Networked Society Lab

ERICSSON

ICT & THE FUTURE OF UTILITIES



INDUSTRY TRANSFORMATION – HORIZON SCAN

STRUCTURE OF THIS REPORT SERIES

This report is one in a series of seven investigating industrial transformation in the Networked Society.

The impact of technology on our everyday lives and economic interactions is undeniable. In conjunction with megatrends such as globalization, climate change, urbanization and aging populations, ICT is helping to transform our society and the economic structures that have formed the basis of industries since the industrial revolution.

Digital technologies allow new organizational forms to emerge within and outside of industrial boundaries, thereby challenging our traditional notions of economic organization in markets. Where once size was an important driver of success, now many smaller companies are able to compete both locally and globally. Where firm, strongly defined boundaries and clearly defined economic roles were necessary, now the ability to dynamically participate in a variety of networks is key to a resilient corporate strategy. ICT is transforming the rules of our world's economic value systems, and industries are being transformed as a result.

It is not possible to provide a deep dive into every industry covered within this series. Instead each report investigates the role of ICT in creating productivity improvements and industrial disruption with a view to gaining a broad perspective on the overall transformation the world is undergoing. Six industries are investigated and across them general themes are identified that form the basis of the final report, the "Economics of the Networked Society", which outlines some of the broad economic principles that may help us understand the era we are entering.

These reports represent the culmination of several years' work investigating the changing economic structures of the world in the digital age. We hope our small contribution helps to further not just the vision of a Networked Society, but also its implementation – a society where dynamic, digitally enabled strategic networks allow us to build an economically, environmentally and socially sustainable world.

METHOD

The reports in this series are developed using systems analysis to identify the operating boundaries of each industrial structure. Through analyzing the boundaries and their associated thresholds, a stronger understanding of capacity for change within an industry is possible to achieve. This method combines systems analysis with traditional measurement methods as well as extensive interviews across various parts of an industry's value chain in order to try and understand the possible emergent characteristics of industrial structures and the role that digital technologies may play in creating innovation, disruptive or otherwise. Many boundaries may be affected by a number of different aspects. Within these reports, however, we focus solely on how these thresholds can be adapted by ICT. Each report outlines the following:

1. The industrial boundaries and associated thresholds

2. The role of data within those boundaries and the emerging information value chains

3. An overview of the industrial archetypes / organizational forms of start-ups in the industry

Each of these industrial analyses has then been further analyzed to understand the emerging characteristics of the Networked Society, which is covered in the final report.

For further information on the method, contact Dr Catherine Mulligan: c.mulligan@imperial.ac.uk

TABLE OF CONTENTS

Structure of this Report Series 2

Method 3

Scope of the Report 5

Executive Summary 6

1. Introduction 7

2. Industrial Structure of Utilities 9

- 2.1 Energy Industry Thresholds 10
- 2.2 Industrial Boundaries of Utilities 12
- 2.3 Impact of Crossing Energy Thresholds 14
- 2.3.1 Renewables and Industrial Boundaries 15
- 2.3.2 Critical Barriers to Renewables 16
- 2.3.3 Renewable Thresholds 17

3. Impact of Digital – Productivity Improvements 19

- 3.1 Supply Chain Efficiency Improvements – Smart Grids 20
- 3.1.1 Structure of Utilities Industry – Smart Grids 22
- 3.1.2 Regulation for Smart Grids 24
- 3.1.3 Information Value Chains & Smart Grids 25
- 3.2 New Data Value Chains for Increased Supply Chain Efficiency 28
- 3.2.1 Increasing Speed to Market 29
- 3.2.2 Use of Iot for Operations and Maintenance 31
- 3.2.3 Cross Supply Chain Data Sharing 32
- 3.2.4 Governance Structures for Complex Supply Chains 34
- 3.3 Digitally Enabled Consumer Efficiency 36

4. Impact of Digital – Industrial Disruption 37

- 4.1 Empowered Consumers 38
- 4.2 ICT Systems for Empowered Energy Consumers 41

Conclusions 43

SCOPE OF THE REPORT

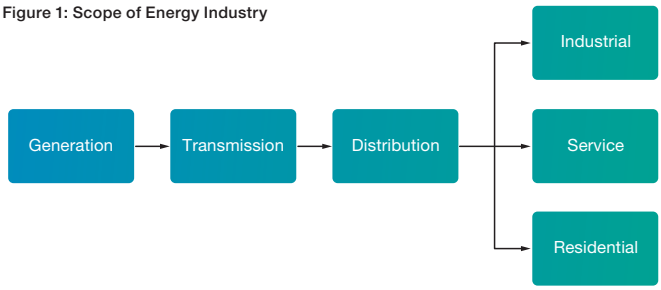
The energy industry covers a broad range of economic activities related to extraction, refining, production and sale of energy as well as industrial and residential end users.

The manner in which utilities are delivered has evolved to support the industrialized nature of the global economy. Today's industry is heavily reliant on economies of scale to provide the centralized production of energy, such as power stations and large-scale infrastructure that deliver energy to homes, companies or other customers. The recent availability of cheaply available and ubiquitous ICT provides opportunities to disrupt this industrial structure.

The choice of energy production methods has been characterized by the constant push and pull of various economic forces, mainly the price of the fuel and its associated transport costs. While fuels may be substituted for one another – e.g. natural gas may replace oil in energy production for electricity – it is far more difficult to replace petroleum products in other areas of the economy, such as the automotive or aeronautical sectors. The reluctance to change, for example in the infrastructure and delivery systems associated with petrol stations, rests on existing infrastructure and the capital costs associated with replacing one delivery infrastructure with another. In addition, petroleum is difficult to replace in many manufacturing processes such as plastics manufacturing.

For the purposes of this document we take the broad scope of utilities, from extraction all the way through to delivery. This is illustrated in Figure 1:

Figure 1: Scope of Energy Industry



For many decades, ICT has played a critical role in the management of energy operations, from extraction through to end-user delivery. From a high-level perspective the role of ICT may be viewed from the four main perspectives outlined in Table 1. The role of ICT is set to expand, however, as the energy industry reaches and crosses critical industrial thresholds. As ICT has become cheap and ubiquitous it can also be applied to mitigate or accelerate the crossing of critical thresholds, thus reforming the industrial structure.

Area	Description
Exploration and Feasibility	Exploration: finding resources and installation of appropriate infrastructure to service customer requirements
	Feasibility: determining the best-value approach to produce the resource
Capital Development	The engineering, procurement, construction and commissioning of assets to produce the resource in question
Operation/ Production/ Maintenance	The use and maintenance of assets in order to produce the resource in question
Retail/ Consumption	The development of customer markets and the sales of resources produced by the asset

This paper takes a global, generic perspective of the energy industry. There are, of course, national differences in the manner in which energy and heat services are delivered to end users, but a detailed analysis of any one country is beyond the scope of this report.

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DISCLAIMER

All care has been taken in the preparation of this document, but no responsibility will be taken for decisions made on the basis of its contents.



EXECUTIVE SUMMARY

Energy is currently one of our most critical resources. Without it, our entire modern industrial and social systems would not function. It forms a critical input into agriculture and food production, ICT, retail and banking, and is a fundamental component in the supply of clean water to people across the world.

The Energy industry has a key role in the future of our society. Today it faces a multitude of challenges from handling decarbonization requirements and bringing online a reliable supply of fuel sources, to ensuring that end users receive secure and affordable heat and energy for their daily lives. ICT has played a critical role over the past decades in various parts of the Energy supply chain, particularly by enabling efficiency improvements for established players. With the introduction of smart grids, ICT will contribute to even greater efficiencies. At the same time, digital technologies offer opportunities for transformation within the energy industry by allowing consumers and producers of electricity to connect with one another in new ways, thereby reconfiguring value chains within the energy industry. Examples include:

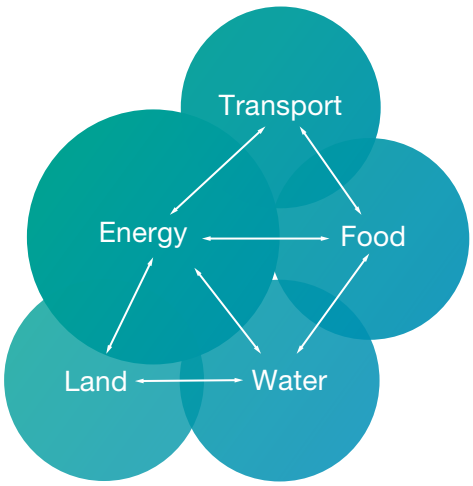
- Increased **integration of data sets** across the energy supply chain. Sharing of data between exploration, feasibility and project design, for example, could dramatically reduce the costs of bringing new fuel sources online.
- Provision of small-scale ICT systems that are able to manage **micro-billing** and **micropayments** for the increasing number of community-based renewable installations. These systems could create dramatic changes in industrial structures by empowering consumers as well as trigger dramatic reductions in carbon emissions.
- New roles emerging within the industrial structure related to **system integration** as utility companies struggle to deal with exponentially larger data sets related to smart grids.
- ICT systems play a critical role in reducing risks associated with large-scale projects and the potential for environmental disasters they entail.

This report covers the role of digital technologies in creating industrial transformation and disruption within utilities.

1. INTRODUCTION

Globally, energy plays a critical role in nearly every form of civil infrastructure. In most major economies, transportation accounts for 28% of energy consumption, industry for 31% and buildings for 41%.[1] Energy also plays a vital role in agriculture, land use and water consumption. This is illustrated in Figure 2 below:

Figure 2: Interaction between energy and other critical subsystems



> ”Demand due to the GFC has slowed and reduced. It is probable that the demand will increase again. We are building systems in our built environment that we never conceived of in the 20th century. If ICT is to be used to control this I don’t think it will have a long-term effect on demand. Rather it will improve the efficient use of supply. Just inputting storage devices into the network, saves power that would otherwise be lost.”
>
> **Manager, Utility Provider, EU**

For example, the moving, treating and heating of water in the US accounts for 520bn kilowatt-hours (kWh). This amounts to up to 60% of the energy bill in some cities, 90% on some farms and 13% of the entire electricity usage in the US.[2] Due to increased pollution and urbanization, the amount of energy required for treating and moving one cubic meter of water is also rising. For instance, urbanization increases the distance that water needs to travel to reach the end user as well as the amount of energy required to pump water to high-rise buildings.[3] There are, therefore, complex interactions between energy and multiple other sub-systems. Energy provision has naturally also had a significant impact on our urban and rural landscapes, as many of our cities have been built to accommodate the large-scale provision of energy and fossil fuel dependent infrastructures, in particular for cars.

