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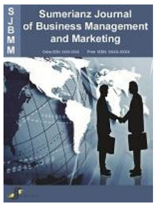

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Commercialising Sustainable Energy Research and Development for Small and Medium-Sized Energy Companies

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Abstract
The aim of this paper is to investigate the commercialisation of sustainable energy research and development for small and medium-sized energy companies. The use of the case study approach has allowed the findings to be intrinsically linked. This has enabled the results to be interpreted ideographically in terms of the case particulars. Information has not been interpreted nomothetically thus ensuring that there are no law-like generalisations inferred. Three case studies have been undertaken in the energy sector and these are reported according to the company background, research and development and conclusions. It is found that an appropriately designed Sustainable Energy business model provides the opportunity to overcome key barriers and challenges to commercialising sustainable energy research and development for small and medium-sized energy companies. The paper indicates that innovative revenue models will enable Sustainable Energy research to be undertaken by small and medium-sized energy companies to maximise their activities.
Keywords: Sustainable; Energy; R&D; SMEs.

1. Introduction
It has been reported that UK public funding for energy R&D has declined significantly in recent years (Packham *et al.*, 2011). In fact, from a position during the 1970s and 1980s where annual funding was several hundred million pounds, funding declined to around fifty million pounds a year by 2001 (this represented as little as 10% of the 1980s annual budgets) (Watson and Scott, 2001). Although the decline in funding has been similar to other countries the UK situation was further exacerbated by the reduction in funding being greater than other member countries of the International Energy Agency IEA (2000). The fact that the UK budget was aligned with small economies (Denmark, Norway, Spain) instead of leading economies (Germany and France) (Watson and Scott, 2001) added to the situation. As a result of, the energy industry being liberalised Newbury (2006) and, privatisation (Department of Trade and Industry DTI, 2007) energy R&D in the UK has therefore dropped 95% since the mid 1990s (Council for Science and Technology CST, 2005; Jones, 2011; Webster, 2010; World Energy Council WEC, 2001). A measure to try to counteract this fall was the creation of the Energy Technologies Institute in 2006 with the aim to increase energy R&D activity (Energy Technologies Institute ETI, 2011). Moreover, the fall in UK energy R&D capacity (NATTA, 2005) has prompted the case for a new energy research, development and promotion policy for the UK (Jamash *et al.*, 2006) and a new energy R&D strategy (IIASA, 2010), and more recently the call for a more effective and efficient energy R&D policy (Science Business, 2011).

As one of the largest sectors of the UK economy, the energy sector accounts for annual sales of around $2,000 billion worldwide (SAM Sustainable Asset Management, 2002). In terms of the trade in individual fuels in 2010, the UK was a net exporter of petroleum products and a net importer for other fuels (MacLeay *et al.*, 2011). For the period 2001-2030 total investment for the worldwide energy supply infrastructure is estimated to be $16 trillion which shows a considerable increase over the previous thirty year period (IEA, 2003). Environmental and security concerns, together with innovation are leading to primary changes to the industry (Wüstenhagen and Boehnke, 2006). The need for sustainable energy is more than evident due to the fact that a considerable percentage of the electricity generated worldwide comes from fossil fuels, resulting in global warming, and nuclear energy with hazardous waste and security issues (EIA, 2019). In these terms the identification of the commercialisation of sustainable energy research and development (R&D) as a key target area for small and medium-sized energy enterprises appears appropriate (BMU, 2005). With regard to this there is a need to have a clear definition of sustainable energy technologies, which are defined by Wüstenhagen and Boehnke (2006) "as providing energy services (such as light, heat or mobility) with a lower environmental impact than today, while maintaining economic efficiency (including external costs) and being socially acceptable". For a sustainable energy R&D strategy for small and medium energy companies to work there is a need for all the internal and external stakeholders to be participative in order for the benefits to be maximised. The supply of expertise and services in the area of sustainable energy, as suggested in the above paragraph, needs to be matched with organisational and industry needs. This paper

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therefore focuses on the broader picture of sustainable energy activities of small and medium energy companies in relation to industry requirements by considering appropriate business models. The research question therefore asks what are the challenges in commercialising sustainable energy research? In order to investigate this the paper is structured according to a literature review of R&D activities in small and medium-sized energy businesses, followed by a categorisation of energy sector firms, the case study approach used to investigate energy sector companies, the results of the case study research and discussion of the findings in terms of the challenges faced by small firms. The paper also proffers a conceptual framework to assist in the commercialisation of sustainable energy for small firms.

2. Literature Review: R and D Activities in Small and Medium Energy Businesses

2.1. Introduction

It has been found that R&D does not provide a true picture of innovation in small and medium energy businesses since smaller enterprises will not have a specialist R&D department (Crespi *et al.*, 2003). Further to this it appears that most innovations originate in certain sectors (Robson *et al.*, 1988) as likewise most R&D (Scherer, 1982). In relation to these aspects this review considers R&D activities in small and medium-sized businesses according to demand, organisation, innovation, imitation and diffusion, complementary assets, networking (Thomas and Murphy, 2019) and government influence on business R&D. With regard to demand it is apparent that the motivation to undertake R&D has involved variables representing market demand conditions which present demand as a major influence on such decisions (Crespi *et al.*, 2003). Unfortunately, as noted by Mowery and Rosenberg (1979) this does not convey much since managers or entrepreneurs will consider the demand outcome before undertaking the development process which is likely to be expensive.

2.2. Organisation

According to the Schumpeterian perspective innovation and R&D activities in modern times have required large firms or concentrated industries (Crespi *et al.*, 2003). Consequently, there will be sectors where the spend on R&D will be determined by the minimum operation scale but there will be other sectors where concentration will be in small and medium sized enterprises (SMEs). Acs and Audretsch (1990) and Audretsch (1995) explain this according to different technological régimes across the different sectors and firm size. Acs and Audretsch (1990), further describe the differences in innovative activity between small and large firms according to the R&D intensities gap. Cohen (1995), notes that the scale economies in R&D may be a possible explanation for the impact of large sized firms. Contrary to this there may be diseconomies with larger firms and as a result government focus in many economies has changed to considering SMEs (Crespi *et al.*, 2003). Further, data on small businesses has tended to underestimate their R&D effort (Tidd *et al.*, 2001). According to Von Tunzelmann (1995) all productive units involve the four functions of administration and finance, products, production processes and technology (with augmentation by R&D). In the literature on scale economies in R&D there is justification for merging large high technology firms (Fisher and Temin, 1973; Kohn and Scott, 1982) and in a literature survey by Martin *et al.* (2003) it is shown that for scale economies in university research at team level scale economies are usually obtained by teams of between five and nine people in a subject. Economies in R&D will involve merging diverse technological fields for production and cost advantages (Crespi *et al.*, 2003). Contrary to examples of fusion that are successful there will also be cases where fusion has not been successful in a company (Kodama, 1991). The cycle time is the speed for R&D to be turned into new products and in order to be first to market there will be pressure for businesses to shorten the time (Crespi *et al.*, 2003). Taking aside increase in complexity a faster cycle time has its own costs (Scherer and Ross, 1990).

2.3. Innovation and R and D

Ownership of innovation and intellectual property rights (IPRs) will be fundamental to determine the attractiveness to carry out R&D. Recent studies, however, have suggested that R&D is often undertaken in ways that appear more like imitation than innovation (Crespi *et al.*, 2003). Indeed, the work of Cohen and Levinthal (1989); Cohen and Levinthal (1990) highlight absorptive capacity, which they describe as the capacity to absorb technologies which are generated elsewhere. They contend that R&D increases absorption even if the R&D is not innovative but rather duplicative.

Within enterprises there is a danger that there will be too narrow a focus on innovation and R&D since as well as the ability to create new products and processes (Thomas and Thomas, 2019), absorptive capacity will depend on the other resources and functions within and outside the organisation (Crespi *et al.*, 2003). Teece (1986), has called these other resources complementary assets. In relation to this Dodgson and Rothwell (1994) have purported that small and medium-sized enterprises (SMEs) will be likely to encounter difficulties translating external opportunities due to limited internal capabilities. According to many studies a significant determinant of R&D in SMEs appears to be financing of innovation and the role of cash flow (Crespi *et al.*, 2003). In the literature on appropriate methods for the evaluation of the financing of R&D (Myers, 1984) has suggested options valuations instead of payback procedures or conventional discounted cash flow (DCF). A problem is that if a small and medium-sized company leaves an R&D project it may be far more expensive to return at a later date (Mitchell and Hamilton, 1988). Marketing functions also need to be taken into account since there may be a considerable gulf between marketing and R&D (Crespi *et al.*, 2003). Most studies have found a positive connection between R&D intensity and diversification and recent research shows that when the share of external contracted out R&D rises this leads to higher returns (Bönte, 2003).

