XODUS PROJECTS

Scotland's International Competitiveness and Benchmarking in Subsea Engineering

Study Report

Scottish Enterprise

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Xodus Group
Xodus House, 50 Huntly Street
Aberdeen, UK, AB10 1RS

T +44 (0)1224 628300
E info@xodusgroup.com
www.xodusgroup.com

xodus GROUP

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INTRODUCTION

- **Definition:** 'Subsea Engineering' encompasses all technology and engineering products and services for application below the surface of the sea. We believe that Scotland's subsea engineering capability has the potential to achieve strong growth across multiple global markets, such as seabed mining, defence, marine renewables and aquaculture.
- **Objective:** Scottish Enterprise is currently engaged in **exploring and exploiting the opportunities of the Subsea Engineering sector**. They have therefore engaged Xodus to assess Scotland's competitive advantages through **assessing Scotland's strengths** in company capabilities, infrastructure, testing / demonstration and academia, with **recommendations on how Scotland can effectively leverage its capabilities**. The analysis will include a comparison internationally through benchmarking against other international subsea hubs

AT A GLANCE

Scotland is	General	Engineering, Procurement, Construction and Installation	Feasibility of New and Emerging enabling Technologies	Inspection, Repair and Maintenance	Decomissoning	Subsea Processing	Digital AI	Offshore Renewables
Norway	N	N	W	SS	N	W	N	S
Houston	SS	N	SS	SS	N	SS	N	S
Perth	S	S	S	S	S	S	SW	S
Malaysia	S	SS	S	S	S	SS	S	S
Rio	SS	N	N	N	S	N	SS	S
Paris/West Africa	S	N	S	S	S	SS	S	S

MW - Much Weaker, W - Weaker, SW - Slightly Weaker, N - Neutral, SS - Slightly Stronger, S - Stronger, MS - Much Stronger

METHODOLOGY

Review of multisource information: Review of previous studies, industry reports and surveys
Scope specific survey: Cross section of the industry covering all focus areas and in multiple locations. 40+ respondees
Expert internal workshops: Subject matter experts within Xodus attended a series of 11 workshops.
Expert external interviews: Expert input was sourced from the likes of Subsea UK, OGTC, The Datalab, NSRI, University of Aberdeen, key individuals from across the Scottish supply chain, experts from the cross sectoral subject areas and experience covering the range of hubs selected for comparison. 12 expert interviews in total were conducted.

Subsea Engineering - Review of Scotland's International Competitiveness

KEY MESSAGES

- **Respect, Experience, Depth, Quality, Confidence, Assurance, Efficiency** were all used regularly to describe the Scottish Subsea Engineering industry
- **Large volume of support and support institutions available**. But do people know how to traverse the support landscape and achieve commercialisation.
- **People are Key**. Make use of those we have at home but also those abroad. Scotland more than any other hub appear to be a nation of travellers. The number of Scots located in other hubs is considerable and this is advantage to make the most of.
- **Maximising emerging economies - Digital and Offshore Renewables**
- **Digital** - Scotland has a strong pipeline of talent for Digital. We need to attract young graduates to the subsea industry then enact the innovations that we task them to provide.
- **Offshore Renewables** - **Fixed offshore wind** is gathering pace as a commercial operation. We should maximise opportunities in the development and service sectors as fields move North.
- **Offshore Renewables - New technologies of Floating Wind, Tidal & Wave** - Scotland needs to embrace these sectors early and ensure these are Scottish based industries with design, manufacture, installation and O&M performed here. We have the skills and facilities. The industry needs governmental support.
- **IRM is a key opportunity sector worldwide.** Our findings were that the respect for the Scottish Subsea sector comes from "seen it, done it, solved it". We can use this to access the high impact/ high cost operational issues market worldwide. When production is halted cost is less critical just experience, efficiency and assurance. Target Areas - Malaysia, Brazil, West Africa & Perth

Strengths to Exploit

- Respect, Experience, Depth, Quality, Expertise
- Operational Solutions/ IRM
- Global Network of expats
- Innovative Spirit
- Adaptability

Opportunities to Maximise

- Intelligence/ Access to immediate critical issues in other locations
- Digital Advances
- Industrialisation of Floating Wind, Tidal & Wave

Weaknesses/ Threats to Address

- Talent Pipeline, Attracting new graduate best talent
- Awareness of digital potential
- Lack of courage to implement change
- Understanding of support landscape
- Support for final testing
- Local content regulations
- R&D spend in other regions

A full report is available by request from Scottish Enterprise

1 INTRODUCTION

Xodus Group have been tasked by Scottish Enterprise to carry out a research study titled 'The Provision of Scotland's International Competitiveness and Benchmarking in Subsea Engineering'.

This study aims to present the current status of competitiveness and innovation in Scotland's Subsea market and how it compares to other international markets. This report represents the results and learnings to date in a format which can be utilised by Scottish Enterprise to more effectively and efficiently manage their Subsea Opportunity Programme.

2 METHODOLOGY

2.1.1 Definition of Subsea Engineering

Scottish Enterprise defined subsea engineering for the purposes of this study as the following:

'Subsea Engineering' encompasses all technology and engineering products and services for application below the surface of the sea. We believe that Scotland's subsea engineering capability has the potential to achieve strong growth across multiple global markets, such as seabed mining, defence, marine renewables and aquaculture.

2.1.2 Project Aims

Scottish Enterprise is currently engaged in exploring and exploiting the opportunities of the subsea engineering sector. They have therefore engaged Xodus to assess Scotland's competitive advantages through assessing Scotland's strengths in company capabilities, infrastructure, testing / demonstration and academia, with recommendations on how Scotland can effectively leverage its capabilities. The analysis will include a comparison internationally through benchmarking against other international subsea hubs.

2.1.3 Process

The study followed three distinct phases

- Assessment of Scotland's capability, strengths, weaknesses, Unique Selling Points (USPs) against the agreed focus areas, based on Scottish strengths and thus define their competitive areas;
- Assessment of international subsea hubs capability, strengths, weaknesses, USPs against the agreed focus areas and then asses the competitiveness of Scotland versus that subsea hub;
- Recommendations particularly on how Scotland can most effectively leverage its capabilities, Reporting and Presentations.

2.1.4 About the Authors

Xodus Group is a multidisciplinary energy consultancy servicing the oil and gas and offshore renewables industries.

Mike Allan is a chartered engineer with over 16 years' subsea engineering experience. Mike has performed senior roles in a variety of development projects from concept through detailed design. He has experience in installation engineering, offshore construction, decommissioning and has specialised in Asset Integrity management for the last three years.

Jamie MacDonald is a senior engineer with more than 6 years' experience including a year seconded in Japan. He has worked on numerous projects from concept level through to detailed design and also in installation.

2.1.5 Inputs

This study utilised a range of methods to pull together its conclusions:

- Review of Scottish Enterprise's previous studies and reports, relating to subsea capabilities;
- Review of multisource information;
- Interface with Scottish Enterprise energy team authoring the subsea engineering opportunities studies;
- Scope specific survey;
- Expert internal workshops;
- Expert external interviews.

2.1.6 Focus Areas

The subsea engineering industry in Scotland is a vast one and thus this study has focused on a range of areas within the overall industry to provide a picture of capability and competitiveness. These are as follows:

- Feasibility of New and Emerging Enabling Technologies; - Covering R&D, support and funding organisations, industry bodies, cluster organisations.
- Engineering Procurement Construction & Installation (EPCI) – Covering all phases of Engineering;
- Inspection, Repair & Maintenance (IRM);
- Decommissioning;
- Subsea Processing;
- Digital/ Artificial Intelligence;
- Offshore Renewables;
- Other - Mineral Extraction/ Aquaculture/ Defence.

2.1.7 Competing International Subsea Hubs

The following regions were selected at the kick off meeting between Xodus and Scottish Enterprise to provide a representation of some of the world's main subsea markets, as a basis for comparison.

- Norway;
- Houston;
- Perth;
- Malaysia;
- Rio;
- West Africa/ Paris.

Other international subsea hubs exist, but often these have less wide-ranging capabilities for comparison with Scotland.

2.1.8 Contributors

The authors would like to thank the following contributors for their valuable input into the study.


SUBSEA UK

Benthic
INNOVATION TO THE CORE

OCEAN INSTALLER EST/ OI.OI.II

HOULDER

UNIVERSITY OF ABERDEEN

4subsea

SAIPEM

THE DATA LAB
value from data

The Oil & Gas Technology Centre
Your Innovation Partner

NSRI
National Subsea Research Initiative

proserv

eni

3 SCOTLAND'S CAPABILITIES AND STRENGTHS WEAKNESSES OPPORTUNITIES THREATS (SWOT) ANALYSIS

3.1.1 General

Scotland retains a high standing in the area of subsea engineering with capability standing up well to scrutiny and comparison with other traditional subsea hubs.

Scotland has a wide range of engineering specialities with a variety of engineering skill sets housed within the full range of the supply chain from operators through to large Engineering, Procurement, Construction and Installation (EPCI) contractors, down through their supply chain of service companies to design houses and consultancies. This breadth of experience and the depth of the talent pool is seen as a key factor to the success of the region.

Innovation is strong in Scotland with novel solutions and cutting edge technology continuing to be developed by the Scottish subsea engineering industry. There is a strong support network in place with a range of institutes in place to assist companies. However whether the landscape for support is completely understood by the industry could be questioned.

Funding support at the early stage of the commercialisation journey is strong with many avenues available. However where Scotland is possibly lacking against some other regions is due to the absence of a National Oil Company (NOC) that is willing to invest in large scale test projects to prove the final steps of the Research and Development (R&D) and commercialisation process, to move on the industry.

Due to the age and the variety of North Sea infrastructure, Scottish engineering companies have tackled challenges that some other international subsea hubs are yet to experience and have a vast range of experience.

Environmental challenges range vastly between the Southern North Sea with the shallow depth, highly tidal waters, the Northern North Sea with the mid-range water depth and harsh conditions and the West of Shetland region where water depths extend beyond the scope of divers, right down to 1000m+ with strong Atlantic swells. These environments have provided varying solutions throughout their lives with a multitude of fixed platform types, subsea tiebacks of all sizes, bundles, flexible pipes, pipe-in-pipe, pipeline diameters ranging from 2" to 40", control systems spanning the computing revolution and a variety of process challenges including wax, hydrates and HP/HT.

This variety of methods and challenges has given the Scottish work force a breadth of knowledge unparalleled worldwide and this has led to Scottish engineering being desired worldwide. This has been seen in many ways:

- The hosting of centres of excellence in Aberdeen by both operators and installation contractors,
- Exports of goods and services by Scottish companies making up 60% of their total sales
- Export of personnel whom can be found in high numbers in all the oil and gas hubs around the world.

While Oil & Gas development and operation has provided the majority of the subsea engineering experience over the last 40 years we now have other subsea industries emerging with the commencement of offshore platform and subsea field decommissioning, industrialisation of fixed offshore wind taking place as well as major advancements in the development of floating wind, tidal and wave energy. These younger industries, while having their own unique challenges, share so much with the engineering skills, knowledge and innovation built up over the years that they are well suited to execution by or in collaboration with the Scottish subsea engineering sector.

There now follows a capability analysis of each of the Focus areas. Where reference has been made to numbers of companies operating in the Scottish subsea supply chain it should be acknowledged that these figures have been taken from the subsea companies database produced by Scottish Enterprise.

Industry Opinion:

The innovative spirit, the innovation culture and the desire to innovate was a constant theme throughout our expert interviews. There remains a will from the Scottish engineering industry to innovate and collaborate and it was felt that the depth of knowledge and experience within Scotland made it the perfect place to evolve new ideas. This point featured regularly as one of the USPs that Scotland's Subsea Industry has.

Scotland is served by numerous agencies tasked with supporting the evolution of new enabling technologies.

Industry Opinion:

While the support is evidently available and the passion and drive of the individuals involved is undoubted, to some within industry the relationships between the bodies is unclear and thus the optimum route to support is not obvious. It may be of value to publicise the support available and the links between the various bodies. A guide to R&D support was suggested during one of the interviews and may have potential. Without the visibility of the roles and interfaces of each player it is unclear if the support landscape is efficiently supporting Scotland's Innovative companies and guiding them to the areas that will most benefit the long-term future of the subsea industry.

Scotland has over the years developed a number of test facilities with the Underwater Centre and the European Marine Energy Centre (EMEC) amongst the most prominent. EMEC is widely considered the world leading marine renewables test facility. As well as devices coming from across the globe to utilise the facilities and the natural environment they have also been the template for a multitude of test sites around the world with delegations regularly visiting from countries such as the US and Japan. This is something Scotland must capitalise on and retain this best in class position.

Industry Opinion:

Where Scotland may be at a disadvantage to some other regions is in the absence of a major National Oil Company (NOC) to power the latter stages of the development process into commercialisation. A number of experts felt that while Scotland excelled in the early phases of technology development, levels 1-6 on the NASA TRL scale, there was a question raised over whether the UKCS was a place where we were likely to see that technology first deployed especially if it is of significant cost. Without a NOC to provide financial backing and long term strategy then the Scottish sector is reliant on independent operators and government to support R&D. This leads to the impression that major technology is being developed by other regions.

A SWOT analysis for this focus area has been performed and is included in the figure below.

Scotland

Feasibility of new & emerging enabling technologies

Based on literature review, workshops, surveys and expert analysis

Strengths

- Culture of innovation
- Large volume of support agencies
- Capability of universities
- Cross sector agencies Oil & Gas Technology Center (OGTC)/ DataLab/ EMEC
- Emerging technologies: TRL levels 1-6

Weaknesses

- Understanding and visibility of support landscape
- Commitment from IOC's
- Long term strategy
- Developing technologies to commercial level: TRL levels 7-9
- Cost perception worldwide - emerging markets

Opportunities

- If we can break down high level issues such as "cost reduction" or "small pools" into technology challenges then Scotland's SME's can grasp the concept and get involved
- To engage academia more and benefit from cross sectional perspective
- Scotland has all the ingredients required to test locally - facilities, infrastructure, government framework, SMEs, ports etc.

Threats

- Funding from other regions - e.g. 1% R&D levy on all CAPEX in Brazil
- Absence of NOC to fund later stage development
- Fear of being unsuccessful - misunderstanding of R&D

Examples of Organisations & Companies

- OGTC
- OGIC
- NSRI
- DataLab
- Censis
- EMEC
- ORE Catapult
- Universities
- Scottish Enterprise
- Innovate UK

3.1.3 Engineering, Procurement, Construction and Installation (EPCI)

The backbone of the Scottish Subsea Engineering sector through the years has been the EPCI industry. Based in the development space of the project lifecycle EPCI, includes all of the concept, feasibility, front end, detailed design, hardware technology and installation & commissioning engineering.

Scotland hosts two of the major Tier 1 companies (Subsea 7 and TechnipFMC) in the EPCI market as well as a string of the Tier 2 companies. Scotland has a strong supply chain with hardware suppliers having manufacturing facilities situated in Scotland while a number of the other hardware manufacturers have representative or engineering offices in Aberdeen. The service sector based in Aberdeen includes multinational companies as well as local firms. Development engineering is well served by a supply chain including multinationals and SMEs.

Scotland is very much a base from which a lot of these companies operate internationally whether directly with clients or via local satellite offices. Whilst many of the hardware suppliers have set up additional facilities in other regions to reduce costs and comply with local content rules, it is firmly believed that the engineering of new products and complex evolutions are driven from the Scotland offices.

Industry Opinion:

Both our survey respondents and our expert interviews pointed at the EPCI sector as a massive success and a massive strength of the Scottish subsea industry. The variety and volume of developments and the age of the basin has given Scotland a quality of capability and depth of capability that is rarely matched around the world. A USP often stated for the Scottish sector was that of assurance: there was a belief that if you contracted a Scottish engineering company there was a confidence that the issue would have been experienced before and that a solution would be delivered.

A SWOT analysis for this focus area has been performed and is included in the figure below.

Based on literature review, workshops, surveys and expert analysis

Strengths

- Major worldwide companies based in Scotland
- Bundle fabrication yard and unique capability
- Rounded engineering talent
- Density of high quality manufacturing
- One stop shop - minimal interfaces
- Experience of a full range of developments - Deep water/ High Pressure HighTemperature/ FPSO/ Tieback

Weaknesses

- Mature basin = smaller prospects
- Acceptance of new technology at middle management level

Opportunities

- Access to major EPCI's in Scotland can lead to worldwide use
- Can export experience to new regions as they enter increasing complex water depths
- Already discovered "small pool" fields would take 15 years to find this volume again

Threats

- CAPEX spend bypassing decommissioning
- Attracting new talent
- Boom and Bust
- High OPEX cost of basin
- Local content regulations

Typical Organisations & Companies

Total Companies in Scotland - 480

- Subsea7
- TechnipFMC
- Bibby Offshore
- DOF
- Boskalis
- Aker Solutions
- GE
- Drill Quip
- FURO
- Altus
- Wood.
- Genesis
- Xodus Group
- Enermech
- Halliburton

3.1.4 Inspection Repair and Maintenance (IRM)

The Inspection, Repair and Maintenance sector is the natural follow on EPCI when the development process is completed and moves to operations, then the support from the IRM sector begins.

This focus area includes regular periodic surveying to ensure continued integrity, internal and external engineering integrity assessments to assure continued safe operation, repair or replacement of faulty components as well as maintenance tasks to retain acceptable condition.

Most of the EPCI vessel companies also inhibit the IRM space but there are also some specialist IRM companies. Inspection companies, Remote Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUV) suppliers and integrity engineering are all well represented.

Industry Opinion:

*IRM, much like EPCI is a key strength of the Scottish subsea industry with a mass of companies SE research shows 209 in total based in Scotland operating in the **subsea** IRM space. It is also seen as the area where Scotland has produced the most innovation and new technology solutions, again with the volume of infrastructure and the duration of service leading to challenges being addressed through innovative solutions, IRM services have been exported worldwide from the Scottish sector.*

IRM is likely to be a key crossover skill with offshore renewables with technology such as AUVs of particular interest to decrease the inspection costs of traditional high specification vessel based inspection. Another key focus area for offshore renewables is the effects of corrosion on subsea and surface piercing structures with the North Sea Solutions for Innovation in Corrosion for Energy (NESSIE) project launched to investigate this, led by SE along with EU partners and co-funded by the EU. Initial findings have placed the possible market size for UK anti-corrosion solution vendors alone as early as 2020 to be as much as £3.3bn with this rising to £14.4bn in 2050.

One of the biggest paradigm shifts in subsea pipeline IRM would be the development of long life AUVs. These have been used for pipeline inspection for over a decade, the most widely publicised being the Subsea 7 Autotracker system. However, their problem is that the battery life is still measured in hours. A lot of development work has been carried out by various organisations to develop tidal, solar and wave powered AUVs but none of it has resulted in an a commercialised system.

A SWOT analysis for this focus area has been performed and is included in the figure below.