[1] http://www.atlanticcouncil.org/images/publications/Envisioning_2030_US_Strategy_for_the_Coming_Tech_Revolution_web.pdf

[2] http://www.theguardian.com/sustainable-business/energy-water-greater-impact-nexus

[3] http://www.atlanticcouncil.org/images/publications/Envisioning_2030_US_Strategy_for_the_Coming_Tech_Revolution_web.pdf

1. INTRODUCTION

The utilities industries currently face a multitude of challenges and increasing requirements on delivery of power, including decarbonization, security of supply, aging infrastructure and protecting the grid from physical, cyber and cyber-physical attacks,[4, 5] as well as population growth. Moreover, with the predicted increase in robotic applications – for example, home care of the young, elderly and injured – it is likely the world will seen an increase in demand for energy. Elsewhere across the Networked Society, improved ICT solutions will lead to a rise in demand for energy in an expanding range of applications.

Energy demand profiles will also change dramatically, for instance if electric vehicles achieve widespread consumer adoption. Such an electric vehicle system will change the nature of the local network in terms of what can be supplied by premises and community systems, before resorting to supply from remote generating systems.

[4] ibid
[5] Davies, S., 2013, "The Grid gets Smarter", IET Wiring Matters

2. INDUSTRIAL STRUCTURE OF UTILITIES

There are four main established industrial structures that coordinate the activities illustrated in Figure 1. These relate specifically to the regulatory environment of the country in question. Briefly, these are:

1. **Vertically integrated monopoly,** in which there is no competition. The electricity utility controls and undertakes all business functions including generation, transmission, distribution, wholesale and retail supply, and services.

2. **Unbundled monopoly,** where generation is separated from all other functions. Generators maintain monopoly status and distribution companies have a monopoly to serve customers in their specified areas.

3. **Unbundled, limited competition,** where many generation companies serve distribution companies through a competitive wholesale market. Government regulates transmission and distribution systems.

4. **Unbundled, full competition,** which allows generation, transmission and distribution functions to be completely separated. There is competition between generation as well as complete competition at the wholesale and retail levels.

These industrial structures are susceptible to change for two main reasons:

1. The increasing use of renewables:
   "All these [industrial] structures will change substantially in the next 50 years, primarily due to the growth in renewable with its different community and customer end (commonly called downstream in the hydrocarbon industries, e.g. refining and petrol stations) structure. ICT will have a significant influence and large part to play in the evolution of these industries."

   Senior Manager, Oil and Gas industry

2. The use of digital technologies to create industrial transformation. Digital technologies have now become widespread enough to create disruption within the energy industry by reconfiguring the connections between producers and consumers.

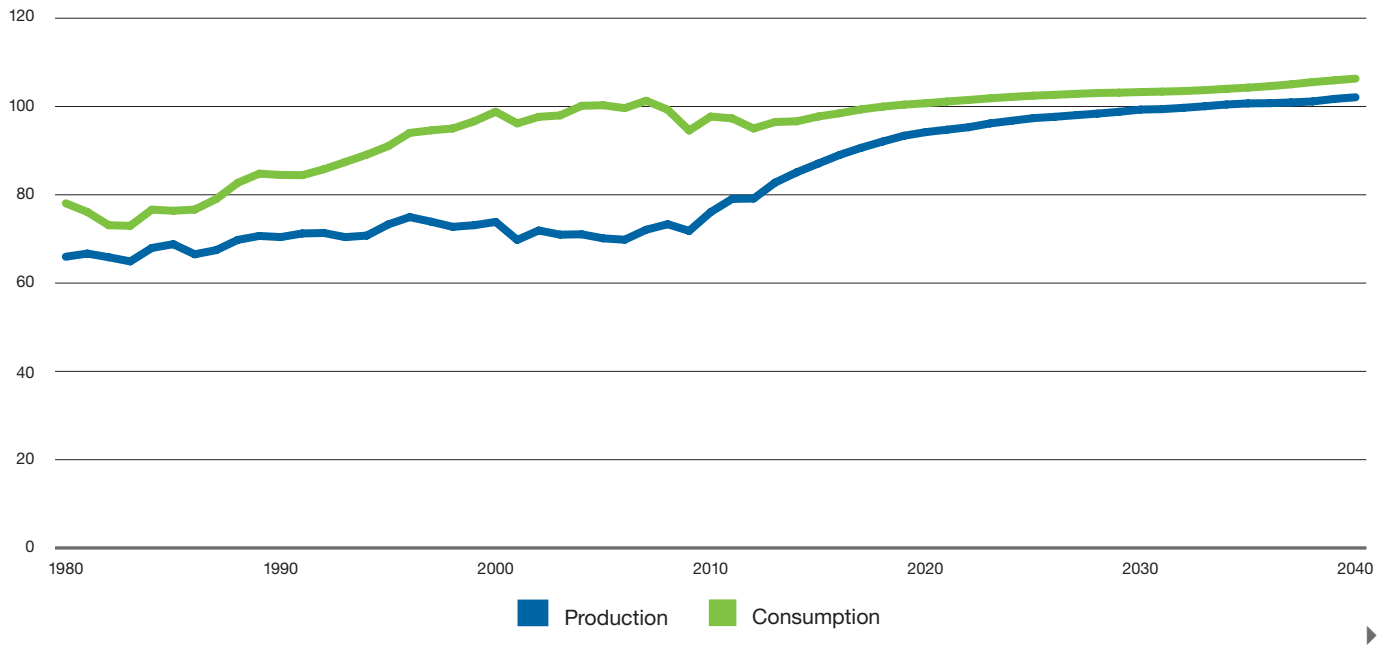
In order to understand these transitions and their impacts on the energy industry, an understanding of industry thresholds is necessary. We cover these in Section 2.3.

2.1 ENERGY INDUSTRY THRESHOLDS

One of the main measures in the fuel industry is reserves, i.e. the amount of a particular fuel that remains to be extracted. Since fossil fuels are finite, equal amounts of new reserves need to be found in order to replace those that have been consumed, if the industry is to continue on its current path. While substantial increases have been added to hydrocarbon reserves over the past decade in the US, for example, the ratio of production to consumption has increased at a greater rate, as illustrated in Figure 3. Consequently, reserve/production ratios for hydrocarbons are falling. At the time of writing, the current reserve-to-production rates for oil and gas will last 50 years. Coal will last 109 years. It should be noted, however, that as more reserves are discovered, their lifespan will extend only if production fails to exceed the current ratio. It seems unlikely at present that this will be the case, as demand for energy is increasing worldwide despite the widely reported drop in demand in countries like the US.

> "Utilities rely heavily on fuel from oil, natural gas and coal. As a result, many of our thresholds can be traced back to this."
>
> **Manager, Oil and Gas industry, EU**

Figure 3: Production to Consumption Ratios – historical and predictive (Data Source: EIA 2013)



2.1 ENERGY INDUSTRY THRESHOLDS

A large number of thresholds in the current industry come down to price and market share:

> "Currently oil and gas will last for approximately 50 years. If this were reduced to less 25 years there would be a strong pressure in the market to look for alternatives. If the price increased 25% there would be a strong pressure to look for alternatives. Coal reserves have fallen from 225 years in 1982 to 100 years in 2012. A 125-year reduction in 30 years! Currently gas, even with the new reserves from shale and coal seam coming into production, has remained steady at 50+ years. Oil has risen from 30 years in 1982 to 50 years in 2012, possibly due to its falling share of the market over the past 13 years and increasingly efficient use."
>
> **Senior Manager, Energy industry, UK**

Rapid price increases have been the norm within the energy industry over the past decade. During 2013, prices for oil have increased from $30 a barrel (2005) to $95 today. With the exception of the US, gas is showing similar price increases.

These rapid increases in price have led to innovation and an incentive to try new techniques. As a result, in today's industry, rising prices have been tempered as innovations in shale and coal seam gas have reached critical mass: "though shale gas and tight oil ramped up in 2007-08, the technology had existed for nearly a century".[6]

In the US, gas has fallen to 33% of its 2005 price due to large shale discoveries, and the country is now considering commencing export. As a result, the US may now become a net exporter of energy, rather than a net importer. Shale and coal seam gas, represent new opportunities for gas and oil provinces in Australia and the United States. China and Russia appear to have the greatest potential for this type of hydrocarbon, which will have interesting repercussions for the global distribution of power in the energy industry. Currently, China is dependent on coal for approximately 70% of its electricity. However, the country has large shale gas reserves that could be substituted for coal.[7]

[6] International Energy Agency, Energy for All: Financing Access for the Poor, October 2011, Energy Agency, World Energy
[7] ibid

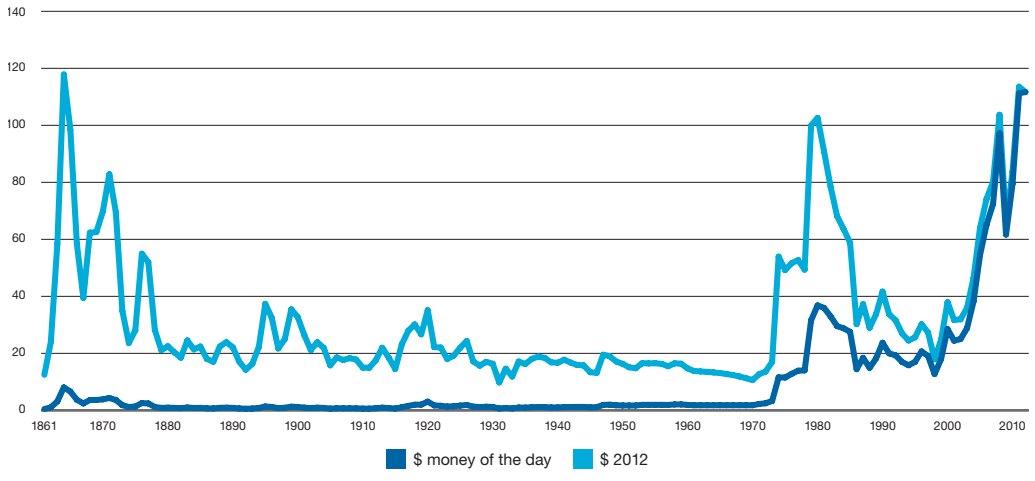
2.2 INDUSTRIAL BOUNDARIES OF UTILITIES

The world's energy supply system is currently in a substantial state of flux. In the past decade, energy prices have begun to oscillate, as illustrated in figure 4 below. Oil prices in 2012 reached $150 a barrel. Massive gas discoveries and developments, especially in the US (e.g. shale gas fields), have pushed both gas and oil prices down, with some oil prices now down to approximately $95.

Other sources of energy that once were economical are therefore also under pressure. Thermal coal, for example, could be replaced by gas. Price oscillations are a direct outcome of increased exploration and new techniques for recovery of previously unknown resources. This is a common occurrence in this industry, causing what were formerly known as "oil shocks", but could now be more accurately described as energy shocks. Oil prices since 1861 are illustrated in Figure 4.