Industries have always depended on sources external to the company for technologies for R&D and some of those that have had in-house R&D in recent times have externalised part of the function (Crespi *et al.*, 2003). The performance of R&D in the UK by higher education institutions (HEIs) has increased from a figure below similar countries in 1980 to the same as similar nations (Von Tunzelmann, 2004). It is thought that this has arisen due to the triple helix of activities between government, industry and universities (Etzkowitz and Leydesdorff, 2002). It appears that the interrelationship between HEIs and industry is a significant driver regarding the intensity of R&D (Crespi *et al.*, 2003).

2.4. Government Influence on Energy Business R and D

There are a number of ways government activities can influence energy business R&D. These include basic research funding, industrial R&D finance (by the tax system indirectly or directly) and through IPR. Gains in technological achievements through more R&D and patents can be caused by rising Gross Domestic Product (GDP) and other macroeconomic forces (Von Tunzelmann and Efendioglu, 2001). Indeed, surveys of business R&D have revealed that a strong incentive is a macro economy in a buoyant situation (Von Tunzelmann, 2003). Furthermore, governments see their contribution to technological advancement from pump priming basic research with an emphasis on research arising from market failure (funding will contribute to business R&D through the subsidisation of private sector laboratories and spillovers complementing private R&D) (Crespi *et al.*, 2003). There has also been concern since the 1980s over private sector R&D being crowded out by government R&D (David *et al.*, 2000; Kealey, 1996). Other studies in the UK have suggested that increases in government R&D in defence activities has resulted in skilled researchers being drawn away from commercial and private R&D (Walker, 1980). A study by Von Tunzelmann and Efendioglu (2001) of the countrywide effects of interest rates on R&D since the 1960s provided a positive long term correlation.

Governments can influence the level of R&D expenditures by firms in two principal ways, by offering fiscal incentives or by directly subsidising such expenditures (an OECD survey in 2002 showed that in order to encourage business R&D countries have used fiscal incentives and these have involved tax deferrals, allowances and credits) (Crespi *et al.*, 2003). In a study of the effect of fiscal incentives on R&D spending (Bloom, 2001) used an econometric model of R&D investment for nine countries from 1979 to 1997 to investigate the relationship between the level of R&D expenditure and tax changes (a ten per cent decrease in the cost of R&D via tax incentives caused a one per cent increase in the short term level of R&D and ten per cent in the longer term). Similar results have been found for US and Canadian studies (Hall and van Reenen, 2000). Furthermore, there is little evidence as to whether non-R&D performing companies can be influenced by tax incentives (Crespi *et al.*, 2003). Governmental considerations over the contribution to R&D are still influenced by supply push and market failure models and the case for market failure is affected by high private and social returns for R&D (Steinmueller, 1994) which is apparent with energy sector firms.

2.5. Energy Sector Firms

In order to help define the energy sector SIC codes can be used to classify energy sector firms (Table 1).

Table-1. Energy sector firms SIC codes

Listing number	Energy sector	SIC code
1.	Coal technology firms	1010
2.	Nuclear power firms	1520, 1610, 2330, 3205
3.	Oil/petroleum firms	1110, 1120, 2320
4.	Liquefied natural gas firms	1300, 1620
5.*	Wind energy firms	4010
6.*	Wave and tidal firms	4010
7.*	Biomass firms	4010
8.*	Solar energy and photovoltaics firms	4010
9.*	Geothermal energy firms	4010
10.*	Hydroelectric power firms	4010

* Electricity generation

The energy sector firms can be categorised according to a classification for energy R&D performers (Welsh Affairs Committee WAC, 2006) as follows:

1. Coal technology firms
2. Nuclear power firms
3. Oil firms
4. Liquefied natural gas firms
5. Wind energy firms
6. Wave and tidal firms
7. Biomass firms
8. Solar energy and photovoltaics firms
9. Geothermal energy firms

10. Hydroelectric power firms

Energy R&D (Energy Information Administration EIA, 1999) can be categorised as:

1. Basic energy research

Basic energy research involves advancing scientific knowledge and understanding phenomena rather than considering particular applications.

2. Developing new energy technologies research

This concerns scientific knowledge that is commercially applicable with known objectives involving research uncertainties and difficulties.

3. Improving existing energy technologies research

This encompasses the design and testing of new processes using scientific knowledge involving cost and technical uncertainty with the beneficiaries being operators and customers of the improved technology and producers and consumers of particular fuels.

The three categories above can be related to the energy R&D performers as (a) Basic Energy Research and (b) Applied Research and Development including Coal (1), Nuclear power (2), Other fossil energy – Oil (3), Liquefied natural gas (4), Renewable energy, Wind (5), Wave and tidal (6), Biofuels and Biomass (7), Solar energy and photovoltaics (8), Geothermal (9) and Hydroelectric (10). In order to investigate the commercialisation of sustainable energy R&D for small and medium-sized energy companies the case study approach involved consideration of the company background as a sustainable energy company, sustainable energy R&D activity and conclusions regarding the company's approach to sustainable energy R&D.

3. Energy Sector Case Study Approach

The use of the case study approach has allowed the findings to be intrinsically linked. This has allowed the results to be interpreted ideographically in terms of the case particulars. Information has not been interpreted nomothetically thus ensuring that there are no law-like generalisations inferred. Since case studies are exploratory in nature and are used in areas where insufficient knowledge exists (Collis and Hussey, 2009) they are appropriate to the case studies researched in this paper. According to Bryman (2008) case studies are important in terms of offering the researchers the opportunity to test theories, which in the terms of this paper is the relative importance of internal and external relationships in R&D. This offers a contrasting view that case study research only offers new research data and information. Since the validity of case study findings from particular organisations is often questioned the corroboration of evidence from other sources reduces the doubts that may arise.

In accordance with Yin (2008) the case study approach used for this work has possessed the following characteristics:

1. the research has aimed to understand and explore the phenomena of the relative importance of internal and external relationships in research and development;
2. the research has not necessarily commenced with a set of preconceived questions and ideas in regard to the organisations which have been researched;
3. the research has used multiple methods to collect the relevant information from the case study sources and the relevant literature.

The main stages of the case study have been followed in accordance with the accepted approach of (a) selecting the cases, (b) preliminary investigations, (c) information gathering, (d) the analysis stage, and (e) the report stage. Also, the research has followed the approach of phenomenological studies to explain patterns from the study (Collis and Hussey, 2009).

Three case studies have been undertaken into the commercialisation of sustainable energy R&D for small and medium-sized energy companies and these are reported below according to the company background, research and development and conclusions.

4. Energy Sector Company Case Studies

4.1. Ensector Ltd

4.1.1. Company Organization

Ensector Ltd is a leading UK sustainable energy company. They are highly skilled and experienced sustainable energy consultants specialising in the design and installation of a range of sustainable energy technologies. These include biomass wood energy, hydro, solar and wind. Services to companies include assistance with the implementation of sustainable energy projects, consultancy work, environmental assessments, technical designs, feasibility studies, resource assessments and help to reach 10% on-site sustainable generation targets. For these activities Ensector Ltd has the requisite experience and capabilities. The company won a Small Business of the Year Award in 2006, and was a winner for the Queen's Award for Enterprise.

4.1.2. Sustainable Energy Innovation and R and D

Since Ensector Ltd does not have the resources of large utility companies and multinationals it has recognised the importance of its own R&D capacity. The company operates in South America, Africa, Asia and Europe and provides power based solutions for a range of renewable energy options. This includes commercial requirements in communities and hospitals in Latin American, African and Asian countries and in the UK. The company's research facility has received funding from ETSU (the former Department of Trade and Industry's Energy Technology

Support Unit), the UK Department for Overseas Development and from Europe. Projects have included heat storage cooking in Nepal, which was a three year project to research ways of maximising the usage of small hydro, in order to improve living conditions in remote villages and prevent deforestation. There has been the design and supply of solar powered medical equipment for use with the World Health Organisation (WHO) cold chain development. This has included electronic control equipment, computer power supplies, operating theatre lights, centrifuges, laboratory power supplies, cooling fans, remote lighting and vaccine refrigeration units. Another project has been solar photovoltaic powered reverse osmosis for village use in remote arid regions to develop an economic small scale water treatment plant. A fourth project has researched stream flow monitoring in remote catchments. This resulted in commercial exploitation of the method and the device. These are examples of the capabilities of Ensector Ltd in sustainable energy research. Some of the projects also result in products for the renewables market.

4.1.3. Conclusions and Government Influence

Ensector Ltd has been an innovator for emissions reductions and future energy systems. As such the company invests in R&D for new applications and technologies. These include rural electrification solutions for the developing world, components for photovoltaics (PV), heat storage and electronic equipment, intake screens for hydropower, GIS applications and resource management instrumentation. Consultancy is provided on biofuels, hydrogen and wave/tidal energy and research is being undertaken into exploring the energy systems of the future. The range of specialisms supports the spectrum of sustainable energy needs. This includes remote off-grid PV and wind systems, photovoltaic and solar power installation (including integrated systems and PV module supply), wind turbine/wind farm and hydro developers and community renewable energy initiatives. Organisations supported are non-governmental organisations, housing trusts and hospitals, energy service providers, overseas development organisations, research organisations and local authorities whose sustainable energy policies are influenced by central government. Ensector Ltd, therefore, has the experience and knowledge to support projects regarding sustainable energy needs both cost effectively and efficiently from inception to installation. Clearly R&D features as a central and important function in the operation of the company. The challenges to commercialisation have included the R&D capacity of the company which is dependent on investment into new applications and technologies and the ability to provide renewable energy solutions to those organisations that are supported.

4.2. Enrenew Ltd

4.2.1. Company Organization

Enrenew Ltd is a sustainable energy company who are involved in the use of innovative sustainable technology to help in the realisation of more environmentally conscious sustainable resources on both a small and large scale. Key services include project management, monitoring services, consultancy and advice on energy saving, sizing of sustainable energy systems, feasibility studies on sustainable energy power supply projects and energy and environmental auditing. Enrenew Ltd has been working in the field of sustainable energy since it began trading in 2000. The company works with the development of innovative sustainable energy technology and the aim is to develop as a trader of products and services in the short term and to carry out work related to the manufacturing of sustainable energy systems and development of sustainable energy projects in the long term. With the growth of the company the emphasis will remain on the development of innovative ideas in the field of sustainable energy and through new ideas in the growing global market of energy production.

4.2.2. Sustainable Energy Innovation and R and D

In the area of R&D Enrenew Ltd is involved in a wide range of sustainable energy services. They are able to provide a complete service through the stages of wind turbine sizing, research, supply and installation. Through their links with wind manufacturers, services are provided with full environmental and financial diagnosis at a competitive cost. The company has considerable experience in producing planning documents for a number of wind farms and single wind turbines and in designing wind farms. Feasibility studies are conducted on sustainable energy projects for export or on-site use. Studies consider which type of unit to use, the payback period to determine the suitability of a system, the cost of installing the system and the power use of the unit. Studies range in scale from large industrial plant to local farmhouses. Depending on the user’s need studies can be undertaken providing a variation of detail. For houses and businesses investigating the utilisation of biomass systems, solar and wind for energy production site visits can be undertaken by Enrenew Ltd. Energy requirements and use will be calculated following a site visit with advice provided on the type and size of system appropriate. The company also provides an optional service with supply and pricing information. Through this service customers have the system provided at competitive cost following information being provided about the types of sustainable energy systems suitable to their requirements.

It is usually best to minimise energy wastage from a financial and environmental perspective as well as offsetting energy use through sustainable energy use. The waste of available energy is a common problem of westernised society and there is a need to reduce this impact. Major energy losses will often occur in those areas which can be easily corrected and are elementary. Indeed, an Energy Agency in a recent survey found that firms could save at least 30% of their energy use and consequently 30% of the costs. Energy saving measures will be low cost or no cost options. As a consequence Enrenew Ltd can provide consultancy and advice on energy saving.

In the area of energy and environmental auditing Enrenew Ltd provide a range of research and consultancy services for both large and small organisations and companies. These organisations will want to reduce their energy costs and to have an environmental policy. In order to assess the annual usage of energy, audits can be carried out on site and will identify areas where there is the potential for a reduction in energy waste. This will be either through investing in sustainable energy technology or through increased energy efficiency. Enrenew staff who undertake the audits are experienced in the areas of sustainable energy and energy efficiency. Detailed advice can be offered on those technological changes that are necessary.

Site surveys are carried out by Enrenew by monitoring wind characteristics for wind turbine installation. Over a 12 month period wind monitoring equipment will be set up and monitored constantly. This will enable the calculation of the annual mean and seasonal variation. Through the use of a transferable weather resistant computer chip information can be transferred to a personal computer in the office for statistical and graphical analysis.

4.2.3. Conclusions and Government Influence

During the six years since Enrenew Ltd has been established the company has been involved with a number of sustainable energy installations throughout the UK for residential customers and businesses which are influenced by sustainable energy government policy. There has been involvement with large and small scale combined wind and solar PV remote installations, wind monitoring, solar hot water and wind. As well as these projects Enrenew Ltd has been able to undertake site work including hands on installations and surveys. Similar to Ensector Ltd, Enrenew Ltd considers the challenges to commercialisation to involve the R&D function as a central and important activity in the operation of the company and for future growth and development.

4.3. Encost Ltd

4.3.1. Company Organization

When Encost Ltd was launched as a spinout company from a university the focus of the company was to reduce utility costs and to provide customised online utility information regarding these costs and to ensure that they remain low. The company works with customers to provide a full energy/utility service ranging from fuel purchasing, meter installation, advanced monitoring and targeting to project engineering and information technology (IT) solutions. In addition to IT and software developments Encost Ltd undertakes remote analysis of customers' consumption patterns and works closely with clients to achieve reduced costs. The company aims to be a professional service provider by establishing trust through building personal relationships. Through this trust it enables Encost Ltd to work with customers, employing the most appropriate technology to gain outstanding results. The products and services provided include metering hardware and connectivity; IT support, hosting, Vector Defined Network (VDN) and networking; installation of metering hardware and network cabling; installation of gas, water and steam meters; Web design, Web development and consultancy.

4.3.2. Sustainable Energy Innovation and R and D

The reasons why customers have chosen Encost Ltd for their energy system requirements are because they have energy bills over £100,000, require a Climate Change Levy (CCL) rebate, have experienced a large rise in energy bills, want to improve their "bottom line" for little capital outlay and are concerned about the environment. Additionally, technical reasons for choosing Encost Ltd include their unique and advanced .Net Web management system, advanced statistical process control and proactive alarming, secure Virtual Private Network (VPN) data connectivity to each company, customisable reporting and visualisation and an exceptional range of business patterns and support. Also, the company is one of the few organisations that offer a full energy management service remotely. So far there have been four pilot customers.

Office space was provided at the University spin-off premises with the help of the University commercial company. The two founders were both employed by the University in the School of Technology and are the two directors of the company. Office space, support staff and facilities have been provided in the School as well as the University spin-off premises. The company is being developed within the University's School of Technology.

4.3.3. Conclusions and Government Influence

When the company commenced trading it was involved in remote utilities monitoring and management which is a sophisticated system developed from proof of concept. As well as the co-founders, who are directors there is a technologist employed under the Knowledge Exploitation Fund (KEF) supported by regional government. Encost Ltd undertakes work for companies with large energy bills (£1m plus per annum) and reduces energy use by up to 20% per year. The four test sites where this technology has been applied include two private manufacturing companies, a public body (hospital) and a leisure organisation (hotel). Challenges to commercialisation again involve R&D which is seen as an important support function to the company for it to stay at the forefront of energy management systems technologies.

5. Sustainable Energy R and D Case Study Conclusions

In this paper sustainable energy R&D activity in specific small and medium energy companies has been investigated in terms of the mechanisms and processes by which it takes place. A case study methodology has been used to examine these processes and three case studies have been undertaken in the energy sector in Wales. The findings of the initial case study research have been analysed in terms of the R&D activities of the businesses according to demand, organisation, innovation, imitation and diffusion, complementary assets, networking (Thomas and Murphy, 2019) and government influences on business R&D as outlined in the review of the literature. The review identified demand as being important in terms of the motivation to undertake R&D (Crespi *et al.*, 2003). This is demonstrated by two of the case study companies in the energy sector (Enrenew Ltd, Encost Ltd).

According to Von Tunzelmann (1995) R&D augments the four main functions of productive units (administration and finance, products, production processes and technology). This is illustrated in the case study companies since they see R&D as an important activity in the operation of the company. Rather than only demonstrating absorptive capacity (Cohen and Levinthal, 1989;1990) the case study companies appear to be innovative in their work. This is shown by Ensector Ltd as an innovator for emissions reductions and future energy systems. The company invests in R&D for new applications and technologies. Enrenew Ltd is also involved in the use of innovative sustainable energy technology and detailed advice is offered on technological changes. In addition, Encost Ltd works with customers, employing the most appropriate technology to gain results.

As well as the ability of R&D to create new products and processes (Thomas and Thomas, 2019) it will depend on the other resources and functions within and outside the company which (Teece, 1986) has called complementary assets. An example of this is Ensector Ltd who do not have the resources of the utility companies and the multinationals and have recognised the importance of their own R&D capacity. Further to complementary assets other sources external to the company can be acquired through networking (Thomas and Murphy, 2019) and this can involve HEIs (Von Tunzelmann, 2004) and government in what (Etzkowitz and Leydesdorff, 2002) have called the triple helix. In order to provide a professional service a company can establish trust through building personal relationships involving networking (Thomas and Murphy, 2019). One of the case study companies that has done this is Encost Ltd.

Finally, there are a number of ways government activities can influence business R&D and these include research funding, industrial R&D finance and through Intellectual Property Rights (IPR). For example, Ensector Ltd's research facility has received funding from ETSU, the UK Department for Overseas Development and from Europe. Another example is Encost Ltd who has received funding from the Knowledge Exploitation Fund (KEF) to employ a research technologist.

The above conclusions provide illustrative examples into the commercialisation of sustainable energy R&D of the case study energy businesses. Through these activities it is shown that sustainable energy R&D is an important function for firms in the energy sector.

6. Challenges in Commercialising Sustainable Energy Research – Towards a Conceptual Framework

It is apparent that sustainable energy technologies, for example heat pumps, solar cells and solar collectors (Dunn, 2000), deploy sustainable and non sustainable fuels to generate energy/heat at lower environmental impact than conventional energy technologies (Wüstenhagen and Boehnke, 2006). The move from conventional to sustainable energy although perhaps resulting in a lower cost for society does not necessarily mean a lower cost to consumer (Wüstenhagen and Boehnke, 2006). Such a discrepancy between public/private benefit/cost can be a major problem for both a small and medium energy business and funding body when making decisions regarding sustainable energy research (Wüstenhagen and Boehnke, 2006). Similarly, sustainable energy developments involve both public and private benefits (Villiger *et al.*, 2000).

The development of sustainable energy research involves considerable time and resources which is characterised by high capital costs and long lead times (Wüstenhagen and Boehnke, 2006). For example, developing a new sustainable energy device requires considerable investment in R&D. Therefore finding funding for new sustainable energy technologies can be challenging (Wüstenhagen and Teppo, 2006).

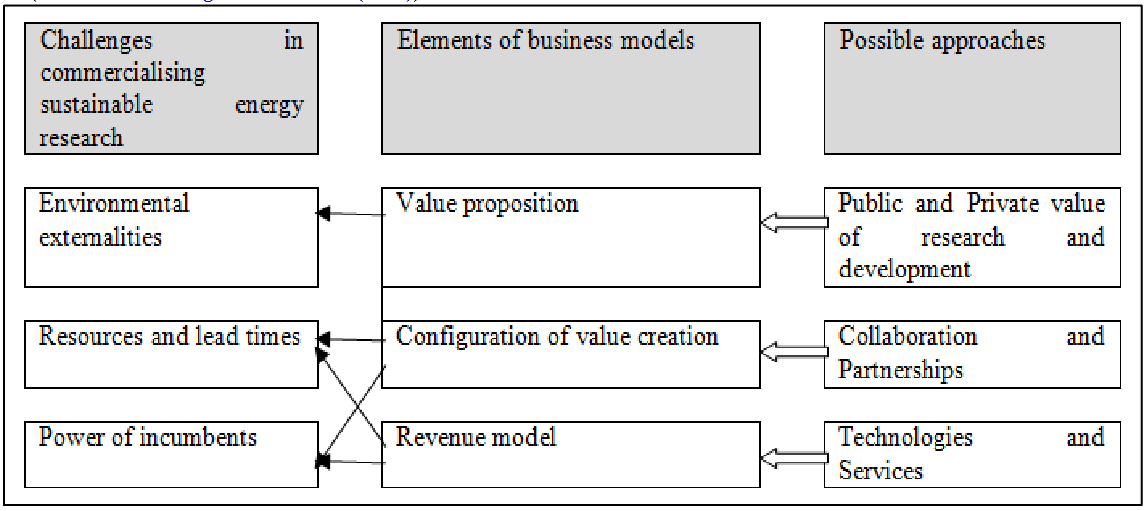
Due to the capital intensive nature of sustainable energy R&D large amounts of resource will have been invested in research infrastructure by the small and medium energy companies. Therefore those companies that control these assets will arguably have a strong position and may be reluctant to participate in any structural re-orientation that can affect their existing activities. This may pose a serious challenge in setting up a workable sustainable energy R&D strategy.

The business model in recent years has become a popular concept in management theory and practice (Chesbrough and Rosenbloom, 2002; Magretta, 2002; Osterwalder *et al.*, 2005; Shafer *et al.*, 2005). A business model can be defined as "a description of planned or an existing business and its specific characteristics with respect to value creation on the one hand and market orientation on the other hand" (Hedman and Kalling, 2003; Osterwalder *et al.*, 2005; Stähler, 2001; Wüstenhagen and Boehnke, 2006). In these terms the business model combines the resource-based and market-based view of the organisation and takes an integrated viewpoint (Kalling, 2002; Morris *et al.*, 2005). Management practice has emphasised the importance of business models (Morris *et al.*, 2005) and although much research has attempted to analyse the business model concept there is no accepted definition by academics (Osterwalder *et al.*, 2005; Porter, 2001; Shafer *et al.*, 2005) and practitioners (Linder and Cantrell, 2000) alike. Academics agree that the business model elucidates how a business creates value and is an important unit of analysis relevant to both management theory and practice (Belz and Bieger, 2004; Chesbrough and Rosenbloom, 2002; Morris *et al.*, 2005; Rentmeister and Klein, 2003). Therefore, the analysis of the business model can aid understanding and communication of key success factors of value creation. Moreover, it can measure, compare and change business logic (Morris *et al.*, 2005; Osterwalder *et al.*, 2005; Shafer *et al.*, 2005).

Among the first to propose a formalised definition of a business model, Timmers (1998) viewed it as a description of the architecture of value creation, potential value generated for partners, sources of revenue and marketing strategy. Following this a further definition by Hamel (2000) noted the four business model components of core strategy, strategic resources, customer interface and value network. In this study we have followed the definition of Stähler (2001) describing a business model as a description of a planned or existing business including the three elements: value proposition, configuration of value creation and revenue model. Value proposition describes how products and services offered by the organisation create value for the stakeholders. Configuration of value creation describes steps of the value chain performed by the organisation and an organisation will develop core competences by which it can be identified. The revenue model describes how the organisation generates revenue.

By designing the three elements of the business model described above a small energy company can tune its offering to meet the three challenges of sustainable energy research and achieve higher penetration of the resultant technologies as well as commercial success to maximise their activities. How the business model configuration addresses the challenges in commercialising the activities of Sustainable Energy is shown in Figure 1.

Figure-1. How the Sustainable Energy business model configuration addresses the challenges in commercialising research and consultancy activities (based on Wüstenhagen and Boehnke (2006))



With the value proposition sustainable energy technologies are characterised with the component of public benefit and pose a challenge to convince users to adopt them rather than other energy technologies with a stronger private benefit. By highlighting the private benefit on top of the public benefit a sustainable energy development will attract a larger set of users (Villiger *et al.*, 2000). Configuration of value creation which is properly designed can help to address the barriers of capital intensity and the power of incumbents by focussing on those components that are key. Innovative revenue models are at the core of success for a Sustainable Energy business model and are important for sustainable energy R&D. This will involve not just the development of sustainable energy technologies but also a comprehensive technical service to underpin these.

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