Cloud Computing in Europe

Appendix 5

Energy

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CONTENTS

1 INTRODUCTION

This demand side study relates to the development of a green paper to support the development of a strategy to guide the EC Cloud research planning in HEU. The energy study is only one of the five demand side themes being studied (the others are: Healthcare, Public sector, Transport and Climate) and, as such, this paper will sit alongside the other four.

We define the term “demand side” as being that part of the EU energy market which may consume any advances that emerge from the research programme, so this includes the energy suppliers as well as the distributors and the end-users. In order to structure the discussions below, a process view of the market has been chosen and a number of discrete steps in this process are examined. We have also taken the view that energy is energy, regardless of how it is generated (fuel, degree of centralisation, etc) and the scale at which it is generated. We are also neutral in relation to size and topology of any distribution networks.

Each stage in the process we have defined is explored through reviews of current industrial expectations and plans. Subsequently, any issues are considered in relation to the major supply side perspectives: Federated Cloud, Edge Migration and Green Computing. The analysis also considers the impact of EU policies and regulations.

Scenarios are then developed to expose potential illustrative use cases.

1.1 In Scope

- Carbon-based energy production life-cycle, from fuel production, through generation to distribution and consumption.
- Nuclear energy production life-cycle, from fuel production, through generation to distribution and consumption.
- Renewable energy production life-cycle, from generation through distribution to storage and consumption. (feed-in problems, solar cars feeding home role reversal)
- Indirect measure to reduce energy demand.

1.2 Out of Scope

- How energy is consumed.
- Scale of smart grids: single dwelling -> community -> region.

The energy sector can be divided into four fundamental areas: Fuel Extraction (Fuel Cropping) and processing, Power Generation, Power Distribution (Energy Storage) and Power Consumption.

Each area has its own special problems. We look at each area and consider what it is, what its problems are and how Cloud solutions might help solve them, from the perspectives of Cloud Federation, Edge Migration and Green Computing issues.

2 FUEL EXTRACTION AND PROCESSING INCLUDING NUCLEAR

Where fuel is extracted from the earth. With the exception of coal/lignite these fuels have to be refined before use and cannot be used directly or indirectly to generate power.

2.1 What

Typically, in this part of the discussion, we are looking at the extraction of carbon/hydrocarbon deposits and fissile materials that have built up over the ages within and between the strata that form the Earth's crust. These deposits include Coal/Lignite, Oil and Gas, and Uranium, which may be extracted from land or at sea.

2.2 Problems

- Reductions
    - The fuel extraction sector is trying to find ways to reduce pollution produced during their extraction activities. Many current measures involve remediation and cosmetic activities alone. More diverse measures are being explored.
    - The fuel extraction sector is trying to find ways to reduce the environmental impact of their extraction activities. Many current measures involve remediation and cosmetic activities alone. More diverse measures are being explored.
    - The fuel extraction sector is trying to find ways to reduce the processing costs of extracted resources (financial and environmental) associated with their extraction activities. Many current measures involve remediation and cosmetic activities alone. More diverse measures are being explored.
    - The fuel extraction sector is trying to find ways to reduce the transport costs of extracted resources (financial and environmental) associated with their extraction activities. Many current measures involve remediation and cosmetic activities alone. More diverse measures are being explored.
- Remediation is a key tool in the fuel extraction industry's armoury, when addressing part of the making-good activity after their extraction operations have been completed at any particular site. New forms of remediation are being sought, especially in the nuclear sector where current techniques are becoming increasingly socially unacceptable.
- In common with the rest of the energy pipeline industrial sector, increasingly stringent environmental regulations are of concern to the mineral extraction industry. They have to balance the opposing demands of supplying low cost fuel to the energy generators to allow them to supply low cost energy to the end-user with the need to spend more on ensuring their activities result in little to no environmental harm. Creative measures to implement current regulations and anticipate forthcoming regulations are being investigated.
- The issue of fuel supply security to feed the energy generation needs of their advanced economies is a huge problem for EU governments. Security in this sense is mainly associated with ensuring that fuel supplies can be sourced and that the supply is maintained. Often these arrangements come with political (direct[1] and indirect[2]) as well as operational and financial costs. Each of these costs have to be assessed for risk and then remediated. After remediation, the remaining risk targets need to be secured from their respective threats in some way. The security of fuel supplies is a key element in any national government's risk register, and with the power generation and power distribution elements, is contained within the Critical National Infrastructure (CNI) of all advanced nations. The CNI is protected by governmental agencies and these have plans in place that are not accessible to us due to their sensitive nature. We can, however, assume that these types of problem are well catered

[1] https://www.ft.com/content/9089d2d4-3d10-11ea-b84f-a62c46f39bc2

[2] https://www.bbc.co.uk/news/world-europe-50875935

for. This does not mean that Cloud computing cannot offer some much-needed additional capability or improve the performance of others.