Oil remains the world's leading fuel source (at 33.1%), but has lost market share in terms of barrels of oil for 13 consecutive years as it has been replaced by alternative sources such as natural gas and coal. Oil is now at its lowest market share since 1965. Natural gas, meanwhile, provides 23.9% of fuel, but is now also declining for the first time on record. Coal is reaching its highest share of primary energy consumption since 1970 and is now at 29.9%. Nuclear, meanwhile, accounts for 4.5%. Renewables show the greatest increase in market share, but from the smallest base. Solar, for example, has increased 58% in the same period. Renewable energy, defined as solar, wind and bio-fuels, now accounts for 2.4% of energy production. In terms of fuel sources, renewable energy holds the greatest potential for disruptive innovation in the energy supply chain. Current market share of energy fuels is illustrated in Figure 5, while energy production by fuel types is shown in Figure 6. ICT may act as a critical enabler for this disruptive innovation, which may ultimately result in the reshaping of the current industrial structure.

Figure 4: Crude Oil Prices since 1861 (Data source: BP Energy Outlook 2013)



2.1 ENERGY INDUSTRY THRESHOLDS

Figure 5 Market Share of Energy Fuels (Data Source: BP Statistical Review, 2013)

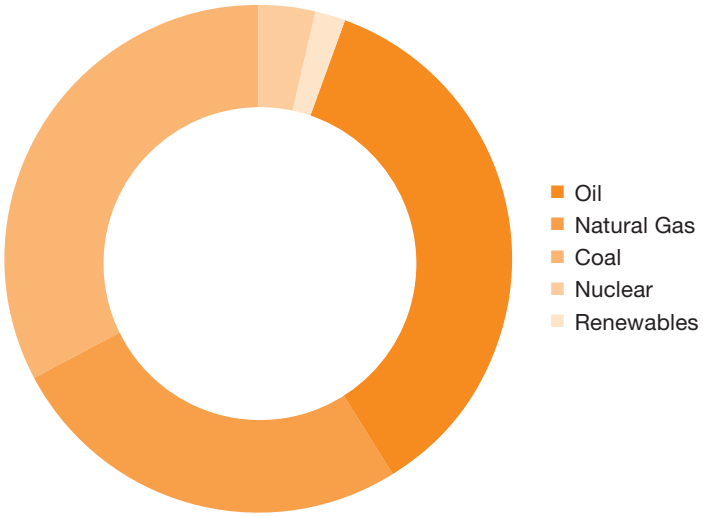
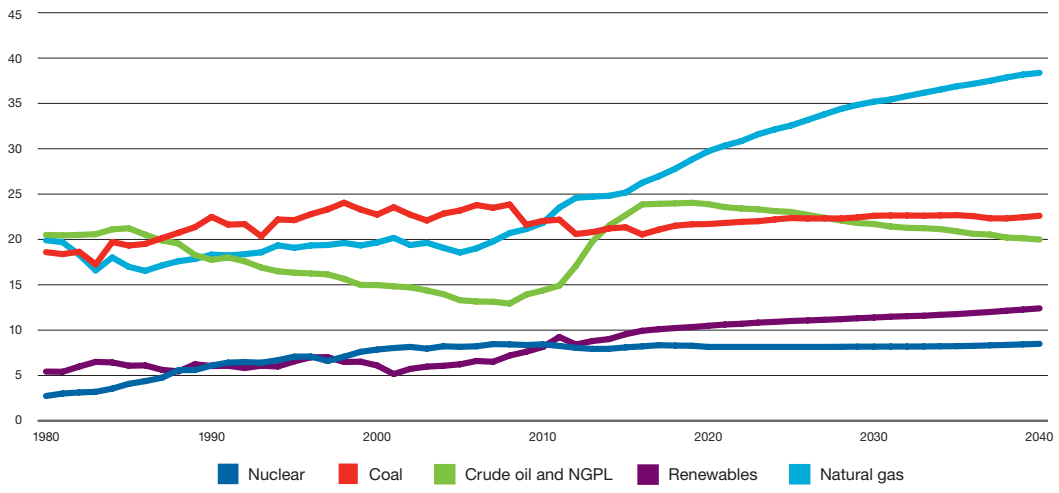


Figure 6: Energy Production by Fuel Type in USA (Data Source: EIA 2013)



2.3 IMPACT OF CROSSING ENERGY THRESHOLDS

The crossing of energy thresholds can change the world's geopolitical arrangements and may have an impact on the global distribution of other industries. For example, as the US reduces its energy dependency, it may become a cost-effective competitor to the other manufacturing bases across the globe.

As certain energy price thresholds are crossed (each nation has a different price threshold), demand is also affected. This causes customers to respond in one or more of the following ways:

1. **Stop using as much energy**
2. **Use it more efficiently (innovation for efficiency)**
3. **Find other methods to fuel their requirements**

As we discuss in Section 4, digital technologies are currently helping to assist customers with all three of these activities.

As prices rise, efforts intensify to improve energy efficiency and discover new resources (reserves). Renewables will have to play a greater role once critical energy thresholds are crossed. This has implications for the sorts of ICT solutions required by various parts of the energy supply chain. ICT solutions themselves, meanwhile, may also act as triggers for the disruption of established power relationships in the energy industry, in particular with regard to consumer control[8]. ICT solutions can enable community-based renewable installations, transferring power over energy production from the hands of traditional service providers to those of end users. This is covered in Section 5.

Price oscillations and market turmoil also change opinions on which energy solutions are best suited to a particular country or industry. In an era of increasing global uncertainty and geopolitical tensions, many countries may start looking for ways to reduce their reliance on tumultuous market conditions and on other countries.

Renewables, on the other hand, are infinite and may offer a way for nations and regions to reduce their dependence on unreliable international energy markets. The nature of renewables, being fundamentally different in many ways from that of fossil fuels, may mean that the structures of the energy industry will need to be transformed to provide new means by which to coordinate between actors. We cover some of these issues in section 2.4.1.

[8] In some sense, the transfer of power towards end users may be viewed as similar in nature to the transfer of power towards end users in the mobile communications industry in connection with the development of smartphones and tablets.

2.3.1 RENEWABLES AND INDUSTRIAL BOUNDARIES

> "Most of the current renewable energy sources can be brought much closer to the customer, including being installed on the customer's premises. This has the potential to turn the current industry structure on its head and will substantially reduce the size of these 20th century energy industries."
>
> **Manager, Utility Provider**

The oil, gas, coal and electricity generation industries currently supplying our energy are based on large capital infrastructure developments, usually a great distance from the final consumer. They involve a great deal of wasted capital and lost energy efficiency in transporting energy to the customer. For example, if gas replaces coal, the coal-generating capacity of an area will come under pressure, and the capital invested in the coal plant may go to waste. If new methods of energy delivery are used, such as generating capacity near the consumer pipelines, the transmission lines become redundant or are not used to full capacity, again leading to wasted investments. Transporting energy from coal generation along transmission lines wastes 40 to 60% of the energy. Non-coal-based generation capacity located within a local community, by contrast, has an energy efficiency of approximately 70 to 80%.

As these types of changes occur, completely new ways of serving customers will be required. More importantly, new organizations, and even new economic actors, will be needed in order to provide these services.[9] The organizational capacity of the existing utilities industries will be challenged. Far more control at the local and customer level will be needed, and ICT will play a significantly greater role in providing enhanced control at the local distribution and individual customer levels.

[9] E.g. Walmart has recently become a renewable energy retailer in the USA.

2.3.2 CRITICAL BARRIERS TO RENEWABLES

A number of critical issues remain to be addressed within the renewables market before there will be a significant restructuring of the industry. One of the most important of these is energy storage. While battery technology is improving, innovation is still required in order to make it cost-effective at the customer level. Alternative storage systems such as geothermal, liquid air, liquid salt under pressure and solar heat are all showing great promise to provide efficient storage systems for renewable energy systems to accelerate their growth. Most of these systems can also be installed at a community level, and possibly on customer premises.

"Better energy storage could be an even bigger game changer if it increases the use of renewable or alternative energy, bringing reliable electric power to businesses and households in developing countries. Growth in market share of cost effective electric vehicles would be a boon in both developed and developing countries where car ownership is increasing."[10]

[10] http://ecowatch.com/2014/01/11/harvard-researchers-renewable-energy-storage/#!

2.3.3 RENEWABLE THRESHOLDS

The global supply of renewable energy begins from a very low base. In BP's 2013 energy outlook, however, it is clear that solar has substantially increased is continuing to do so. Many nations are already recognizing the role renewables can play in their energy systems. Germany, for example, has a target of 80% renewables by 2050, while New York, Berlin and Seoul already have city-wide trigeneration networks in place. China has a 50 GW trigeneration target. California has a million solar roofs initiative and plans to obtain 33% of its energy from renewables, including hydrogen and biofuel battery driven cars. The state is now 40% more energy-efficient than the US average.

The thresholds associated with the development of renewables are dependent on a push/pull between costs and the price of energy supply. Extremely high energy prices have meant that some customers have already installed renewable sources of energy.

"All private companies want a discounted cash flow return of a certain level – e.g. Network Present Value Cash Surplus. The return will vary according to current interest rates. You won't invest if you can get more in a bank account – at present, I would think 10-15%. However, residential in recent years has had an approximately 100% increase in electric costs. If they can get a payback of 5 years on say, solar, they may decide to install. I think the threshold is on 2 levels – one for private companies and another for the public. This is what is influencing our company more than its own threshold. If we were private, we would have been looking for the more {sic} efficient solutions at the outset to contain prices."

Manager, Utility Provider

2.3.3 RENEWABLE THRESHOLDS

There are two main ways to install renewables:

1. Develop large ‘farms’ (e.g. wind, solar) that connect to the traditional transmission systems. Often, these can introduce new ‘generators’ into the energy supply chain.
2. Customer-led renewable installations, which come in a variety of forms and are starting to increase in number. Many renewable installations are not large-scale and are installed by customers and sometimes retailers, rather than the generators.

Digital technologies are rapidly being applied in the energy industry in order to create efficiency improvements not just for the large corporations involved, but also for end users. Section 4 covers the interactions between industrial thresholds and the creation of these efficiency improvements. Section 5, meanwhile, outlines where digital technologies are creating industrial transformation – the reconfiguration of existing industrial structures.

3. IMPACT OF DIGITAL – PRODUCTIVITY IMPROVEMENTS

There are two main forms of efficiency improvements enabled through the use of digital technologies in the energy industry:

1. Efficiency improvements for the supply chain, reducing time required to develop energy production, reducing waste in the supply chain and better interaction between economic actors

2. Efficiency improvements for consumers and other end users, allowing them to better manage and control their overall energy use, mainly to reduce bills and total energy costs

3.1 SUPPLY CHAIN EFFICIENCY IMPROVEMENTS – SMART GRIDS

Today's electrical infrastructure was designed over a century ago. It is based around installation of large-scale generation and transmission systems that connect centralized power sources to a 'grid', which in turn distributes power to both residential and business consumers. The US power grid alone comprises approximately 15,000 generators operating in 10,000 power plants and 260,000 km of high-voltage transmission lines, accounting for approximately 3.95 TWh during 2009.