Based on literature review, workshops, surveys and expert analysis

Strengths

- Experience, company depth, capability, company base
- Innovation
- New technology
- Integrity engineering
- Life extension

Weaknesses

- High cost perception in emerging markets
- Historical data
- Data management/sharing
- OPEX Cuts

Opportunities

- Operational issue solutions
- Cluster of SME's could potentially address international issues better
- Offshore wind corrosion issues
- Cabling issues
- AUV's
- Exporting lessons learned to new regions
- Data management

Threats

- Access to immediate international issues without significant global presence
- Cost pressure on smaller players
- Commitment to innovation by IOCs

Typical Organisations & Companies

- Technip FMC
- Subsea7 - iTech7
- Bibby Offshore
- Fugro
- Deepocean
- Oceaneering
- ROVOP
- Wood.
- Xodus Group
- Innospection

Total Companies in Scotland - 222

- Sonomatic
- Stats group
- Lloyds

3.1.5 Decommissioning

Decommissioning is perceived as value erosion for operators across the development lifecycle. Therefore, achieving cost reductions through either innovative technologies or alternative approaches to executing decommissioning projects, such as contracting strategies, is necessary to reduce the current trend forecasting rising decommissioning costs.

Both development and decommissioning projects face technical, execution, market, socio-political and organisational risks. However, the technical, commercial and stakeholder ambiguity in decommissioning projects is perceived to be greater, with reason. A common risk is where facilities have changed hands and collation of sufficient data of the core structures – wells, topsides, jackets and pipelines – is inadequate, leading to greater uncertainty. Data availability and the management of data is considered a key pillar to the success of any decommissioning project as it enables issues to be identified at an early stage and mitigations to be put in place.

Industry Opinion:

There is perception that much of the decommissioning business is not being won by Scottish and/or UK companies. With a significant percentage (50-75%) of decommissioning costs being borne by the UK tax payer via tax refunds, it is likely that there will be political pressure exerted to keep these rebates within the Scottish and UK economy.

Innovation will be paramount to ensure that Scotland's subsea engineering expertise are carried forward to the future in the same way that we have provided innovative solutions for the oil and gas industry for many years in the past. The advantage that innovation has in decommissioning is that a Best Available Technology (BAT) assessment is performed for each field meaning that new innovations will be assessed and able to break in if they prove valuable.

Industry Opinion:

Scotland's success in this area going forward will be based and built on the excellent capabilities developed during the development and operational lifecycle phases of projects and through connections between world-class research facilities, education providers, funding sources and international partners. There are several organisations in Scotland currently involved with research and innovation.

From a subsea perspective well Plug and Abandonment (P&A) is the biggest market that can be exploited by Scottish subsea supply chain. P&A standards and designs vary by operator and country. Since well P&A typically constitutes between 40% and 50% of offshore decommissioning spending each company's approach plays a significant role in overall costs.

Many operators have opted for P&A procedures that go far beyond the minimum regulatory requirements of the countries where they operate.

It is also clear that many regions around the world are adopting the standards set out by Oil and Gas UK rather than developing their own. For example, the well abandonments on Jabiru and Challis (Australia) were carried out to the standards OGUKs well abandonment guidelines. In the Bahamas, new oil and gas regulations have lent heavily on standards all over the world particularly the UK. This adoption of OGUK guidelines globally presents a significant opportunity for the Scottish supply chain to export their expertise in emerging decom markets.

A SWOT analysis for this focus area has been performed and is included in the figure below.

Scotland Decommissioning

Based on literature review, workshops, surveys and expert analysis

Strengths

- North Sea standards leading the world
- Large volume of companies already active
- Building experience quickly
- Well Plugging & Abandonment
- Pipelines Make Safe
- Infrastructure Removal
- Site Remediation and Monitoring

Weaknesses

- Lack of visibility of upcoming projects
- Estimation of costs

Opportunities

- Collaboration to provide "Scottish" solution - Government Support
- Need for new cost effective technologies
- BAT (Best Available Technologies) review included in process
- 100 Platforms, 1,800 wells & 7500km pipelines in next decade
- £50bn over next 40yrs

Threats

- Volume of UKCS contracts going to competing nations
- Talent Attraction/ Retention
- Foreign Ports with Government backing

Typical Organisations & Companies

Total Companies in Scotland - 167

- Fisher Offshore
- Tracerco
- Oceaneering
- Decom North Sea
- OGA, OGTC, OGIC
- Bibby Offshore
- Flowline Specialists
- Global Energy Group
- TechnipFMC
- Subsea7
- Wood.
- Xodus
- Apollo
- CSL
- Genesis

3.1.6 Subsea Processing

Subsea processing can help oil and gas producers increase production and reduce the costs associated with recovery. Around the world, governments are focusing on subsea processing technologies and this is expected to propel the growth of the market in the coming years.

The global subsea processing market is split into four divisions: boosting, compression, separation and injection with significant advances being made in these technology areas making it possible to process oil and gas in harsh temperatures and pressures.

One of the major challenges faced by this market is the reliability and subsequent uncertainty associated with subsea production. Subsea processing requires a high level of technical expertise and any failure in the system may lead to significant loss in revenue.

Europe (specifically Norway – in terms of technology development) leads the subsea processing market segment and it appears it will continue its dominance. Subsea compression is the latest technology under development and although remains to be proven, Statoil/Equinor has qualified two different systems on their projects, Aasgard and Gullfaks. In addition, the technology has been tested in an onshore pool on the Ormen Lange Pilot project, where Shell is the operator. However, in April 2014 Shell put the concept selection for Ormen Lange on hold citing costs as too high and an option value in compression not being time critical. Aker Solutions is working on the Aasgard project, and they also had the Ormen Lange pilot, while OneSubsea is to deliver the system for Gullfaks South.

Booster pumps are mainly used on oil fields with low gas to oil ratios, both for heavier and lighter crudes. The key regions have been, and will continue to be, Brazil, the US Gulf of Mexico, the North Sea and West Africa due to the water depths, reservoir characteristics and tie back distances.

Subsea separation is the concept of separating gas/liquids or oil/water at the seabed. Subsea separation systems have now been installed at 11 fields operated by Petrobras, Statoil/Equinor, Shell and Total. All the fields lay in Brazil, Norway, US GoM or Angola, and going forward these areas and West Africa, are seen as the primary markets for such systems.

A SWOT analysis for this focus area has been performed and is included in the figure below.

Scotland Subsea Processing

Based on literature review, workshops, surveys and expert analysis

Strengths

- Manufacturing of hardware in Scottish factories
- SME's providing components/ancillaries
- Development engineering of fields using sub-sea processing
- Initial technology originated in Scotland

Weaknesses

- Recently driven by Statoil/ Equinor and Petrobras
- Requirement for this technology in UKCS? Thus lack of exposure.

Opportunities

- All hardware manufacturers involved have offices/plants in Scotland therefore access to knowledge and likelihood of utilisation if tech is commonly used
- SME's to develop technology to integrate different suppliers

Threats

- Reliability of technology
- Perceived to be high cost
- Lack of understanding/familiarity with technology may risk missing opportunities

Typical Organisations & Companies

- TechnipFMC
- Aker Solutions
- GE
- OneSubsea

3.1.7 Digital/ Artificial Intelligence

The first of the cross sectoral industries in this study, digital, is represented in many areas of the country. A thriving gaming industry in Dundee, financial services hubs in Edinburgh and Glasgow and Oil & Gas (O&G) in Aberdeen.

Digital is:

- an existing area for subsea engineering with several companies providing digital solutions to production monitoring, integrity management, data management and subsea surveying,
- a growth area for subsea engineering as there has to date been limited uptake of digital innovations with new capabilities being added all the time
- a necessary area for subsea engineering as smarter ways of working is essential to increased efficiency and extending the lives of fields for as long as possible and to make currently uneconomic stranded fields viable.

Industry Opinion:

The digital data industry within Scotland is booming and subsea requires to take advantage of that. The level of talent being produced by our universities is of a high standard with the volume of digital engineers growing every year. Our expert interviews were very positive about the work being done by the universities and the innovation centres such as the Data Lab and Censis.

The subsea industry and O&G, in particular, has long been thinking about the transformation to a digital industry but until recently had not committed to that future with actions and investment.

Industry Opinion:

Digital is an area where subsea engineering can readily gain from the achievements of other industries. Blockchain, FinTech, Communications & Machine Learning may all have application in Subsea. While the early days of Oil & Gas were built on transferring technologies from other industries of late Oil & Gas has been poor at learning from others, so as well as technological shift within the industry, a cultural shift may also be required.

The renewable industry has been more open to digital experimentation and sees the opportunity and necessity to maximise efficiency in a lower cost model business. However, this very same low cost model that has encouraged the interest also limits the investment possible in R&D. Offshore wind is the one area where scale has allowed commercial competitiveness with recent large decreases in the cost of electricity contracts. To achieve reduced costs, the offshore wind industry will require to embrace the efficiencies that new digital technologies could provide.

Looking beyond energy creation to an integrated energy mix system with generation, storage, smart grids etc. digital will be the key component gluing this future development together. If subsea is to be part of this, and with a large volume of energy generation taking place offshore, then digital transformation and uptake is required.

Aquaculture is an area looking to take advantage of digital innovations with Artificial Intelligence (AI) being used to investigate whether fish health can be determined by computer monitoring of behavioural changes. Development and implementation of AI solutions for monitoring of feeding levels and waste are also key to expanding the industry.

The major players are all realising that digital is key to the future success of their businesses and are now beginning to act. To date while the digital engineering sector has had the capability and the innovation they have had limited opportunity.

A SWOT analysis for this focus area has been performed and is included in the figure below.

Based on literature review, workshops, surveys and expert analysis

Strengths

- Renewables
- Digital supply chain
- Universities and support centres
- Innovation and ideas
- Survey technology

Weaknesses

- Middle management 'permafrost'
- Data management
- Information silos and incompatible systems
- Poor at opening up to other industries ideas
- Poor at data collaboration through fear of losing commercial information

Opportunities

- Optimise IRM campaigns
- Reduce requirement for vessel based visual inspection with use of remote sensors or AUVs
- Integrated energy mix needs digital drivers
- Renewables

Threats

- Fear/ Misunderstanding of too much data
- Talent pipeline vs other industries
- Lack of digital strategy

Typical Organisations & Companies

Total Companies in Scotland - 130

- Censis
- Data Lab
- OGTC
- Coda Octopus
- Aker Solutions
- Forum Engineering Technology
- DNVGL
- Xodus Group
- Infotechnics
- iSurvey Offshore

3.1.8 Offshore Renewables

Offshore Renewables

Offshore renewables are estimated to play a major role, driven by both political and economic factors. The renewables-based electricity generation is projected to triple over 2013-2040, overtaking coal to become the largest source of electricity. According to the new policies scenario, 33% of the world electricity generation by source will come from renewables in 2040 (IEA, 2014).

For all offshore renewables Scotland has excellent capabilities in the majority of required disciplines. One area in particular where there has been significant work is in the environmental engineering area where a number of projects have been consented using the UKs high standards of regulation.

Industry Opinion:

Environmental science and engineering is a strong capability that is attractive to a number of geographical areas whom are keen to apply similar standards of Environmental policy. On the positive side the UK is seen as an attractive place to develop technologies and energy projects as the consenting framework while comprehensive, is seen as consistent and transparent and thus can be predicted and planned for allowing investment decisions to be taken.

Offshore Wind

The UK has seen a large amount of offshore wind projects over the last few years, many of which have been developed in the shallower waters of the Southern North Sea, much as the O&G industry did at its outset. Of late, the developments have progressed further north with wind farms under construction in the Aberdeen and Moray Firth areas.

Employment in the sector is on the increase with the number of people employed in Scotland's offshore wind sector increased by 300%, to 2,000 in 2016 from 2015 according to the Office of National Statistics.

A large volume of Scottish companies are involved in Offshore wind already: 265 of the overall 652 subsea engineering companies identified by Scottish Enterprise. These include major developers with projects in our waters, engineering, procurement, construction and installation (EPCI) and vessel companies of varying sizes, manufacturers and engineering.

Industry Opinion:

IRM in renewables is a strong area for the Scottish Engineering Sector and should be a benefit to the offshore wind as well as an opportunity for expanding Scottish Capability.

The Scottish capability is in competition with North East England where a number of centres of excellence have recently been opened, Hull looking to make itself a hub for Offshore Wind O&M. Wales is also making their intentions clear that they want to gain a foothold in the market.

Subsea engineering input will increase as deeper water depths are accessed with installation techniques becoming more complex, environments harsher and substructures and foundations becoming more complex.

The next evolution of wind power generation is the advent of floating wind which has its first large scale project hosted in Scotland albeit with Norwegian investment via Statoil/Equinor Hywind. The development of floating wind in much deeper waters will escalate the requirement for complex subsea engineering with mooring designs, anchoring dynamic cables and connectors being strong areas for subsea engineering.

Industry Opinion:

Hywind is seen by several of our expert contributors as a strong selling point for Scotland and a USP that should be built upon.

Marine Renewables

Consisting of tidal and wave technologies as well as a few other smaller innovations the marine renewables sector is as yet a precommercial sector. However, it is one where Scotland has a world leading track record and reputation and one where subsea engineering capability is most suited to support.

Scotland have had a number of “world firsts” and “world’s largest” in this area:

The European Marine Energy Centre (EMEC) is widely considered the world leading marine renewables test facility. As well as devices coming from across the globe to utilise the facilities and the natural environmental they have also been the template for a multitude of test sites around the world with delegations regularly visiting from countries such as the US and Japan.

Atlantis Meygen project is currently the largest planned tidal stream project in the world, and was the first commercial multi-turbine array to have commenced construction. Phase 1a has been installed with four 1.5MW turbines with the plan to install a total of 261 turbines on the site off the coast of Scotland’s northern tip.

Scotrenewables launched the full commercial scale SR2000 2MW, the world’s most powerful tidal turbine, at the EMEC in 2016. In 7 days of generation, the single 2MW device generated circa 7% of the Orkney Islands electricity demand, with shorter periods exceeding 25% of demand.

While the industry is in its infancy there is a high level of interest from the Scottish engineering supply chain with 180, over 25% of Scottish companies with capabilities in the marine renewables market, a figure greater than those specifying themselves as Oil and Gas (O&G) decommissioning, within the subsea sector.

Industry Opinion:

While marine renewables are currently trailing offshore wind with regards commercialisation and struggling to match the Contract for Difference (CFD) prices achievable by large scale developments what should not be overlooked is the opportunity to retain the manufacturing of these wave and tidal devices within Scotland and the UK. While offshore wind has grown in UK waters the UK has missed out on the lucrative turbine manufacture market with the majority of turbines coming from Continental Europe. Scotland is currently considered a leader in the market, but countries such as Wales, Sweden, France, US and Spain are very keen to close the gap.

A SWOT analysis for this focus area has been performed and is included in the figure below.

Scotland
Offshore Renewables

Based on literature review, workshops, surveys and expert analysis

Strengths

- Environmental Consulting
- Strong transparent legislative framework
- World leaders in wave & tidal energy
- Top class test facility and natural resources
- Existing IRM capability
- Worlds 1st multi-turbine floating wind farm - Hywind

Weaknesses

- Experience - a lot of engineering done in south England local to first developments
- Cost alignment between renewables and O&G supply chain

Opportunities

- Create a wave & tidal industry
- Strong cross sector capability
- Lessons and experience from O&G
- Greater need for Scottish subsea expertise as floating wind targets deeper water

Threats

- Commitment to supply chain should oil price rise
- Brexit - EU currently play a leading role in renewables funding and long term strategy
- Grid constraints

Typical Organisations & Companies

Total Companies in Scotland - 298

- SSE
- Scottish power renewables
- Atlantis
- Scotrenewables
- EMEC
- ORE Catapult
- Proserv
- Oceaneering
- JDR Cables
- ABB
- Wood.
- EC-OG
- Aquatera
- Subsea7

3.1.9 Aquaculture/ Defence/ Subsea Mining

Mineral Extraction

The National Subsea Research Institute (NSRI) recently released a study into the UKs capability in the areas required for Deep Sea Mineral Extraction. They selected the following areas: Environmental Science, Mining Processing /Technologies, Prospecting & Geotechnics, Sea Monitoring, Vessels where they found good capability in the UK Subsea engineering sector to meet these challenges. However, they also believe that the industry is around 10 years from reaching commercialisation so the short term cross sector opportunities may be limited to the innovation space until disruptive technologies emerge. It is thought to be potentially worth between £20 – 60 Billion to the UK economy. A summary of key points is included below.

- It is critical for the UK to be involved in this industry as it emerges to capitalise on the exploitation of subsea mining, but also to ensure that the UK has the security of supply of critical minerals that it needs to support other industries.
- At present the barriers to commercialisation of subsea mining are: technological, environmental, economic and regulatory. Scarcity of some minerals coupled with increasing usage is quickly driving the supply and demand curves to a price point where subsea mineral mining is becoming feasible.
- Lack of experience with subsea mining means that to date no unifying standards exist for environmental impact assessments and seabed monitoring and thus it is difficult to attain consensus on what is acceptable.
- There is a renewed interest in subsea mining with new research activity underway with the aim of understanding better the environmental impact and reducing the uncertainty of evaluating finds and reducing the risk of operations.

Aquaculture

Aquaculture, the practice of farming aquatic organisms, fish, crustaceans and aquatic plants in offshore, coastal and inland waters is already an established major industry in Scotland and worldwide with total UK production valued at £766m. With demand for fish projected to increase with population growth, traditionally caught fishing levels are stagnant and aquaculture is overtaking traditionally caught fish in 2016. It is expected that aquaculture will be required to provide this increase in levels.

While to date fish farms have been located in sheltered waters or inland there is a drive to host farms further offshore in an attempt to find new locations and to tackle some of the challenges with fish health and seabed damage caused by the density of fish. To support this Ministerial Group for Sustainable Aquaculture (MGSA) (2014) has defined some priorities for technology and engineering in the aquaculture sector and where opportunities may exist for expertise and capabilities to be transferred from the offshore sector.

- Fish Health and Welfare
  - Better tools for prevention and control of disease, including non-medicine technologies, vaccine delivery methods
  - Optimisation of harvesting methods (automation)
- Environment
  - Environmental risk assessments and analysis
- Capacity of coastal environment to assimilate discharges from aquaculture
  - Interactions between wild and cultivated species
- Anchors and Moorings
  - Little or no data on mooring line forces for aquaculture specific issues.

- Potential to use existing modelling infrastructure used for offshore applications, e.g. wave tanks, etc.

> Sensors and Monitoring
  - Tools for health and performance monitoring

Ocean Farm 1, believed to be the first offshore aquaculture site, was recently launched in Norway. It is a 110m wide cage capable of containing 1.5 million fish.

Industry Opinion:

Only 39 companies within the Scottish engineering supply chain identify themselves as active in the aquaculture industry. However, with the move to further offshore sites the following groups would become more relevant: Environmental Science – 81 Companies, IRM – 209 Companies, Digital, Data and Comms – 130 Companies as well as many others.

While there is an opportunity for diversification we should be careful not oversell the opportunity as it is likely to be a small low margin market.

Defence

Marine defence is certainly not a new industry and one which the Subsea Oil & Gas industry initially based some of their technology on. A number of companies have throughout their history provided engineering support and services to both industries.