2.3 Possible cloud-related supply-side solutions

- Federation
    - Data and best practise shared between private clouds and also with government / regulatory clouds.
- Edge
    - Sensor deployment to monitor activities.
    - Local analysis and processing to determine immediate actions.
    - Deploy actuators with immediate spot remediations.
- Green
    - Correlation of energy sector needs and solutions with some greening aspects of the computing lifecycle will help to close one of the loops there. (Reducing the energy demands of processors and their manufacture, deployment and operation means that less fuel is required to generate the demanded power).

3 FUEL CROPPING AND PROCESSING, INCLUDING BIOGAS

Not all fuels (and potential fuels) are extracted from the earth. Biofuels are grown as a crop and can be used directly or indirectly to generate power.

3.1 What

Peat and wood are often used directly to fuel a traditional fire; however, wood is starting to be processed as a green fuel for domestic and industrial boilers. Vegetable oil is extracted from other crops, usually cereal crops of some kind before being processed into a fuel for vehicles and boilers. Biogas is a by-product of various waste management processes.

3.2 Problems

- Reductions
    - Reducing pollution caused by cropping. Crops have to be harvested and this usually involves the deployment of heavy machinery of some kind. Many crops fix carbon from the atmosphere while they are growing and are considered self-mitigating: at least partially. However, improved measures are required to properly compensate.
    - Reducing the environmental impact of cropping (direct and indirect e.g. deforestation).
        - The selection of locations to grow fuel crops must be carried out carefully.
            - How is it possible to relatively value a hectare of Brazilian bio-fuel crop in comparison with the same hectare of rainforest which was felled to create space for growing the crop?[3].
            - It can be argued that every hectare of African bio-fuel crop increases hunger and destroys homes and communities because food plants are destroyed and people are displaced to make way for the bio-fuel plantations.[4]
    - Reducing the transport costs of cropped resources (financial and environmental) are not yet considered in this context.
    - Reducing the processing costs of cropped resources (financial and environmental) are not yet considered in this context.
- It seems that remediation is given superficial consideration at best in this area. Continued rainforest destruction[5] and African evictions[6] are evidence of this. Clearly remediation has to be moved further up in the list priorities here but, right now, this is a political problem and lies outside of scope of this Cloud research focussed report. Remediation of waste processing sites is more mature.
- Environmental Regulations are still in their infancy in this sector. Biogas, as a by-product of an existing process, is better regulated. Remediation of waste processing sites is more mature.
- The level of supply in this sub-sector has not yet achieved the significance to have resulted in any thinking around security of supply.

[3] https://www.rainforest-rescue.org/topics/biofuel

[4] https://www.theguardian.com/environment/2011/may/31/biofuel-plantations-africa-british-firms

[5] https://news.mongabay.com/2018/07/brazils-political-storm-driving-amazon-deforestation-higher/

[6] https://www.telegraph.co.uk/news/earth/earthcomment/charlesclover/3339496/Biofuel-rules-could-make-millions-homeless.html

3.3 Possible cloud-related supply-side solutions

- Federation
  - This area of the energy cycle is not sufficiently mature to obtain direct benefit from Cloud technology.
  - However, there is a strong argument to monitor cropping activities from space and to analyse data to detect compliance and behavioural traits. Similar analysis is currently carried out on Cloud platforms[7] [8], and there is no reason why the current biodiversity monitoring trials[9] should not apply here.
- Edge
  - It is possible that Edge computing techniques could be deployed at sensors on the ground or even in the air using drones or lighter than air vehicles, to monitor environmental and agricultural signals. In remote areas the success of traditional Cloud computing will become dependent upon the ubiquity of a 5G infrastructure, while with Edge computing this is unlikely to be the case.
  - It is also possible that Edge sensors and actuators can be deployed to more effectively and efficiently manage biogas production.
- Green
  - Again, the correlation of energy sector needs and solutions with some greening aspects of the computing lifecycle will help to close one of the loops here. (Reducing the energy demands of processors and their manufacture, deployment and operation means that less fuel is required to generate the demanded power).

[7] https://climate.copernicus.eu/global-agriculture-project

[8] https://climate.copernicus.eu/climate-advisory-services-agriculture

[9] https://climate.copernicus.eu/biodiversity

4 ELECTRICAL POWER GENERATION

Electrical power can be generated centrally or locally. Central generation requires national infrastructure support to become operational. This infrastructure is mainly associated with distribution. See below.

Local electrical power generation is usually achieved using renewable energy sources and only requires local infrastructure support; however, this infrastructure inevitably has a storage requirement. See below.

4.1 What

Electrical power is generated from a range of traditional fuel sources, typically hydrocarbons and solid fossil fuels. Current forms of nuclear power are seen a transition away from traditional fuels towards sustainable sources as they are, technically, low carbon. Nuclear fusion research continues but fusion-based power generation is not yet a practical reality.

Renewable electrical power generation sources are diverse. Hydro-electric generation can be derived from gravity turbines, offshore wave and tidal generators and on-shore turbines which may be placed in tidal lagoons or in rivers. Solar-electrical energy can be generated from photovoltaic cells while heat energy can be generated from solar-thermal cells. Wind energy is created by windmills, while Geothermal energy from boreholes is used to drive electrical generators. So far as electrical power generation is concerned, Biogas can be treated as any other form of gas fuel. Fuel cells, while seen as sources of power are actually energy stores and are discussed below:

4.2 Problems

- Traditional forms of power generation are only approximately 35% efficient[10]. Increasing the generating efficiency of traditional power stations is a key objective of many EU power generating entities. Much of the focus is now on green technologies, or carbon-reduction; however, many efficiency advances in traditional generation plant have also been made in recent years[11], with the most recent having with condensers[12]. This has extended the economic life of these traditional plants but the shift to green sources has considerable public backing and the generating authorities seem paralysed regarding their immediate future direction.as they fit into the gap between the high-level policies being developed throughout the EU and consumer demand. Very little practical work seems to have been done in respect of bridging this gap with a dependable capability[13].
- Since the advent of feed-in tariffs to encourage the uptake of domestic green power generating sources, balancing and managing baseload demands with variable outputs from renewable sources (of any size) is causing problems from knowing when to run down turbines, shut off an entire station or the opposite.
- Security.
    - Power generation is a key element in any national government's risk register, and with the fuel supply and power distribution elements, is contained within the Critical National Infrastructure (CNI) of all advanced nations. The CNI is protected by governmental agencies and these have plans in place that are not accessible to us due to their sensitive nature. We can, however, assume that these types of problems

10 http://insideenergy.org/2015/11/06/lost-in-transmission-how-much-electricity-disappears-between-a-power-plant-and-your-plug/

11 https://www.sciencedirect.com/topics/engineering/power-generation-efficiency

12 https://www.weforum.org/agenda/2015/06/how-to-make-power-plants-more-efficient/

13 https://ec.europa.eu/energy/en/topics/renewable-energy/national-renewable-energy-action-plans-2020

are well catered for. This does not mean that Cloud computing cannot offer some much-needed additional capability or improve the performance of others.

- Cybersecurity of control systems, including supervisory control and data acquisition (SCADA) systems.
    - Again, as part of the CNI in many EU nations, we can, however, assume that these types of problems are well catered for. This does not mean that Cloud computing cannot offer some much-needed additional capability or improve the performance of others. The generators are looking to find ways of improving the efficiency and durability of their SCADA systems, which if deployed in any kind of Cloud would require comprehensive and demonstrable security measures to be built into the infrastructures at both IaaS and PaaS levels.
    - In particular, it is relatively easy for a government agency to oversee the measures put in place within a centralised system but the move towards decentralised smart systems will make their jobs more difficult.
- Reducing pollution
    - All aspects of current upgrades to traditional power plants and the deployment of new power plants are focussed on the move to renewable energy sources[14].
- Remediation measures are well practised and managed in this context.
- Increasing Environmental Regulations are driving many of the most recent developments in this sector but of special concern is the relatively fast-moving regulatory landscape which is difficult to address in this infrastructure context where changes and investments are planned over decades.