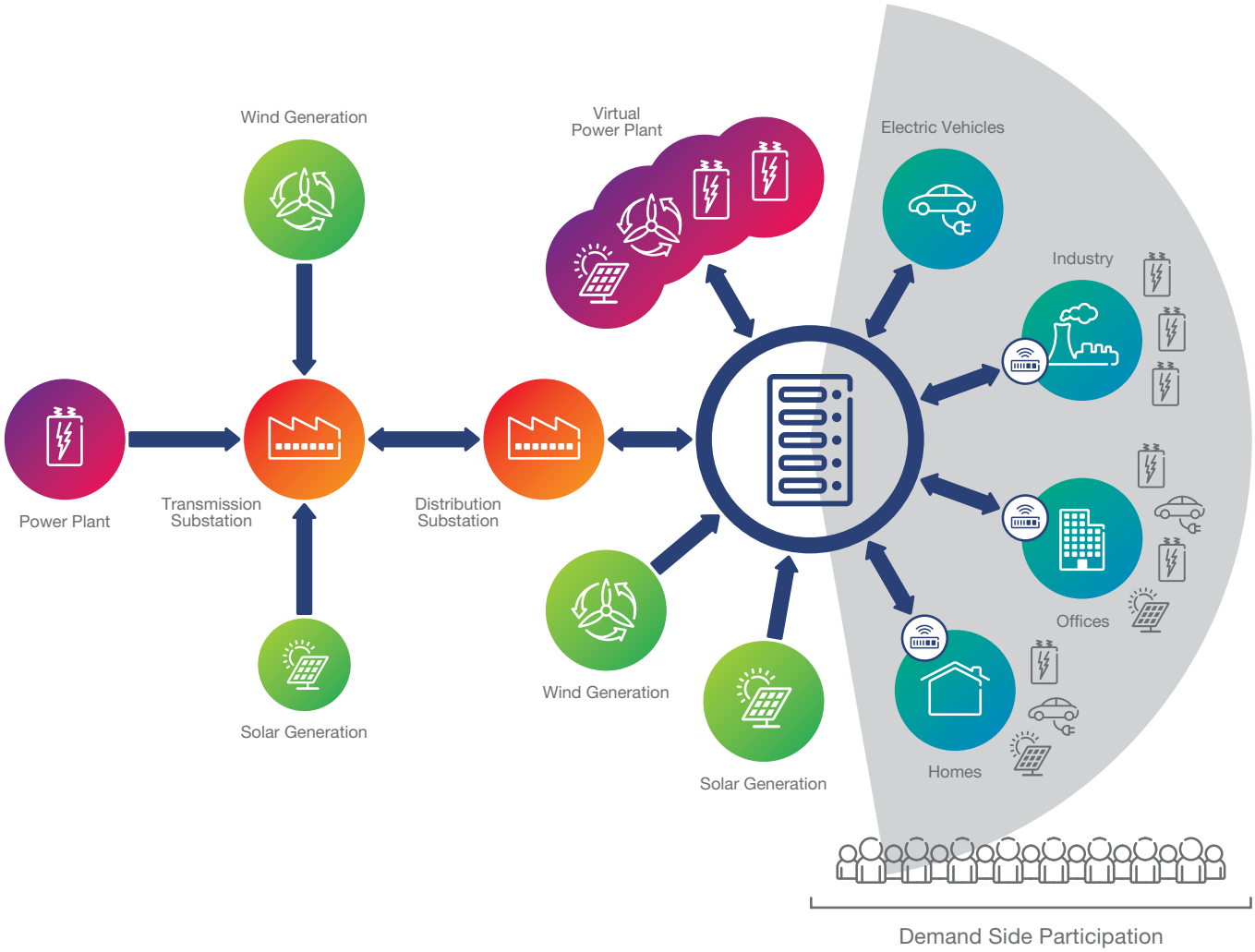
However, as power requirements have increased in recent decades, this traditional infrastructure has started to show signs of struggling under a multitude of challenges for which it was not designed. "Smart" grids are therefore being developed to enable "network operators to maximize their assets with real-time information, which allows them to react to changing demand and fluctuating generation patterns, as well as power disruption caused by failures in part of the system".[11] A smart grid can take many forms, but often includes real-time monitoring and autonomous controls, two-way communications across the network, smart meters and energy storage. From a functional perspective, a smart grid provides the following, according to EISA 07,[12] and is illustrated in Figure 7.

1. Increased digital information and controls
2. Dynamic optimization of grid operations, including cyber security
3. Deployment of distributed resources, including renewable resources
4. Incorporation of demand-side resources and demand response
5. Deployment of "smart" technologies and integration of "smart" appliances and consumer devices
6. Deployment of storage and peak-shaving technology, including plug-in hybrid electric vehicles (PHEV)
7. Provision of timely information and control options to consumers
8. Standard development for communication and interoperability of equipment

[11] Davies, S., 2013, "The Grid gets Smarter", IET Wiring Matters
[12] http://www.nist.gov/smartgrid/upload/EISA-Energy-bill-110-140-TITLE-XIII.pdf

3.1 SUPPLY CHAIN EFFICIENCY IMPROVEMENTS – SMART GRIDS

Figure 7: The Smart Grid



3.1.1 STRUCTURE OF UTILITIES INDUSTRY – SMART GRIDS

The value chain of the energy industry is complex and multinational, covering a large variety of global manufacturers who depend on economies of scale and specialization for revenues. ICT solutions such as communication networks and data storage, management and analytics capabilities are now critical parts of the delivery of any major smart grid installation. This is still an emerging market, however, meaning there is a clear emerging role for large-scale system integrators who can combine the variety of technologies on behalf of utility companies.

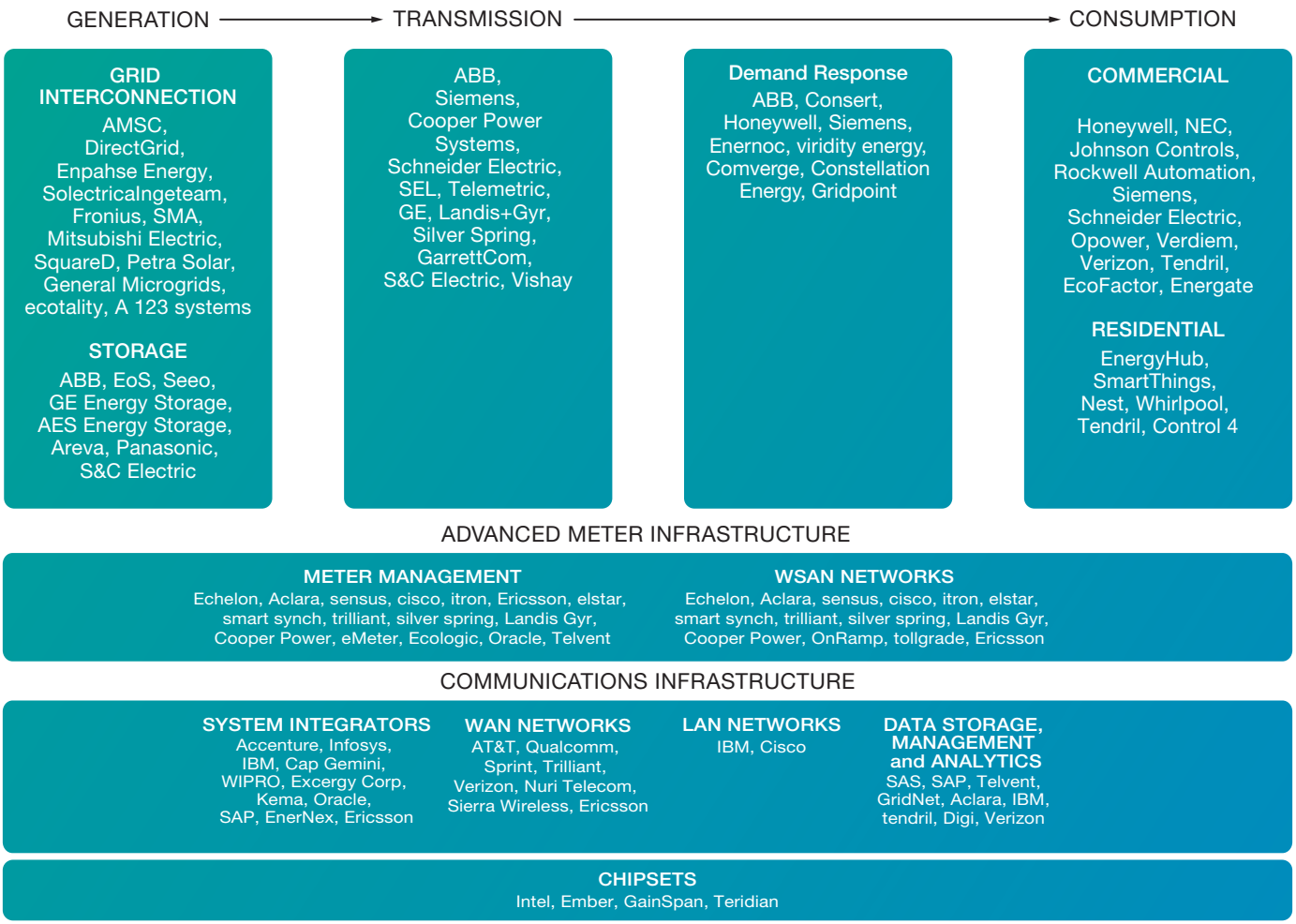
An overview of the major suppliers of each stage of generation, transmission and consumption within the energy and heat value chain is illustrated in Figure 8.

EPRI estimates that national deployments of smart grid technologies could provide net economic benefits of between $1.3 and $2.0 trillion over 20 years, but that in order to accrue these benefits, utility companies need to invest up to $24 billion a year. A key factor in achieving the vision of the smart grid is therefore the regulatory environment. Many regimes across the globe regulate by reviewing utility costs, but for smart grids to be viable, a results-driven regulatory framework that incentivizes innovation may be more suitable.[13]

[13] GE Digital Energy, Results-Based Regulation: A Modern Approach to Modernize the Grid

3.1.1 STRUCTURE OF UTILITIES INDUSTRY – SMART GRIDS

Figure 8: Smart Grid Value Chain – From Generation to Consumption (Source: Ericsson)



3.1.2 REGULATION FOR SMART GRIDS

Creating a 21st century smart grid that balances the many issues faced by participants in the energy supply chain is significantly more than just a technical issue. One of the core challenges in integrating ICT into a country's power delivery systems is regulation.