Industry Opinion:

82 companies within the Scottish engineering supply chain identify themselves as active in the defence space. It was also interesting to note that of those 82 companies over 65% are involved in Offshore wind and over 45% are active in marine renewables. Therefore, it can be extrapolated that while Scotland looks towards renewables and defence for diversification those other sectors are also diversifying and will provide competition.

Previous studies have not found it easy to define the specific requirements in a defence scenario; this is often discovered through private discussion. Nevertheless, the strength of capability within the subsea supply chain that could be of use to the defence sector have been identified below. Where available we have indicated the approximate number of the Scottish supply chain that are active in this area.

> Diving, Remote Operate Vehicles (ROVs), Autonomous Underwater Vehicles AUVs, and equipment – 113 Scottish companies.

> Underwater sonar and vision systems

> Vessels, Moorings, and Foundations – 41 Scottish companies;

> Survey and positioning - 56 Scottish companies;

> Structures and particularly new materials;

> Controls, sensing, monitoring, and communications – 99 Scottish companies;

> Umbilicals and cables – 45 Scottish companies;

> Subsea inspection, repair, and maintenance – 209 Scottish companies;

> Buoyancy and protection – 16 Scottish companies;

> Environmental, site studies, and monitoring – 81 Scottish companies;

> Marine Renewables to power remote communications – 180 Scottish companies;

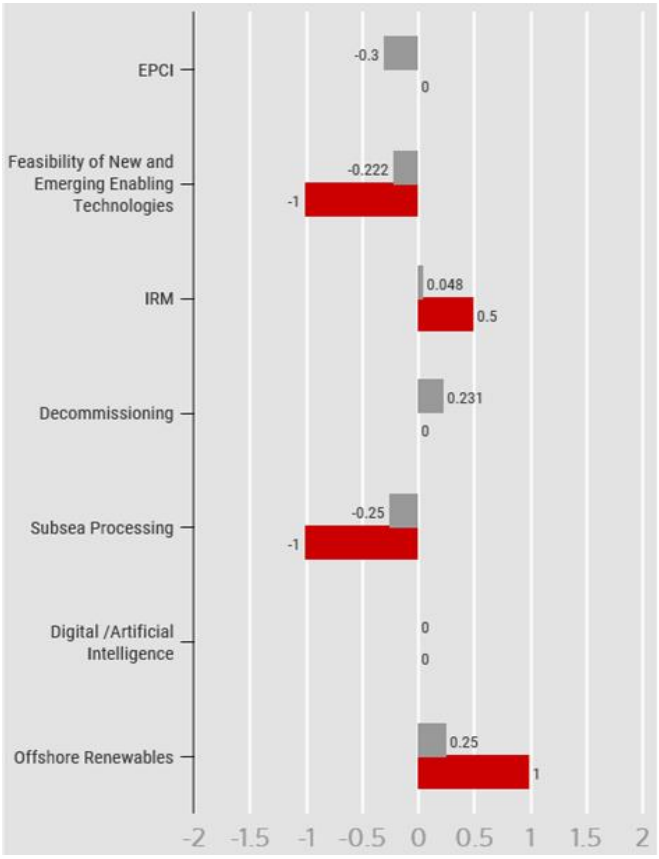
Mineral Extraction Companies – 34 or 5%	Aquaculture Companies – 39 or 6%	Defence Companies in – 82 or 13%
Environmental Science - Companies in Subsea Supply Chain– 131 or 20% 1. World leaders in conducting Environmental Impact Assessments.	**Fish Health and Welfare - Companies in Subsea Supply Chain– 131 or 20%** 1. Better tools for prevention and control of disease, including non-medicine technologies, vaccine delivery methods 2. Optimisation of harvesting methods	**Market Access** 1. Not easy to define the specific requirements in a defence scenario; 2. For example the military lead the market in AUV development and only release capability when appropriate
Mining Processing /Technologies 1. Risers design 2. Underwater Mining Vehicles (ROV knowledge) 3. Experience Of Geotechnics (Prospecting Knowledge) 4. Vessels (Strong Capability)	**Anchors and Moorings - Companies in Subsea Supply Chain– 41 or 6%** 1. Little or no data on mooring line forces for aquaculture specific issues. 2. Potential to use existing modelling infrastructure used for offshore applications, e.g. wave tanks, etc.	**Marine Renewables to power remote communications - Companies in Subsea Supply Chain– 180 or 28%**
Methane Hydrates 1. Technology deployed to extract methane hydrates similar to current subsea processing equipment.	**Sensors and Monitoring – Companies in Subsea Supply Chain– 99 or 15%** 1. Tools for health and performance monitoring	

4 INTERNATIONAL BENCHMARKING

The following section provides the results of the international comparison and benchmarking phase of the work.

The benchmarking results are presented by region in each section and have been broken into two perspectives: -

- The grey bar represents the average survey results (42 Repsondees)
- The red bar represents Xodus Groups interpretation of the survey results in conjunction with further analysis and insight gained from, the following:
  - Literature review
  - Workshops
  - Industry Expert Interviews;



An overall summary of the results is provided in the table overleaf. Scotland stands up well in comparison to all other hubs. While other hubs may have more complex developments or greater water depths to surmount the engineering capability to perform this work is available and strong in Scotland. When this is combined with the depth and variety of experience available in Scotland it provides a compelling case for the Scottish capability.

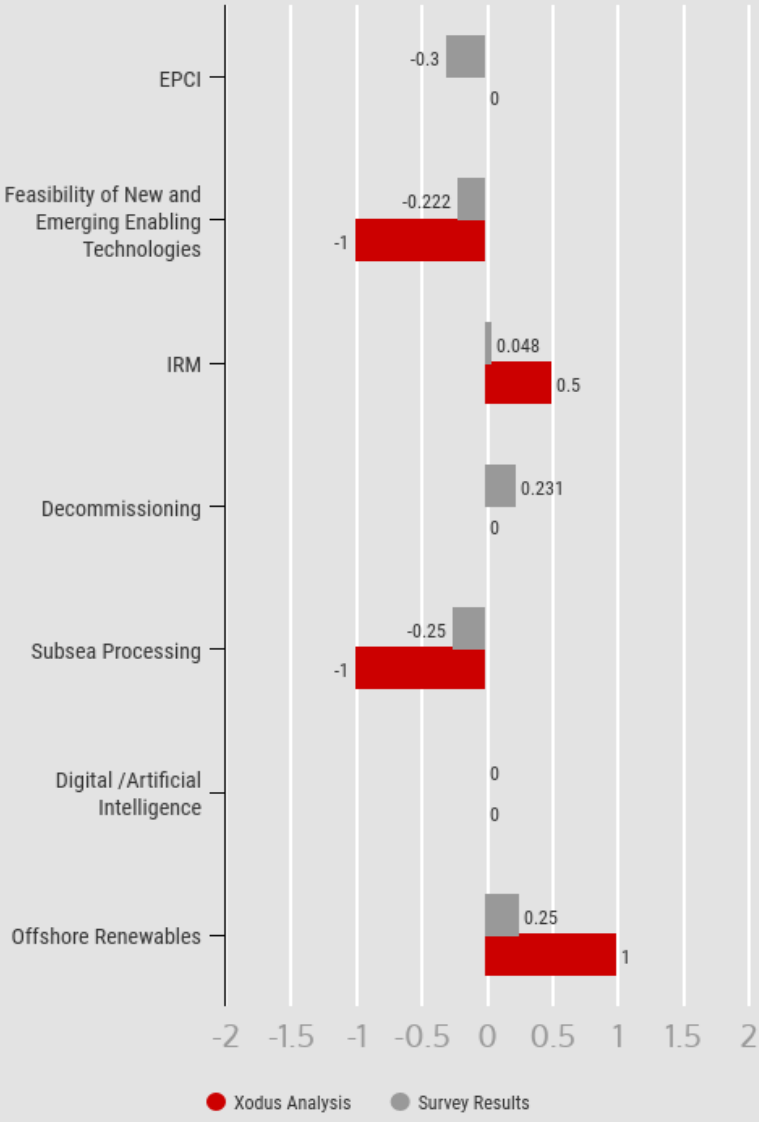
Scotland is …..	General	Engineering, Procurement, Construction and Installation	Feasibility of New and Emerging enabling Technologies	Inspection, Repair and Maintenance	Decomissoning	Subsea Processing	Digital AI	Offshore Renewables
Norway	N	N	W	SS	N	W	N	S
Houston	SS	N	SS	SS	N	SS	N	S
Perth	S	S	S	S	S	S	SW	S
Malaysia	S	SS	S	S	S	SS	S	S
Rio	SS	N	N	N	S	N	SS	S
Paris/West Africa	S	N	S	S	S	SS	S	S

Legend Weaker (W), Slightly Weaker (SW), Neutral (N), Slightly Stronger (SS), Stronger (S)

Scotland Vs. Norway

The Scottish sector is perceived as being on equal footing with Norway. There are areas where Norway excels including diverless technology and subsea hardware however overall the depth, quality and adaptability of the Scottish engineering sector is most often quoted as its strength and advantage over Norway

Range
Weaker (-1)
Slightly Weaker (-0.5)
Neutral (0)
Slightly Stronger (+0.5)
Stronger (+1)



Neutral - Same two Tier 1 contractors dominating the market. Local variations in contractors were seen as balanced through the supply chain. Perceived as technically more challenging. Could pull away as development in UKCS falters.

Weaker - Norwegian NOC Statoil have been committed for decades to the evolution and creation of innovative subsea technology. Additional R&D tax breaks. Norway has two significant Cluster organisations with GCE Cluster and Subsea Valley.

S.Stronger - a competitive advantage will be in IRM solutions companies where niche products and problem solving capability will be required. The depth of variety in UKCS gives Scotland experience in a multitude of solutions

Neutral - The Norwegian decommissioning industry is very similar to Scotlands from a regulatory standpoint and as such many of the engineering services and technologies developed in Norway could be deployed in Scotland and vice versa.

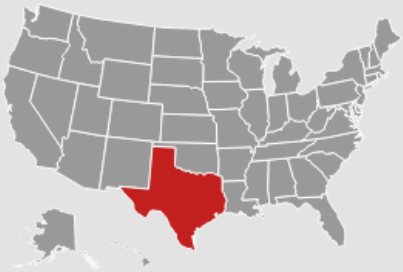
Weaker - Statoil have been instrumental in the advancements of 'game-changing' subsea processing technologies in particular subsea compression and are regarded as 'world-leaders' in developing this technology. Manufacturing of hardware in Scotland should not be overlooked.

Neutral - Norway is believed to have a good fiscal arrangement for digital start-ups and are more accustomed to sharing data within or between companies. It is felt that the regulator has had an influence in driving some of these positive moves. Scotland has a strong talent pool

Stronger - UK has seen a far greater development of offshore wind on its shores than Norway most likely due to incompatible water depths therefore the UK and Scottish supply chain have greater experience and capability.

Scotland Vs. Houston

All sectors are perceived as between neutral and slightly stronger (with the exception of Offshore renewables). With regards to Scotland's competitiveness with the Houston region participants sited ease of doing business, quality of personnel and innovative approaches as Scotland's key advantages.



Range
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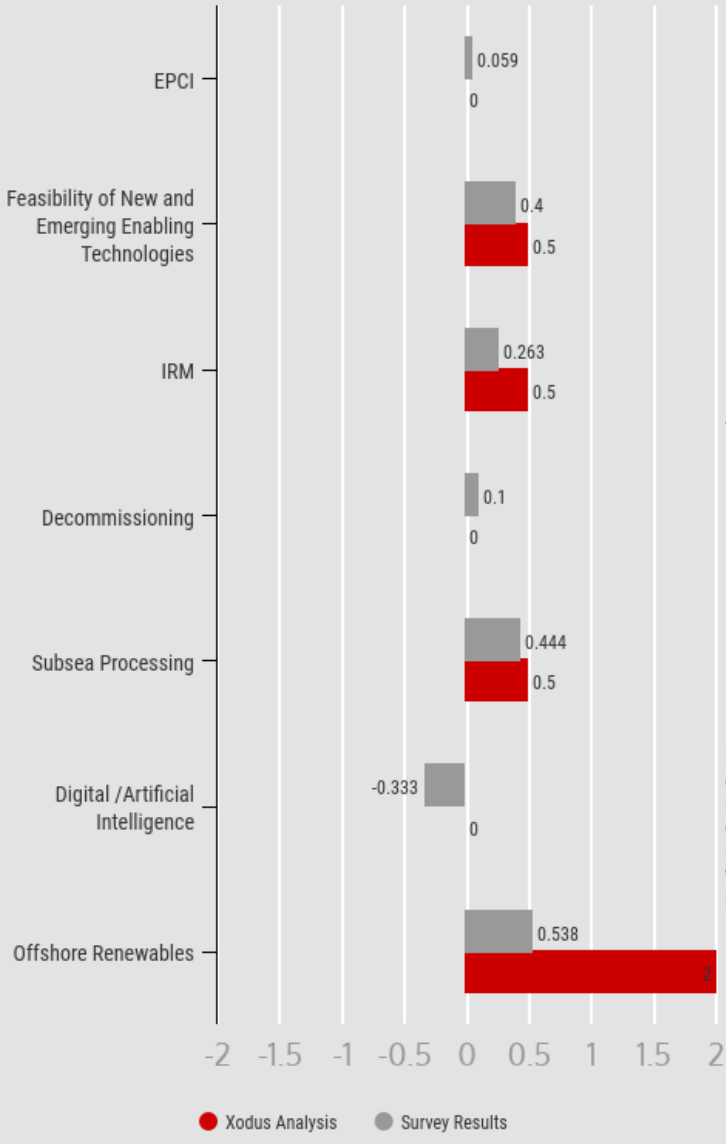
Slightly Weaker (-0.5)
Neutral (0)
Slightly Stronger (+0.5)
Stronger (+1)



Neutral - Houston, like both Scotland and Norway hosts the main EPCI & IRM companies with TechnipFMC, Subsea7 and Saipem all located there with significant fleets. It was felt global distribution of EPCI knowhow in major hubs made the capability levels quite flat.

S. Stronger - DOE's National Labs, one of 17 national labs situated across the US, are developing technologies to reduce carbon emissions and ensure fossil energy sources play a role in America's clean energy future. Lack of evidence in general in this area

S. Stronger - Houston, like both Scotland and Norway hosts the main EPCI & IRM companies with TechnipFMC, Subsea7 and Saipem all located there with significant fleets. The depth of variety in UKCS gives Scotland experience in a multitude of solutions

Neutral - This is the region in which the majority of oil and gas decommissioning has been carried out to date and there are potential lessons learned from activities carried out here. Around 12% of the structures were decommissioned using the 'Rigs to Reefs' option that is not currently permitted under UKCS.

S. Stronger - Houston hosts the head offices of some of the words largest SPS suppliers, however with the first development projects being engineered out of Norway and largely manufactured in Scotland then it is uncertain whether they have any competitive advantage.

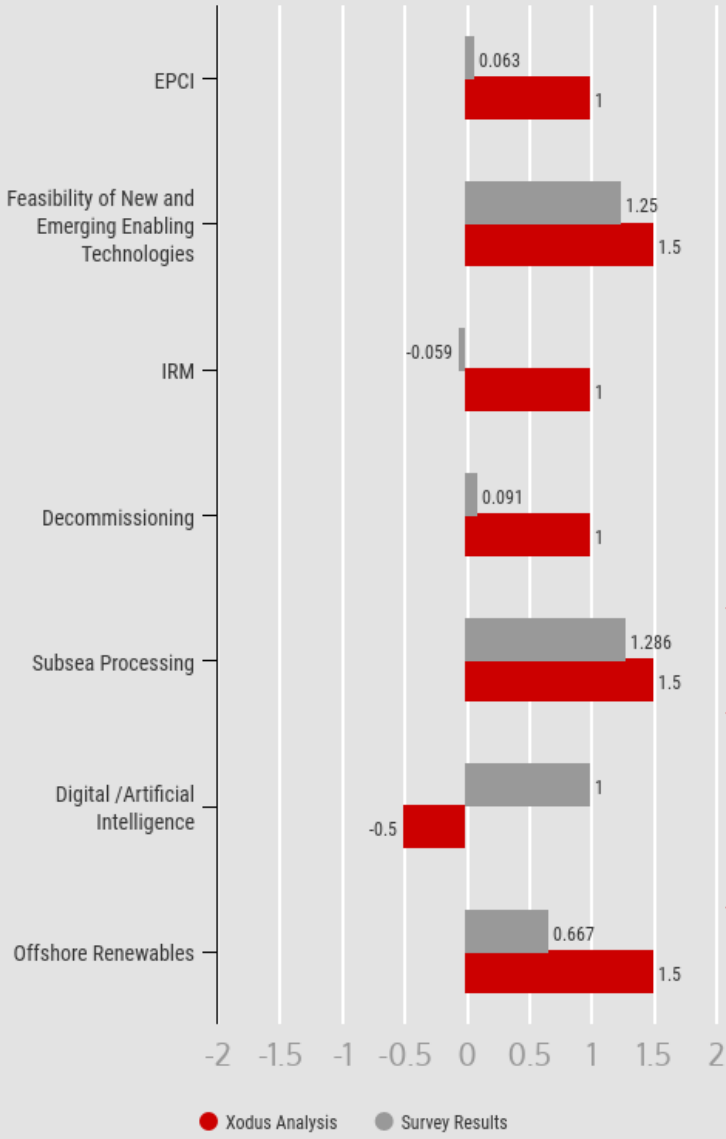
Neutral - With Silicon Valley the best known of digital development hubs then we can expect that the US will have a strong influence in this sphere however the digital subsea engineering landscape in Houston was not clear from our research. An interesting observation was data science without subject matter experts has proven ineffective in the past

M. Stronger - Offshore renewables are not a focus area for the Houston engineering community. In contrast Scotland is a world leader in both marine renewables and offshore wind.

Scotland Vs Perth

Perth is a high cost market with regards to vessels, due to remoteness and local marine crew regulations. There are no major SPS manufacturing facilities therefore all subsea hardware is imported from Scotland, Norway and the US. Engineering is often performed locally for only the early phases due again to cost issues. Scotland is seen as generally stronger than Perth with the main reason being the level of experience within the supply chain.

Range
Weaker (-1)
Slightly Weaker (-0.5)
Neutral (0)
Slightly Stronger (+0.5)
Stronger (+1)



Stronger - While Australian EPCI capability is increasing, it is limited by the opportunities to work on only one or two projects a year due to local regulations whereas the original international crew may be completing eight to ten projects a year. The detailed engineering for projects will also be outsourced to lower cost engineering centres. Scotland is in a stronger position due largely to these experience issues.

Stronger - National Energy Resources Australia completed a study in 2017 which found the Australian sector to be lagging behind the best in the world in R&D. while Australia ranked in the top ten worldwide for Academic publications it ranked towards the bottom for collaboration between industry and academia. UK was given gold standard.

Stronger - Vessel companies locate their regional fleet in Singapore and KL rather than Perth due to cost issues meaning vessel availability is compromised. Additionally regulations enforce that when installation vessels enter Australian waters the regular crew must be replaced by an Australian crew, which carries economic and experience implications.