4.3 Possible cloud-related supply-side solutions

- Federation
    - In-depth cyber security is a key element in Cloud deployment of the management and control systems.
    - There is a possible opportunity for Cloud federation in the context of nationally supervising power generation in an era of decentralised smart grids. Each power generator would manage its own local distribution network and how this network may cooperate with neighbouring smart grids on its own Cloud, neighbouring, regional and national authorities could federate these individual Clouds to achieve a unified management platform.
    - Federation needs to address the problem associated with data migration. The diverse ways in which each Cloud technology handles, processes and stores data results in anomalies when data currently crosses Cloud boundaries, even if that is operationally possible.
- Edge
    - Individual generators could be monitored and controlled in real time by edge devices, possibly possessing a specialised AI capability.
- Green
    - Again, the correlation of energy sector needs and solutions with some greening aspects of the computing lifecycle will help to close one of the loops here. (Reducing the energy demands of processors and their manufacture, deployment and operation means that less power needs to be generated).

[14] https://ec.europa.eu/energy/en/topics/renewable-energy/national-renewable-energy-action-plans-2020

- An inclusive knowledge-sharing platform could be deployed on the Cloud which would allow the generators to collaborate with each other and consult with the regulators more efficiently.

5 ELECTRICAL POWER DISTRIBUTION (AND HYDROCARBON FUEL DISTRIBUTION)

5.1 What

The power to be distributed over traditional centralised (inter)national grids or over distributed smart grids. Smart grids are a recent concept where green power is generated by local (typically Green) power generators.

The vast majority of electrical power is transmitted by over-ground electric transmission line, with some metropolitan transmission lines having been moved underground. Gas supplies are always transmitted through underground gas (and oil) pipelines, some major oil supplies also involve underground transit; however, regional and local supplies rely on rail and road haulage, as do other forms of solid and liquid fuels.

5.2 Problems

- While transmission and distribution efficiency are not as bad as generating efficiency, together these still account for approximately 8% of total energy loss[15].
- The transmission and distribution networks have to be maintained. Reducing the lifecycle costs of these networks is a key objective. Experiments are ongoing with super-conduction[16].
- Improving the amenity value[17] of landscapes and reducing the health concerns[18] of citizens requires the industry to explore the possibilities of “undergrounding” vast lengths of transmission and distribution cables. This is a hugely expensive and technically challenging task[19].
- Security.
    - The physical security of the transmission and distribution network is a key element in any national government’s risk register, and with the fuel supply and power generation elements, is contained within the Critical National Infrastructure (CNI) of all advanced nations. The CNI is protected by governmental agencies and these have plans in place that are not accessible to us due to their sensitive nature. We can, however, assume that these types of problem are well catered for. This does not mean that Cloud computing cannot offer some much-needed additional capability or improve the performance of others.
    - As the management and maintenance systems of the transmission and distribution networks move onto various Cloud (mainly private) platforms, the need for increased Cyber security increases. The distributors are looking to find ways of improving the efficiency and durability of their management and maintenance systems, which if deployed in any kind of Cloud would require comprehensive and demonstrable security measures to be built into the infrastructures at both IaaS and PaaS levels.

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15 http://insideenergy.org/2015/11/06/lost-in-transmission-how-much-electricity-disappears-between-a-power-plant-and-your-plug/

16 https://www.sciencedirect.com/science/article/pii/S0378779616302620

17 https://api.parliament.uk/historic-hansard/lords/1964/nov/17/electricity-pylons-in-areas-of-natural

18 https://hps.org/hpspublications/articles/powerlines.html

19 Undergrounding high voltage electricity transmission lines, National Grid. 2015. Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwilub6r_IPoAhVVhlwKHXJfB1QQFjAAegQIARAB&url=https%3A%2F%2Fwww.nationalgrid.com%2Fsites%2Fdefault%2Ffiles%2Fdocuments%2F45349-Undergrounding_high_voltage_electricity_transmission_lines_The_technical_issues_INT.pdf&usg=AOvVaw0MVLL6e9oR26PiN_jXdB98

5.3 Possible cloud-related supply-side solutions

- Federation.
    - In-depth cyber security is a key element in Cloud deployment of the management and maintenance systems.
    - Opportunities exist for greater knowledge sharing on Cloud platforms, especially as Smart grids become more common. With federation being a likely solution to the aggregation and consolidation of small private Cloud-based systems, the ability to easily, efficiently and securely share data across platforms will be essential.
- Edge
    - Using intelligent sensors and actuators to monitor and maintain the power lines will reduce power losses and reduce the need for expensive interventions, especially where cables are “undergrounded”, thus reducing financial losses.
- Green
    - Again, the correlation of energy sector needs and solutions with some greening aspects of the computing lifecycle will help to close one of the loops here. (Reducing the energy demands of processors and their manufacture, deployment and operation means that less power needs to be generated).
    - An inclusive knowledge-sharing platform could be deployed on the Cloud which would allow the networks to collaborate with each other.

6 ENERGY STORAGE

6.1 What

Storage is often overlooked as an energy supply problem because of the overwhelming dominance of electricity in satisfying society's energy demands and the "invisibility" of energy storage in that context. However, with the advent of local and regional sustainable energy schemes, energy storage has become a topic of interest once again. Of course, oil and gas storage tanks have always been necessary and these kinds of technology are well understood. Log piles, bags of pelleted wood and charcoal are still surprisingly common in rural areas.

Where decentralised electrical smart grids and/or renewable generation sources are employed, over-generated surplus energy must be stored until required. Electrical energy storage is a relatively new research area.

6.2 Problems

- Electrical energy storage technologies are relatively inefficient, with the most popular and most efficient being Pumped-storage hydropower (PSH) at 70% - 80% efficient[20]. Other technologies are being developed but many are only currently suitable for domestic deployment[21].
    - Batteries composed of various compounds, including sintered metals
    - Capacitors
    - Electro-pneumatic conversion
    - Electro-chemical conversion, including ionic membranes and fuel cells
    - Electro-thermal conversion
    - Kinetic solutions, including flywheels and gyroscopes
- Increasing the efficiency of electrical energy storage devices is a current research theme. The efficiency of flywheel devices looks set to overtake PSH in the near future[22], so much so that NASA is planning to use them aboard spacecraft.
- Local management solutions are becoming a problem for the traditional power industry as they destabilise the current unidirectional distribution pattern. Surplus power trading of energy that cannot be locally stored (for whatever reason) results in reverse flows of feed-in currents that are truly stochastic, related to user-centric capacity and needs, and the weather to name just two variables.

6.3 Possible cloud-related supply-side solutions

- Federation
    - Energy startup Stem has developed a Cloud-based AI-driven energy storage platform capable of providing power quality and backup power services for uninterruptable power supplies (UPS), and solar/energy storage platforms. Athena uses machine learning and big data analytics, which power companies can use to adapt to energy fluctuations in energy usage quickly. The company also provides energy storage and demand-charge management tools, as well as the ability to utilize virtual power plants

[20] https://en.wikipedia.org/wiki/Energy_storage

[21] https://www.drax.com/technology/every-electricity-storage-technology-need-know/

[22] https://ntrs.nasa.gov/search.jsp?R=19840014960

for energy storage simulations and projections that help maximize power plants and storage services.

- Edge
    - No application
- Green
    - Again, the correlation of energy sector needs and solutions with some greening aspects of the computing lifecycle will help to close one of the loops here. (Reducing the energy demands of processors and their manufacture, deployment and operation means that less power needs to be generated).

7 POWER CONSUMPTION

7.1 What

How end-users consume power has an impact in all other up-chain activities.

7.2 Problems

- Smart metering is often supplier-based and in phase 1 deployments, meters were provided that would not work if a consumer changed suppliers. Phase 2 meters are slow in arriving[23]. Smart metering also relies on minimum data capacity connections being available and this is not uniformly the case across Europe.
- Reducing end-user demand on their energy supply lies at the heart of reducing carbon footprint. However, the demand level is often more closely related to a building's thermal efficiency than any other factor. For this reason, the energy suppliers are required to invest some of their profit in improving the insulation of domestic properties[24].
- Maintaining profits (for suppliers). Given the regulatory pressure in the power suppliers to be "good citizens"[25] combined with official energy saving advice for consumers[26], many smaller companies fail[27].
- Many of the energy reduction measures depend upon savings to be made outside of the energy generation pipeline. For example, the construction of passive and energy-positive buildings, and the installation of heat recovery systems depend upon building regulations and the construction industry's ability to meet them and learn how to handle new materials as well as to learn new techniques.

7.3 Possible cloud-related supply-side solutions

- Federation
  - Possible to use federation to improve data access for smart meters (with 5G and/or WiFi).
- Edge
  - An improved third generation of Smart meters could employ IoT technology to improve performance and extend capacity (possibly to include intelligent heat and power management).
- Green
  - Again, the correlation of energy sector needs and solutions with some greening aspects of the computing lifecycle will help to close one of the loops here. (Reducing the energy demands of processors and their manufacture, deployment and operation means that less power needs to be generated).

