The role of the system architect

National Centre for Energy Systems Integration (CESI)

Urban Sciences Building,
Newcastle University,
Newcastle upon Tyne,
NE4 5TG, UK

Telephone: +44 (0) 191 2088404

Email: cesi@ncl.ac.uk
Twitter: @cesienergy
Web: www.cesienergy.org.uk

The Role of the System Architect

About the Centre

The £20M EPSRC National Centre for Energy Systems Integration (CESI) brings together an interdisciplinary team of experts to gain a deeper understanding of the value of taking a whole systems energy approach to the energy trilemma. Led by Newcastle University, CESI is a consortium of five research intensive universities and a wide range of public and industrial sector partners.

Working with Industry

CESI currently has over 34 industrial and government organisations collaborating with our team of academics and researchers. They provide:

- a steer on the relevance of our work
- access to their experts for consultation
- access to resources such as engineers, labs, data and other valuable assets
- front-line insight to the needs of the industry and their customers

SIEMENS: CESI Lead Industry Partner

Siemens are a significant contributor to the Centre providing over £7.2M of support.

About the Authors

Professor Phil Taylor is the Director and Principal Investigator at CESI. He is an internationally leading researcher and industrial expert in energy systems, electrical distribution networks, smart grids and energy storage integration and control.

He is the Siemens Professor of Energy Systems, Deputy Pro Vice Chancellor of SAgE Faculty and Head of the School of Engineering at Newcastle University.

Contact details: phil.taylor@ncl.ac.uk

Dr Sara Walker is an Associate Director and Co-Investigator at CESI. Her research focus is regarding renewable energy technology and transitions to low carbon systems, with a particular focus on policy and building scale solutions.

She is Director of Expertise for Infrastructure at the School of Engineering for Newcastle University.

Contact details: sara.walker@ncl.ac.uk

Acknowledgements

While the opinions expressed in this piece are the responsibility of the authors alone, they would like to thank the academic and industrial partners of the Centre who contributed to discussions on the topic of this article.

We would like to express our gratitude in particular to:

- Professor Keith Bell, Scottish Power Professor of Smart Grids, University of Strathclyde
- Prof Gordon Mackerron, Professor of Science and Technology Policy, SPRU Science Policy Research Unit, School of Business, Management and Economics, University of Sussex
- Dr Gareth Powells, Lecturer in Human Geography, Newcastle University
- Andrew Wright, Senior Partner, Energy Systems, Ofgem
- Colin Henry, Head of Business, Digital Grid Automation Systems, Siemens plc
- Carl Ennis, Managing Director, Siemens Power and Gas and Power Generation Services, UK and Ireland
- Keith Owen. Head of Systems Development and Energy strategy, Northern Gas Networks
- Jim Cardwell, Head of Regulation & Strategy, Northern Powergrid

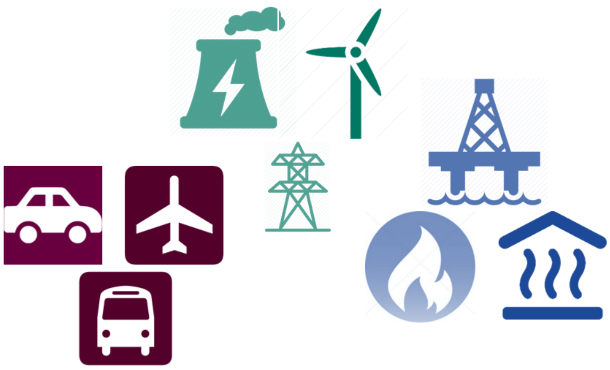

Table of Contents

1. Introduction

Energy infrastructure is considered a critical infrastructure for the UK, vital to economic prosperity. Current and future changes to the way we use energy will increasingly impact on local and national energy infrastructure. HM Treasury describe drivers of change for UK infrastructure as: obsolescence, globalisation and competition, growing demand and expectations, climate change, and interdependency (HM Treasury 2010).

