Routes to Market Report

10 -Satellite Technologies for Energy Infrastructure Monitoring

Innovate UK

Cooper & Walsh Ltd
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CATAPULT
Satellite Applications

Contents

1. Introduction and Scope

The overall aim of this paper is to consider potential opportunities for satellite services related to energy infrastructure management and operation that arise from integrating current earth observation satellite data (e.g. weather, high quality images) with new sensors (IoT, GNSS etc.), with other devices (UAV etc.) and with applications such as asset management. We will also comment on the opportunity for using satellite bandwidth as a pure communications channel.

In this paper, we will primarily review the opportunities arising from the GB Energy Systems market as many of the major energy systems around the world are based on the UK system designed by the CEGB in the 1930s and mainly built during the 1950 / 60s. All of these systems face similar issues (primarily due to the age of assets, regulatory environment, maintenance / repair cost implications) as they use similar equipment made by relatively few manufacturers and suppliers (due to the considerable consolidation within the manufacturers and suppliers community the main remaining ones are ABB, GE, Siemens, Schneider, …). There are only a small number of international players, such as EdF and National Grid, with individual countries having their own generation, transmission and distribution industries. Energy infrastructure is always viewed as key national infrastructure and so there is always government involvement in the sector, with some organisations owned at least in part by the government or heavily regulated (including innovation).

Whilst the focus is on electricity and gas (generation, transmission, distribution) many of the characteristics will apply equally to offshore the gas / oil industries.

2. The market Overview and Opportunities

2.1. The Energy Systems market

Energy is delivered as electricity, natural gas, and oil for both heating and transport. These are referred to as 'energy vectors' and there are a number of further vectors that will emerge in the future, such as heat or cold delivered by fluids.

The international Energy Systems market is an established major market with identified needs across the supply chain for the foreseeable future, and with many established suppliers. State owned companies (i.e. companies in which the state owns more than 50%) own nearly half of the world's power generation assets and, along with their host governments, more than 70% of the global oil and gas reserves. State owned companies also have prominent positions in the coal sector and in many pipeline networks and electricity transmission grids.

In their report, World Energy Investment Outlook 2014, the International Energy Agency provide their view of the global energy supply investment by energy system type for the years 2014-35 – the total size of the capital investment required (i.e. excluding operating expenditure) exceeds $40 trillion (i.e. around $2 trillion per year based on 2012 values). The main elements of the investment are the $23 trillion in fossil fuel extraction, transport and oil refining; almost $10 trillion in power generation of which low-carbon technologies – renewables ($6 trillion) and nuclear ($1 trillion) – account for almost three quarters, and a further $7 trillion in transmission and distribution. Nearly two thirds of these investments take place in emerging economies, with the focus for investment moving beyond China into other parts of Asia, Africa and Latin America; but ageing infrastructure and climate policies also create large requirements across the OECD. Compensating for output declines absorbs more than 80% of upstream oil and gas spending. Replacing power plants that are retired triggers almost 60% of investment in electricity generation in OECD countries, although a much smaller share in emerging economies. These declines and retirements set a major re-investment challenge for policymakers and the industry, but they also represent a real opportunity to change the nature of the energy systems by switching fuels or deploying more efficient technologies. The investment was broken down as:

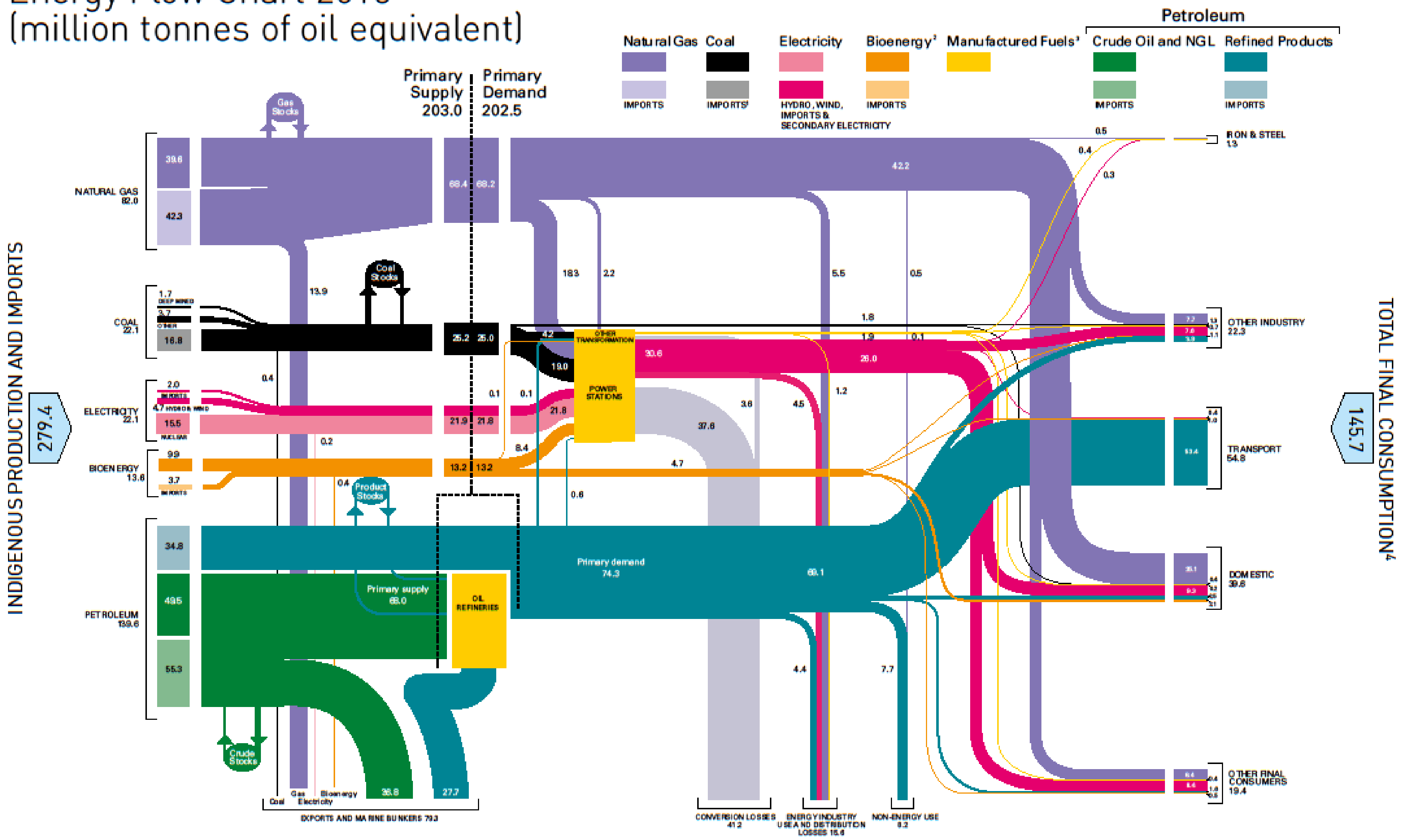
Type	Group	$m	Total $m
Gas	LNG	736	8,771
	Transmission & Distribution	1,897	
	Upstream	6,138	
Coal	Transport	298	1,034
	Mining	736	
Oil	Refining	1,401	13,671
	Transport	986	
	Upstream	11,284	
Power	Transmission	1,787	16,370
	Distribution	5,030	
	Fossil fuel plants	2,635	
	Nuclear	1,061	
	Renewables	5,857	
Biofuels		320	320
		TOTAL	**40,166**

2.2. Structure of the UK Energy Industry

In the UK, electricity and natural gas are mainly delivered by large scale systems that have been in existence since the 1930s, with much of the plant now more than 50 years old. Some of following background information is taken from a draft IET Energy Executive draft white paper whose authors include Dr Jenny Cooper. The age of the system assets is one key issue of concern to the owners of the assets, the government and the regulator. In general, delivery goes from a centralised supply, through cables or pipes, and is delivered directly to loads. There are similarities in the scale and nature of the systems that support liquid hydrocarbon fuels for transport from distribution depots to engines. Heat delivery is not currently used on a wide scale in the UK, though some local examples of community heating arrangements exist.

An energy flow chart that was recently published by the UK government is shown below. It captures the complexity of the energy processes, and details the energy flows from primary fuel through its conversion and transformation to end-users. It can be seen that the conversion and transportation losses between “energy in” and “energy out” are more than 50%, and when the losses associated with the end-use are taken into account it can be seen that the whole energy supply chain is remarkably inefficient. Waste heat is a key loss and is set to become a massive challenge for the UK, as heat demand peaks at 300GW on the coldest days at end-user premises.

Energy Flow Chart 2015
(million tonnes of oil equivalent)



FOOTNOTES:
1. Coal imports and exports include manufactured fuels.
2. Bioenergy is renewable energy made from material of recent biological origin derived from plant or animal matter, known as biomass.
3. Includes heat sold.
4. Includes non-energy use.
This flowchart has been produced using the style of balances and figures in the 2016 Digest of UK Energy Statistics, Table 1.1.

The process of getting energy from the source to the user consists as a sequence or chain of key stages including transportation. There will also be a number of threads that run throughout the process chain such as information systems and communications.

The GB electricity and gas markets involve a number of key parties:

- **GENERATORS (ELECTRICITY)** – large power stations connected to the transmission network, smaller stations, often renewable sources, connected to the distribution networks (Distributed Generation), and domestic scale (Micro Generation) connected locally.
- **GAS PRODUCTION AND CENTRAL SUPPLY (GAS)** – large centralised gas sources for extraction and processing of natural gas and storage. This is increasingly supplied from overseas via pipes or ships.
- **NETWORK OPERATORS** – electricity and gas networks comprise transmission that carries energy long distances, and distribution that links transmission to users. As customers have no choice as to which network provides their connection, it is a regulated monopoly service.
- **SYSTEM OPERATOR** – National Grid is the gas and electricity system operator in GB, and interacts with generators to ensure that supply and demand is balanced at all times.
- **USERS** – currently most energy users do not 'interact' with the energy system beyond connecting to it, using it and paying for it. This is starting to change as households generate their own power from solar panels and export their surplus back into the grid, or connect intelligent energy management systems, and use storage devices. Smart meters will also offer new functionalities likely to engage customers more actively.
- **SUPPLIERS** – energy suppliers buy energy from the wholesale markets, sell it to customers, and provide metering and billing services. They compete for customers.
- **REGULATOR** – Ofgem protects the interests of electricity and gas customers; it promotes competition, and regulates and encourages innovation in the network companies.

The 6 major companies which dominate the British electricity market ("The Big Six") are: EDF, Centrica (British Gas), E.ON, RWE npower, Scottish Power and Southern & Scottish Energy.

Distributed generation (DG) is also known as embedded or dispersed generation. DG is electricity generating plant that is connected to a distribution network rather than the transmission network. There are many types and sizes of DG, including Combined Heat and Power (CHP) plants, wind farms, hydroelectric power, solar farms, or one of the new smaller generation technologies. The key DNO companies are Electricity North West, Northern Powergrid, Scottish Power Energy Networks, Scottish and Southern Energy Power Distribution, UK Power Networks, and Western Power Distribution.

As with electricity and gas, there is an established market structure for sourcing, transport, and distribution of transport fuels.

Heat networks, where heat is delivered to users through networks of hot fluid (generally water) for space and water heating, have been in operation in GB for decades, but in limited locations. They generally provide heat at a lower cost and environmental impact compared with individual fossil fuel boilers in each building, as they can use waste heat, or a more energy efficient centralised heat source. However, they are only operational in localised areas and there is no widespread market structure, operational approach, or regulation. This is a further challenge for their expansion.

It has been estimated that more than 10% of electricity generated in the UK is used for cooling purposes, and that more than £5bn per year is currently spent on energy for cold / cooling (grid and transport). This is a relatively new area, and the Birmingham Policy Commission on Cold are developing requirements for an innovative 'cold economy' that will ensure that the UK is at the forefront of developments in this area.

There are other vectors in use in GB, including solid fuels such as wood, coal, or biomass being used for cooking and space and water heating. There are also other vectors, which are not widespread, but could have the potential to become more so in the future, for example, bio-gas (from waste digestion) and hydrogen.

The UK government tracks investment in infrastructure through the National Infrastructure Pipeline – the pipeline currently captures the details of more than 600 private and public infrastructure projects and programmes planned across the UK. The total investment for the first five years running up to 2020 equates to £47.9bn per year with £27.8bn of the total privately funded.

The pipeline is broken down as:

Average spend per year to 2020	**£bn**
High Speed 2	2.7
Rail	6.5
Roads	4.9
Local transport & ports	3.5
Transport total	**17.6**
Energy Networks	7.5
Oil & gas (inc decommissioning)	6.8
Renewable electricity generation	3.8
Gas-fired & other generation	3.4
Hinckley Point C nuclear plant	1.1
Nuclear decommissioning & waste	0.9
Energy total	**23.5**
Water, waste & flood defence	4.5
Communications (inc broadband)	1.2
Research	1.1
Other total	**6.8**
OVERALL TOTAL	**47.9**

2.3. Opportunity areas for consideration

The opportunities for innovation and change, including the use of space assets, will come from within the process / value chain, at the interfaces of each step within the process / value chain, and from other key drivers of change that have been identified within the Industrial Strategy (Ref Feb 2017) and others by the energy industry.

The Industrial Strategy has identified the following areas that are applicable to energy systems:

- Approach to affordable energy.
- Changes to energy infrastructure.
- Harnessing the industrial opportunities from new energy technologies.

2.4. Potential opportunities

There is a lot of scope for using data from satellites in the energy industry, some of which have almost certainly already been or are being considered by the Satellite Applications Catapult or internationally.

The most immediate applications would be using the GPS time sync (broadcast from GPS / GLONAS / Galileo / Compass etc.) for smart grid synchronisation, or using imaging satellites for resource monitoring (oil fields, gas etc.). In renewable energy sectors, weather prediction and monitoring is important for placing and maintaining installations (wind maps, average hours of sunshine etc.). Satellites allow for large scale global level data gathering, rather than having to rely on multiple local ground based systems. Radar satellites and other earth sensing systems could be used for prospecting of untapped oil and gas fields. Essentially anything that requires high quality time synchronisation or large scale monitoring of the earth has solutions partly or entirely based on satellite technology. Given the significant investment in energy systems infrastructure and the aim to minimise customer bills, a whole energy systems approach is being emphasised and supported by government funders and industry. Due to their large scale application, satellite systems could have direct relevance to the whole systems approach.

The following are some more defined potential opportunities for application of satellite technology but it is certainly not a comprehensive list as infrastructure owners, operators and contractors develop their innovative solutions and as satellite companies and innovators develop their technical capability. In addition, there are opportunities relating to the management and analysis of big data, the economic value of energy data was estimated as £5,430m from 2012 to 2017 (ref RAE report Nov 2015) although the value will be focussed on specific opportunities for satellite applications.

In addition to current or near future opportunities related to current or future infrastructure developments, there are longer term space related opportunities that are currently ideas rather than applications. This may include launching huge solar collectors that use laser or microwave power transmission to beam power back to earth for electrical grid use though this is not a short term issue and perhaps more a discussion for popular and challenging science http://www.popsci.com/for-nearly-infinite-power-build-self-replicating-solar-panels-on-moon.

2.4.1. Coastal Power station cooling outflow:

Need: The owner of a coastal power station (e.g. Pembroke CCGT), as part of their environmental performance monitoring and reporting, wants to see the size, shape, temperature and movement of the cooling outflow from the power station (both absolutes and changes) that will allow them to calibrate their mathematical models for assessing the environmental impact of the station.

Impact: There are environmental impacts (on sea life, conservation etc.), efficiency / cost impacts (operating the power station at optimal efficiency, identifying heat that can be recycled / sold), PR impacts (demonstrable proof of the way the station is being operated and its local impact).

2.4.2. Gas network issues:

Need: Gas network owners need to identify and manage third party interference (assets damaged by, or operated by, an unauthorised third party) and environmental conditions or natural disasters (including vandalism, earthquakes, flooding, landslides etc.) on their network of pipes.

Impact: Managing risk and safety, including potential loss of life, is critical to network owners, staff and the general public. Being able to avoid wasted journeys, deployments of crew – being able to target resources, and maintenance more efficiently.

2.4.3. Planning and delivering new infrastructure:

Need: Designers and planners of new energy infrastructure (local, national and international), including to meet growing global needs in developing countries, need to identify and optimise potential routes for the infrastructure, and then monitor the build out to ensure compliance with the approved plans / land agreements / regulatory requirements.

Impact: Use of high quality images that will facilitate the planning, that will demonstrate compliance by the construction team, and that will allow the detection of non-compliance at an early stage, and to ensure continued compliance throughout the life of the infrastructure assets.

2.4.4. Asset management of overhead lines:

Need: Tracking of tree / vegetation growth, integrity of insulators, towers and other assets including thermal imaging to locate discharges and corrosion monitoring (likely to be a resolution issue).

Impact: Trees in the vicinity of overhead lines are a significant risk / threat to electricity supply reliability, particularly in extreme weather conditions where trees / branches will be the cause of supply interruption. The Network Operators are required to keep their overhead electricity lines clear of vegetation and therefore resilient to weather events. Given that vegetation can grow over a meter in a year and there are over 25,000km of transmission overhead line circuit (and significantly more at distribution), there are significant opportunities for incidents and a significant need to manage the vegetation to reduce likelihood of fault leading to circuit interruption and or safety issues.

2.4.5. Smart Grid – asset health check:

Need: To understand the operation of the assets in normal and bad weather conditions, asset owners need more data about more of their assets. There are many assets that are currently not monitored (e.g. poles and towers) that could be with low power transmitting devices. Critical assets in particular could provide a heartbeat response when they detect a satellite passing overhead (integrated with an app like SpyMeSat) which could avoid unnecessary visits by maintenance work crews.

Impact: Low cost, low power devices transmitting simple data to indicate that all is well – e.g. a pole / pylon / tower reporting that it is still upright. Enhanced capability for managing smart grids. Avoidance of costly / unproductive maintenance trips.

2.4.6. Satellite communications:

Need: Asset owners / operators want to be able to communicate with new / existing energy systems that have no access to land based communications infrastructure. This is to operate the asset, provide visibility of the operation of the asset, and monitor the performance / reliability and maintenance of the assets.

Impact: Avoids the cost of additional communications infrastructure (such as phone lines) to remote structures e.g. substations, compressor stations etc. in terrain that may have no communications facilities, and overcomes wireless line of sight / seasonality issues.

2.4.7. Disaster or Emergency Decision-making Support:

Need: Asset owners / operators, governments and emergency services want Information on the impact of a natural disaster, e.g. consequences of an earthquake or tsunami, on co-located energy infrastructure, or a man-made emergency, e.g. terrorist attack on energy infrastructure or oil spills, to enable fast decisions to be made to address critical services and therefore consequent effects on members of the public.

Impact: Potentially faster and more effective emergency response globally leading to reduced loss of life through timely and focussed emergency action.

2.4.8. Offshore wind Infrastructure:

Need: Monitoring or surveying offshore wind installations (potentially similar to offshore oil installations) and increasingly tidal installations.

Impact: The UK is currently the largest market for offshore wind energy, with over 5GW of capacity installed and set to double by 2020 (https://www.thecrownestate.co.uk/energy-minerals-and-infrastructure/offshore-wind-energy/). Given this represents an investment of around £20bn, the facilitation of asset condition assessment in a reliable and economic fashion with minimal manpower intervention is a beneficial proposition in the UK but will be an ever-expanding market worldwide.

2.4.9. Biomass harvesting:

Need: Owners and purchasers of biomass material (e.g. trees, straw etc.) want to be able to determine the optimum time (in terms of potential energy produced) to harvest the material for use in energy generation.

Impact: Biomass material harvest at right time to maximise energy produced, giving greater yield and financial return.

3. Revenue Projections

The potential value of the opportunities described in the following sections are summarised below:

	2017	2020	2030
Opportunity	**Current levels**	**Annual Potential Value**	**Annual Potential Value**
Coastal Power station cooling outflow	0	<£1M	£50M
Gas network issues	0	<£1M	£25M
Planning and delivering new infrastructure	0	<£1M	£10M
Asset management of overhead lines	0	<£1M	£25M
Smart Grid – asset health check	0	<£1M	£25M
Satellite communications	0	<£1M	£10M
Disaster or Emergency Decision-making Support	0	<£1M	£10M
Offshore wind Infrastructure	0	<£1M	£25M
Biomass harvesting	0	<£1M	£5M

Note: These estimates are based on our current knowledge and understanding of potential market growth. The estimates strongly depend on appropriate investment in innovation e.g. through the networks innovation strategy under Ofgem's Innovation Stimulus.

Estimate for selected Global Markets

	2017	2020	2030
Opportunity	**Current levels**	**Annual Potential Value**	**Annual Potential Value**
Coastal Power station cooling outflow	£140M	£184M	£361M
Gas network issues	£5M	£10M	£250M
Asset management of overhead lines	£10M	£50M	£100M
Smart Grid – asset health check	NA	£5M	£250M

4. SWOT Analysis

4.1. Coastal Power station cooling outflow

Strengths: Provide time stamped high resolution, large scale visual and thermal images.
Weaknesses: Only one image per day unless multiple satellites are used. The UK has 2 tides per day so would need several intra-day images to confirm impact of tides on temperature distributions.
Opportunity: ~30 coastal power stations in the UK (around 5% of the total UK power stations). Around £10k to confirm a modelling scenario for the power station. Seasonality may be important. In the UK, this would suggest an annual £1.2m opportunity. Assuming 5% of worldwide generating plant is also coastal based, this would suggest a market of ~3.5k plants, and an annual opportunity of ~£140m. Customers are owners / operators of coastal power plant. There could be an additional opportunity for mapping the impact of the inflow / outflow on the populations of fish, jelly fish, and underwater

vegetation through the use radar data – currently the owners / operators rely on, for example, counting and reporting for environmental purposes the number of fish caught in the inflow filters.
Threats: Local solutions using aeroplanes to photograph the area, their weaknesses include their time to photograph, repeatability and scale – the images are usually relatively narrow strips taken at different times.

4.2. Gas network issues:

Strengths: Remote monitoring of pipeline routes using high quality images and other sensors (e.g. to detect if the pipeline has moved, water levels, local hotspots etc.) that provide a 'heart beat' to indicate that all is well. Reporting by exception is used to allow efficient targeting of resources.
Weaknesses: Monitoring is not continuous, and a critical change may not be reported quickly enough.
Opportunity: Ability to respond reactively to environmental changes (e.g. gradual landslips along a section of pipeline), or large scale events (e.g. flooding).
Threats: Insufficient frequency or resolution and therefore may not be a dependable part of the safety case.

4.3. Planning and delivering new infrastructure:

Strengths: Shortens the time taken to plan and deliver new infrastructure – typically a transmission line can take up to 5 years to plan, survey, consider alternatives etc. For the planning stage images from big data stores can be used to provide high quality images which would avoid the need for several detailed 'on the ground' surveys as many potential issues along a proposed route can be removed before going to site. High quality imagery over the build-out period of new infrastructure, and throughout the life of the assets. Could be combined with data from other sensors (e.g. thermal to detect inappropriate activity, radar to detect movement etc.). The target market would include planners, builders, owners, regulators etc. Builds on work being done for wireless network planning for 4G & 5G networks – which will also need to be linked to energy systems for supply.
Weaknesses: Would need very high resolution images using a variety of sensors that can be integrated into GIS and planning applications.
Opportunity: Wherever new energy systems infrastructure is required – for example fracking sites or anaerobic digester companies that are building solutions globally include Hitachi Zosen, PlanET Biogas and Lockheed Martin. Nearly two thirds of energy systems investments are taking place in emerging economies where there will be little or no modern energy systems infrastructure.
Threats: Localised solutions such as UAV, helicopter and 'on the ground' surveys.Asset management of overhead lines:

4.4. Asset management of overhead lines:

Strengths: For overhead line asset management, regular surveys covering a wide geographical distance are needed to make assessments on management activity to the defined clearance. Currently the assessments are high resource, manpower or helicopter time and costs, and focus on a specific overhead line route. Satellite applications could cover a significantly larger geographical area and provide more frequent assessments. A solution could also be applied to other above ground energy systems infrastructure such as pipelines and distribution networks.
W***eaknesses***: The information is required at a resolution of less than a meter with reliable location stamping to enable the assessment of vegetation growth to be made over a defined period. Both the ingress (i.e. distance from the asset, and the height of the vegetation) will need high quality imagery that can be used to determine the most appropriate time to remove vegetation growth. Overhead line asset integrity or condition assessments require resolution of visual or thermal images of the order of a centimetre to assess damage.
Opportunity: Globally there are millions of kilometres of overhead line, with all requiring some asset condition or integrity assessment and risk management with respect to vegetation. Many contractors or utilities have skilled resources to both perform the assessment and carry out any resultant vegetation or asset maintenance. Providing the data on which to base asset management activity reduces the need for high resource surveying and therefore could be a cost-effective alternative.
Threats: Contractors providing vegetation mapping services, e.g. Fountains and ADAS, or those providing condition assessment information use mobile GIS or LIDAR data collection capability,

determining visually or via thermal imaging with specialist knowledge to perform surveys real time and provide a risk report including site access as well as the asset condition information. Typically, the contractors will have built up a data base to enable the information to be processed and developed as effectively and economically as possible. Asset integrity will typically be assessed via helicopter or from the ground with development of UAVs/drones being the next likely focus if Civil Aviation Authorities allow.

4.5. Smart Grid – asset health check:

Strengths: Potentially cheap solution that could provide data on asset health to operators / owners / users of energy and other utility assets.

Weaknesses: Not currently able to use devices in high voltage electricity situations where hotspots in insulators, conductors etc. would indicate a potential issue for repair / maintenance. These however could be picked up using thermal images from satellites with appropriate resolution.

Opportunity: Quick asset health check system using low cost, low power devices – could impact all utilities by improving their response times to potential performance issues, and by avoiding unnecessary maintenance trips.

Threats: Do nothing situation – most utilities have been 'running blind' about many of their assets for a long time and may not place value of the additional data.

4.6. Satellite communications:

Strengths: Cost effective when not competing with an existing communications infrastructure as it avoids a costly build of land based telecommunications. Avoids the cost of crews driving unnecessarily to plant that may be in difficult to reach locations. A recent paper for a population of 10,000 metering points in area of 27,000 square miles of barren terrain on the US / Mexico border, linked to 18 substations, showed a costing of $2500 for the satellite system, with a monthly fee of $200 for a permanent Ethernet connection between the substations and the servers in the head office.

Weaknesses: Not cost effective in direct competition with existing land based communication systems.

Opportunity: In developing countries, and in barren / sparse areas that typically do not have pre-existing telecoms infrastructure. For a system with around 1m meter points, that would equate to around 2,000 systems at a capital cost of £5m, and an opex cost of £96m over a 20-year period. For a system with 60m meter points (about the size of the UK electricity market) that would equate to an opportunity worth £300m of capex and £5.7bn of opex over a 20-year period. The addition of other utility meters could have a significant impact on the size of the opportunity.

Threats: Wireless technologies. Extensions of nearby communications infrastructure.

4.7. Disaster or Emergency Decision-making Support:

Strengths: Global footprint with timed and spatial recognition of events tracked against previous norm. No initial manpower resource in hazardous areas, potential to target manpower and resources appropriate to the identified needs.

Weaknesses: Resolution and need to be aware of changes, images or data may not be available at critical time.

Opportunity: On call image and data production based on need from local governments or industry bodies in response to requests or newsfeeds. Every day there are natural or emergency events world-wide.

Threats: Not reacting quick enough or with sufficient resolution to be useful or costed inappropriately as a second line support service.

4.8. Offshore wind Infrastructure:

Strengths: A global opportunity based on current satellite positioning to provide data based on discussions re: need with the UK industry as the world leaders.

Weaknesses: Lack of relevant data or inability to provide the frequency of resolution required by the industry.

Opportunity: As above the offshore industry is capital intensive so data to make the right decisions on location then when in place on condition will be cost effective to the industry currently in the UK and

increasingly developing globally. Denmark, Germany, Belgium and the Netherlands are the other top offshore wind producers. In addition, the wave and tidal energy installations may become a more significant opportunity, including with the current innovators to identify the needs.
Threats: Alternative technology providing the same data via different technical solutions with better reliability or costs.

4.9. Biomass harvesting:

Strengths: Can produce high quality images to be integrated with computer algorithms to calculate the potential energy produced, and to determine the best time to harvest the crop and deliver it to the power station.
Weaknesses: Need access over time to high quality, stereo imaging to determine, in the case of trees, the canopy height and the range of diameters of the trunks.
Opportunity: Biomass is a huge growth market on a global scale, and this is an opportunity to improve their efficiency.
Threats: Local solutions, surveys and use of aircraft / UAV.

5. Market Trends

There are a number key drivers of change that that have been identified by the energy industry:

- **Energy supply 'trilemma'**
  - The need to protect the environment, while maintaining an energy supply that is affordable and reliable.
  - There are trade-offs to be made between these requirements; energy sources that are low carbon (e.g. solar heating) are not always low cost, energy efficient or secure.
  - Similarly, low cost energy (e.g. coal and natural gas) may not be low carbon or secure in the long term.
  - Much of the UK's energy infrastructure is aging and will need replacement, and there is an opportunity to ensure that carbon, cost and technical efficiencies can be part of a future re-visioning of our energy system.
  - There is also a need to change the architecture and functionality of some of this infrastructure, notably the electricity networks due to the characteristics of renewable energy sources.

- **The opportunities of new technologies** – There are opportunities emerging all the time for exploitation of technological developments and innovation. This includes innovation within the energy industry, and innovation in related sectors, such as in IT and communications.

- **Changing trends in energy use** – The way energy is used, and the interaction that users have with the rest of the system, is constantly evolving. The more recent trends include the adoption of low carbon technology such as renewable generation, electric vehicles, and energy monitoring and management technologies. There is starting to be more direct consumer interaction with the energy system, for example through smart meters and home displays.