Stronger - With more than 100 platforms and subsea structures the current cost of decommissioning Australia's oil and gas infrastructure estimated at over US$21 Bn over the next 50 years. Australia needs evidence-based policy and regulation, relevant to location and environment, for optimal decommissioning solutions.

Stronger - Without any presence from the main manufacturers of subsea processing equipment Perth will have limited access to the capabilities involved in subsea processing.

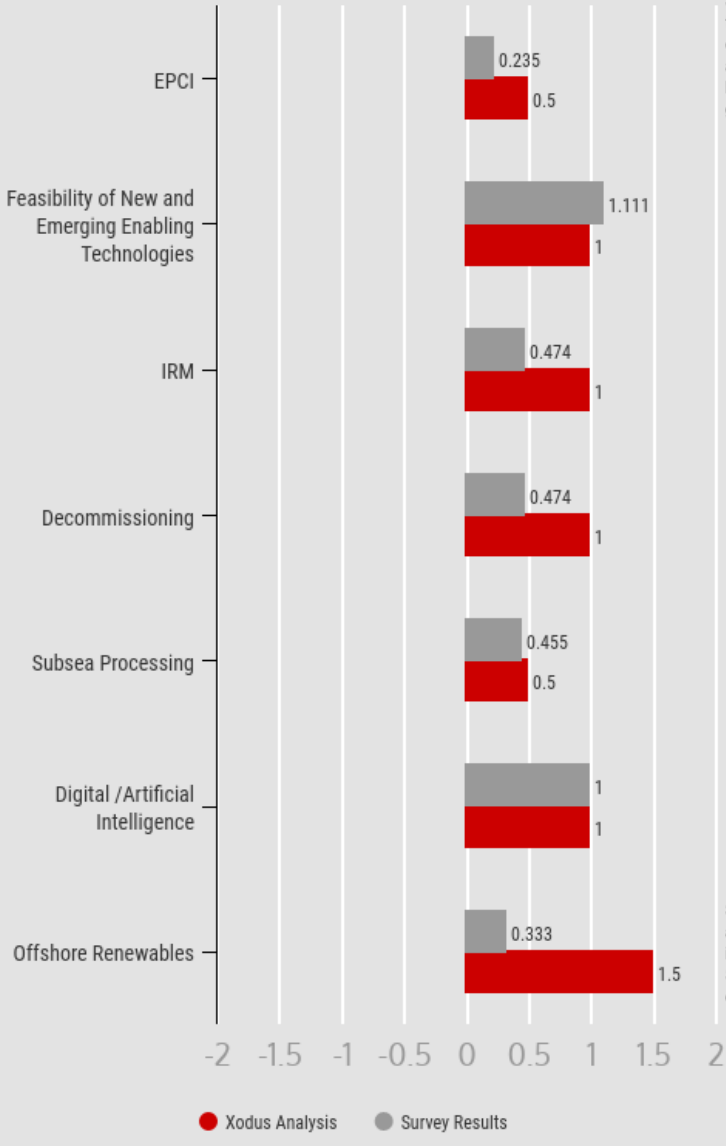
S. Weaker - The main oil companies in Perth have embraced and enacted digital transformation more obviously than some of the other sectors. Woodside and Santos were highlighted as companies that have taken large steps, investing in systems like data lakes and IBM Watson for machine learning. Having a receptive audience to digital innovation may allow Perth to gain an advantage over Scotland.

Stronger - Offshore renewables in Australia will encounter the same cost issues as traditional oil and gas which may make it cost prohibitive especially in a country where there is a large land mass with low population density that may be more suited to onshore wind or solar. Scotland in contrast is a world leader in the offshore renewables industry.

Scotland Vs. Malaysia

Malaysia is fast becoming the regional centre for subsea engineering and procurement activities, with many well-known names like TechnipFMC, Aker Solutions and others establishing a manufacturing base in the country. Many UK oil and gas service providers and equipment suppliers are doing well in the market, thanks to the UK's strong reputation in Malaysia. It is perceived as weaker than Scotland in every category (bar EPCI).

Range
Weaker (-1)
Slightly Weaker (-0.5)
Neutral (0)
Slightly Stronger (+0.5)
Stronger (+1)



S. Stronger - Malaysia hosts a large EPCI fleet including al the major international companies as well as some local companies servicing the local area for shallow water as wel as the Perth region. With these major companies comes a level of experience and competency spread across the globe. Require international input for deeper waters.

Stronger - Petronas is committed to improving the capabilit and competitiveness of the Malaysian subsea industry by investing in R&D. They are looking to create a hub bringing together international operators, international service and manufacturing companies based in Malaysia. Seen as a region that will import technology at the moment.

Stronger - For deeper water developments, at least at the moment, Malaysia looks more to international contractors t provide experience and assurance. Due to the less mature infrastructure the IRM sector in Scotland will have experience of issues yet to become commonplace in Malaysia giving it a competitive advantage.

Stronger - Decommissioning related activity in the region is currently concentrated on well plug and abandonment. Individual companies have developed their own approaches, but best practice guidelines would be helpful for issues such as cost estimation. Scottish opportunities may be limited by local content regulations.

S. Stronger - There is limited experience of subsea processing to date in Malaysia however as designs become more developed and less of an R&D exercise some of the major suppliers may choose to manufacture in Malaysia du to the reduced costs.

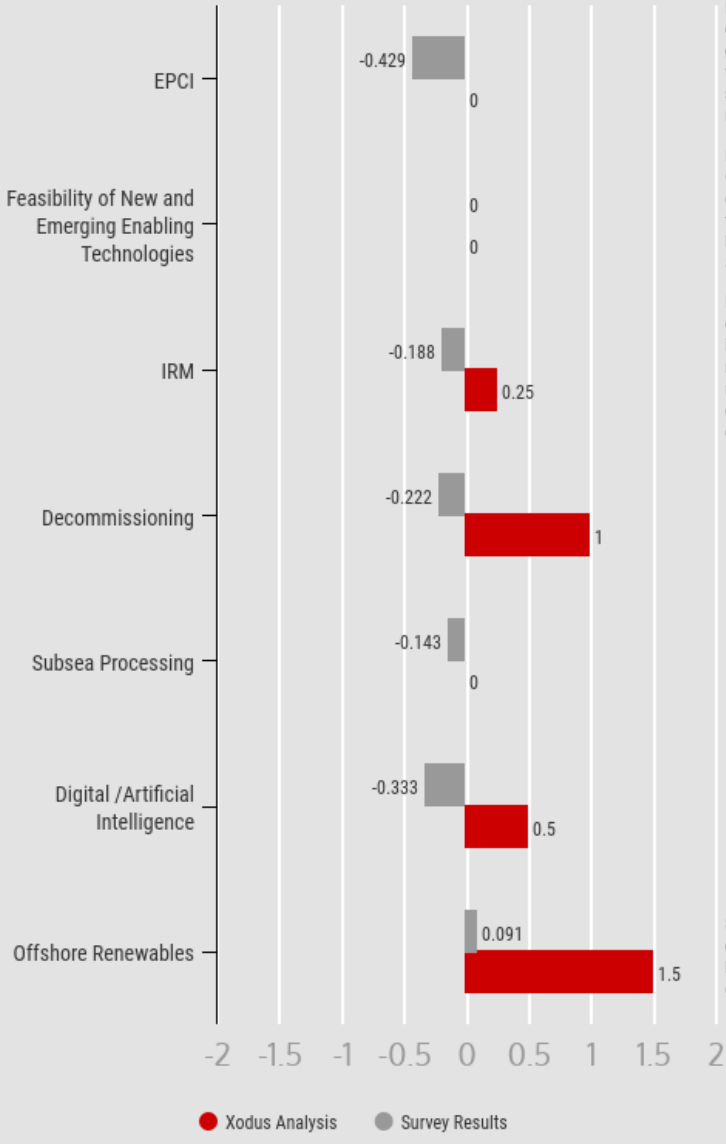
Stronger - Malaysia is promoting a digital economy with moves recently by the Malaysian government digital arm and the Chinese tech giant Alibaba to set up a digital free trade zone in Malaysia, however whether there has been penetration into the oil and gas market is unclear.

Stronger - The Asia Pacific region is an area with significar activity is renewables however no evidence of development in Malaysia could be found during our review. In contrast Scotland is a world leader in both marine renewables and offshore wind.

Scotland Vs. Rio de Janeiro

Brazil leads all other South American countries with its development in terms of infrastructure and technology. The subsea supply chain was in growth phase for some time until recent financial and corruption issues. Brazil has capacity for growth going forward in Ultra Deep Waters which should drive a need for innovation and requirements for new technologies creating opportunities.

Range
Weaker (-1)
Slightly Weaker (-0.5)
Neutral (0)
Slightly Stronger (+0.5)
Stronger (+1)



Neutral - Current local content requirements oblige operators of oil and gas blocks to procure a certain level of goods and services from Brazilian sources as a condition thus limiting the opportunities for the smaller Scottish supply chain to export services and capabilities. Large multinational companies are exporting via local bases.

Neutral - Brazil has recently introduced a 1% levy on all CAPEX projects to fund R&D activity. This forced contribution may steer multinational companies to base their R&D in Brazil as they are already investing. R&D will likely focus on ultra deep water technology. Historically Scotland would have been stronger until large investment.

Neutral - Subsea hardware spending in this region is expected to continue and significantly increase the size of installed subsea infrastructure. The outlook for the requirement of high quality subsea inspection, repair and maintenance (IRM) is positive. Scotland has a greater capability but whether local content rules will allow an opportunity for export is an issue.

Stronger - Brazil also has about 10,000 km of subsea pipeline, with almost a third of this installed more than a 25 years ago. Therefore a demand for the decommissioning is inevitable over the next five years, with several production platforms and hundreds of offshore wells falling out of use. However decommissioning activity has so far been sluggish in Brazil therefore Scotland has the experience.

Neutral - Partly state owned NOC, Petrobras, are driving the developments behind subsea processing, together with the equipment manufacturers. Brazil is an ideal candidate for subsea processing. To date subsea processing hardware has been largely manufactured in Scotland. Local content rules may see Brazil catch up and bypass Scotland quickly.

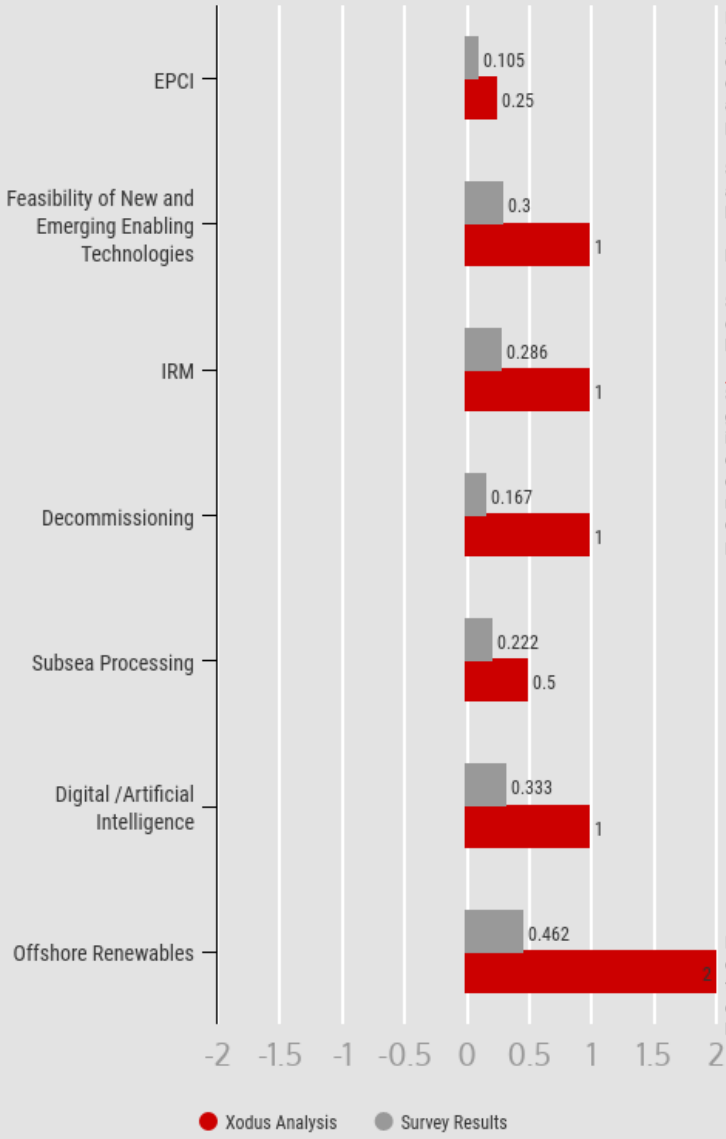
S. Stronger - The support for Digital innovation is strong in Brazil as is the opportunity/ prize however the study found little evidence or opinion on the track record or capability of the local supply chain.

Stronger - To date Brazil only has some small wave developments progressing. As such it is significantly behind the curve when it comes to offshore renewables, compared to Scotland which is a world leader.

Scotland Vs. Paris/ West Africa

West Africa has a significant portion of the world's largest projects and thus is of great interest to all engineering companies as a potential market. The majority of West African developments have significant ownership from IOCs and thus receive engineering input and leadership from their organisations. Scotland is rated in our survey as stronger than this hybrid region in most areas. Its supply chain provides a far greater level of efficiency, knowledge and experience than those in place in country even when supplemented by the support by Paris.

Range
Weaker (-1)
Slightly Weaker (-0.5)
Neutral (0)
Slightly Stronger (+0.5)
Stronger (+1)



Neutral - Local content rules ensure that indigenous supply chain provides a significant portion of EPCI engineering with support from external centres. This has cost and schedule implications for projects with the quality and efficiency of local contractors falling below that of that provided in Scotland, Norway or London.

Stronger - West Africa has below average spend on R&D as a whole and investment in science and technology is believed to be declining. Specific subsea R&D was unclear. It may be that R&D aimed at the region is being performed by IOCs in other areas

Stronger - IRM engineering is most often performed out of country by international contractors thus while the region ha limited capability it receives good quality support.

Stronger - Due to the relatively young nature of the oil and gas industry in offshore West Africa a great deal of this infrastructure is relatively new and not due for decommissioning in the near to mid-term. Whilst the African decommissioning industry lags behind the more mature regions, policy makers will soon be forced to establish detailed legislation in order to govern and regulate the process of infrastructure removal

S. Stronger - West Africa could be one of the key regions for subsea processing because of its already extensive deepwater production, significant oil reserves, and, most importantly, the geographical distribution of fields. While West African projects may purchase subsea processing equipment the likelihood of manufacture or engineering of this hardware being performed in the region is unlikely.

Stronger - There is a large market place for digital innovation and automation with West African developments amongst the most inefficient in the world due to an unskilled workforce and outdated technology. It is likely that Scotland would have a significant competitive advantage in this area with technology as well as lessons learned from the aged North Sea infrastructure.

M. Stronger - In the African content there is some development of wave energy in Ghana and advances towards wave in South Africa and potential for offshore win development in East Africa. Conversely Scotland is a world leader in this industry.

5 KEY MESSAGES, CONCLUSIONS AND RECOMMENDATIONS

5.1.1 Key Messages

- **Respect, Experience, Depth, Quality, Confidence, Assurance, Efficiency** were all used regularly to describe the Scottish subsea engineering industry.
- **Large volume of support and support institutions available**. There is, however, some ambiguity about how to traverse the support landscape and achieve commercialisation.
- **People are Key**. Make use of those we have at home but also those abroad. Scotland more than any other hub appear to be a nation of travelers.
- **Digital -** Scotland has a strong pipeline of talent for Digital. We need to attract young graduates to the subsea industry and then enact the innovations that we task them to provide.
- **Offshore Renewables** - **Fixed offshore wind** is gathering pace as a commercial operation. We should maximise opportunities in the development and service sectors as fields move North.
- **Offshore Renewables - New technologies of Floating Wind, Tidal & Wave** - Scotland needs to embrace these sectors early and ensure these are Scottish based industries with design, manufacture, installation and Operation and Maintenance (O&M) performed here.
- **IRM is a key opportunity sector worldwide.** Our findings were that the respect for the Scottish Subsea sector comes from "seen it, done it, solved it". We can use this to access the high impact/ high cost operational issues market worldwide. When production is halted cost is less critical. Target Areas suggested for Scottish supply chain are Malaysia, Brazil, West Africa & Perth.

5.1.2 Thoughts for Scottish Enterprise

While Scotland has a capability advantage, in the focus areas, the question is whether this is enough to translate to a competitiveness advantage when cost, local rules and existing relationships are taken into account. Further areas to explore are:

- Linking Scottish companies with local partners to provide the experience and assurance while local company provides access/leads and gain capabilities.
- Accessing high value streams – operational issues. Creation of cluster organisations to access?
- Finding niche capabilities or products – R&D/ Digital.
- Emerging technologies – floating wind, wave, tidal, aquacultures and mining.

- Do Scotland advertise its successes well enough? Should the sector in Scotland be more vocal about Scotland's worldwide impact as the UK Continental Shelf (UKCS) resources decline, so that the assumption isn't that the subsea industry is declining as a result.
- Is there a message in the difference between the public survey perception of Scotland's capability and the expert opinion which almost always elevated the Scottish position?
- How does Scotland attract and retain talent in the subsea engineering industry in an oil 'boom & bust' environment?
- Innovation centres, testing facilities, industry body organisations and regulators are operating in a crowded landscape of public sector initiatives for supporting businesses in Scotland. It is recommended the outward appearance of arrangements for business support are simplified, better defined and explain its specific benefits to individual businesses.
- Forums do exist for sharing best practice (e.g. the pipeline users group) but their effectiveness is often curtailed due to commercial or legal restrictions. The improvement of the way that integrity data (e.g.

corrosion rates) is shared between operators is paramount to ensuring Scotland remains at the forefront of the IRM market.

- The development of intelligent pipelines, fibre optics and other sensors built into the pipeline structure which would be able to provide real-time information on the pressure and temperature of the pipeline are key to ensuring our continued success in this sector. Scotland has the technology, infrastructure and know-how to exploit this market further.
- Stronger and 'smart' collaboration between with Scottish ports and supply chain (primarily Tier 1 contractors) is needed to efficiently exploit the recycling and disposal portion of subsea infrastructure decommissioning.
- Enabling and qualifying the integration of subsea processing equipment is key, i.e. cooperation between all of the components is a challenge. Standardisation has long been a key topic, but progress has not been forthcoming. A facility to test and integrate equipment from multiple suppliers would enhance and compliment Scotlands already strong manufacturing capability in this area.

APPENDIX A STUDY SURVEY QUESTIONARE

SCOTLANDS SUBSEA SECTOR INTERNATIONAL COMPETITIVENESS QUESTIONAIRE

Introduction

Xodus Group have been tasked by Scottish Enterprise to carry out a research study titled 'The Provision of Scotland's International Competitiveness and Benchmarking in Subsea Engineering'. This study was commissioned to understand the current status of competitiveness and innovation in the Scotland Subsea market and how it compares to other international markets. It will ultimately be used by Scottish Enterprise to more effectively manage their Subsea Opportunity Programme and inform future funding planning.

Name of Company

Number of Employees (Scotland and Global)

Turnover (Optional)

Main Area(s) of Business, (please circle)

EPCI (all project phases)	Project Enabling Methods	IRM	Decommissioning	Subsea Processing	Digital, Artificial Intelligence	Offshore Renewables	Mineral Extraction / Aquaculture / Defence

Business Area(s)/Tech Area(s) Under Development (please circle)

EPCI (all project phases)	Project Enabling Methods	IRM	Decommissioning	Subsea Processing	Digital, Artificial Intelligence	Offshore Renewables	Mineral Extraction / Aquaculture / Defence

How does your company specifically compare with competition in these subsea hubs?

	Much Weaker	Weaker	Neutral	Stronger	Much Stronger
Paris/West Africa					
Norway					
Houston					
Perth					
Singapore/KL					
Rio					

How does the Scottish Subsea Sector generally compare with these subsea hubs?

	Much Weaker	Weaker	Neutral	Stronger	Much Stronger
Paris/West Africa					
Norway					
Houston					
Perth					
Singapore/KL					
Rio					

If known, who would be your direct local competition in these subsea hubs?

	1	2	3
Paris/West Africa			
Norway			
Houston			
Perth			
Singapore/KL			
Rio			

In the areas you feel you have sufficient market experience - how do you feel Scotland compares to these other hubs?

	EPCI	Project Enabling Methods	IRM	Decommissioning	Subsea Processing	Digital, Artificial Intelligence	Offshore Renewables	Mineral Extraction / Aquaculture / Defence
Paris/West Africa								
Norway								
Houston								
Perth								
Singapore/KL								
Rio								
Scotland								
Legend	Much Weaker = MW	Weaker = W	Neutral = N	Stronger = S	Much Stronger = MS			

EPCI = Engineering, Procurement, Construction and Installation; Engineering includes all project phases from concept through to detailed design
IRM = Inspection, Repair and Maintenance;

How could Scottish Enterprise best support the growth of your business. Either in Scotland or through supporting the growth of your company into overseas markets?

Areas that Scotland holds a competitive advantage in that you think the study should focus on?

Additional Information if required

Xodus and Scottish Enterprise thanks you for your time and contribution. Should you wish to discuss this topic in more detail please get in touch.

Please send all responses to jamie.macdonald@xodusgroup.com or return to Xodus stand 106 at Subsea Expo. Deadline for submission to be included within the report is 21 Feb 2018

APPENDIX B INTERNATIONAL BENCHMARKING – FURTHER INFORMATION

Appendix B.1 International Benchmarking – Norway's Capabilities

Appendix B.1.1 General - **Rated as Neutral**

Our research found that the Scottish sector is perceived as being on equal footing with Norway. There are areas where Norway excels including diverless technology and subsea hardware manufacture due to the nature of the development of the Norwegian sector and its particular challenges however Scotland also has countering strengths and overall it is the depth, quality and adaptability of the Scottish engineering sector that is most often quoted as its strength and advantage over Norway.

Scotland is ….. Than …… Wrt ……	General	Engineering, Procurement, Construction and Installation	Feasibility of New and Emerging enabling Technologies	Inspection, Repair and Maintenance	Decomissoning	Subsea Processing	Digital AI	Offshore Renewables
Norway	N	SW	N	N	N	N	N	N

Table 5.1 Summary of *Survey Results* comparing Scotland with Norway

Norway	N	N	W	SS	N	W	N	S

Table 5.2 Summary of *Xodus Analysis* comparing Scotland with Norway

Legend Weaker (W), Slightly Weaker (SW), Neutral (N), Slightly Stronger (SS), Stronger (S)

A key strength for Norway was highlighted as their trade organisations. Norwegian Energy Partners (NORWEP) is the result of a merger between INTSOK and Intpow in 2017. Norwep has a vision to "use its international competence, experience and knowledge to open doors for Norwegian partners with technology, products and services needed abroad and bringing customers and suppliers together". The differentiator to our own trade organisation was the level of political support that they received with trade missions regularly being attended by government officials and even on occasions by the Royal family which obviously elevates events and access to a significant level.

Norway is seen as quite an insular country, by Norwegian respondents to our study as well as others, focusing very much on the Norwegian way of doing things and while there are positive aspects to their approach it is not always suitable for all regions of the world and especially not where a low cost model is required. Cost is likely a key advantage for Scotland over Norway, while both are seen as technically excellent Norway is often perceived as cost prohibitive. This cost delta combined with the adaptability of the Scottish supply chain should allow Scotland to more easily compete in lower cost markets such as Asia.

A key competitive advantage for the Scottish sector raised by several Norwegian respondents was the openness and desire of Scottish engineers to travel and experience the other regions of the world. They believed that while the engineers and thus the industry overall benefitted from this experience Scotland's companies also held a distinct advantage due to the number of global Scots spread throughout every oil and gas hub. This is not something that Norway has and they believed that they would benefit from

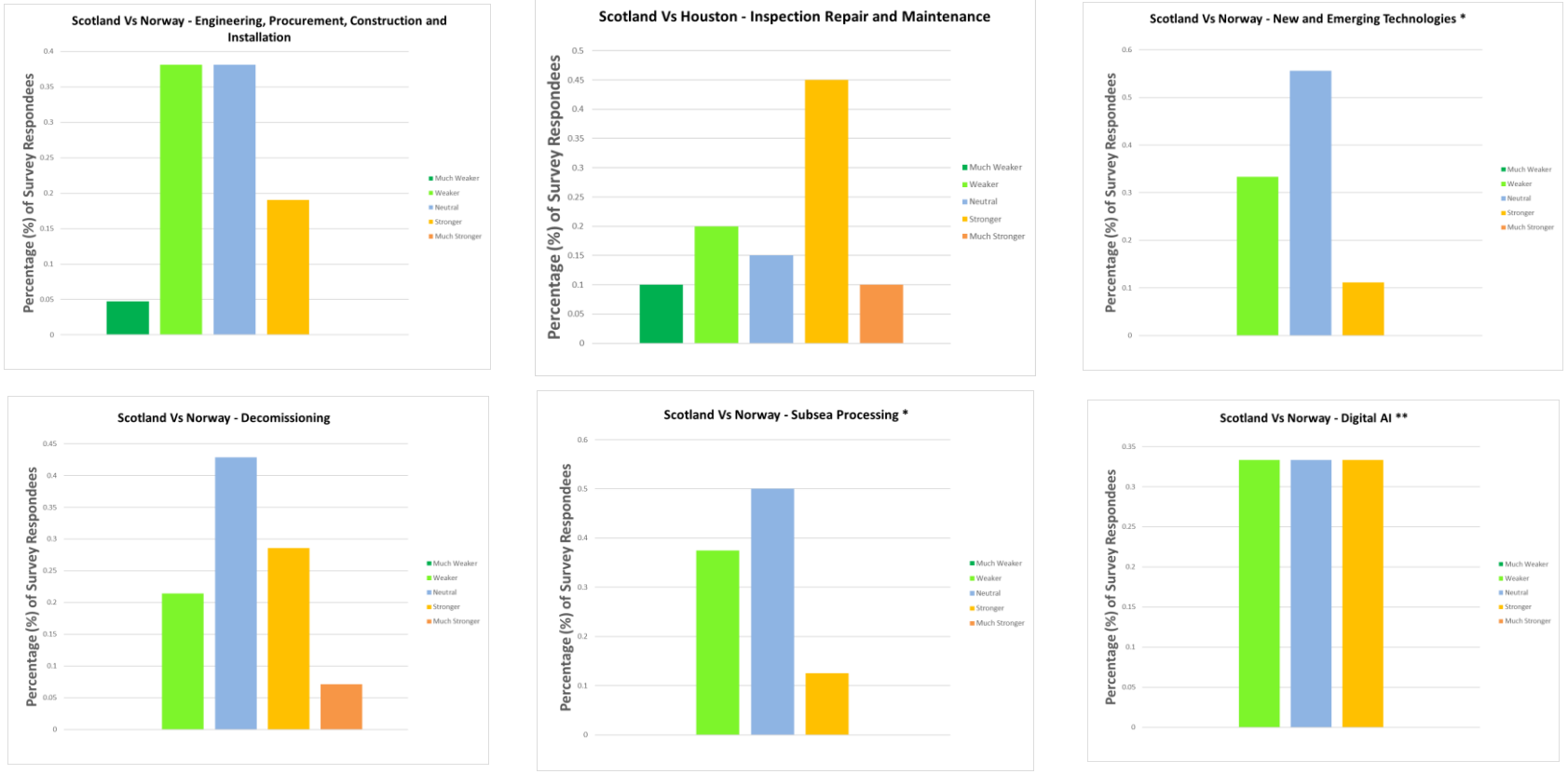


Figure 5.1 Scotland Vs. Norway Focus Area Competitiveness (survey results)

Appendix B.1.2 EPCI & IRM - **Rated as Neutral & Slightly Stronger**

The EPCI & IRM markets in Norway are relatively similar to that of Scotland with the same two tier 1 contractors dominating the market in Technip and Subsea7. Local variations in contractors were seen as balanced through the supply chain.

Throughout the history of the North Sea basin technology and engineering approaches have transferred from Scotland to Norway and vice versa. Complex projects including deep water, diverless technology and High Pressure / High Temperature (HP/HT) have been performed in both sectors. One area where Scotland does have a competitive advantage is in the area of bundle pipeline technology with the Subsea7 base in Wick being the only facility worldwide.

Norway continues to sanction major projects while the UKCS is very much focused on small infill projects so there may be a divergence in experience going forward but at the moment it is a very level comparison.

With regard to competitiveness again Scotland is seen as less cost prohibitive than Norway with regards to engineering. It is likely that projects on the Norwegian Continental Shelf (NCS) will be performed in Norway, projects in UK Continental Shelf (UKCS) in Scotland but Scotland may have an advantage for international projects where minimal local presence needs significant support.

An area where there will likely be an opportunity and a competitive advantage will be in IRM solutions companies where niche products and problem solving capability will be required.

Appendix B.1.3 Feasibility of New and Emerging Enabling Technologies - **Rated as Weaker**

The most famous institution in the global subsea engineering industry with respect to new and emerging technologies is undoubtedly Statoil/Equinor the Norwegian NOC. Statoil/Equinor have been committed for decades to the evolution and creation of innovative subsea technology culminating recently in the completion of Subsea compression from the Asgard Field. Statoil/Equinor achieves this reputation with a number of methods including long term internal technology development programs, technology investment funds and innovation challenges. Statoil/Equinor invests over £8m a year in the 10 universities worldwide that they collaborate with.

Norway has two significant Cluster organisations with GCE Subsea Cluster and Subsea Valley.

GCE Subsea Cluster is a subsea hub hosting centres of excellence for Statoil/Equinor, TechnipFMC, Aker Solutions and One Subsea. Several educational establishments such as the University of Bergen, Western Norway University of Applied Sciences and BI Norwegian Business School. The R&D organisations in the cluster are Christian Michelsen Research, UNI Research, Institute of Marine Research and SINTEF. R&D Infrastructure includes subsea test sites, advanced multiphase flow rigs, facilities for pressure and temperature testing, environmental laboratories, advanced chemical laboratories for fluid characterization and dedicated experimental facilities for enhanced oil recovery.

Subsea Valley is part of the Norwegian Innovation Clusters program. (NIC) and has close to 200 active participant companies in the capital region of Norway. The cluster has a broad competence base within subsea technology development and engineering of large scale, complex and safety critical systems, at high pressures and temperatures. The largest member companies provide world-class products and services to the global energy market supported by a strong and diversified local supplier base.

Norway has an advantage unavailable to Scotland in the shape of Statoil/Equinor that allows it to lead the world in the development of large scale, high cost innovative technologies. While Scotland cannot compete with the scale of the innovations, it was felt that Scottish companies have a great record of innovating on a smaller scale constantly bringing to market, technologies that have greatly improved the subsea industry but do not garner the same level of publicity.

Recently a government program (SkatteFUNN R&D tax incentive scheme) has been rolled out and is designed to stimulate R&D in the Norwegian trade and industry. The incentive is a tax credit and comes in the form of a possible deduction from a company's payable corporate tax.

Appendix B.1.4 Decommissioning - Rated as Neutral

On the Norwegian shelf, there are currently 12 concrete facilities, 21 floating steel facilities and 70 steel facilities resting on the seabed. In addition, there are nearly 350 subsea systems.

Decommissioning in Norway is regulated by Norwegian law and under the Petroleum Act a detailed plan for decommissioning must be submitted up to five years before the oil production license expires. The is to ensure that talent and knowledge retention has been considered. The Norwegian government is focused on ensuring their ambition for Norway's petroleum industry, to be a world leader in health, safety and environmental work.

The Norwegian decommissioning industry is very similar to Scotlands from a regulatory standpoint and as such many of the engineering services and technologies developed in Norway could be deployed in Scotland and vice versa.

Norway acts in accordance with international regulations and agreements, such as the Oslo-Paris Convention (OSPAR) and pipelines are covered by the Petroleum Act, but not the OSPAR Convention. The choice of disposal method is determined in each individual case based on an assessment of costs, weighed against the consequences for safety, the environment, fisheries and other users of the sea etc,

In Norway, five facilities currently have permission for receiving and processing disused facilities. These are

- AF Miljøbase in Rogaland County,
- Aker Stord in Hordaland County,
- Scandinavian Metal in Hordaland County,
- Lyngdal Recycling in Vest-Agder County and
- Lutelandet Offshore in Sogn og Fjordane County.

Since the scrapping facilities in Norway are located on deep fjords and have deep-water quays, it is anticipated that other countries on the North Sea are likely to consider utilising these facilities over Scottish facilities in the future.

Appendix B.1.5 Subsea Processing - Rated as Weaker

Statoil/Equinor have been instrumental in the advancements of 'game-changing' subsea processing technologies in particular subsea compression and are regarded as 'world-leaders' in developing this technology.

Statoil/Equinor, has an ambition to achieve about a complete subsea factory by 2020. Although significant process has been made and in the current economic this deadline is likely to slip. There are several challenges towards the full-fledged subsea factory.

- *Power distribution:* Variable speed drives (VSD's) are required to convert and distribute power. Major companies like ABB and Siemens are involved from this aspect.
- *Oil storage:* A system is required to be tested and qualified. Kongsberg Oil & Gas have an ongoing development project for Statoil/Equinor.
- *Reliability:* The reduced accessibility of a subsea equipment compared to a topside brings additional requirements to the system up time and maintenance/intervention frequencies. To handle the up to 400-ton modules at Aasgard, TechnipFMC is supplying Statoil/Equinor with a new handling systems to lower and raise modules over the side of the vessel.
- *Integration and cost:* Enabling and qualifying the integration, i.e. cooperation between all of the components is a key challenge. Standardisation has long been a key topic, but progress has not been

forthcoming. A facility to test and integrate equipment from multiple suppliers are limited and generally operated owned (Shell's test facility at Nyhamna in Norway for example).

Appendix B.1.6 Digital/ Artificial Intelligence - **Rated as Neutral**

The Norwegian oil and gas industry has a proud history of digital solutions including early stage seismic interpretation stations in the late eighties and the development and implementation of the first digital Exploration and Production (E&P) databank.

There are a number of Norwegian companies actively involved in digital engineering in the subsea space. Respondents felt there was a strong message to embrace digitalisation coming from the Norwegian operators at a senior level but they were struggling with implementation at the budget holder level.

Norway is believed to have a good fiscal arrangement for digital start-ups and are more accustomed to sharing data within or between companies. It is felt that the regulator has had an influence in driving some of these positive moves.

In a newly evolving market it is probably too early to judge competitiveness between the regions but Scotland may be slightly behind Norway with regards R&D.

Appendix B.1.7 Offshore Renewables - **Rated as Stronger**

The UK has seen a far greater development of offshore wind on its shores than Norway most likely due to incompatible water depths therefore the UK and Scottish supply chain have greater experience and capability.

Norwegian suppliers have only taken a relatively modest slice of the overall offshore wind market, accounting for an estimated 5 percent or less of deliveries to offshore wind projects since 2010. But in some offshore wind sub-segments the Norwegian presence is considerably higher than this average number indicates. Within cable supply and installation, marine operations and supply of O&M and installation vessels and services Norwegian suppliers have demonstrated competitiveness.

However with the advent of floating wind, by Norwegian developer Statoil/Equinor, opening up new water depths it is likely Norway will aim to increase their influence, much like Scotland, as their O&G transferrable subsea skills become more relevant and more critical to success.

Appendix B.2 International Benchmarking – Houston's Capabilities

Appendix B.2.1 General - **Rated as Slightly Stronger**

Houston is the second of the long established Subsea engineering hubs in this study. Houston has a strong capability in all things oil and gas with most major companies either based there or with a presence. Houston has a large Subsea Production Systems (SPS) manufacturing capability, is a home base for a portion of the worldwide EPCI vessel fleet and performs some of the development engineering for West Africa developments for US based operators. Houston hosts the centre of excellence for many large multinational companies.

The perception of Houston's capability was varied in our study with a range of opinions within the survey but also within the expert interviews. Input from the Houston based participants was much more favourable to the region than the perception from out with.

With regards to Scotland's competitiveness with the Houston region participants cited included ease of doing business, quality of personnel and innovative approaches as Scotland's key advantages.

With regards to Scotland's companies' prospects in Houston, there was a perception offered by a number of interviewees that it is a challenging place to do business with long term relationships being the key to securing work.

The results of our survey are summarised below with the all sectors coming up pretty much neutral with the exception of Offshore renewables. The survey participants put Scotland slightly ahead in the areas of emerging technologies, IRM and possibly surprisingly subsea processing and just behind on Digital.

Scotland is ..... Than ..... Wrt	General	Engineering, Procurement, Construction and Installation	Feasibility of New and Emerging enabling Technologies	Inspection, Repair and Maintenance	Decomissoning	Subsea Processing	Digital AI	Offshore Renewables
Houston	N	N	SS	SS	N	SS	SW	S

Table 5.3 Summary of survey results comparing Scotland with Houston

Houston	SS	N	SS	SS	N	SS	N	S

Table 5.4 Summary of survey results comparing Scotland with Houston

Legend Weaker (W), Slightly Weaker (SW), Neutral (N), Slightly Stronger (SS), Stronger (S)

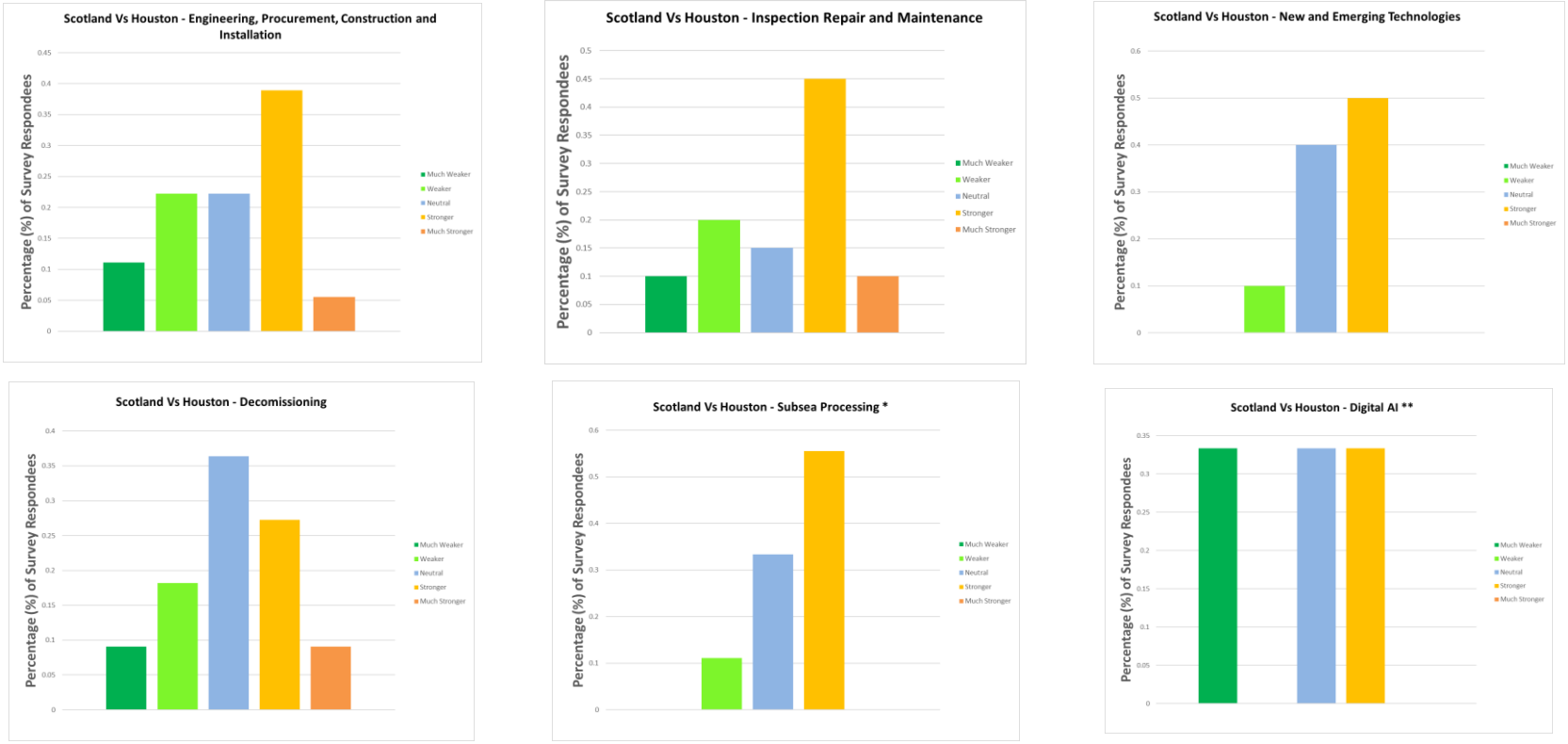


Figure 5.2 **Scotland Vs. Perth Focus Area Competitiveness (survey results)**

With regards to Scotland's competitiveness with the Houston region participants sited ease of doing business, quality of personnel and innovative approaches as Scotland's key advantages.

With regards to Scotland's companies prospects in Houston there was a perception offered by a number of interviewees that Houston is a challenging place to do business with long term relationships being the key to securing work.

Appendix B.2.2 Feasibility of New and Emerging Enabling Technologies - **Rated as Slightly Stronger**

Energy Department's National Labs, one of 17 national labs situated across the US, are developing technologies to reduce carbon emissions and ensure fossil energy sources play a role in America's clean energy future. They support the integration of academia with industry to commercialise new technology in the Oil and Gas sector.

The National Wind Technology Center (NWTC) at the National Renewable Energy Laboratory (NREL), another of the 17 national labs, is the nation's wind energy, water power, and grid integration research facility. They have R&D initiatives in the following areas: Wind turbine control, reliability, design, resource characterisation, grid integration, technology development and manufacturing.

The National Wind Technology Center (NWTC) is the nation's premier wind energy technology research facility. The goal of the research conducted at NWTC is to help industry reduce the cost of energy so that wind can compete with traditional energy sources, providing a clean, renewable alternative for our nation's energy needs.

Appendix B.2.3 EPCI & IRM - **Rated as Neutral**

Houston, like both Scotland and Norway hosts the main EPCI & IRM companies with significant fleets located locally. Houston has a mix of shallow and deep water developments. The Gulf of Mexico presents significant challenges to oil field developments with hurricanes regularly passing through the area. It was felt that the global distribution of EPCI knowhow in major hubs made the competitiveness quite flat.

It would be interesting to investigate further if the barriers to new entrants of existing relationships filters down through the supply chain or whether international SMEs can make easier progress with the EPCI and IRM contractors.

Appendix B.2.4 Decommissioning - **Rated as Neutral**

This is the region in which the majority of oil and gas decommissioning has been carried out to date and there are potential lessons learned from activities carried out here. The peak in decommissioning during the period 2009-2014 followed the impact of Hurricane Katrina in 2005, which damaged many offshore oil and gas structures. Subsequently the Idle Iron legislation was introduced by the US government to ensure non-operational wells and offshore platforms were decommissioned within 5 years to ensure that 'idle' infrastructure was removed, to minimise environmental impact during future storms.

Around 12% of the structures were decommissioned using the 'Rigs to Reefs' option which has been particularly prevalent in the shallow waters of the Gulf. This approach is not typically used in the North Sea but is being considered in shallow waters in south-east Asia for example. Research in the US has shown that this method can help to protect fish breeding grounds and increase fish stocks.

As this approach is not permitted in the UKCS, there is very little engineering capabilities or track record directly related to this approach. As such, should the 'Rigs to Reefs' option to decommission become more common the Scottish supply chain would not be in a position to support on a competitive basis.

Appendix B.2.5 Subsea Processing - **Rated as Slightly Stronger**

Houston hosts the head offices of some of the words largest SPS suppliers with significant manufacturing capability and should have access to the recent advances in subsea processing. However, with the first development projects being engineered out of Norway and manufactured in Scotland then it is uncertain whether they have any competitive advantage over Scotland.

Appendix B.2.6 Digital/ Artificial Intelligence - **Rated as Neutral**

With Silicon Valley the best known of digital development hubs then we can expect that the US will have a strong influence in the digital sphere however the digital subsea engineering landscape in Houston was not clear from our research. Expert input was unaware to the level at which the US oil industry had embraced Silicon Valley however it was felt that the Shale gas industry had made strides in this sphere and where companies have interest in both shale and conventional offshore oil and gas that these innovations may start to be brought in.

Appendix B.2.7 Offshore Renewables - **Rated as Stronger**

Offshore renewables are not a focus area for the Houston engineering community. With wind resource believed to be relatively equal with that offshore and having sufficient space for expansion within Texas then the driver to move offshore is absent especially when the added complexity and risk of regular hurricanes is considered.

Houston would undoubtedly have the engineering capability to input to marine renewables but to date experience is limited.

There is more interest in other areas of the United States with interest on the east coast in offshore wind and tidal and wave energy of particular interest to the west coast. Oregon have recently developed PMEC the Pacific Marine Energy Centre having visited EMEC for input and lessons learned.

The first US offshore wind development was completed off the coast of Rhode Island in 2016 with five 6MW turbines installed. Projects totalling 24GW are in the pipeline with developments also planned offshore New Jersey, New York, North Carolina, Maryland and Massachusetts.

Appendix B.3 International Benchmarking – Perth's Capabilities

Appendix B.3.1 General - **Rated as Stronger**

Natural gas (LNG) accounts for just under two thirds and crude oil accounts for almost 22% of total production. There are approx. 18,000 oil and gas wells in Australia. Australia is predicted to become the world's largest LNG exporter, overtaking Qatar, by 2020.

Australia has 3 major domestic oil/gas companies – Woodside Petroleum, BHP-Billiton and Santos. Many of the largest multinational oil companies are also exploring, operating, and partnering in one or more projects. Where the local market differs to the UK is in the absence of smaller operators.

Service companies such as Halliburton, Bechtel, Schlumberger, and Technip further enhance the international nature of the local industry.

Having recently constructed a number of large LNG developments it is expected that the focus for Perth will transition from construction to Operations and Maintenance as well as starting to develop the next phase of projects needed to tieback to these LNG facilities as the plateau of the initial developments passes.

Perth is a high cost market with regards to vessels, due to remoteness and local marine crew regulations. There are no major SPS manufacturing facilities therefore all subsea hardware is imported from Scotland, Norway and the US. Engineering is often performed locally for only the early phases due again to cost issues with more manpower intensive phases moving to the low cost centres of Malaysia and India.

Scotland is seen as generally stronger than Perth with the main reason being the level of experience within the supply chain. With Perth being dominated by a few very large projects the opportunity to gain the range of experience developed in the North Sea is not available.

As with many other regions Scotland benefits from a large expat community in Perth and thus contacts and product recognition is made easier by this fact.

Scotland is ..... Than ..... Wrt	General	Engineering, Procurement, Construction and Installation	Feasibility of New and Emerging enabling Technologies	Inspection, Repair and Maintenance	Decomissoning	Subsea Processing	Digital AI	Offshore Renewables
Perth	S	N	S	N	N	S	S	S

Table 5.5 Summary of *Survey Results* comparing Scotland with Perth

Perth	S	S	S	S	S	S	SW	S

Table 5.6 Summary of *Xodus Analysis* comparing Scotland with Perth

Legend Weaker (W), Slightly Weaker (SW), Neutral (N), Slightly Stronger (SS), Stronger (S)

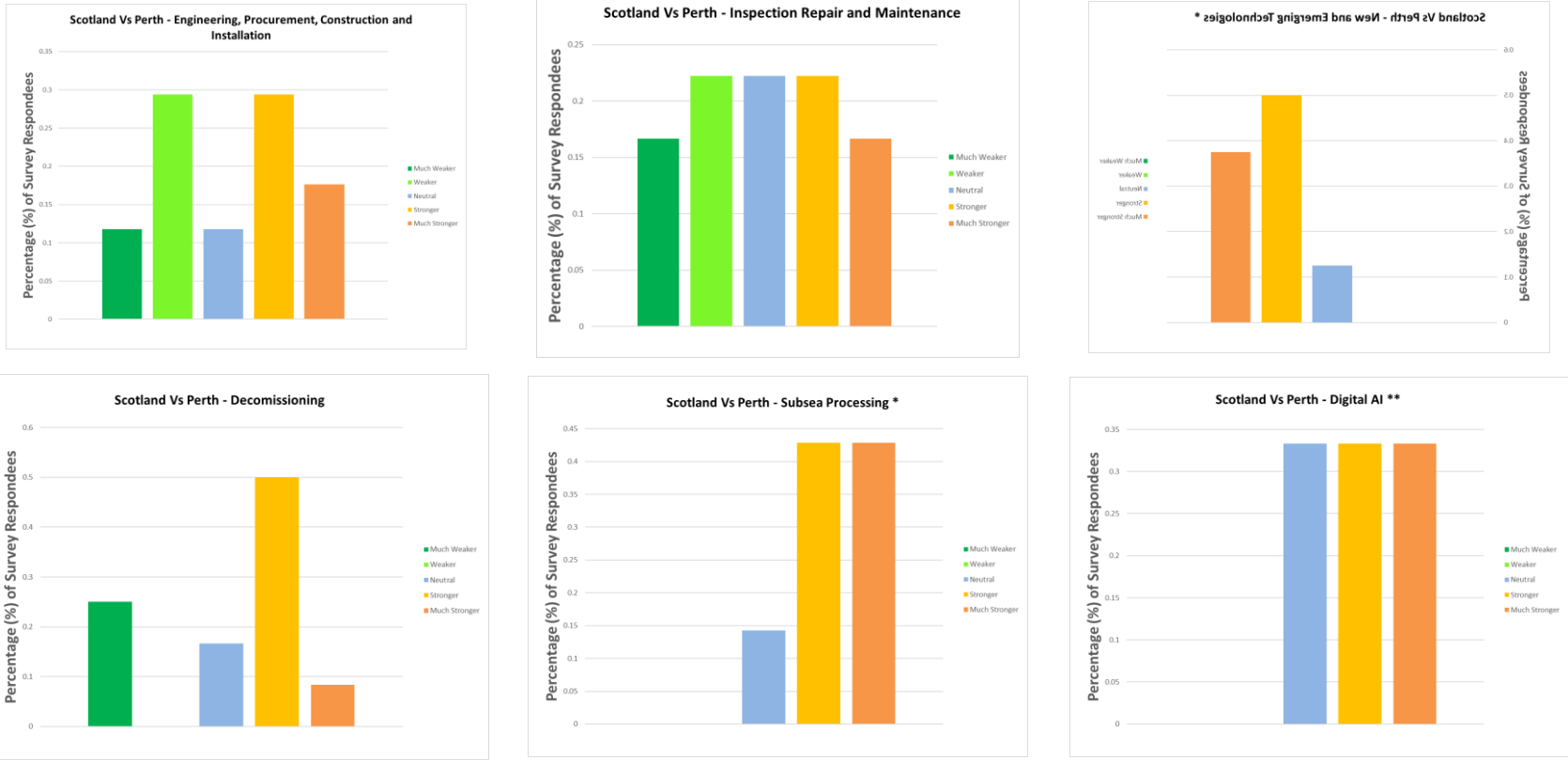


Figure 5.3 **Scotland Vs. Perth Focus Area Competitiveness (survey results)**

Appendix B.3.2 EPCI & IRM - **Rated as Stronger**

As touched upon above Australian labour and marine regulations make Perth a challenging place to operate. Vessel companies locate their regional fleet in Singapore and KL rather than Perth due to cost issues meaning vessel availability is compromised. Regulations enforce that when installation vessels enter Australian waters then the regular crew must be replaced by an Australian crew. This has a cost impact due to the premium charged for those local skills but also effects project efficiency with the experience of the crew limited. While Australian EPCI capability is increasing, it is limited by the opportunities to work on only one or two projects a year whereas the original international crew may be completing eight to ten projects a year. The detailed engineering for projects will also be outsourced to lower cost engineering centres.

Due to the size of the large LNG projects available in Perth all of the main contractors are active in the area so capability is available however experience is limited due to the restrictions already covered. All hardware is imported form international markets.

While our survey placed Perth on a neutral capability footing with Scotland our expert interviewees with detailed knowledge of the market placed Scotland in a stronger position due to some of the experience issues detailed.

The high cost of engineering services means that Perth would be far less competitive than Scotland in a non-Australian setting.

Appendix B.3.3 Feasibility of New and Emerging Enabling Technologies - **Rated as Stronger**

National Energy Resources Australia (NERA) has been established to maximise the value to the Australian economy by having an energy resources industry that is globally competitive, sustainable, innovative and diverse.

Through a national focus, NERA's role is to grow collaboration and innovation to assist the energy resources industry manage cost structures and productivity, direct research to industry needs, deliver the future work skills required and promote fit for purpose regulation.

NERA is one of six Growth Centres established by the Australian Government under the Industry Growth Centres Initiative.

NERA performed their own competitiveness study in 2017 where they found the Australian sector to be lagging behind the best in the world at R&D, they scored the best in the world as USA, UK and Netherlands. The study identified that while Australia ranked in the top ten worldwide for Academic publications it ranked towards the bottom for collaboration between industry and academia. The issue being the requirement of Australian operators to see international working models before willingness to implement new technology, this proves uneconomic and is stifling innovation.

Appendix B.3.4 Decommissioning - **Rated as Stronger**

With more than 100 platforms and subsea structures located in Australian waters, in some of the most unique marine environments on the planet, offshore decommissioning is likely to be complex, challenging and expensive, with the current cost of decommissioning Australia’s oil and gas infrastructure estimated at more than US$21 billion over the next 50 years.

Australia needs evidence-based policy and regulation, relevant to location and environment, for optimal decommissioning solutions. A range of decommissioning approaches may be needed to align with investment in the industry.

The Australian supply chain needs additional vessels, tooling, disposal facilities and a trained workforce for offshore decommissioning. Opportunities exist to export decommissioning capability to Perth and further afield

to SE Asia where 50% of offshore platforms are >20 years old and >600 fields are expected to cease production within 10 years.

Developing regional-specific techniques and technologies for decommissioning presents an opportunity for supply chain looking to export to Australia and Oceania.

Appendix B.3.5 Subsea Processing - **Rated as Stronger**

Without any presence from the main manufacturers of subsea processing equipment Perth will have limited access to the capabilities involved in subsea processing.

Appendix B.3.6 Digital/ Artificial Intelligence - **Rated as Slightly Weaker**

The main oil companies in Perth have embraced and enacted digital transformation more obviously than some of the other sectors. Woodside and Santos were singled out as companies that have taken large steps by investing in systems like data lakes and IBM Watson for machine learning. As well as these large investments and corporate cultural shifts examples were also provided of small scale investments in digital process surveillance tools to improve production efficiency and remove manpower intensive tasks from key personnel.

Whether there is a material difference in capability between the regions at this moment is unclear however having a receptive audience to digital innovation may allow Perth to take a lead in this area and gain an advantage over Scotland unless we too can gain that corporate buy in at all levels of our operators for that reason we have scored Scotland as slightly weaker than Perth in this area.

Appendix B.3.7 Offshore Renewables - **Rated as Stronger**

Australia has stated a desire to be involved in offshore renewables and development is underway for their first offshore wind farm a 2GW project off the coast of Victoria.

Australian Wave Power company Carnegie deployed the world's first grid-connected wave energy array on Garden Island in 2015, with $13m in support from the Australian Renewable Energy Agency (Arena).

Three CETO 5 buoys, each seven metres in diameter, generated clean power and desalinated drinking water for the country's largest naval base. The array, which has since been decommissioned, operated over 12 months for a cumulative 14,000 hours. It set a world record for a grid-connected wave energy system.

Carnegie are now deploying their next generation of the CETO device at the Wave Hub facility in Cornwall.

While Carnegie's progress in wave power is impressive the limited development of offshore renewable developments and devices would indicate that the industry in Australia is lagging behind Scotland.

Offshore renewables in Australia will encounter the same cost issues as traditional oil and gas which may make it cost prohibitive especially in a country where there is a large land mass with low population density that may be more suited to onshore wind or solar.

Appendix B.4 International Benchmarking – Malaysia's Capabilities

Appendix B.4.1 General - **Rated as Stronger**

Malaysia is fast becoming the regional centre for subsea engineering and procurement activities, with many well-known names establishing a manufacturing base in the country. Many UK oil and gas service providers and equipment suppliers are doing well in the market, thanks to the UK's strong reputation in Malaysia.

Malaysia have a goal to be the number one hub in the region and to this end they are proceeding with the following initiatives that are of interest to Scotland:

- Developing small fields through innovative solutions.
- Rejuvenating existing fields through enhanced oil recovery.
- Attracting multinational companies to bring their global oil field service and equipment operations to Malaysia.
- Developing engineering, procurement and installation capabilities and capacity through strategic partnerships and joint ventures.

