate South Africa.

Youth Employment Summit,YES,(2002). *Youth Employment Opportunities in Renewable Energy.* Education Development Center Inc.

25 Degrees Net. (2006). CDM Executive Board registers two South African projects. *25 Degrees in Africa* , Volume 1, Journal 2 .
Available:
http://www.25degrees.net/index.php?option=com_zineandview=articleandid=552:cdm-executive-board-registers-two-south-african-projectsandItemid=81

A review of the Country Submissions to the UNFCCC in section 3.1.3 are based on:
***EU**: FCCC/AWGLCA/2009/MISC.1/Add.4*
FCCC/AWGLCA/2008/MISC.5/Add.1, a negotiating text for consideration at AWG-LCA 6,
***Australia**:FCCC/AWGLCA/2009/MISC.1/Add.3,*
FCCC/AWGLCA/2008/MISC.5/Add.2 (Part I), FCCC/AWGLCA/2008/MISC.2/Add.1
FCCC/AWGLCA/2008/MISC.4/Add.1
FCCC/AWGLCA/2008/MISC.1/Add.2

Japan
FCCC/AWGLCA/2009/MISC.1/Add.3
FCCC/AWGLCA/2009/MISC.1
FCCC/AWGLCA/2008/MISC.5/Add.2 (Part II)/Corr.1
FCCC/AWGLCA/2008/MISC.5/Add.2 (Part II)

FCCC/AWGLCA/2008/MISC.5
FCCC/AWGLCA/2008/MISC.4

USA
FCCC/AWGLCA/2008/MISC.5/Add.2 (Part II)/Corr.1
FCCC/AWGLCA/2008/MISC.5/Add.2 (Part II)

G77 + China
Proposal by the G77 and China for A Technology Mechanism under the UNFCCC