[23] https://www.telegraph.co.uk/money/consumer-affairs/six-reasons-say-no-smart-meter/

[24] https://ec.europa.eu/energy/en/topics/energy-efficiency/targets-directive-and-rules/national-energy-efficiency-action-plans

[25] https://www.ofgem.gov.uk/consumers/household-gas-and-electricity-guide/extra-help-energy-services/energy-saving-support-schemes-and-advice

[26] https://ec.europa.eu/clima/citizens/tips_en

[27] https://www.energyscanner.com/which-energy-suppliers-have-gone-bust/

8 SCENARIO OUTLINES

1. Edge sensors are used to monitor generating and transmission/distribution equipment in real time to improve reliability, efficiency and flexibility, and also to reduce maintenance costs. AI-based Edge actuators are used to autonomously repair and maintain any anomalies detected by the sensors, leaving only major issues to require human intervention. However, this is not going to happen until security is taken seriously at the network edge[28].
2. Power generation SCADA systems are currently secure through design, centralisation and isolation. As micro-generation and micro/smart grids evolve and represent an increasing contribution to the energy capacity of any nation, new forms of SCADA will be required to manage the highly distributed assets. A Cloud based system is an obvious choice for such systems and a federated approach makes sense. Local micro generators only need to deploy the system suitable for their own needs. Regional management functions could aggregate these local controllers through a federation, which national controllers applying the most stringent control through a final stage of federation. However, once again the security of (federated) Cloud systems is of paramount importance. Cloud migration of SCADA will not (cannot) happen until security is taken seriously
3. Edge sensors are used to monitor extraction and cropping activates in real time to police (environmental) compliance. Edge actuators could be used, to an extent, to enforce compliance, leaving only major events to require human intervention. Security is still an issue here but mainly in relation to assuring privacy issues and dealing with aggressive and possibly kinetic attacks. The big issue here is how to deploy the sensors and actuators. An obvious choice is to employ air and space-based platforms; however, this then introduces issues related to platform management that fall out of the scope of this paper.

[28] This is a future view where there is a possibility that the deployment of EDGE sensors might be thought of in this role. The EDGE currently poses many unanswered security questions. No part of the CNI exists at the EDGE and it is difficult to understand how this may change, unless security issues are fully addressed

9 CHALLENGES

9.1 Cloud security of energy management systems

- **D-E Challenge 1:** Highly secure cloud-based environments are needed to support very sensitive energy management and control systems. [Deployment]
- **D-E Challenge 2:** Security must be identified as a priority aspect of applied Cloud research in this area. Security aspects should be a fundamental component of all Cloud-related research (from project work-plan to programme design) rather than addressed as a separate issue. [Research]
- **D-E Challenge 3:** The migration from central Clouds to federated Clouds requires a broadening in the scope of security thinking. Security aspects of federated cloud services might be inherently more secure than centralised cloud services in some aspects but be much less secure in other aspects. [Research]

9.2 Data sharing across the sector to create insights

- **D-E Challenge 4:** Data sharing across the sector. Data and information need to be able to move freely between cloud services and data domains in order to enable practical information and knowledge sharing to take place. [Research]

9.3 Edge opportunities

- **D-E Challenge 5:** Edge-based IoT automation can enable efficiency increases in the generation, transmission and distribution components of the supply chain. [Research]
- **D-E Challenge 6**: Air- and Space-Based Edge infrastructure. Edge infrastructure needs to include space-based, and loiter-capable lighter than air and air-breathing assets such as dirigibles or drones. [Research]
- **D-E Challenge 7:** Good network connectivity to support the edge. Edge infrastructure requires network connectivity, which is not always available or of low quality. For instance, 5G deployment cannot be restricted to urban areas in the same way that 4G has been. [Deployment]

9.4 Effects of regulation and challenging environmental targets

- **D-E Challenge 8**: Balance energy demand side management with green ICT targets. Balance increased (demand-side) energy efficiency targets and (supply-side) green computing targets. Regulatory measures on either side impact the other. [Policy]
- **D-E Challenge 9:** Dynamic energy regulation limits adoption of new ICT technology. The very dynamic energy sector regulatory environment limits the energy sector's ability to make plans and innovate. A long-term strategic plan is required to bridge the current gap between policy and consumer-led demands. [Policy]