These energy issues require long term solutions based around a systems thinking approach (particularly given the interdependency of energy with other key infrastructures such as transport and water) which is immune to short term commercial and political pressures. This is important given that investment decisions can take decades to be realised and can be locked in for the next 50 years or more. However, it is worth clarifying that it is difficult to be immune from commercial and political pressures given that these investment decisions will create winners and losers.

The challenges of creating a UK energy system which meets the needs of a modern economy have led to the notion of a System Architect (IET 2014; Taylor 2014). The concept was initially assumed to be a centralised planner role. However, this could be viewed as too prescriptive. In this paper, the System Architect concept is revisited. The role is considered as a facilitator of bottom up regional energy approaches, and the strengths and weaknesses of a regional versus centralised system architect are discussed.

2. The UK energy sector and the need for a System Architect

The UK Government has a legally binding target to reduce greenhouse gas emissions by 80% by 2050, compared to 1990 levels (HM Government 2008). Whilst the UK is currently on target to meet the 3rd carbon budget (37% by 2020), emissions reduction must ramp up significantly if the 4th (51% by 2025) and 5th (57% by 2030) carbon budgets are to be achieved.

Associated with the UK greenhouse gas emissions reduction target are a number of policies which consider how this challenging target could be achieved. The 2050 pathways report (Department of Energy and Climate Change 2010) outlines a number of scenarios which achieve the 80% reduction target, many of which involve significant electrification of heat, transport and industrial demand parallel to decarbonisation of the electricity grid. The UK approach to delivery of targets in liberalised energy markets is one of market based policies and mechanisms, typical of neoliberalism. However, more recently a failure of the markets to deliver on particular elements has led to a more interventionist role, for example in Government-sponsored subsidy of some technology-specific new electricity generation plants.

For the UK, the management of critical energy infrastructure is complicated by the challenge of dealing with infrastructure in private ownership. Operation and management of critical infrastructures involves a greater number of actors, with increased splintering of management and development responsibility, as a result of privatisation and restructuring policies (de Bruijne and van Eeten 2007). This has continued more recently, as evidenced by the proposed split of the Transmission System Manager and System Operator roles at the transmission level (Ofgem 2017).

Energy systems are highly complex interacting, interdependent entities that are strongly coupled with society and the environment. However, a common view is that the industry is fragmented and disaggregated in a way that creates broken value chains and split incentives. For example, landlord domestic and commercial tenants pay energy bills, but landlords are responsible for energy efficiency investments. Energy supply companies have a business model based on units sold, and this conflicts with Government targets on energy-related emissions reduction as well as concerns of fuel poverty and affordability. These split incentive and broken value chains are reflective of an energy system which is not fit for purpose today (IET 2014; Taylor 2014; Lockwood 2014) as the UK faces unprecedented challenges regarding energy sustainability, security and affordability. These challenges are long term and require systems thinking which has public accountability and national challenges in sharp focus. In addition to this any decisions to invest in energy systems infrastructure take decades to be realised and have implications and 'lock in' good or bad for 50 years or more.

The concept of a System Architect has been noted by the UK Government:

"We conclude that it is imperative that the electricity system is viewed as a whole in order to enable effective engineering integration across the electricity system as changes occur. We look forward to analysis from the new Energy Systems Catapult—or another suitable organisation—about how effective decisions can be made in the context of the whole electricity system. This should include examining the thinking underpinning the Institution of Engineering and Technology's proposed 'system architect.'" (House of Lords Science and Technology Select Committee 2015)

The EPSRC National Centre for Energy Systems Integration is taking a whole system approach to investigating the UK's energy infrastructure. The intention of the project is to trial different manifestations of the System Architect role or function, as part of the co-evolution cycles stage of the project. The co-evolution stage takes findings from work on supply, demand, infrastructure and policy, and evaluates them in a coherent way to better understand linkages between these sectors and between energy vectors, and to evaluate the effect of linkages on the way in which supply, demand, infrastructure, policy and energy vectors can co-evolve. The co-evolution method has two main features: one is robust long term planning and operation of whole energy systems (co-evolution cycles), which incorporates accurate operational models and deals coherently with future uncertainties; the other is to develop scenarios that illustrate policy issues, in particular ones which require accurate operational models. During the project these two features will positively interact: co-evolution cycles will generate the scenarios, and a trilemma evaluation of the scenarios will guide the development of the planning and operational system.

3. The role of a System Architect

The challenges of creating a UK energy system which meets the needs of a modern economy have led to the notion of a System Architect (IET 2014; Taylor 2014). The concept was initially assumed to be a centralised planner role, with a focus on the needs of the electricity sector and on standards. For example, the IET proposed:

"The System Architect would take a whole system and long-term responsibility for developing and agreeing the framework of architectures, standards, protocols and guidelines needed to ensure seamless technical integration of the sub-systems of the many market players and parties, enabling a seamless response to the challenges arising from policy imperatives as they emerge over the coming decades." (IET 2014) p9.

More recent work by the IET in conjunction with the Energy Systems Catapult has continued the focus on the electricity sector, with the Future Power System Architecture project. Their report identified key functionality for system architecture across the electricity system which

"…runs counter to today's stratification of system architecture that, to a large extent compartmentalises generation, transmission, distribution and consumers." (IET 2016) p20.

However, this view of the System Architect for electricity in isolation could be viewed as too prescriptive. In previous work the authors have advocated the role of the System Architect to:

"..think about the energy system as a whole, building plans that consider how heat, power, water and transport systems are all linked together" (Taylor 2014).

The iGOV project also made the case for co-ordination across the energy sector:

"In Britain, the combination of slow progress on energy transition and extensive reliance on markets (or delegation to network companies) to make decisions points to the need for greater coordination." (Lockwood 2014).

The notion of a System Architect remains highly relevant today but the energy landscape has changed since 2014 and therefore this document seeks to revisit the idea and review its relevance to today's energy challenges. The role is considered as a facilitator of bottom up regional energy approach, and the strengths and weaknesses of a regional versus centralised System Architect are discussed.

4. The revisited role of a System Architect

i. The System Architect and system planning

The System Architect as previously proposed by the authors (Taylor 2014; Taylor 2015) was envisaged as taking a long term, non-political, non-commercially based view of energy industry and system strategy, which all remain valid today. The System Architect was also seen as an organisation (or group of organisations) that would take a whole systems approach to energy. This aspect is now seen as even more important than when first mooted, as evidenced by RCUK funding priorities, Energy Systems Catapult (ESC) involvement in the Future Power Systems Architecture strategy, and activities of international organisations such as the International Institute for Energy Systems Integration (iiESI).

The System Architect could provide long term plans for the development of the UK energy infrastructure along with high level transparent design and decision making tools and methodologies. This would provide clarity about where we are going and the principles used in deciding which way to go. This would give much needed certainty to investors (*"Political uncertainties around the lack of a clear decarbonisation target and the future of the carbon price floor at both the domestic and European levels have been identified as barriers to continued private investment in the growth of renewable technologies beyond the near term"* (Institute of Civil Engineers 2014)), since the private sector would be key in the delivery of development plans. It would also avoid piecemeal short term decisions which lead to sub optimal solutions system wide. More specifically the System Architect could make decisions about capacity margins for the electricity sector, the desired energy mix, roadmaps and timescales for energy mix transitions, how many interconnectors are required and when, and pricing models that are conducive to energy efficiency.

These planning considerations are not entirely absent from the current UK system. For example, the Committee on Climate Change has made recommendations for the UK electricity generation mix in the fifth carbon budget (based on the TIMES model) (Committee on Climate Change 2015). The UK Government has instigated a capacity auction to deliver on desired electricity system capacity margins from 2018 onwards (margins advised by National Grid), although the amount procured has been criticised (Newbery 2016; Hawker, Bell, and Gill 2016). The criticism is partly around the lack of consideration of interconnectors. Merchant interconnectors, with revenue gained from price differentials across markets (i.e. NorNed (Traustason and Hilmarsson 2016)), could provide an additional mechanism to secure supply.

There are clear links between the UK electricity generation mix, capacity margin and interconnector provision, but at present a separation of entities involved in, or responsible for, the planning of these elements.

Whilst some planning roles therefore exist, they are not co-ordinated and have a limited ability to deliver change in energy markets. Furthermore, the spatial and time resolution of tools used do not lend themselves to locally appropriate energy planning. For example, MARKAL uses 1 zone for the whole of the UK (Dodds, Keppo, and Strachan 2015). The planning function of the System Architect could be undertaken at multiple geographical scales, i.e. bottom up regional planning co-ordinated across the regions.

The System Architect can make decisions about when, where and how to integrate emerging technologies into energy systems such as demand side response, real time ratings and importantly energy storage. Another crucial role a System Architect could play is to think in a more integrated way and to make decisions and build plans considering the interdependent nature of heat, power, water and transport systems such that we not only have independent long term plans but that they are much more holistic. The establishment of the National Infrastructure Commission (NIC) in January 2017 could, in theory, offer support to this role. However, at present, the role of NIC has been very much concerned with high level national planning, with very little consideration of regional and local approaches.

The most recent iteration of the Future Power System Architecture project (The Institute of Engineering and Technology and Energy Systems Catapult 2017) has come to the same conclusion that here is a requirement for a *"potentially multi-part series of activities under the overall accountability of an Enablement Organisation."* (p19).

ii. The System Architect and a separation of planning, management and operation

The authors previously made the case for a System Architect function that would offer leadership by taking independent, transparent decisions on how to move towards a low-carbon economy (Taylor 2014; Taylor 2015). The articles recommended a separation of the design from the operation and asset management of our energy systems. This would reduce the conflict of interest which arises when these vital roles are undertaken by the same private company.

For the electricity transmission sector, the regulator OFGEM recently proposed just such a change, with a proposal to create a more independent electricity system operator (BEIS 2017) within National Grid Group (which is not the same as a fully independent System Operator (Lockwood and Mitchell 2017)). Other developments that are of relevance are the emergence of the concept of an electricity Distribution System Operator (DSO). The existing Distribution Network Operator (DNO) model has been discussed and proposed to expand to incorporate a System Operator role (Scottish Power Networks 2016), thereby merging the planning and operation at the electricity distribution level. This is in contrast to the increased separation of the role at the electricity transmission level.

iii. The System Architect and local system needs

The current industrial and academic discourse suggests the System Architect role is predominantly top down. For example, the Future Power System Architecture project (IET 2016) connoted a central governance, design and control paradigm. This may be inappropriate for a decentralised unbundled energy system in need of new entrants, and for an environment which is conducive to local, community and municipal energy initiatives.

There may be many architectures[1] which co-exist, working with different geographies or energy vectors. In such circumstances the overarching role becomes one of defining the interfaces between architectures. The System

[1] "Architecture: the designed and emergent structure of a system, and the manner in which the physical, informational, operational and economic components of a system are organised and integrated" (IET, 2016).

Architect function could be provided on a regional basis, for example for cities or city regions. This would allow for different strategies to co-exist in different regions but with sufficient high level coherence that the interfaces with them remain compatible. The compatibility issue is one which needs to be addressed, since different geographical areas may have priorities which are in conflict with, or not fully aligned to, their neighbours. Case studies of Boston (USA) and Cambridge (UK) indicated different government priorities at the national, regional and local level. This fragmented political geography resulted in (national and regional) economic development policies which were instigated to attract private investment in industry, and which the authors suggest were not appropriately funded to deliver on consequential increased (local) demands for infrastructure and service (Jonas, While, and Gibbs 2010).

There are some risks of a bottom-up regional approach. Firstly, a regional bottom-up starting point runs the risk, however well-co-ordinated, that it is difficult for regional emissions savings to add up to a national level emissions commitment, particularly as there are going to be top-down national decisions that will be part of the overall emissions reduction commitment. Secondly, at present there is insufficient regional political and financial muscle to make significant regionally-based investment decisions, unless there are major devolutions of political power. Thirdly, there is the potential lack of capability in the regions to deliver the decisions, markets, regulation and technical underpinning needed for a Regional System Architect. