Exploring Research Institutes: Structures, Functioning and Typology

Simon P. Philbin[1], David Jones[2], Nigel P. Brandon[3], Adam D. Hawkes[4]
[1] Business School, Imperial College London, London SW7 2AZ, UK
[2] BG Group, Thames Valley Park, Reading, Berkshire RG6 1PT, UK
[3] Department of Earth Science and Engineering, Imperial College London, London SW7 2AZ, UK
[4] Centre for Environmental Policy, Imperial College London, London SW7 2AZ, UK

Abstract--**Research institutes play an important role as part of the innovation landscape, which includes industrial, academic and governmental organisations. Although there is often much confusion over what constitutes an institute and there can even be a number of different terms associated with such organisational forms, including centres, networks, programmes and laboratories. Indeed institutes can enable multidisciplinary research and the translation of knowledge generated to deliver societal benefits and address industrial requirements. However, despite the benefits offered by establishing research institutes, there has been a distinct lack of studies in this area. Therefore, this paper provides the findings from an initial research study into the structure, functioning and typology of institutes. Following a literature review on institutes, a benchmarking study involving examination of 25 research institutes associated with the energy sector has been carried out. This study identified key features of the institutes, in regard to the research area, technology readiness level, funding, partners, organisational structure, leadership and governance arrangements. Subsequent analysis of these findings has resulted in three main types of institute being identified. The pros and cons for each institute type are provided along with recommendations on the development and management of research institutes.**

I. INTRODUCTION

Research institutes provide an important function as part of the innovation landscape and such organisations (or units within organisations) can be established for a number of different reasons [1]. Institutes that are engaged in the delivery of research activities will be aligned towards either a specific societal (e.g. energy, climate change or healthcare), an industrial remit (e.g. manufacturing, production or power systems) or an emerging subject (e.g. nanotechnology, materials modelling or data analytics). While some institutes are standalone entities others are part of academic or healthcare institutions. Institutes that are located at universities are generally distinct from traditional academic departments (such as physics, chemistry and biology) due to their remit (either societal, industrial or emerging subject) that is likely to require contributions from different academic disciplines. Furthermore, there is often much confusion over what constitutes an institute and there can even be a number of different terms associated with such organisational forms, including centres, networks, programmes and laboratories. Indeed institutes and centres are often perceived as being interchangeable terms although centres are sometimes (but not always) viewed as being smaller or more focused organisational entities when compared to institutes.

Institutes are often considered as "centres for excellence" in a specified area, which provide a mechanism to support the delivery of focused technical activities, involving research and also in some cases education and/or translation, within the remit of the institute. However, organisations (including those people involved) contemplating the development of new institutes are faced with significant uncertainties in regard to the design of the institute, including the supporting resources and management processes. There does not appear to be an established basis for the categorisation of institutes and there is an apparent lack of material in the literature that may provide practitioners with guidance on how to develop and subsequently manage research institutes. Equally, when confronted within an existing institute, how can an organisation or individual make an informed judgement on whether to partner with or participate in the work of the institute? An assessment of the technical quality of the institute can be undertaken but will this reveal whether the institute has been structured in the most optimal manner to meet the needs of the institute's key stakeholders? Will partnership with an institute provide the required technical benefits, while also demonstrating appropriate 'value for money' for an investment made by a company? Finally, when setting up a new institute, which type of organisational structure should be adopted and how should the resources be allocated across the institute? These are just some of the questions that can be encountered when considering both the strategic rationale and supporting operations for new and existing institutes. Therefore, this paper provides the findings from a preliminary study into the structure, functioning and typology of research institutes.

II. LITERATURE REVIEW

Institutes are often regarded as having leading research capabilities established in response to a particular need and Bozeman and Boardman [2] have described how academic research centres (or institutes) can be viewed as nationally (in the United States) important enablers of innovation. This work sought to differentiate research centres from traditional academic departments. Academic departments are viewed as having highly decentralised research, where faculty members pursue their own research agendas in relation to the academic discipline of the corresponding department, e.g. mechanical engineering, chemical engineering or physics. Conversely, research centres offer a mechanism for more centralisation of research through the direction and coordination that is

afforded by a centre structure and supporting processes. This work also considered the operational characteristics of such centres, including the need for clear leadership as well as clarity over reporting lines, e.g. ensuring the centre director has a direct reporting line to a Dean or other senior academic leader at the university. Bozeman and Boardman also examined centre leadership roles, finding that it can be useful to have a clear distinction between the roles and responsibilities of the overall director and the administrative director within the centre. The overall director (generally being at professorial level) tending to lead on the technical direction of the centre as well as being the centre 'figurehead' in regard to external relations and especially international relations. This then allows the administrative director within the centre to focus on managing the administrative processes and non-academic activities. Such a differentiation of centre management activities can also help avoid 'role strain', where centre directors have to deal with the sometimes conflicting demands made upon them from departments and centres [3].

The transformation of traditional university structures through the adoption of multidisciplinary institutes has been considered in regard to meeting the needs of the knowledge economy thereby addressing industrial and societal problems [4]. In many Western countries, such as the United States and United Kingdom, this has been substantially impacted by successive ring-fenced governmental funding schemes, which have specified the need for multidisciplinary research approaches that leverage insights from different disciplines. However, it has been found that traditional universities often need to undergo significant change in their orientation and structures to successfully engage in such multidisciplinary research and especially with industry [5]. Further, sustaining entrepreneurial behaviours in academic faculty that support multidisciplinary research to meet industrial needs can prove difficult and without adequate incentives faculty members can easily revert to their former ('home') academic discipline. Consequently, the ability to sustain a multidisciplinary focus for an institute can be an important factor that may ultimately impact the long-term sustainability of the institute, which is therefore driven by both academic and financial considerations.

Indeed Geisler et al. [6] have viewed university centres (and institutes) in terms of an overall development cycle and a series of critical success factors for university-industry research centres were identified. These success factors include the following: relations with focal university, relations with industrial companies, internal management practices, strategies for research and technology as well as the individual attributes and competencies of the centre's founding staff. At the early stages in the centre lifecycle, the performance of a centre can be largely dependent on the contributions of the founders; their ability to bring the contributing academic faculty together and to properly embed the new centre at the university. Whereas in the later stages in the centre development cycle different factors can have the greatest impact, such as the importance of working with industrial research funders as part of collaborative research projects, which involves the translation of knowledge generated by the centre into industrial benefits for the partner companies [7]. Moreover, research by Feller et al. [8] examined the difficulties that US NSF (National Science Foundation) supported engineering research centres encounter when trying to secure financial support beyond the initial NSF funding period and this underscores the need for centres and institutes to develop long-term plans that will enable continued resourcing and operation of the centre beyond the period associated with any initial investment.

In regard to the particular challenges encountered by centres and institutes embedded at academic institutions, Speier and Palmer [9] found that at industry supported centres there can be a continuing 'struggle' between the need to pursue problem-driven research required by companies (i.e. having a higher technology readiness level or TRL) and the potentially more intellectually rigorous research (both fundamental and applied that is a lower TRL), which is suitable for publication in appropriate technical journals. Strategies can be developed to mitigate this issue through, for instance, the centre's research agenda being led by faculty members according to a 'bottom-up' research development process, whilst still of course being aligned with the overall remit of the centre. Such a strategy would thereby ensure faculty have the necessary confidence that research undertaken has a realistic prospect of being published in journals of an appropriate standing, i.e. in journals that may have a positive impact on the faculty member's tenure or promotion prospects. In other work, Vinkler [10] has described a management system that allows fundamental research to be balanced against so called mission-oriented research (MOR), thereby maintaining academic freedoms. The system is based on the planning and supervision of research activities, an evaluation of scientific and economic results as well as rewarding researchers at an appropriate level. In this approach a scoring system that is based on impact factors for periodicals and also from citations received is used to inform the quality measure for scientific publications. Such an approach would be of potential use in research institutes to help deliver research outputs for industrial and other sponsors while maintaining academic interests to disseminate research findings through publications, conference presentations and other such outlets.

In regard to innovation clustering, Chen and Kenney [11] found the positive contributions that university and research institutes in China can make to the development of regional technology clusters and this highlights the integrating role that institutes can play in innovation networks. Furthermore, research institutes will often collaborate with other research providers, which include both universities and research institutes [12], for example in Europe as part of research projects funded by the European Union's Framework Programmes [13].

Industry supported institutes are able to provide research as part of an 'academic service model', which can act as a

knowledge input to the industrial innovation process [14]. Such transfer of scientific knowledge between organisations has given rise to new approaches to innovation, which transcend disciplinary interfaces, organisational boundaries as well as the distinction between basic and applied research [15]. Moreover, this can be considered through the 'open innovation lens' [16], where a company's innovation portfolio is essentially expanded through harnessing both knowledge in-flows as well as out-flows of knowledge and technologies, thereby resulting in enhanced market opportunities for research, technology and NPD (new product development) activities carried out within the company's innovation portfolio. Historically companies undertook significant levels of research in-house but it has become increasingly difficult for this to continue due to the complexity of products and the high costs associated with maintaining the full range of technical capabilities required to bring technologies to market. As companies have become more adept at sourcing knowledge from external sources, this has increased the scope and appetite for university-industry research collaboration, which can be an important channel for institutes to work with companies and provide challenging engineering problems for institute research to be focused towards. Fig. 1 provides a schematic view of how research institutes can participate in the industrial innovation cycle as part of the open innovation model. In this model research institutes are able to provide ideas and research findings to expand the research portfolio of the company, which can be further expanded through in-licensing by the company of intellectual property (IP) generated by the institute that is available for commercialisation by an industrial partner [17]. In this latter scenario, such an institute (and faculty members) would need to have the requisite entrepreneurial behaviours associated with technology transfer [18] and the commercial development of IP [19].

The performance of any institute will be significantly impacted by the ability of the institute to retain, synthesise and apply knowledge that is generated within the institute and also through gaining access to external knowledge, either through accessing open source channels or through collaboration and partnership with other organisations. Institutes can be viewed as being part of knowledge networks and where an institute has developed a nationally or internationally leading position, the institute can be considered as the network node. On this matter Pires et al. [21] have identified how the performance of research centres (in regard to the diffusion of research and knowledge outputs) in Brazil funded by the oil and gas sector can be hampered by the absence of a supporting knowledge management strategy. Such as a strategy should ideally extend to knowledge generation, capture, communication and application, and in the case of industry supported institutes would include identification of the necessary resources, structures and management processes that allow research findings to be translated into industrial impact and benefits. This translation would potentially capture the commercialisation of research [22] and any impact on wider economic performance [23] as well as the application of academic knowledge and insights to inform other areas, such as policy-making and regulation [24].

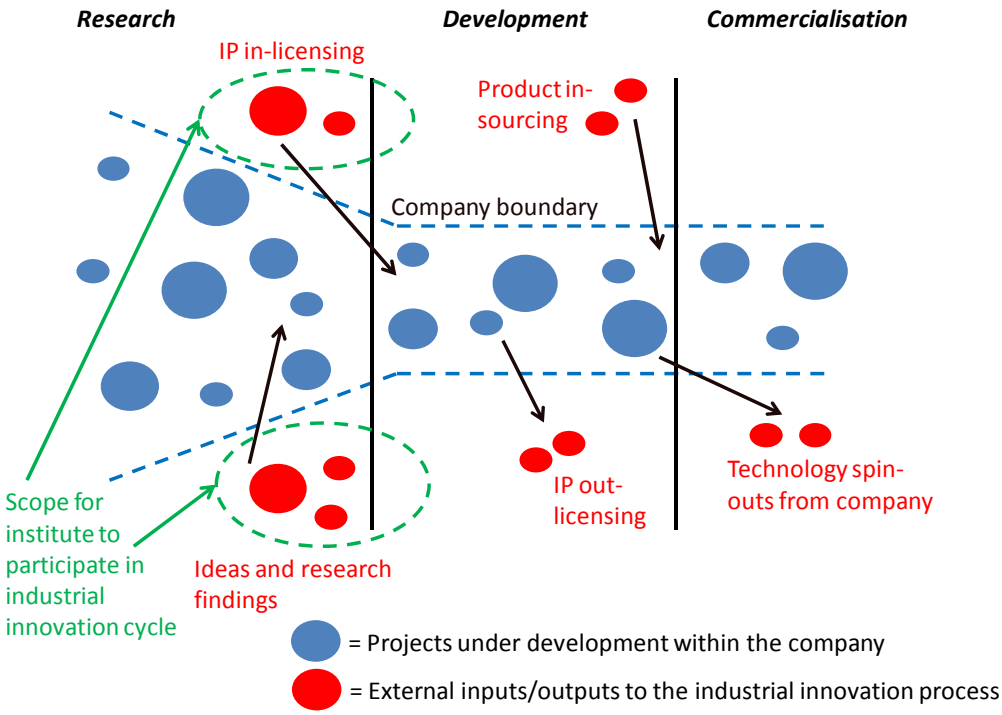

Fig. 1. Institute-industrial collaboration as part of the open innovation model, adapted from Chesbrough, Vanhaverbeke and West [20].

Institutes that have been established at universities will clearly have a research as well as an education remit and in terms of applying the knowledge outputs, this will often extend to the translation of research outputs as previously described. Indeed there are a number of different types of organisations involved in the knowledge production process, including universities, hospitals, industries and governmental laboratories [25]. Public sector research and development (R&D) institutes are by definition formed by governmental bodies and are often required to address a particular national or governmental need. Although such institutes are faced with many of the same issues as university based institutes, such as the need to secure long-term and stable funding for research as well as the need to collaborative with other organisations (such as universities) related to the technical field and scope of the institute [26].

Public sector institutes are increasingly required to engage in the commercialisation of research and technology [27] and to justify how they are contributing to the economic development of the local region [28], working with small and medium enterprises (SMEs) [29] as well as demonstrating wider societal benefits or end use relevance [30]. Furthermore, Savory [31] has investigated public-sector research institutes that have implemented processes to increase the rate at which new technological innovations are adopted and commercialised for the benefit of societal stakeholders. Independent research institutes that are outside of higher education institutions can sometimes encounter challenges in regard to sustaining organisational legitimacy and this can be seen through the science–non-science dimension and the public–private dimension, which can become in conflict with one another [32]. Therefore, these independent research institutes need to ensure the long-term strategic proposition for the institutes remains valid.

III. RESEARCH METHODOLOGY

The research methodology employed consisted of three main stages (see Fig. 2). The first stage involved review of the literature on research institutes and related organisations such as centres in order to assemble background information in the area and also ensure existing best practice on institute design and management is captured.

Following the literature review a benchmarking exercise was conducted of institutes and centres established to support the delivery of research and technology programmes and in some cases additional services such as education and teaching as well as commercial activities. The benchmarking exercise involved online searches of research and technology institutes (comprising institutes, centres, programmes and related initiatives), and in particular those related to the energy sector including those that have received a substantial level of investment from an oil and gas sector company. The energy sector was selected since it is a knowledge-intensive industry [33] that currently faces major technical challenges [34, 35], which has given rise to the need for a significant number of research institutes to address this need. Moreover, oil and gas companies have a track record of investing in technical institutes in order to gain access to the latest research and technologies and also as part of developing enhanced organisational capabilities, e.g. through recruitment of postgraduate (Masters' and PhD levels) students who have completed their studies at university-based institutes.

Table 1 provides details of the 25 research and technology institutes (comprising institutes, centres and programmes) that were searched online (with hyperlinks included) and which are all involved in some form of activity related to research, technology, education and/or the industrial application of research associated with the energy sector. The institutes reviewed included 12 from the UK, 9 from USA and 4 from Australia. One of the institutes from the UK has the institute hub located in this country along with two of the spokes also in the UK but a further spoke is located in USA. A further institute has a co-location centre in the UK as well as other co-location centres located in several other countries across Europe.

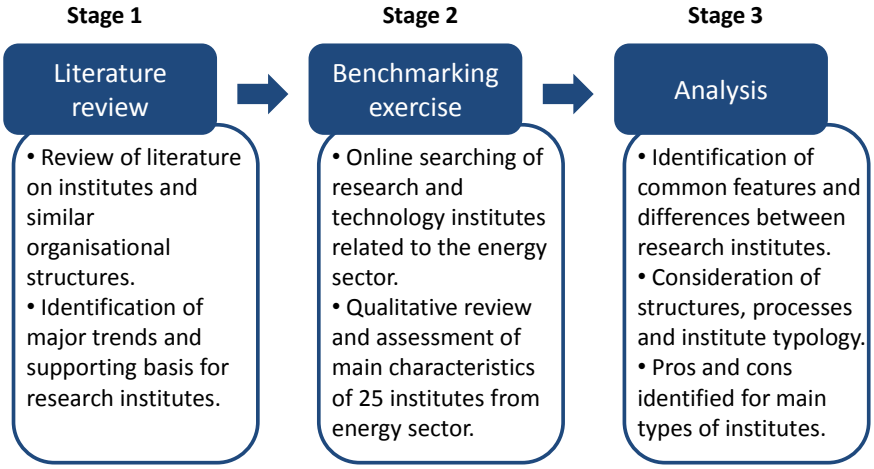

Fig. 2. Research methodology employed in the research study.

TABLE 1. RESEARCH AND TECHNOLOGY INSTITUTES IDENTIFIED AND REVIEWED THROUGH ONLINE SEARCHING.

No.	Research and Technology Institute	Country	Website Hyperlink
1	Aberdeen Institute of Energy, Aberdeen University	UK	http://www.abdn.ac.uk/aie/
2	Advanced Energy Consortium (AEC), University of Texas at Austin	USA	http://www.beg.utexas.edu/aec/
3	Centre for Advanced Materials (ICAM), University of Manchester	UK (& USA)	http://www.icam-online.org/
4	Centre for Coal Seam Gas (CCSG), University of Queensland	Australia	http://www.ccsg.uq.edu.au/
5	Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)	Australia	http://www.co2crc.com.au/
6	Climate KIC (Knowledge and Innovation Community)	UK (& Europe)	http://www.climate-kic.org/
7	Energy Biosciences Institute (EBI), University of California Berkeley	USA	http://www.energybiosciencesinstitute.org/
8	Energy Futures Lab (EFL), Imperial College London	UK	http://www3.imperial.ac.uk/energyfutureslab
9	Energy Technology Institute (ETI)	UK	http://www.eti.co.uk/
10	Gas Technology Institute (GTI)	USA	http://www.gastechnology.org
11	Global CCS Institute (GCCSI)	Australia	http://www.globalccsinstitute.com/
12	Global Climate and Energy Project (GCEP), Stanford University	USA	http://gcep.stanford.edu/index.html
13	Institute for Sustainable Energy Solutions (ISES), Northern Arizona University	USA	http://nau.edu/cefns/centers-institutes/sustainable-energy-solutions/welcome-to-ises/
14	Institute of Petroleum Engineering (IPE), Heriot-Watt University	UK	http://www.pet.hw.ac.uk/
15	Oxford Institute for Energy Studies (OIES)	UK	http://www.oxfordenergy.org/
16	Qatar Carbonates and Carbon Storage Research Centre (QCCSRC), Imperial College London	UK	http://www3.imperial.ac.uk/qatarcarbonatesandcarbonstorage
17	Renewable and Sustainable Energy Institute (RASEI), Joint Institute of University of Colorado Boulder and US National Renewable Energy Laboratory (NREL)	USA	http://rasei.colorado.edu/
18	Rolls-Royce Control & Systems University Technology Centre (RR UTC), University of Sheffield	UK	http://www.sheffield.ac.uk/systemsutc/index
19	Shell Center for Sustainability, Rice University	USA	http://shellcenter.rice.edu/
20	Sustainable Minerals Institute (SMI), University of Queensland	Australia	http://www.smi.uq.edu.au/Home.aspx)
21	Scottish Carbon Capture & Storage (SCCS)	UK	http://www.geos.ed.ac.uk/sccs/home/
22	UCL (University College London) Energy Institute	UK	http://www.bartlett.ucl.ac.uk/energy
23	Unconventional Natural Gas and Oil Institute (UNGOI), Colorado School of Mines	USA	http://ungi.mines.edu/
24	UK Energy Research Centre (UK ERC)	UK	http://www.ukerc.ac.uk/support/tiki-index.php
25	University of California, Davis Energy Institute (UCDEI)	USA	http://energy.ucdavis.edu/centers-and-programs/

Once the research and technology institutes were identified, a detailed review was carried out of the available data and information that could be captured from the corresponding websites. Supporting details were gathered in five main areas: the institute description (1), strategic driver (2), institute sponsor (3), funding base & duration (4), and leadership & governance (5). In this regard, representative details are provided for three of the 25 institutes that were reviewed as part of the benchmarking exercise and this information is provided in Table 2.

After the data and information had been gathered for the 25 research and technology institutes, qualitative analysis was undertaken in order to identify areas of commonality as well as the main differences between the 25 institutes. This analysis involved sorting and grouping together the data and information for each of the institutes to identify trends and common themes (in an analogous manner to clustering). Viewing the institute data and information according to this approach highlighted that although all the organisational entities may be broadly regarded as research institutes, they have clearly been established for different purposes. The institutes have their own unique strategic drivers, which encapsulate the 'value proposition' for the institute, and it is this value proposition that essentially attracts the necessary funding (e.g. from industrial, governmental, charitable or philanthropic means) in order to provide capital to support the institute's functioning. Institute operations require necessary resourcing (through staff and facilities provision) as well as implementation of appropriate management processes (such as governance arrangements) to allow institute activities to be properly directed, managed and delivered. Therefore and through consideration of the qualitative analysis undertaken as part of the benchmarking exercise it was possible to conceptually derive the main institute operating models, which are described in further detail in the next section.

TABLE 2. REPRESENTATIVE DETAILS OF INSTITUTES EXAMINED AS PART OF BENCHMARKING EXERCISE

Institute (and organisations)	Description of institute	Strategic driver	Institute sponsor	Funding base & duration	Leadership & governance
Climate KIC (Knowledge and Innovation Community), Co-Location Centres in UK, France, Germany, Switzerland, Netherlands, Europe.	Research organisation designed to leverage research and technology, higher education, business and entrepreneurial drivers. Technical focus includes the following areas: Assessing climate change and managing its drivers; Transitioning to resilient, low-carbon cities; Advancing adaptive water management; Developing zero-carbon production systems.	Shape Europe's climate change agenda through research, education and promotion of entrepreneur-ial activity.	EU (European Institute of Innovation and Technology) plus other industrial funding.	Created in 2010 with 25% funding from EU EIT and the other 75% funding to be provided by partner institutions.	Leadership: CEO and Co-Location Directors from each country. Governance: Co-location structure supporting by six Regional Centres, collectively managed by a Steering Group.
Energy Futures Lab (EFL), Imperial College London, UK.	The Lab leads and integrates research across the university including: Energy Efficiency; Nuclear Power; Renewable Energy; Transport; Electrical Networks; Economics and Policy Development. Research portfolio includes a series of Grand Challenges, such as the Urban Energy Systems Project funded by BP, and also research on Clean Fossil Fuels funded by Shell. Offers a postgraduate degree (MSc) in Sustainable Energy Futures.	Leading centre for excellence and university hub for multi-disciplinary energy research, education and partnerships.	Various (industry including BP and Shell, research councils, others).	Established in 2005 to co-ordinate research from the energy industrial sector, which amounts to £50M per annum.	Leadership: Professorial Director, Professorial Deputy Director, Director of Education, other management staff. Governance: Strategy Board (Independent Chairman), Advisory Board, Technical Working Group.
Qatar Carbonates and Carbon Storage Research Centre (QCCSRC), Imperial College London, UK.	New research centre that aims to strengthen Qatar's engineering talent and expertise and expand research capacity in carbon capture and storage (CCS) and cleaner fossil fuels, involving over 40 academic staff, postdoctoral researchers and PhD students.	Develop technologies for enhanced production from carbonates and CCS along with technical capacity building in Qatar.	Qatar Petroleum and Shell.	Established from a $70M 10-year contract jointly funded by Qatar Petroleum and Shell, with additional support from Qatar Science and Technology Park (QSTP).	Leadership: Professorial Programme Director, Programme Manager.

IV. RESULTS

A. Institute Operating Models

The benchmarking exercise identified the main types of research institutes and it can be observed there are broadly three operating models adopted by these institutes, which are Research Programme, Research Centre and Independent Research Organisation (see Fig. 3), and Table 3 highlights the main features and differences for the three institute operating models.

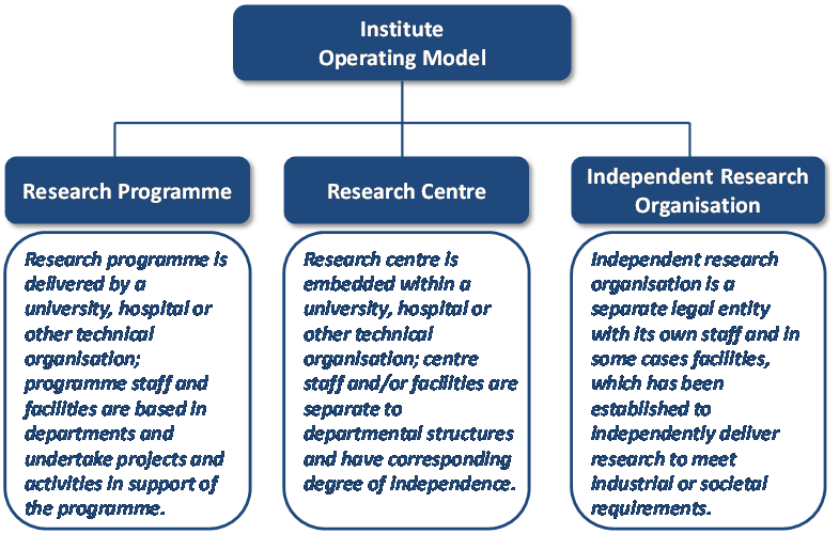

Fig. 3. Institute operating models (including definitions) identified.

TABLE 3: MAIN FEATURES FOR THE THREE INSTITUTE OPERATING MODELS.

Features	Research Programme	Research Centre	Independent Research Organisation
(a). Structural characteristics:			
• Dedicated staff		✓	✓
• Dedicated headquarters facilities		✓	✓
• Located at university (or hospital)	✓	✓	
• Can be located anywhere			✓
• Independent organisation			✓
(b). Commercial arrangements:			
• Industrial and government funding	✓	✓	✓
• Small or large in terms of revenues	✓	✓	✓
(c). Main activities undertaken:			
• Research projects	✓	✓	✓
• Translation of research/knowledge	✓	✓	✓
• Education/teaching activities	✓	✓	
• Broader societal engagement			✓

The respective features for each of the three institute operating models are considered further as follows.

B. Research Programme

Research programmes generally involve delivery of a defined portfolio of research projects and supporting activities within a specific (programmatic) remit. These institutes are likely to be undertaken by a university (or group of universities) and be funded by either a single or multiple organisations, such as research councils/agencies or industrial companies. In regard to the staff engaged in delivering such programmes, they will likely also be based within a particular academic department, where they will conduct their other (wider) job duties, i.e. working on the programme will probably constitute only part of their overall work portfolio. Since programmes generally do not have dedicated staff or facilities they are not independent from existing departmental structures and processes; they will therefore utilise the management and administration functions of the academic department.

Research programmes may be financially supported through a major programme funded by a third-party organisation (such as an industrial company) and this may be through a framework agreement or other such contract. In this scenario the contract would include provision for funding of individual projects either at the single university or multiple universities. These types of contract can involve tasking arrangements (or call-off), where there is flexibility for tasks (or projects) to be placed under an overall scope of work.

Research programmes can either have a broad scope, or a more focused technical remit. Research and knowledge translation from research programmes often involves commercialisation of research and this is a particularly important feature for industrial supported institutes. Fig. 4 provides an illustrative view of how research programmes can be organisationally structured. In regard to the three representative institutes detailed in section III, the Qatar Carbonates and Carbon Storage Research Centre can be considered as a research programme.

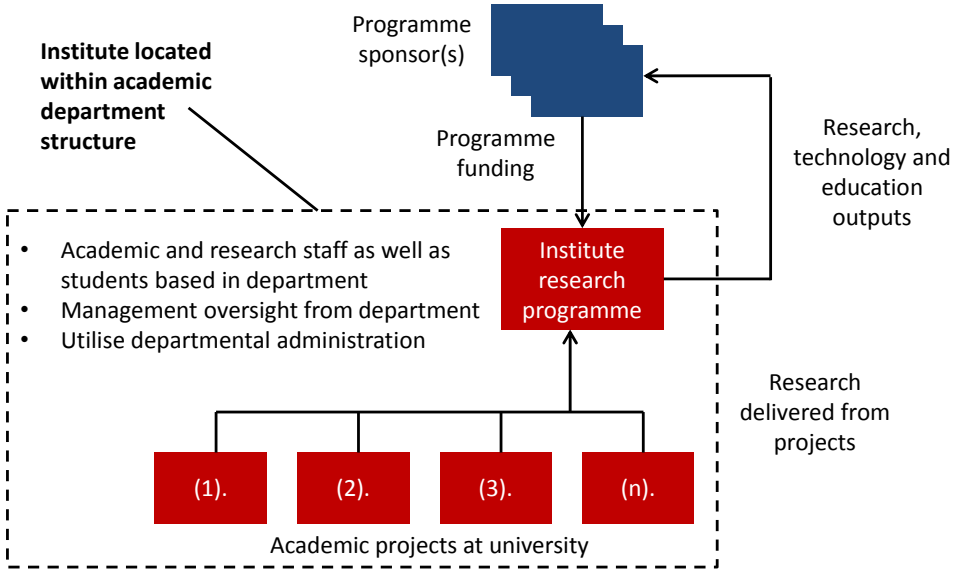

Fig. 4. Representative organisational structure for research programmes.

C. Research Centre

Research centres generally enable delivery of a defined grouping of initiatives or projects that also span a number of academic disciplines. These institutes are based at universities and are therefore able to gain access to university support services as a recognised organisational unit within the university. However, since research centres operate outside of traditional departmental structures they have a greater degree of independence when compared to research programmes. They are also likely to be more strategic in focus and have a higher profile at the host institution and externally (and especially internationally) when compared to research programmes.

Research centres may be existing initiatives that receive funding from a range of different sources, or alternatively they may have been established to meet a particular requirement or industrial contract. Such institutes can involve a single university, or alternatively there may be several partnered universities that collectively constitute the institute. This latter type will usually have a main university (the hub) that leads and co-ordinates the other universities (spokes) as part of a so called 'hub and spoke' model.

These institutes will most likely have dedicated staff, such as a professorial director, management and administrative staff and potentially other academic and research staff as well as postgraduate students. Although in some cases a wider set of academic staff located in other academic departments may still be associated with the institute through supervision of research projects and students as well as from contributions to education and teaching activities carried out by the institute. Research centres may also have dedicated facilities, such as a headquarters (office accommodation and meeting rooms) and larger research centres may even have dedicated research facilities, while smaller ones are able to draw on experimental facilities in different departments at the host university.

Research centres can be financially supported through different contractual mechanisms. New industrially supported institutes may in some cases receive a major contract from a single company that can be regarded as a founding partner of the institute. Alternatively, research centres that have been established for a number of years may receive a number of supporting contracts that collectively provide the financial underpinning of the institute. Moreover, as research centres become more financially sustainable over a number of years, they are likely to receive a more diverse range of contracts (i.e. a higher granularity of funding) as the institute becomes less reliant on the initial investment by a company or other sponsoring organisation. Indeed it is possible to consider the funding lifecycle for a research centre, with an initial and often major (strategic level) investment often secured to initiate the research centre and then a progressive transition to a range of other sources of contracts and forms of financial support to underpin the long-term financial sustainability of the research centre.

Research translation activities can include the transfer of technology and knowledge into partner organisations, including industrial companies and other partner institutions. Also, research centres have a broad scope, or a more focused technical remit. Fig. 5 provides an illustrative view of how multidisciplinary institutes can be organisationally structured. In regard to the three representative institutes detailed in section III, the Energy Futures Lab can be considered as a research centre.

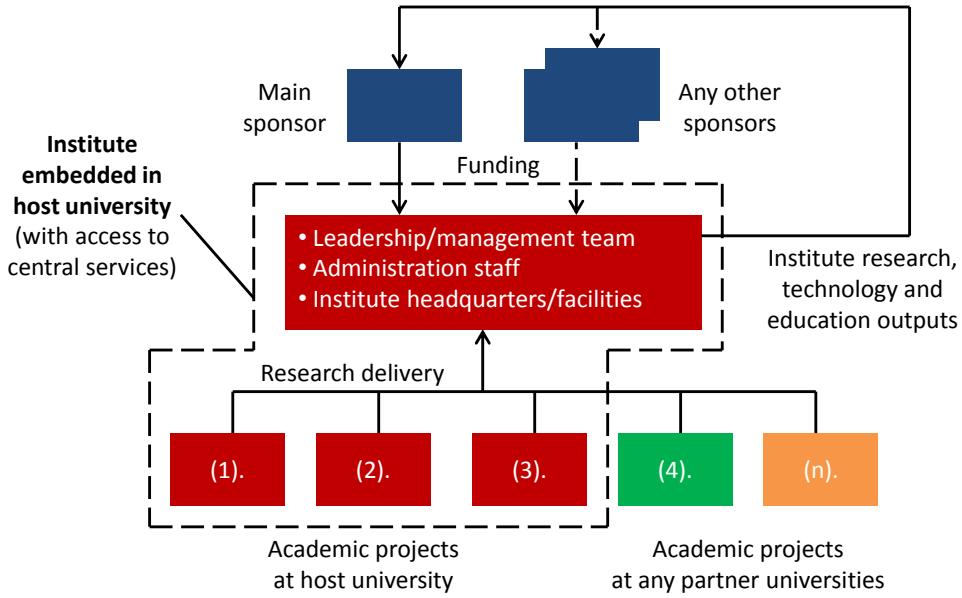

Fig. 5. Representative organisational structure for research centres.

D. Independent Research Organisation

Independent research organisations are generally created to enable delivery of a strategic objective (such as a broad industrial sector remit, or address a societal or grand challenge remit) and such institutes are likely to require access to a significant level of capital and resources. These separate legal entities will need to have dedicated staff and headquarters and in some case dedicated technical facilities although they may be housed or co-located at other partner institutions. Independent research organisations often receive funding from different sources, including both government agencies and industrial companies, although such institutes may have been originally initiated in response to a major investment as in the case for research centres.

Forming this type of institute clearly involves creation of a separate organisation that is implicitly more independent in regard to strategic direction, outlook and operations when compared to both research programmes and research centres. Establishing an independent research organisation through a new legal entity can involve the formation of different types of companies, e.g. a private company limited by guarantee (often a not-for-profit company), or a private company limited by shares (which can be held by a single organisation or by several thereby creating a joint venture initiative). Furthermore, independent research organisations may receive funding from different sources, although this can be from governmental agencies possibly augmented with industrial funding. When an independent research organisation type of institute is established, the parties that are driving the creation of the institute may in some cases commit to financially support the institute for a given period of time.

The research translation focus of these institutes can include technology development and assessment as well as the transfer of knowledge to inform government policy, which is a primary objective of many of the institutes initiated and supported by governmental bodies. Moreover, independent research organisations can have a broad scope, or a more focused technical remit. Fig. 6 provides an illustrative view of how independent research organisations can be organisationally structured. In regard to the three representative institutes detailed in section III, the Climate KIC (Knowledge and Innovation Community) can be considered as an independent research organisation.

V. DISCUSSION

The institutes that have been reviewed as part of the benchmarking exercise have varied sizes and scopes that differ according to the particular research field pursued by the institute. They also have different operating models (including the associated organisational structures, funding arrangements and management processes). Moreover, the features and activities undertaken by a given institute will largely be contingent on the specific requirements for establishing the institute and the operating model employed. Therefore, it is useful to identify the relative pros (advantages) and cons (disadvantages) for the three institute operating models (see Table 4).

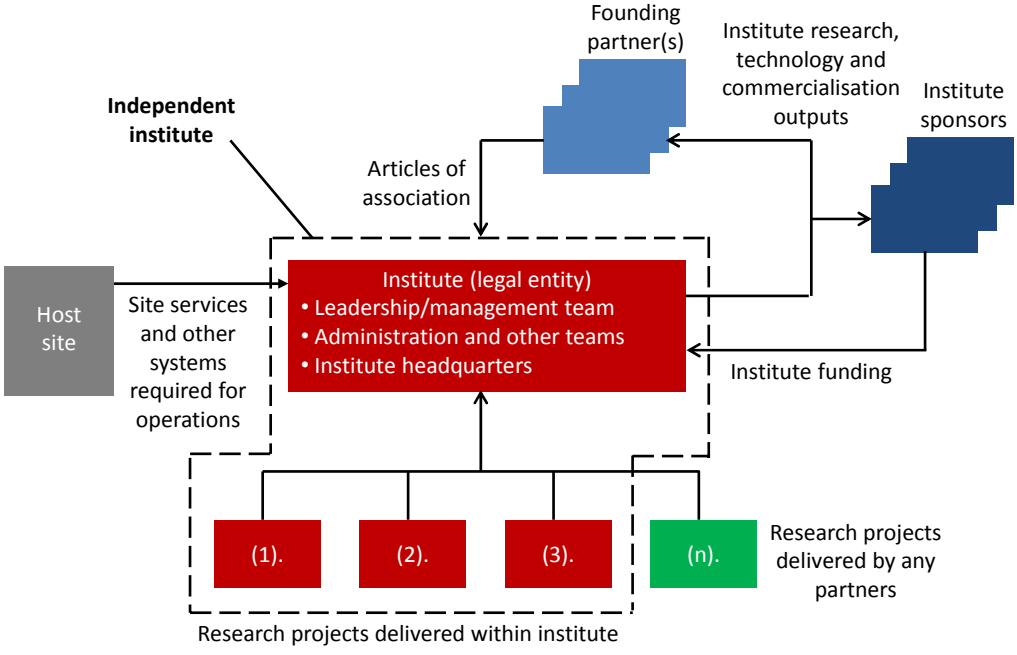

Fig. 6. Representative organisational structure for independent research organisations.

TABLE 3. PROS AND CONS FOR THE INSTITUTE OPERATING MODELS

Operating Model	Pros	Cons
Research programme	• Designed to deliver a specific and focused research and education initiative. • Easier to terminate as the programme may not have dedicated staff and/or facilities. • Can be supported through a framework or master agreement that provides flexibility and ease of contracting.	• Associated staff may have more focus and allegiance towards their own academic department. • Lack of independence when compared to other operating models. • Strategic direction can be set by departmental structures and processes. • Can be difficulty in managing and co-ordinating different projects and activities across departments. • Can be difficult to steer and control.
Research centre	• Multidisciplinary focus leverages expertise from different academic disciplines. • 'Hub and spoke' type of model can incorporate other partner universities (both nationally and internationally). • Efficient resource usage through benefiting from accessing university services, such as research administration, contracts, human resources and academic committee structures. • There is flexibility with the structure to accommodate different partners (industry and academic). • Can be supported through a framework or master agreement that provides flexibility and ease of contracting.	• Initial major investment is often required in order to justify establishment of the institute. • Financial sustainability beyond the initial investment can be a concern. • The need for strong leadership (academic/technical and operational management) of the institute to ensure it becomes adequately embedded within the university can represent an area of risk. • High profile nature of a strategic multidisciplinary institute can lead to reputational risk should the initiative not be successful.
Independent research organisation	• Greater degree of independence when compared to the other operating models. • Strong degree of control afforded to shareholders. • Possible flexibility to contract with a range of partners. • Can be located anywhere and not necessarily at a university.	• Initial major investment often required and this includes legal costs for drafting and review of legal agreements. • Legal risk associated with company formation. • Financial liabilities in regard to company dissolution and staff redundancies. • Need to gain access to commercial services at host site, which may be costly. • Can be more difficult to terminate due to liabilities. • Greater degree of reputational risk for founding organisations.

The benchmarking exercise has sought to clarify the features of research institutes and this has been achieved through the review of 25 institutes related to the energy sector. Three institute operating models have been identified for these institutes and it can be discerned that each model has certain features and characteristics that contribute to delivering the objectives of the institute. Through considering the reviewed institutes that are related to the energy sector it can be observed that oil and gas majors have invested in a number of research institutes. It can also be elucidated that there are a range of institutes that have a broad scope across the energy sector, whereas others have more focused remits, indeed there are institutes that are focused on specific areas related to the energy/oil & gas sector.

Many institutes may have been originally set up a number of years ago and they are subsequently supported through a range of research grants and contracts. Conversely, other institutes may have been established in response to support the delivery of a specific programme or industrial requirement. The institutes reviewed have different scopes in terms of the breadth of the research areas covered and also in regards to the institute's activities and outputs. Some institutes are focused on delivery of a defined research programme, whereas others may be involved with a wider set of activities, ranging from academic research at postgraduate and post-doctoral levels, delivery of postgraduate masters degrees, short courses, outreach and external engagement as well as translation and commercialisation activities. Consequently, establishment of a new institute through one of the operating models identified can provide the mechanism for different forms of activities (in different configurations) to be pursued within a given research field.

The institutes reviewed that are based at universities will most often have a professorial director leading the initiative. In many cases there may also be another director focused on programmes or operations plus additionally in a smaller number of cases a further director with educational responsibilities. This allocation of responsibilities can ensure a senior academic (faculty member) is able to adequately focus on the overall leadership of the institute, including technical direction as well as promoting the institute across the host university and also internationally. Institute directors can have a significant impact on the development and eventual success of newly established institutes and consequently the recruitment of such individuals requires particular attention. Moreover, appointment of other

directors or managers focused on administration, programme delivery or development activities will allow these aspects of institute operations to be professionally managed. The governance arrangements adopted by institutes may involve a management board that includes the institute directors as well as representatives from founding organisations or major sponsors. In some cases institutes may also have additional advisory boards, executive committees and other groupings that provide further levels of oversight of the institute.

The strategic drivers for the institutes reviewed often relate to the provision of research, technology development, education and in some cases policy outputs to inform either a broad energy position or alternatively to make a major impact in a specific technical field related to the energy sector. Institutes are generally created in order to service a requirement (relating to societal, industrial or academic needs) that cannot ordinarily be delivered through existing organisational units or mechanisms. Establishment of a new institute can often require significant resources and financial commitment from the founding organisations as well as a significant commitment by the individuals involved. Consequently, the strategic driver(s) for a new institute need to adequately support delivery of substantial benefits for the organisations involved including those providing substantial capital to support creation of the institute. For industrial companies, this can be through preferential access to research and technology (supported through an appropriate intellectual property regime), which may be evaluated and considered for further development towards new products or improved industrial processes. Additionally, through close association with an institute, a company is able to gain early insight into emerging research areas (i.e. through pursuing an open innovation agenda) as well as the ability to steer and influence the direction of academic research conducted at universities.

The technical work undertaken by institutes can range from fundamental research through to more applied research (i.e. relating to a higher technology readiness level) and for companies to benefit from engaging with university institutes they will need to have the necessary resources in place to support the knowledge transfer process, e.g. a company needs to employ appropriate management and technical staff to coordinate activities with the institute and help contribute to the institute's research direction. A failure to employ such resources could potentially diminish the quality of the benefits sought by the company through its investment in the institute.

It can be discerned that institutes may be contractually supported through a range of different mechanisms. Research programmes and research centres may be contracted (and funded) through a framework (or master) agreement. These framework agreements allow standard terms and conditions to be agreed from the outset along with an overall technical scope of work. Such a contracting mechanism can provide a streamlined and efficient approach, where research and technology projects can be easily set up throughout the term of the overall agreement. Arrangements for the allocation of intellectual property rights (IPR) may be decided as part of negotiation of the framework agreement, or alternatively they can be handled on a case-by-case basis for individual projects. In either scenario, universities will often seek to own foreground IP for research conducted within the university institute but a preferential position on licensing will often be granted to the company funding the work, e.g. through granting the company a non-exclusive royalty free (NERF) license for arising IP. The establishment of independent research organisations requires drafting of the company formation agreements in addition to placement of contracts to financially support the operations of the institute.

In terms of the operating models employed by institutes, where there is a major investment by a company, the institute will generally either be a research programme or research centre. Where there is a single company that provides the initial investment in an institute then it is likely to have a significant impact on the design of the institute structure and processes as well as the recruitment of key institute staff (namely institute director and other senior staff). Conversely, where an institute is supported by a consortium of companies, any single company will need to position its requirements and interests in relation to the other consortia members, which may in some cases have competing or conflicting demands on the objectives and functioning of the institute. However, consortia supported institutes do offer the investing companies both a reduced level of risk and lower level of financial commitment. Furthermore, independent research organisations are often initially funded by governmental bodies.

In regard to the relative funding levels for the three institute types, it can be observed that in some cases research programmes require a lower level of funding than research centres, which in turn may require a lower level of funding than some independent research organisations. However, there appear to be many exceptions to such a trend and it is therefore difficult to assign a particular operating model to a level of funding (or corresponding cost base). Nevertheless, it would be useful to explore institute funding in more detail; especially the distribution of funding levels for the different operating models and in particular how this may influence institute structure, management processes and performance in terms of research, education and translation outcomes.

In order to assist practitioners seeking to establish a new institute Fig. 7 provides an organising framework, which highlights various criteria that can be considered and which are grouped according to being strategic requirements, structure factors, people factors and process factors. Consideration of the points from the framework will support the institute design and development process and thereby ensure the institute organisational structure, resourcing and supporting management processes are aligned with the strategic need for creating the institute.

Strategic requirements

- Identify strategic requirements to be addressed by establishing the institute in terms societal, emerging subject or industrial benefits.
- Articulate institute business areas in regard to relative focus on research, education and translation (inc. commercialisation & knowledge transfer).
- Determine the institute value proposition that will attract funding.
- Ascertain technical facilities required to support the value proposition.

Structure factors

- Institute pros and cons used to decide which institute operating model.
- Consider the level of independence required for institute (high independence being offered by Independent Research Organisations).
- Consider the level of integration with academic/hospital organisational structures for Research Programmes and Research Centres.

People factors

- Identify key leadership posts (Institute Director, Administrative Director and any other senior posts required to lead and manage the institute).
- Consider attributes required for founding Directors (skills, competencies, technical specialism, profile and networked connections).
- Consider reporting lines for the Institute Director to avoid role strain.

Process factors

- Identify governance arrangements (management board, advisory board).
- Ensure efficient reporting processes (internal and external).
- Consider how institute performance will be measured.
- R&D project management and commercial/IP management processes.
- Need for effective external communications to promote institute.

Fig. 7. Organising framework to support institute design and development.

VI. CONCLUSIONS AND FUTURE WORK

This paper has provided the findings from a preliminary assessment of research institutes based on a supporting literature review and benchmarking exercise of 25 research and technology institutes related to the energy sector. The literature review highlighted the issues encountered by research institutes as well as the different reasons for establishing a new institute. Through building on both the literature review and analysis following the benchmarking exercise it has been possible to identify and articulate three main operating models for institutes, which are as follows: Research Programme ("delivered by a university, hospital or other technical organisation; programme staff and facilities are based in departments and undertake projects and activities in support of the programme"), Research Centre ("embedded within a university, hospital or other technical organisation; centre staff and/or facilities are separate to departmental structures and have corresponding degree of independence") and Independent Research Organisation ("a separate legal entity with its own staff and in some cases facilities, which has been established to independently deliver research to meet industrial or societal requirements").

The three operating models each have their own pros and cons, and therefore selection and adoption of one of the models for a new institute requires careful consideration so that the institute's requirements can be delivered efficiently and effectively. However, the design of any new institute should also be contingent on the organisational circumstances and wider environment as well as the needs of the stakeholders concerned. Nevertheless the paper has included managerial insights into how institutes can be designed and operated and this should be of particular interest to practitioners looking to establish a new institute or engage in collaboration or partnership with an existing institute. These insights have been brought together as part of an overall organising framework to support the institute design and development process.

Research institutes are able to undertake different activities depending on the reasons for establishing the institute along with the requirements from sponsors and other key stakeholder organisations. Some institutes are able to pursue a technology and knowledge translation agenda in addition to fundamental research and education, whereas others may focus more on the translation aspects without undertaking basic research or teaching. Understanding the balance between research, education and translation required

to meet the strategic objectives of the institute will help support the long-term sustainability and viability of the institute. Moreover, research institutes can also be viewed as part of a development cycle and consequently there are benefits from establishing and retaining flexibility in how an institute is structured and operated so that an institute's strategic direction may be refocused in order to remain aligned with stakeholder needs.

The benchmarking exercise focused on research and technology institutes related to the energy sector, incorporating the oil and gas industry. It can be observed that there are a significant number of cases where oil and gas companies that are active in the exploration and production of hydrocarbons have made major investments in institutes; including those based at universities and also at independent institutes not directly affiliated with an academic institution. Such companies will be motivated for a number of different reasons to partner with research institutes, e.g. development of new membranes and materials technologies to enhance carbon capture and storage, or improving the energy efficiency of power systems used in hydrocarbon production. Industry also seeks knowledge and expert insights to inform policy developments and other strategic decisions as well as a need to recruit well qualified graduates and postgraduates from academic institutes. Industrial companies can therefore capture the respective requirements and then map these against the features of the three institute operating models (i.e. through considering institute pros and cons, and also through use of the organising framework) in order to improve how they interact with research institutes and ultimately improve the value derived from this interaction. Further, institutes can be positioned in the context of wider innovation systems through collaboration and partnership with industry, academia and governmental organisations, i.e. relating to the triple helix view of innovation [36] as well as national innovation systems [37].

The research reported in this paper has highlighted the differences between the proposed three types of research institutes and this has been augmented by guidance on how these types of institutes can be structured and managed. Future work is suggested in the area of improved management processes to support institute operations and specifically focused on identifying new approaches required to support institutes both in the start-up as well as delivery phases. Such management processes could be in the area of performance measurement, financial management and also improved techniques to support the knowledge translation and commercialisation activities with third-party organisations. The development of an improved understanding of the distribution of investment for the three operating models is also suggested through considering the relative levels of investment required to generate impact and deliver value (especially for commercial sponsors) as well as determining whether a linear relationship exists between investment level and value delivered. Finally, it is recommended that this current work is extended through considering institutes beyond the energy sector (such as those from the medical and biosciences arena) and to thereby assess any synergies associated with certain types of operating models adopted in specific environments or industrial sectors.

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