Utilities regulation has traditionally focused on a core price mechanism or a cost of service model, which looks at the 'reasonableness' of utility costs, and any changes need to be justified from this perspective. The type of market that utility providers now face, however, has fundamentally changed since this regulatory regime was established. "While cost of service regulation supported the 20th century expansion of electric services, it did so largely during periods of falling costs and increasing sales. Today, electric companies face increasing costs and investment requirements with slow growing or declining sales."[14]

So, while core price mechanisms encourage companies to perform more efficiently, as it has direct impact on their bottom line, it does little to incentivize utility companies to innovate. In order for the smart grid to become a reality, innovation must also be triggered across all sectors of the industry.

Therefore, along with technical innovation, business model innovation will be required to ensure that companies do not defer investment in upgrading infrastructure. Increasing rates is not necessarily a viable solution for utilities, as customers may reduce energy consumption in response, thereby further reducing sales. What is required, therefore, is a framework that drives efficiency gains, promotes innovation and keeps costs low for consumers.

One example of regulatory innovation in the energy space is the Revenue=Incentives+ Innovation+Outputs, or RIIO, model implemented by Ofgem, the UK energy regulator.[15] RIIO supports innovation via the Network Innovation Competition (NIC), the Network Innovation Allowance (NIA) and the Innovation Rollout Mechanism (IRM).[16]

[14] ibid

[15] https://www.ofgem.gov.uk/ofgem-publications/64003/pricecontrolexplainedmarch-13web.pdf

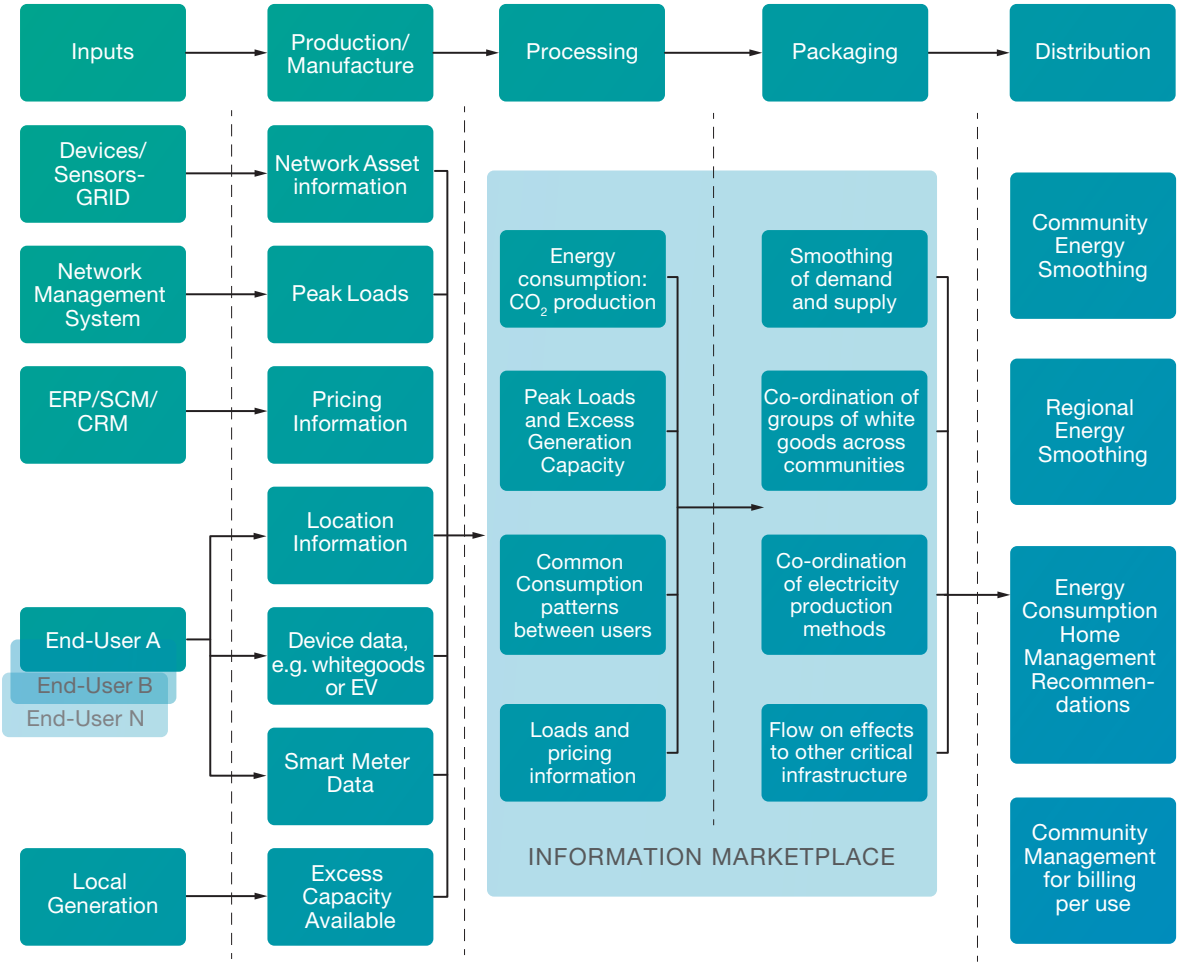
[16] https://www.ofgem.gov.uk/ofgem-publications/56919/march-decision-document-final.pdf

3.1.3 INFORMATION VALUE CHAINS & SMART GRIDS

Since the smart grid is based on the exchange of real-time information across the network, a new form of value chain emerges across the physical energy value chain: an information value chain.

This section describes the emerging information value chain and illustrates the potential for information products created from smart grid installations.

Figure 9: Information-Driven Value Chain for Smart Grids



3.1.3 INFORMATION VALUE CHAINS & SMART GRIDS

As discussed in "The Impact of Datafication on Strategic Landscapes"[17], we investigate the value chain created by data and information by breaking it up into several parts: Inputs, Production Processes and Packaging/Distribution. Here, we focus on how these may be connected to provide a unified information value chain with information products that provide decision-making improvements to existing actors as well as opportunities for transformative digital innovation in the energy industry.

INPUTS:
Devices/Sensors: the devices and sensors here include the sensors used within the network infrastructure as well as sensors used in the consumption processes on end-user sites. Some examples include:

- **Network Load** – amount and peaks of demand/supply over the network or portions of the network
- **Pricing Information** – dynamic pricing information based on type of fuel used for generation and overall demand across network
- **Operating Conditions across the Infrastructure** – these sensors measure heat, humidity and other environmental parameters that may affect the asset performance or longevity, or cause critical disruptions to the delivery of energy
- **Open Data:** open data may be used as an input into an energy information value chain in the form of maps, transport and water data, and housing stock data
- **Corporate Databases:** A significant number of corporate databases are available within a country's energy networks, including manufacturers' corporate databases as well as the customer relationship management databases of energy providers
- **End Users/Consumers:** End users now have the ability to contribute directly to information marketplaces of energy data through the use of home automation systems, energy management apps on smartphones and on the web. More importantly within the energy value chain, end users can work together in groups to get better performance out of the energy network. For example, a community of consumers in the same geographical location may choose to share information between one another so that a local ICT system can coordinate load across their houses in order to provide the optimum balance between demand and supply from a consumer price perspective
- **Local Generation:** With greater levels of renewables being integrated not at a large-scale level, but at a micro-generation level, the ICT systems at this level will need to be more deeply integrated into the information value chain

Processing: During the processing stage, data from various sources is mixed together to create insight and information necessary for decision-making at different levels within the energy supply chain. Decision-making in the context of energy is tremendously complex and often includes economic pricing models as well as technical issues such as load balancing. Many examples, however, relate to the smoothing of supply and demand between various parts of the network as well as managing peak loads.

[17] http://www.ericsson.com/res/docs/2014/the-impact-of-datafication-on-strategic-landscapes.pdf

3.1.3 INFORMATION VALUE CHAINS & SMART GRIDS

Examples of the processing required here include:

- Combining energy consumption data together with the CO_2 production data associated with the fuel used to generate it
- Combining loads and pricing information to find the optimal price and energy match fit based on environmental, load and economic factors
- Comparing usage patterns between end-user community groups – e.g. across a particular industry, such as energy consumption patterns in manufacturing or water processing

Packaging: After the data from various inputs has been combined, the packaging section of the information value chain creates information components. These components could be produced as charts or other traditional methods of communicating information to end users. Within the energy scenario, the packaging of information would be shared between a broad group of end-user actors. Due to the sensitive nature of the information being shared, it is likely that this information marketplace would be a private one – one that initially does not make too much data publicly available. The actors would therefore be able to package and share the data between one another with an established set of design patterns and data sharing rules.

One difficulty with the packaging of information across any information-driven value chain for energy is the broad number of actors that will need to be able to quickly view and understand the data. As will be discussed in Section 4, this requires integrating across previously closed silos of information.

Distribution/Marketing: The final stage of the information value chain is the creation of an information product. As discussed, there are two main categories into which these products fall:

- Information products for improved internal decision-making: These information products are the result of detailed information analysis that allows better decisions to be made. They are generally used internally, e.g. to create greater efficiency gains for grids or to provide end users with greater control over their energy usage in the home.
- Information products for ‘re-sale’ or ‘re-use’ by other economic actors: These information products have high value for other economic actors and can be sold and/or shared with them. Within the energy supply chain, the ability to integrate more tightly across all aspects of exploration, generation, transmission and consumption will provide greater efficiency gains and innovation opportunities within the ICT industry while providing significantly better service models to consumers.