Our findings were that Scotland is seen as slightly stronger or stronger in almost all focus areas of the study. The Malaysia capability is considered competent and improving in all areas. Investment by Petronas is driving R&D and improving local skills while local content regulations ensures that opportunity to gain experience is available. Malaysia has become a manufacturing hub for the Asia region with companies such as TechnipFMC opening Asiaflex to supply flexible flowlines and risers. In addition to Asia, Malaysia also services the Perth market for both manufacturing, vessels and low cost engineering manpower. There is a large international engineering personnel presence providing operational and project experience as part of local teams.

Scotland is ..... Than ..... Wrt	General	Engineering, Procurement, Construction and Installation	Feasibility of New and Emerging enabling Technologies	Inspection, Repair and Maintenance	Decomissoning	Subsea Processing	Digital AI	Offshore Renewables
Singapore/KL	S	N	S	SS	SS	S	SS	S

Table 5.7 Summary of *Survey Results* comparing Scotland with Malaysia

Malaysia	S	SS	S	S	S	SS	S	S

Table 5.8 Summary of *Xodus Analysis* comparing Scotland with Malaysia

Legend Weaker (W), Slightly Weaker (SW), Neutral (N), Slightly Stronger (SS), Stronger (S)

With regards to competitiveness Scotland will struggle to compete on cost for standard engineering activities such as shallow water development studies however for more complex developments that have deep water or for challenging integrity or operational issues Scotland with its greater quality and depth of experience should be able to compete.

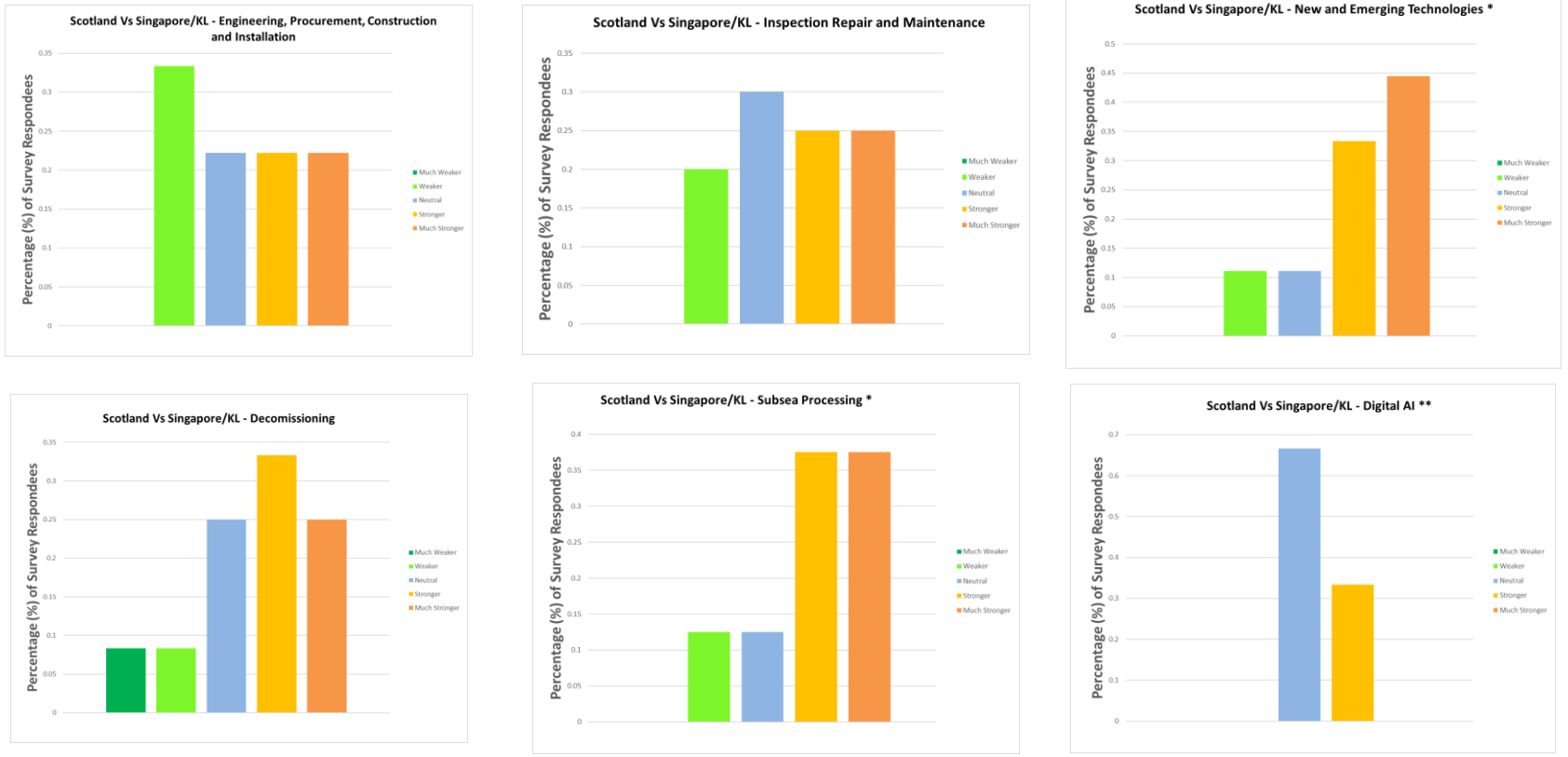


Figure 5.4 Scotland Vs. Malaysia Focus Area Competitiveness (survey results)

Appendix B.4.2 EPCI & IRM - Rated as Slightly Stronger

The Malaysia subsea industry is seen as competent in shallow water developments where they have developed experience over many years. Many developments have been platform based and subsea tiebacks while not uncommon are not the norm. For deeper water developments, at least at the moment, Malaysia looks more to international contractors to provide experience and assurance.

Malaysia hosts a large EPCI fleet including all the major international companies as well as some local companies servicing the local area as well as the Perth region. With these major companies comes a level of experience and competency spread across the globe.

Due to the less mature infrastructure the IRM sector in Scotland will have experience of issues yet to become commonplace in Malaysia and thus there are opportunities for innovative solutions and exporting capabilities

Appendix B.4.3 Feasibility of New and Emerging Enabling Technologies - Rated as Stronger

Petronas is committed to improving the capability and competitiveness of the Malaysian subsea industry by investing in R&D.

One such objective is to encourage capability and capacity growth of service companies providing deep-water and subsea technology and expertise while also encouraging oil companies and service companies to collaborate. To this end, they are looking to create a deep-water hub bringing together international operators located in Malaysia with international service and manufacturing companies based in Malaysia.

Appendix B.4.4 Decommissioning - Rated as Stronger

The Asian Council on Petroleum launched its ASCOPE Decommissioning Guideline for Oil and Gas Facilities (ADG) in 2015 – designed to be regional decommissioning guidelines tailored to the ASEAN countries (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand & Vietnam). In 2006, 54% of the offshore infrastructure in the ASEAN region was over 20 years old so the ASCOPE guidelines were planned, to form the basis for additional technical handbooks which needed to be developed in detail. The 2015 guidelines cover environmental protection, cost, safety and technical considerations in line with applicable global and regional conventions and guidelines and have received approval from the relevant National Oil Companies.

Decommissioning-related activity in the region is currently concentrated on well plug and abandonment. Individual companies have developed their own approaches, but best practice guidelines are generally not readily available and as such activity in this area is limited to date.

It was hoped the ADG would kick-start decommissioning, but it was left to individual countries to develop regulations on specific aspects of decommissioning and Brunei is one of the few countries which has made substantial progress. Brunei Shell Petroleum have worked with the Brunei government to drive decommissioning at a national level, and it is expected that countries like Indonesia and Malaysia will adopt many similar practices.

The fall in the price of oil underscores the need for the legislation. Operators in the Asia-Pacific region could face pressure to push forward asset-retirement plans. An indication of the contraction in E&P activity are reports that around 180, half, of the drilling rigs in the region are idle.

Scotland has far more experience and capability than the local market however opportunities could be limited by local content regulations

Appendix B.4.5 Subsea Processing - Rated as Slightly Stronger

There is limited experience of subsea processing to date in Malaysia however as designs become more developed and less of an R&D exercise some of the major suppliers may choose to manufacture in Malaysia due to the reduced costs.

Appendix B.4.6 Digital/ Artificial Intelligence - **Rated as Stronger**

Malaysia is promoting a digital economy with moves recently by the Malaysian government digital arm and the Chinese tech giant Alibaba to set up a digital free trade zone in Malaysia. There is also a Malaysian digital hub being set up to encourage collaboration and access private and government funding. We therefore believe that there is digital capability in the country however whether there has been penetration into the oil and gas market is unclear from our expert interviews or our research. We therefore conclude that there is a potential competitiveness advantage for Scotland. The efficiency savings of digital innovations could be of great value in a region where experienced personnel are at a premium however they will also have to prove cost effective against a lower manpower cost than in some other regions.

Appendix B.4.7 Offshore Renewables

The Asia Pacific region is an area with significant activity in renewables however no evidence of development in Malaysia could be found during our review. There was discussion of a feed in tariff system around 2012 however like some other countries when the feed in tariff was delayed or cancelled then the development options may well have fallen away with them.

Taiwan, Japan, China and Vietnam are the most active in the region.

South East Asia is a target area for many wave and tidal companies with the premise being that while they cannot at present be competitive with oil and gas and other renewable projects for mass grid connected energy generation they could find a market in non-grid connected areas such as the many small islands in South East Asia. For wave and tidal developments to become economic in these circumstances they do not have to be cheaper than mass energy generation but rather better value than shipping in diesel to run generators. A key to this may be the advent of economic energy storage whether in battery or hydrogen form.

Appendix B.5 International Benchmarking – Rio de Janeiro's Capabilities

Appendix B.5.1 General - Rated as Slightly Stronger

Brazil has a significant subsea industry and access to some of the largest remaining untapped discoveries in the world making it a focus area for many International Oil Companies (IOCs) and large engineering, procurement construction and installation (EPCI) companies. The Brazillian pre-salt fields are located in ultradeep water and will require some technological innovation to develop these fields.

Due to local content requirements, the majority of the major oilfield service (OFS) companies have been forced to establish dedicated manufacturing and installation capabilities in-country in order to service this region thus we rate this region as neutral to Scotland with many of the same companies involved in both markets. With regards to offshore renewables and decommissioning however it is our opinion that Scotland holds a competitive advantage in these areas.

Due to the large nature of the Brazilian developments and the depth of water it is perhaps perceived as a highly complex region thus explaining the scores from our general survey however much of the expert input with experience of the region ranked Scotland as more capable.

Industry Perception:

Due to similarities in water depth and technology requirements Brazil has routinely looked to Norway for guidance and support

Rich in natural resources with a developed industrial base, Brazil has high standards in scientific research and substantial human capital.

It is the sixth largest economy in the world overtaking the UK at the end of 2011. Brazil leads all other South American countries with its development in terms of infrastructure and technology. Combine this with the more stable political and economic landscape and it is easy to see why Brazil attracts a higher percentage of total global foreign investment year on year.

The subsea supply chain has been in growth phase for some time and in the early days most of the buying was done directly by Petrobras. They have good knowledge of the supply chain capability and up until more recently tended to contract with construction companies mainly for installation services only. Today most of the business is in the hands of the local subsidiaries of principal international subsea contractors and more responsibility for managing the supply chain to support their engineering requirements is being passed to them. Most manufacturers see the region as a target for future growth in the medium term. Petrobras has proved to be a highly efficient user of the industry, and typically operates large scale multi-year frame agreements for key equipment which are shared fairly evenly around the industry. One aspect which is important for Petrobras and Brazil is to develop standardisation in many of the subsea component parts such as trees, wellheads and interfaces as well as pipe dimensions. Once you have established your market and customers, you may have a number of options on how to enter the Brazilian market supply chain. It may be via one of the large subsea construction subsidiaries or directly with an operator. If your aim is to conduct business directly with Petrobras you may have to register on the Petrobras Supplier Approval Register.

Material	Unit	2013	2014	2015	2016	2017	Total
Risers	Km	294	412	456	606	995	2.763
Flexible Pipes	Km	1.409	1.493	812	1.637	2.416	7.767
Umbilicals	Km	817	717	648	1.192	1.191	5.275
Manifolds	Un	24	17	21	35	26	123
Tubing	ton	13.947	13.947	13.947	13.947	13.947	69.735
Wet Christmas Trees	Un	117	132	114	200	244	807

Figure 5.5 Subsea Equipment - Source Petrobras 2013

As Petrobras has sold off assets, the emergence of international oil companies (IOCs) in Brazil such as Total, Statoil/Equinor, Chevron, and Shell will drive new projects and investment. Others, such as Exxon, are also looking closely at opportunities in the country.

The IOCs' eventual development of their Brazilian deepwater assets will make up for a large portion of Petrobras' recent downsizing. Although Brazil's offshore market won't return to its former scale anytime soon, it will be a key region in the deepwater market recovery going forward. Combining this with proposed reforms regarding local content requirements (reduction to 50% proposed) the opportunity to for the Scottish subsea supply chain is substantial.

Scotland is ..... Than ..... Wrt	General	Engineering, Procurement, Construction and Installation	Feasibility of New and Emerging enabling Technologies	Inspection, Repair and Maintenance	Decomissoning	Subsea Processing	Digital AI	Offshore Renewables
Rio	S	SW	N	N	N	N	SW	N

Table 5.9 Summary of *Survey Results* comparing Scotland with Rio De Janeiro

Rio	SS	N	N	N	S	N	SS	S

Table 5.10 Summary of *Xodus Analysis* comparing Scotland with Rio De Janeiro

Legend Weaker (W), Slightly Weaker (SW), Neutral (N), Slightly Stronger (SS), Stronger (S)

The survey results have indicated that in general there is a perception that Scotlands Subsea industry is stronger than that of Rio de Janeiro. However the results from the individual focus areas don't seem to support this sentiments with Scotland being ranked as with neutral or slightly weaker than the capabilities in Rio.

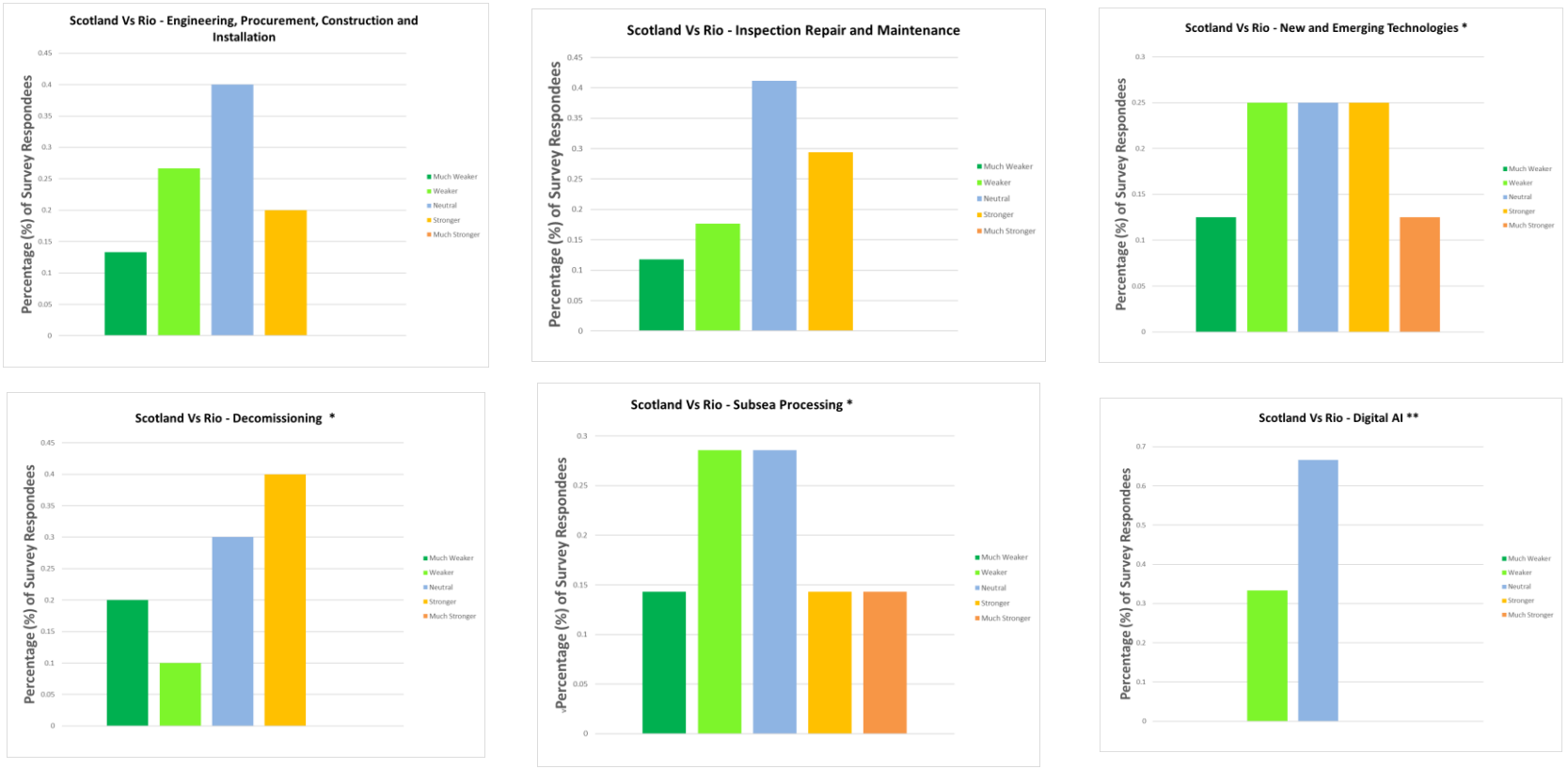


Figure 5.6 Scotland Vs. Rio De Janeiro Focus Area Competitiveness (survey results)

Appendix B.5.2 EPCI - Rated as Neutral

Current local content requirements oblige operators of oil and gas blocks to procure a certain level of goods and services from Brazilian sources as a condition of their concession or production sharing agreements and thus limiting the opportunities for the Scottish supply chain to export services and capabilities.

Over recent years, these requirements have been widely criticised for their complexity and the additional costs they have imposed on the industry. The mechanism has been politically motivated to protect sectors of Brazilian industry from competition, which has resulted in local content being associated with a substantial premium over international prices in many cases. Operators have been forced to try to anticipate the levels of local content that they will be able to secure in the development of a field at the bidding stage, when they do not know what kind of reservoir they may discover, nor what technology will be available, nor what capacity local suppliers will have at that time, which may be five to ten years after bidding.

Industry Opinion

A global subsea equipment supplier currently providing systems to the Brazil market commented on the fact that any services they provide for this region are done so through their bases in Scotland rather than from their Houston bases, at the request of the Client located in Brazil, despite the significant time differences.

This relates back to the unique selling points (USP) often stated for the Scottish industry that issues experienced in new oil and gas projects around the world would have been experienced before in Scotland and that a solution would be delivered through the detailed capabilities of the Scottish supply chain.

The following graph illustrates sentiment in the Scottish supply chain with regards competitiveness versus Brazil in the EPCI industry. Results obtained from the survey conducted as part of this study.

Appendix B.5.3 Feasibility of New and Emerging Enabling Technologies - Rated as Neutral

Technological Park of Rio - URFJ

In partnership with Petrobras, UFRJ intends to convert an area of 350 000 m² into the world's largest oil-related technological research centre, given that exploration and oil extraction from the recently discovered pre-salt layer fields is in urgent need of new, more affordable techniques. Intense has been provided from private and state investments in the region. Main facilities include:

- Leopoldo Américo Miguez de Mello Research Centre (CENPES): founded in 1962 and managed by Petrobras, it is responsible for research and development (R&D) and for the company's basic engineering matters; it is the largest oil research pole in the southern hemisphere.
- Electric Energy Research Centre (CEPEL): founded in 1974, it is part of group Eletrobrás and manages R&D related to the generation, transmission and distribution of electric energy. It is also the hemisphere's largest research centre in the field.
- Mineral Technology Centre (CETEM): founded in 1978 and under direct command by the Ministry of Science, Technology and Innovation (MCTI), it acts on the technological development concerning to minerals;
- General Electric Global Technological Centre (GE): home to GE's newest multidisciplinary Research and Development Centre, employing researchers and engineers who are solving the toughest challenges for GE's customers in Brazil and South America. When fully operational, the Centre will employ 400 GE technologists.
- Alberto Luiz Coimbra Institute of Post-Graduation and Research in Engineering (COPPE): UFRJ's supplementary organ, it is Latin America's largest research and learning center of engineering. Also notable for owning the world's largest (volume terms) and deepest oceanic tank, which is used to simulate sea-life conditions.

Research 'Levy'

Oil and Gas (O&G) operators working in Brazil are required to pay 1% of their gross revenue to the Government to be invested in R&D schemes in Brazil. This program is managed by ANP (the oil and gas regulator). At least 50% of the money must be channeled to universities or research centers in Brazil, and the other 50% can be invested by the operators in their own research centers.

The 1% levy is a contractual obligation applied to all concessionaries whenever their oil and gas production surpasses a specific threshold by field. As a result, a single operator has quoted that its expects to invest approximately $2 Billion in R&D in Brazil up to 2025.

The Brazil R&D levy, as it is commonly known, is having profound consequences for how operators are going to implement their global technology strategies. now and in the future. Operators may operate more centralised key global technology activities in Brazil, taking away from any reliance they may have on Scotlands supply chain, universities and innovation centres etc.

A Subsea Cluster

Prior to the recent downturn and corruption cases in Brazil It was anticipated that almost half of all the future deepwater activities in the world would be developed in Brazil, and by 2020, Brazil would have 44 percent of the subsea Christmas trees and 26 percent of the FPSOs in the world. A majority of the pre-salt blocks are located in the state of Rio de Janeiro. As a result of the increase in subsea service requirements this would bring the Brazilian government are investigating the creation a subsea cluster in Rio de Janeiro. Together with Petrobras, they have identified several focus areas, and have a comprehensive list of technical gaps, services and products that they are going to need. Forges alloys, coatings, bolts, subsea valves for example.

Appendix B.5.4 IRM - Rated as Neutral

Subsea hardware spending in this region is expected to continue and significantly increase the size of installed subsea infrastructure. With non-productive time and delays prohibitively costly for operators, the outlook for the requirement of high quality subsea inspection, repair and maintenance (IRM) is positive.

Growth in subsea infrastructure spend, in Brazil, continues trending towards deeper waters. which will positively impact IRM expenditure in the future.

A large proportion of subsea IRM work is executed by remotely operated vehicles (ROVs). IRM support typically entails work-class ROV inspection, replacement tasks, cutting operations, hatch operations on subsea structures and valves, as well as cleaning tasks. Scotlands vast IRM experience is well placed to support these operations

A sector where subsea IRM growth shows promise, relates to autonomous underwater vehicle (AUV) operation. Increasingly used for deepwater surveys, at present a range of technological advancements in the space are being developed. Evidence is sparse in relation to Brazils development in this area and therefore could present a significant opportunity for AUV technologies currently being developed in the Scottish supply chain.

Appendix B.5.5 Decommissioning - Rated as Stronger

Brazil currently has 160 offshore production platforms in place, 42% of which have been in service for more than 25 years, according to the National Petroleum Agency (ANP).

Brazil also has about 10,000 km of subsea pipeline, with almost a third of this installed more than a 25 years ago.

A demand for the decommissioning is inevitable over the next five years, with several production platforms and hundreds of offshore wells falling out of use.

Much of the older infrastructure is located in shallow waters in the Sergipe-Alagoas, Ceara and Potiguar basins, where domestic oil company Petrobras began offshore production.

More are found in the Campos basin with FPSO units (including the presence of subsea pipelines extending over great distances.) in deeper waters also beginning to come into the frame for decommissioning.

That being said decommissioning activity has so far been sluggish in Brazil. A pilot project involving the complete decommissioning of a platform at the end of its life — the Petrobras-owned Cacao platform off Espirito Santo — has been held through the regulatory process since 2010. ANP acknowledges the regulatory process to be too prescriptive and unwieldy with reform due in 2018.

Decommissioning represents an opportunity for a whole new chain of suppliers form Scottish subsea industry. The regulatory reform that Brazil is currently preparing will be underpinned by a report prepared by UK-based engineering consultancy Arup, and delivered to the ANP in May 2018.

Brazil have already acknowledged that the UK example currently offers the best lessons so far but have reiterated they will also take account of Brazil's own special characteristics and other global lesson learned including solutions that may not require outright removal of installations, similar to the 'rigs-to-reefs' program employed in the US GoM.

Decommissioning represents an opportunity for a whole new chain of suppliers form Scottish subsea industry. The experience gained in the UK Continental Shelf (UKCS) to date gives Scotland a capability advantage in this area however competitive challenges from Norway and Houston could be expected. Local content will also be an issue.

Appendix B.5.6 Subsea Processing - **Rated as Neutral**

Partly state owned National Oil Company (NOC), Petrobras, are driving the developments behind subsea processing, together with the equipment manufacturers.

Brazil is an ideal candidate for subsea processing due to the fact that its Campos basin fields hold significant amounts of heavy oil which are more difficult and expensive to extract and process than lighter crude oil. Oil water separation, raw water injection and subsea multiphase pumps are critical to the success and efficient extraction of this basin.

Industry Opinion

Due to similarities in water depth and technology requirements Brazil has routinely looked to Norway for guidance and support

The extensive equipment already deployed in Brazilian Oil and Gas fields. Of the 59 subsea projects listed 17 (29%) are located in the Brazil representing a sizable share of the subsea processing market.

Appendix B.5.7 Offshore Renewables - **Rated as Stronger**

Although Brazil has made significant progress in divesting from fossil fuels (In 2009 the country produced a staggering 85% of its electricity from renewable resources. This has been through mainly through heavy investment in hydro power, with 75% of its total renewable energy coming from this resource. As such it is significantly behind the curve when it comes to offshore renewables.

The first Brazilian generation of power from ocean waves was obtained in a prototype located at Porto do Pecém, in São Gonçalo do Amarante (Ceará), the plant is part of the R&D project called "Deployment of Onshore Waves Converter Prototype on Sea Conditions of the Northeast of Brazil", initiated in, 2009.

The project had Tractebel Energia S.A as proponent company and University of Rio de Janeiro's Foundation of Project Coordination, Research and Technological Studies (COPPE, in Portuguese) as executor institution.

The still initial small generation of power represents progress, as the Brazilian coast presents good conditions for energy use, due to its proximity to the consumers composed by high population density cities and an established supply chain.

Appendix B.6 International Benchmarking – West africa / Paris's Capabilities

Appendix B.6.1 General - **Rated as Stronger**

While West Africa and its constituent countries are the oil producing hub a significant portion of engineering for this region is done out with country in engineering centers in Paris, London and Houston. For this study Paris was selected to accompany the region in order not to underestimate the engineering support these locations already receive and thus oversell any possible competitive advantage or opportunity.

West Africa has a significant portion of the world's largest projects and thus is of great interest to all engineering companies as a potential market. The majority of West African developments have significant ownership from International Oil Companies (IOCs) and thus receive engineering input and leadership from their organisations. There is a major EPCI fleet in the region due to the volume of projects executed over the last two decades and all major EPCI & IRM companies are represented providing engineering capability. Local content rules mean that not all engineering is performed from out with country and significant portion of manufacture or fabrication is required to be performed in country. Some Scottish companies have become established in this market providing services to EPCI and IRM contractors.

Scotland is rated in our survey as stronger than this hybrid region in most areas and this is backed up by our expert interviews. Scotland and its supply chain provide a far greater level of efficiency, knowledge and experience than those in place in country even when supplemented by the support by Paris.

Scotland is ..... Than ..... Wrt	General	Engineering, Procurement, Construction and Installation	Feasibility of New and Emerging enabling Technologies	Inspection, Repair and Maintenance	Decomissoning	Subsea Processing	Digital AI	Offshore Renewables
Paris/West Africa	S	N	SS	SS	N	N	SS	SS

Table 5.11 Summary of *Survey Results* comparing Scotland with West Africa/ Region

Paris/West Africa	S	N	S	S	S	SS	S	S

Table 5.12 Summary of *Xodus Analysis* comparing Scotland with West Africa/ Region

Legend Weaker (W), Slightly Weaker (SW), Neutral (N), Slightly Stronger (SS), Stronger (S)

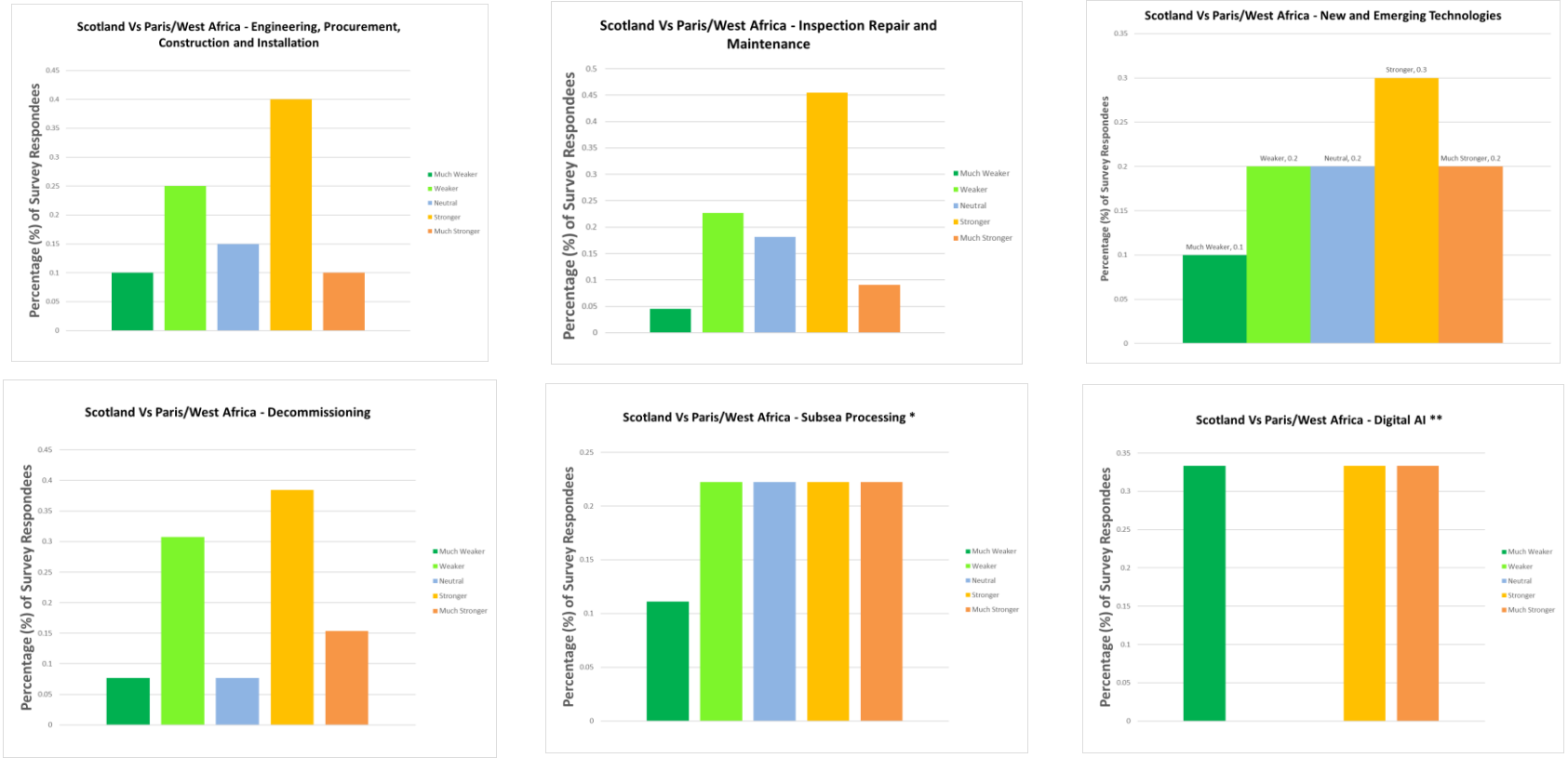


Figure 5.7 **Scotland Vs. West Africa/Paris Focus Area Competitiveness (survey results)**

Appendix B.6.2 EPCI & IRM - **Rated as Neutral & Stronger**

As with many of the regions assessed the presence of major EPCI players levels the capability range with capability transferrable through the company structure.

Local content rules ensure that indigenous supply chain provides a significant portion of EPCI engineering with support from external centres. This has cost and schedule implications for projects with the quality and efficiency of local contractors falling below that of that provided in Scotland, Norway or London.

There are a significant portion of international engineers providing support to Nigerian companies to increase experience

IRM engineering is most often performed out of country by international contractors thus while the region has limited capability it receives good quality support.

Scotland's EPCI competitiveness is quite strong in this area with knowledge and experience of operational issues required by limited operational teams in country.

Appendix B.6.3 Feasibility of New and Emerging Enabling Technologies - **Rated as Stronger**

West Africa has below average spend on R&D as a whole and investment in science and technology is believed to be declining. Specific subsea R&D was unclear. It may be that R&D aimed at the region is being performed by IOCs in other areas

Appendix B.6.4 Decommissioning - **Rated as Stronger**

Currently, an estimated 867 offshore platforms, 877 subsea wells and over 15,000km of offshore pipelines are installed in the African region.

Due to the relatively young nature of the oil and gas industry in offshore West Africa a great deal of this infrastructure is relatively new and not due for decommissioning in the near to mid-term.

Whilst the African decommissioning industry lags behind the more mature regions of the US Gulf of Mexico and the North Sea, policy makers will soon be forced to establish detailed legislation in order to govern and regulate the process of infrastructure removal. Upon establishment of the legislation it will become clear the potential opportunities for the Scottish supply chain to support this region.

Appendix B.6.5 Subsea Processing - **Rated as Slightly Stronger**

West Africa could be one of the key regions for subsea processing because of its already extensive deepwater production, significant oil reserves, and, most importantly, the geographical distribution of fields, whereby multiple discoveries are gradually being tied-back to one central processing facility.

One of the most actives regions to date for subsea pumps is offshore West Africa.

While West African projects may purchase subsea processing equipment the likelihood of manufacture or engineering of this hardware being performed in the region is unlikely.

Appendix B.6.6 Digital/ Artificial Intelligence - **Rated as Stronger**

There is a large market place for digital innovation and automation with West African developments amongst the most inefficient in the world due to an unskilled workforce and outdated technology. With the involvement of IOCs in the region then digital transformation capability will be available however whether this has as yet been initiated is unknown.

It is likely that Scotland would have a significant competitive advantage in this area with technology as well as lessons learned from the aged North Sea infrastructure.

Appendix B.6.7 Offshore Renewables - **Rated as Much Stronger**

In the African continent, there is development of wave energy in Ghana and advances towards wave in South Africa and potential for offshore wind development in East Africa.

Scotland will have a strong competitive advantage in this area should there be desire to involve international partners in the development of offshore renewables. Competition will come from worldwide with evidence of this recently when Ghana signed a wave power deal with a Swedish wave power developer.

APPENDIX C ABBREVIATIONS

Acronym	Definition
ADG	ASCOPE Decommissioning Guidelines
ANP	National Agency of Petroleum, Natural Gas and Biofuels
ASCOPE	ASEAN Council on Petroleum
ASEAN	Association of Southeast Nations
AUV	Automated Underwater Vehicle
BEIS	Dept. of Business Energy & Industrial Strategy
BGS	British Geological Survey
CENPES	Leopoldo Américo Miguez de Mello Research Centre
CENSIS	Centre of Excellence for Sensor and Imaging Systems
CEPEL	Electric Energy Research Centre
CETEM	Mineral Technology Centre
CFD	Computed Fluid Dynamics
COPPE	Alberto Luiz Coimbra Institute of Post-Graduation and Research in Engineering
DNV	Det Norske Veritas
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre
EPCI	Engineering, Procurement, Construction and Installation
FPSO	Floating Production Storage and Offloading
GCE	Global Centre of Excellence
IEA	International Energy Agency
ILI	In-Line Inspection
INTSOK	Norwegian Oil and Gas Partners
IOC	Independent Oil and Gas Company
IOR	Improved Oil Recovery
IRM	Inspection, Repair and Maintenance
ISA	International Seabed Authority
ITF	Industry Technology Facilitator
ITT	Invitation to Tender
LARS	Launch and Recovery System
LNG	Liquid Natural Gas
MCTI	Ministry of Science, Technology and Innovation
MER	Maximising Economic Recovery
MGSA	Ministerial Group Sustainable Aquaculture
NASA	Nationals Space Agency
NCS	Norwegian Continental Shelf.
NERA	National Energy Resources Australia
NIC	Norwegian Innovation Clusters
NOC	National Oil Companies
NORWEP	Norwegian Partners Association
NOV	National Oilwell Varco
NREL	National Renewable Energy Laboratory
NSRI	National Subsea Research Institute

Acronym	Definition
NWTC	National Wind Technology Center
OFS	Oilfield Services
OGA	Oil and Gas Authority
OGIC	Oil and Gas Innovation Centre
OGTC	Oil and Gas Technology Centre
OGUK	Oil and Gas UK
OPEX	Operating Expenditure
OPITO	Offshore Petroleum Industry Training Organization
ORE	Offshore Renewable Energy
ORI	Offshore Renewables Institute
OSPAR	Oslo Paris Agreement
PMEC	Pacific Marine Energy Centre
ROV	Remote Operated Vehicle
SAMS	Scottish Association of Marine Science
SDI	Scottish Development International
SINTEF	The Foundation for Scientific and Industrial Research
SIS	Sensor and Imaging Systems
SME	Small Medium Enterprises
SPS	Subsea Processing Systems
SURF	Subsea Umbilical Riser and Flowline
SUT	Society of Underwater technology
TEN	Tweneboa, Enyenra and Ntomme fields
TLB	The Technology Leadership Board
TMS	Tether management system
TRL	Technology Readiness Level
UFRJ	Technological Park of Rio
UKCS	United Kingdom Continental Shelf
UNCLOS	United Nations Convention of the Law of the Sea
USA	United States of America
USP	Unique Selling Point

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