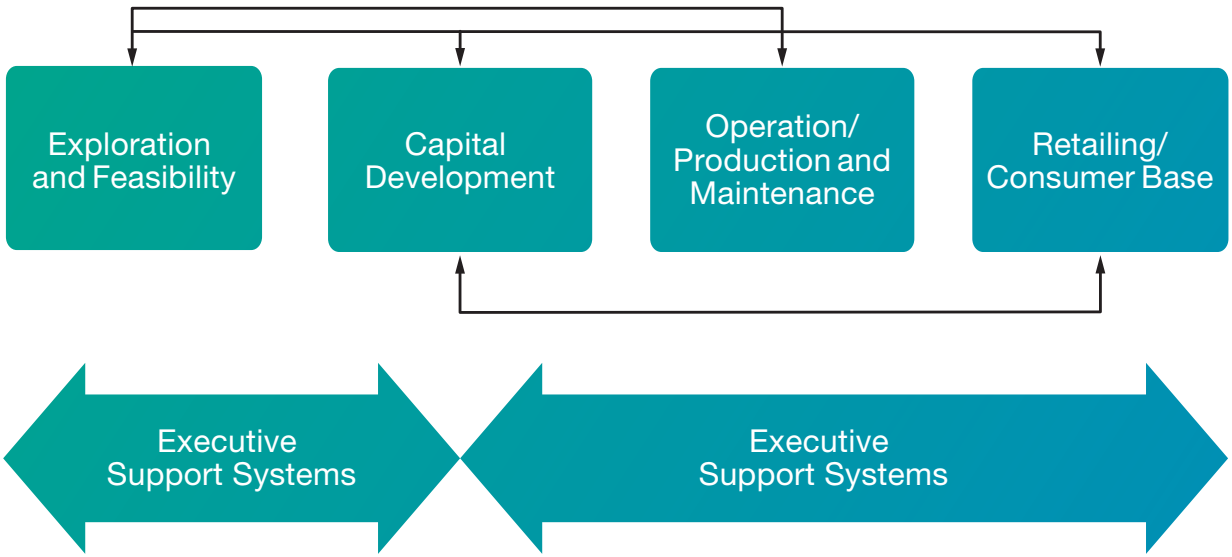
3.2 NEW DATA VALUE CHAINS FOR INCREASED SUPPLY CHAIN EFFICIENCY

Beyond smart grids, ICT has a significant role to play across the entire energy supply chain, including:

- Increasing speed to market of new energy sources
- Governance of complex supply chains, which allows for:
  - Traceability
  - Reducing the risk of accidents and environmental disasters
  - Creation of better insurance models

A key issue currently faced within all such ICT systems is the lack of integration across data silos, which are often linked to industry roles. For example, a sub-contractor to an energy utility does not usually have real-time access to information contained in the design systems. By providing better linkages across this supply chain, the industry could gain significant efficiency improvements as well as reduce time the time needed to integrate new fuel sources into their networks. Figure 10 provides a high-level overview of the data connections required across the supply chain.

Figure 10: New data flows required between ICT systems and across energy value chain



3.2.1 INCREASING SPEED TO MARKET

ICT has a role to play in creating efficiency improvements within companies. As an example, exploration and feasibility analysis are extremely expensive and time-consuming processes within the energy industry.

Those companies or new entrants that are able to perform this integration will have a critical competitive advantage compared to companies without such capacity.

As a simple example, ICT could be used to determine over a time-phased profile the capital investment and production costs required and the output/revenue that would be generated, connecting reservoir seismic analysis, design tools such as autocad, estimating software and planning/scheduling software.

Currently, much of the data required for such analyses is split across economic actors and internal company information siloes. Integrating these data sets requires the creation of appropriate ICT systems with appropriate security mechanisms to share data across stakeholders in the design process.

> "The feasibility stage of an oil and gas development takes at least 6 months. Some of the oil/gas projects cost US $45 – 60bn. If you can save 3 months at 6% p.a. interest, that's the equivalent of $600 million (on a $40bn project) and production would start 3 months earlier. The effect this could have on discounted cash is massive – a 150,000 barrel per day production at $100/barrel = $15 million per day, or $1.365bn a quarter."
>
> **Senior Manager, Oil and Gas industry, EU**

3.2.1 INCREASING SPEED TO MARKET

Table 1 illustrates some of the data sources and how these could be integrated together.

Table 1: Data Sources and Integration

DATA SOURCES		DATA INTEGRATION	
OPEN DATA Weather patterns (for solar, wind and ocean renewable).	COOPERATE GOVERNMENT DATA Many oil provinces have extensive seismic and drilling data, generally used form exploration and production from traditional hydrocarbon reserves. Satellite mapping of different regiions as a result of Loon project.	CURRENT Using engineering and production standards determine the best asset construction configuration to best exploit that resource, from cost and duration data.	FUTURE Combined analysis of mapping, aerial data and possibly drilling data available from other exploration activity.
Surface ground compostion for more accurate targeting of exploration prospects.	Heat sensing (for geothermal), aerial laser or sounding technology.		

Several examples of potentially disruptive data sources already exist. For example, oil provinces could decide to release mapping of oil sources as open data for integration into feasibility analyses. Alternatively, initiatives such as Google's "Loon" project could be used for much more than just LTE or internet connectivity by providing extremely detailed photographic coverage of landscapes traditionally only available via satellite imagery. By making such images available through a publicly available API, they could be combined with heat-sensing readings or aerial laser to provide extremely detailed physical landscape analyses for oil, gas and renewable sectors at significantly lower costs than are currently available to the industry.

Due to the complex nature of the work performed by each subcontractor and the necessity to comply with strict regulatory frameworks, detailed project management is required. ICT can help bring these together in a more coherent form. This is outlined in Section 4.2.3.

"This integrated approach to development is a key issue in bringing energy systems into production that otherwise would be left undeveloped. This is especially important for renewables. In the early stages of new technological development it is usually associated with higher costs as participants go through a learning curve. Lots of developments lie incomplete or unprofitable, encouraging many participants to drop the new technology."

Manager, Oil and Gas industry

3.2.2 USE OF IOT FOR OPERATIONS AND MAINTENANCE

There are already significant M2M solutions implemented within the energy industry today. “SCADA, telemetry and M2M solutions can be found throughout the oil & gas value chain including applications such as drill and well monitoring, fiscal metering and pipeline monitoring”.[18] Significant portions of such solutions apply wireless or satellite communications, as they are often inaccessible for wired connectivity. The use of M2M and emerging IoT solutions is a growth area, since “the installed base of active oil & gas M2M devices is forecasted to grow at a compound annual growth rate of 21.4 percent from 423,000 units at the end of 2013 to 1.12 million units by 2018”.[19] Implemented solutions vary across different sectors of the energy industry. Table 2 illustrates the data sources from M2M within the oil/gas and electrical utilities sectors:

The most basic applications of IoT within the energy industry are creating efficiency improvements in operations, maintenance and structural health monitoring of existing and new installations. For example, M2M and IoT solutions may be implemented to analyze wear and tear on equipment, pipelines and other critical physical infrastructure, helping to save costs and reduce lost lives or workplace injuries. All these data sets, however, need to be connected to provide the detailed insights required and to coordinate the efforts across the supply chain.

Table 2: Use of M2M and Emerging IoT Applications in Energy Industry

Manufacturers – electrical
Cable
Poles
Overhead conductors
Transformers
Switch gear
SCADA
Fire protection equipment
Aircon equipment

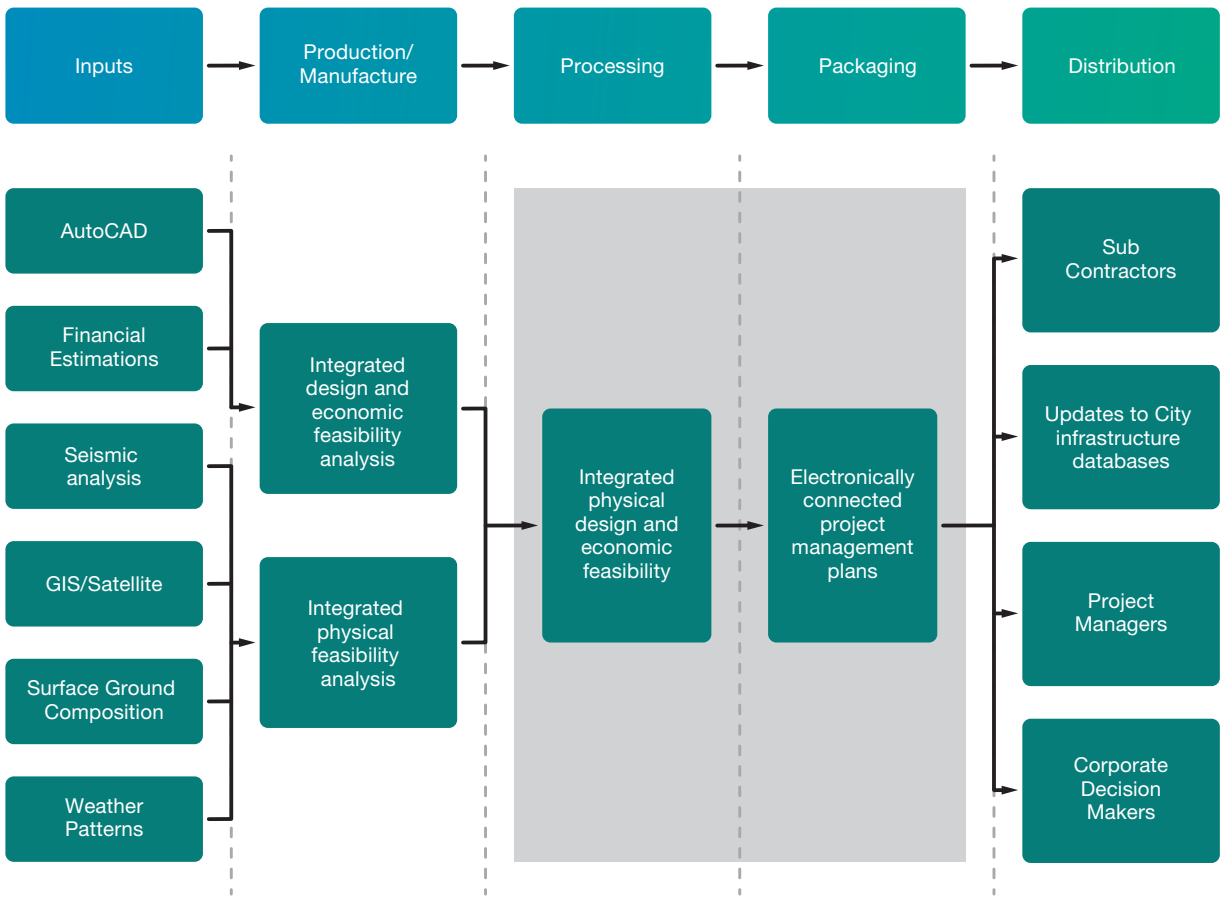
Manufacturers – Oil and Gas
Cable
Transformers
SCADA
Fire protection equipment
Pipe
Compressors
Turbine generators
Water treatment
Helipad landing gear
Accommodation and furnishings
Valves
Mechanical handling

[18] Berg Insight AB, April 2014, M2M Applications in the Oil and Gas Industry
[19] ibid

3.2.3 CROSS SUPPLY CHAIN DATA SHARING

Creating open, interoperable standards between these types of data sources within the energy industry can give rise to a data value chain between economic actors. Such integrated data management can provide greater oversight over subcontractors and how they are following project specifications, leading to increased security and safety for the overall project. These aspects are covered in more detail in Section 4.2.3. An example of an information value chain crossing industry boundaries for development of fuel sources is illustrated in Figure 11:

Figure 11: Information Value Chain for Integrated Management of development process



3.2.3 CROSS SUPPLY CHAIN DATA SHARING

Through integrating these data sets and fuel sources, both fossil fuels and renewables could be brought online much more quickly.

In order to create such information value chains across the industry, several issues need to be overcome in particular with relation to data formats and security.

These include:

1. Separate design standards for civil, pipework, electrical, instrumentation and other engineering standards need to be aligned so they can be fully integrated into the drafting/drawing software.

2. Drawings and engineering standards[20] should also be directly transferable to the fabricators, manufacturers and constructors, obviating any need for major redrafting. The products they produce should be seamlessly incorporated into the main drawing and engineering standards of the design. Any errors, manufacturing / fabrication / construction changes should again be in the same format for review and adjustment by the designer.

While efficiency improvements are important for various sectors in the energy industry, IVCs can also help the energy industry through the creation of detailed oversight and governance of the complex supply chains associated with large-scale infrastructure. This is discussed in Section 3.2.3.

[20] These are international, national and company standards. The company standards are based on these other standards, but according to the company's own interpretation.

3.2.4 GOVERNANCE STRUCTURES FOR COMPLEX SUPPLY CHAINS

Extremely large and complex supply chains are responsible for the development and delivery of energy infrastructure today, with one company generally acting as the system integrator[21] connecting disparate organizations together. More than just creating great complexity in project management, these complex contractual arrangements can cause large-scale disasters that have dramatic impact on the economic, environmental and social systems in the affected area. The best-known recent disaster is perhaps Deepwater Horizon, an oil platform that caught fire in the Florida gulf in 2010 where BP was acting as the system integrator of a large, complex supply chain consisting of a web of several thousand sub-contractor organizations connected together in an accordion of contracts. Many of the tier one subcontractors had in turn subcontracted parts of commitments out to other companies, and some of these sub-sub-contractors were very small companies of about 20 people.[22]

Such contractual arrangements are very common in the development of large-scale infrastructure projects, as many companies have developed specializations that allow them to deliver targeted products and services within a niche area. Management of the risks associated with subcontractors has been part of supply chain management for many decades. Many companies, however, tend to focus on due diligence and implementing contractual safeguards, rather than investing in the innovation required to create ongoing and real-time maintenance, not just of project management processes but of the safety and risk governance management required to identify issues early and communicate them across all partners in the supply chain quickly and effectively.[23] The implementation of appropriate, cross-partner information value chains in the energy industry is not just a matter of increasing efficiency, therefore, but is rather a critical business tool enabling system integrators such as BP to detect and eradicate serious, costly risk from projects while providing appropriate incentives across the supply chain to manage them. Effective communication methods across vast, complex networks of companies are an urgent issue.

[21] Nolan et al, 2008, The global business revolution, the cascade effect, and the challenge for firms from developing countries, Cambridge Journal of Economics, 2008, 32, 29–47

[22] http://spendmatters.com/2010/06/18/bps-deepwater-horizon-supply-chain-supplier-complexity-may-be-part-of-the-blame/

[23] https://www.executiveboard.com/blogs/learning-from-bp/

3.2.4 GOVERNANCE STRUCTURES FOR COMPLEX SUPPLY CHAINS

BP's experiences in Deepwater Horizon illustrate that lack of visibility and isolated decision-making compounds errors not just across physical supply chains, but also in service supply chains. As service supply chains become increasingly common – and are increasingly enabled by ICT – these supply chain issues become an issue of foundational importance in the technology industries. Many value chains emerging in the information era are complex accordions of data contracts spanning many organizations and connecting partners that may or may not even know of one another's existence. This is compounded by the fact that many of the contracts are signed electronically via the use of APIs, where end users often have not read the terms and conditions of use. Governance of these data supply chains, and the management and oversight of the risks associated with them, are a critical emerging area in the Networked Society. Without properly established real-time integration, risk management and the creation of appropriate risk and insurance models, the occurrence of a data-based equivalent of Deepwater Horizon is only a matter of time. This is an area that requires urgent and detailed investigation by companies wishing to build such systems. There is a role, therefore, or system integrators who are able to assist companies with the management and oversight of such data and information supply chains. In the Networked Society, these new system integrator roles will perform a critical function in ensuring the safety of our environment, economy and society. Only then will the full benefits of the productivity improvements available through ICT be realized within the energy industry.

The lowering costs of ICT create opportunities not just for energy producers, but for many end users who are now also able to invest in productivity improvements in their own homes. This is covered in Section 3.3.

3.3 DIGITALLY ENABLED CONSUMER EFFICIENCY

A number of relatively new technology developments have created the possibility for another type of productivity improvement for residential end users. Residential control and automation systems allow home users to monitor and control their energy consumption in greater detail. Newer solutions, such as Nest[24], which was bought by Google for $3.2 billion, even train themselves "according to your comings and goings".[25] These solutions aggregate information about end users' real usage of energy, rather than on estimates built on models of human behavior.

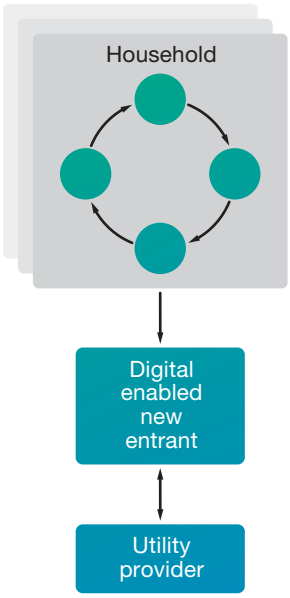
In addition, these devices are networked not just within an end user's home, but also across a large number of Nest devices in the 'network'. As the network of installed devices expands, aggregate patterns of human behavior become discernable, allowing products to be continuously improved to increase energy efficiency. In a sense, end users are co-creating the next version of the software or hardware through their continued use of the product, as illustrated in Figure 12:

These technologies are also a precursor to larger-scale industrial disruption as they allow new, relatively small, players to enter into a market that is extremely highly regulated and dominated by economies of scale. Ubiquitous, cheaply available digital technologies create a 'space' in the industrial structure of utilities, which allows new, comparatively small, entrants to compete in areas where the traditional grid is relatively poor by delivering highly efficient use of energy to consumers, rather than to producers. Through applying innovative digital technologies, consumers and soon industrial end-users will be able to dramatically improve productivity and efficiency associated with energy use.

This fine-grained control is something that traditional utilities providers have seldom been able to achieve. As covered in other reports in this series, this ability for small entrants to disrupt an established industrial structure is one of the key features of the digitally enabled Networked Society. The impacts of these changes are covered in more detail in the final report of this series – The Economics of the Networked Society.

Efficiency improvements at both grid and consumer level are only one part of the industrial transformation of energy triggered by digital technologies. ICT also enables industrial disruption and a fundamental reforming of the industrial structure by shifting the balance of power between economic actors within the value chains. This is covered in Section 4.

Figure 12: Aggregation across devices within a household



[24] http://www.wired.com/2014/01/googles-3-billion-nest-buy-finally-make-internet-things-real-us/
[25] http://www.wired.com/2014/01/googles-3-billion-nest-buy-finally-make-internet-things-real-us/

4. IMPACT OF DIGITAL – INDUSTRIAL DISRUPTION

The main role that ICT can play in helping to redefine the industrial structure of the energy system is through broadening the scope and adoption of renewables. By empowering consumers to install and run their own community-based generation capacity, digital technologies can help to share energy resources across streets and neighborhoods. Through combining the digitally enabled energy efficiency improvements outlined in Section 4.3 with locally based energy production, end users can challenge the established industrial structure.

4.1 EMPOWERED CONSUMERS

Renewable production of energy has long been understood as a potentially disruptive element within the traditional utilities industry. With cheaper and more readily available ICT, these forms of energy production are increasingly available to end users. Consumers are now empowered to build their own energy production systems or connect into larger ones delivered by well-known brand names such as Walmart. In the US and many other markets, customers are installing energy generation systems on their premises in complete contrast to the traditional large, remote central production units. Networks and customers are installing solar, insulation, energy-efficient household equipment, fuel cells, gas, various forms of heat sinks (e.g. swimming pools) and remote utility switch-off of customer air conditioning during peak demand. This has often happened due to price increases by the energy/utility suppliers, thereby driving customers to take action. It is already affecting utility networks: Some installations cannot feed into the network because there are already too many in an area for the network's installed capacity.

These initiatives are a possible precursor to wider developments. Australia, California and Germany envisage that by 2020 a significant part of energy will come from renewables. Australia, for example, looks as if it will get 20-27% from renewables, much of this at the customer level. Empowered consumers are able to disrupt the manner in which energy is produced. This section discusses the role ICT can play in expanding these customer and community installations to a much broader range of consumers. ICT may therefore lay the path for a more significant form of industrial disruption as economies of scale are challenged in the energy production market. Agglomerated small-scale energy production can occur through digitally mediated small-scale installations.

Networks are slowly waking up to the new location of generation capacity and to improved efficiency systems that active and passive customers have installed on their premises. Many networks are investigating on-premises or local community storage.

If the prediction that 50% to 80% of energy will be supplied from renewable sources eventuates as aimed for by Germany and other nations, there will no longer be any need for the large generators and producers of hydrocarbons, as the roles of these suppliers will be significantly reduced. There will be a vast reduction in production facilities such as oil wells, pipelines, refineries, power stations, and transmission lines. The bulk of energy supply would be very much at the community level. Storage would have to be included as the networks change to accommodate solar, some wind and local community energy storage systems. The major distribution hubs that until now have received energy via transmission lines would probably still be required but used instead to balance supply between the community-based generation networks. There would be some remote generators supplying just 20% of the demand, again to assist in balancing demand between community groups.

4.1 EMPOWERED CONSUMERS

> "The ICT system that was previously developed aimed to provide a central system with basic information centered on supplying demand from no more than ten large producers. The system of the future must balance supply from thousands of devices to meet demand."
>
> **Manager, Utility Network, EU**

As community networks increase, the mix of economic actors within the energy supply chain will increase and allow for possible new entrants in the form of:

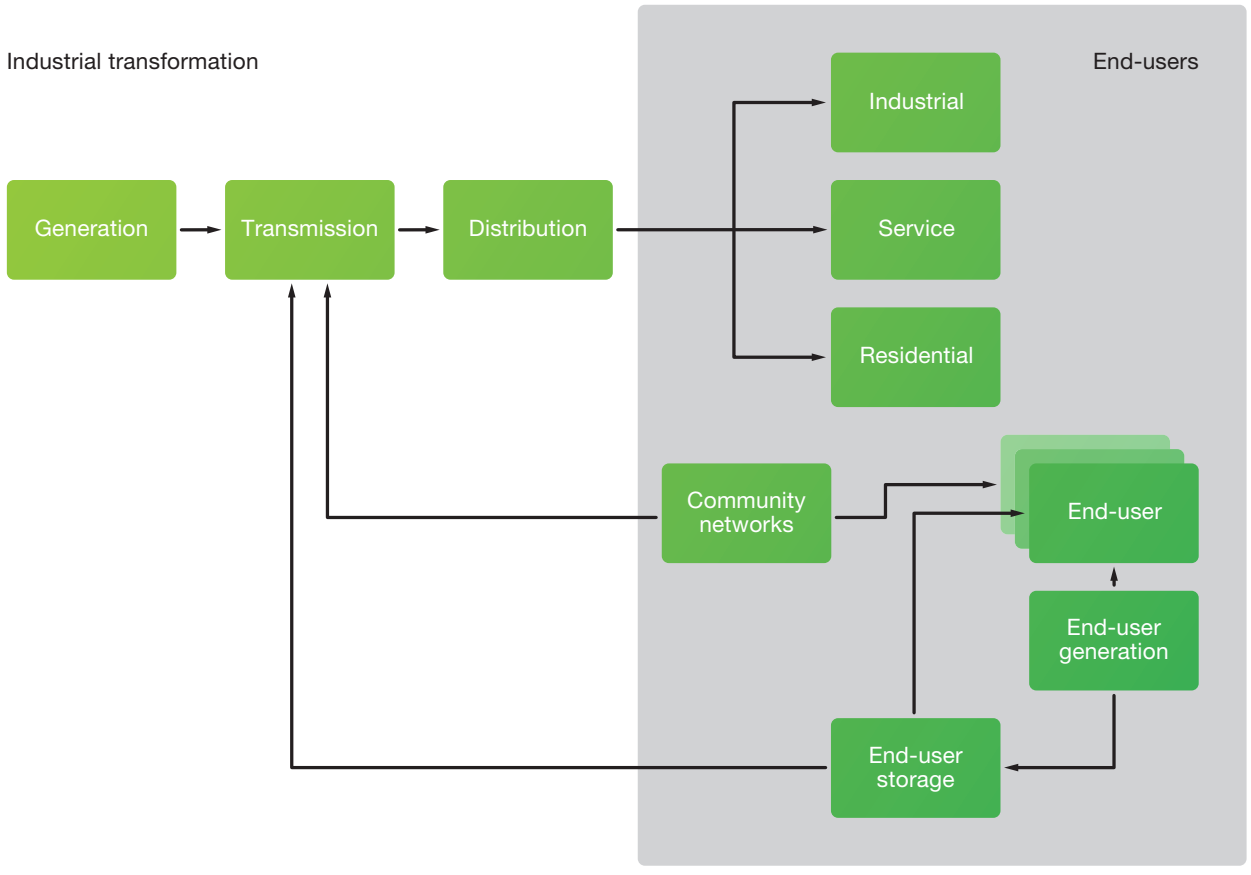
- **System Integrators:** System integrators will become necessary in order to manage the complexity of the ICT and data systems involved. In order for community networks to become commercially viable on a large-scale, system integration of micro-billing and payment as well as the ICT capacity to help smooth supply and demand at a local level will be critical.
- **New entrants to the generation sector:** As battery storage improves, there is strong likelihood that new entrants may enter the energy sector by creating larger-scale renewable installations such as the solar farms owned and operated by Walmart. Using established consumer brands, they will be able to provide alternatives to existing generation and transmission solutions.
- **As increasing costs of fossil** fuels hollow out the existing generation sector, new forms of extraction will be developed such as shale gas. This will change the extraction and generation sectors, as only those companies skilled at the complex technical requirements of shale gas extraction will be successful. A consolidation of this market can therefore be expected.
- **New entrants in other parts of the economy:** As energy sources change, demand for existing transmission and distribution networks such as petrol stations will reduce and be replaced by other forms of infrastructure.

4.1 EMPOWERED CONSUMERS

If community-driven energy generation takes hold, a new power dynamic will emerge in the industrial structure as an increasing number of end-user communities become both energy generators and consumers. This is illustrated in Figure 13:

In order to deliver and coordinate a large network of community-driven renewable projects, ICT solutions are required.

Figure 13: New Industrial Structure for the Energy Industry



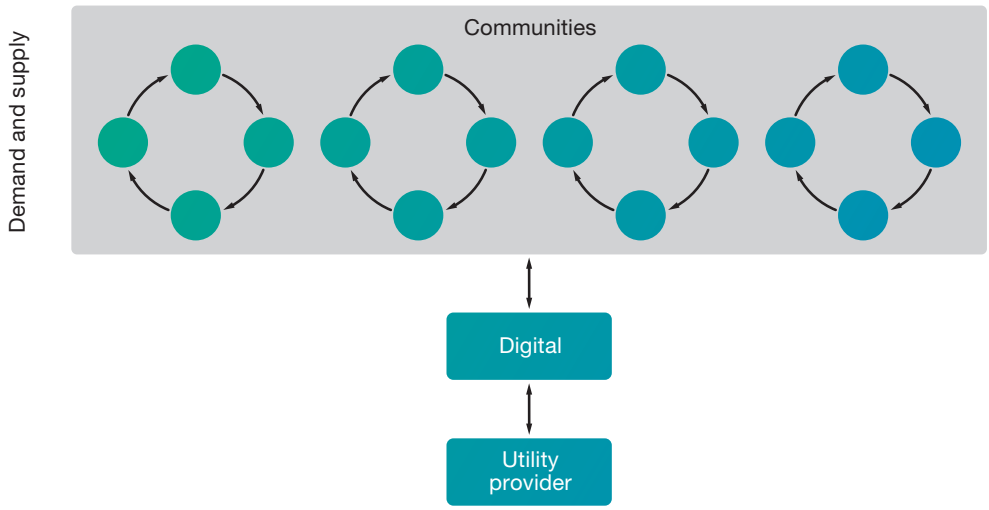
4.2 ICT SYSTEMS FOR EMPOWERED ENERGY CONSUMERS

The ICT requirements for local, community-sized renewable installations are distributed, requiring remote coordination between the network and the community installations. ICT must be able to combine and provide traditional energy functionality in a new manner by:

- Keeping consumers informed about the performance of their systems and what actions may be needed
- Conveying information about the state of the community systems and provide demand forecasts for another community or remote supply
- Calling for planned maintenance and unplanned outages / wear and tear of the systems
- Ordering maintenance: Provide information or requests for further development or removal of assets as customer demand patterns change
- Providing micro-billing and micro-payment options for local communities to keep track of what energy is used and by whom
- Smoothing supply and demand
- Reporting faults between the network and the community installation

A series of coordinated community renewable installations may therefore be viewed as a number of interconnected units of energy production that require micro-billing as well as management of subscriber access to energy resources or services. This is illustrated in Figure 14.

Figure 14: Coordination of cells of consumer-based renewable installations



4.2 ICT SYSTEMS FOR EMPOWERED ENERGY CONSUMERS

ICT can also assist community installations during the development process. By assessing the standard characteristics of the community's demand profiles, the design inputs can be streamlined into a small-scale ICT solution, allowing development design and costing to be simplified. Design input will still be needed, but many of the basic requirements will have already been determined by the demand characteristics of the community. Repetitive standard designs will make procurement and construction simpler, particularly if the design process is integrated.

Such ICT solutions will coordinate as and when required with the broader back-end network, balancing supply and demand and creating greater negotiating power for consumers by aggregating demand across a number of consumers.

The customer will therefore gain more consumer power as a result of these changes to the structure of the networks. At the moment there is a utility asset monopoly that disallows two assets side by side supplying the same service. If the community networks connect to what remains of the previous network asset owner, there will be a large number of community networks that need integration and maintenance.

The communities in question could tender the maintenance and development of their community networks to system integrators who have the capacity to do this at scale for many renewable communities. Such a combination of ICT and integrator capacity, if done in a cost-effective manner, could trigger the broad-scale adoption of renewable energy sources.

CONCLUSIONS

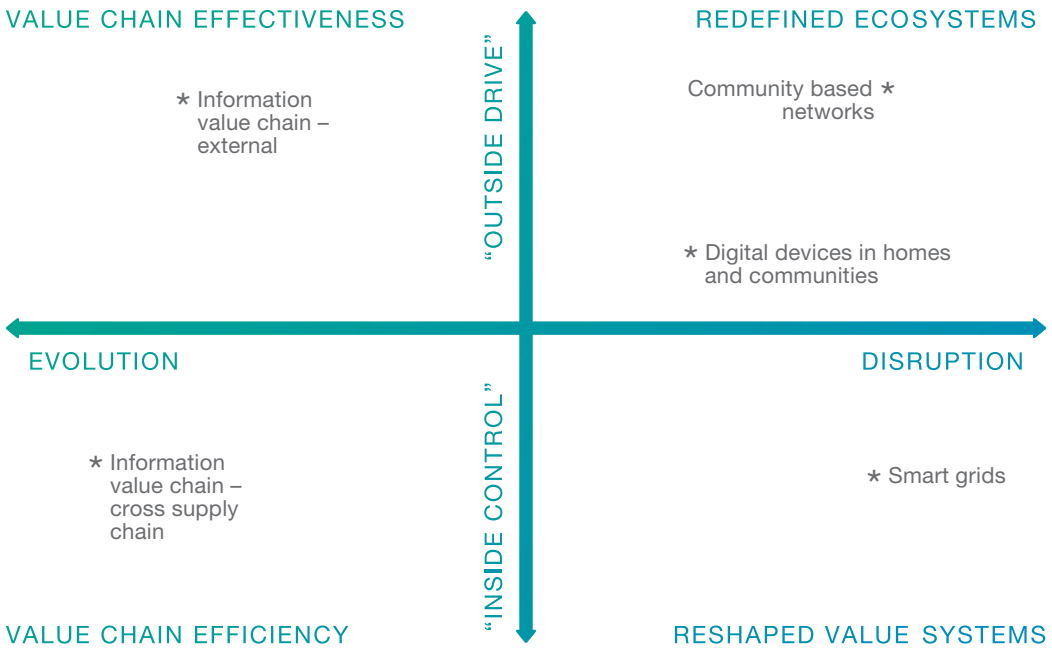
The energy industry is has been dominated by economies of scale and centralized production in order to deliver the energy requirements of our industrialized economy. ICT has played a critical role in ensuring that these mechanisms are provided efficiently and at low cost.

As the industry adjusts to face the multiple challenges of climate change, environmental protection, increasing regulation and the changing demand profiles of both residential and industrial end users, ICT will increase in profile within the industry through both smart grids and new digital entrants that assist consumers with everyday energy savings.

Moreover, ICT has a role to play in the disruption of the industrial structure by enabling the connection and coordination of community-based renewable energy installations that may challenge the established methods of energy production and delivery. These issues are illustrated in Figure 15.

As this and other reports in this series indicate, the potential for ICT to create significant industrial disruption is one of the key aspects of the emerging Networked Society.

Figure 15: Matrix of Digitally Enabled Disruption in Energy Industry



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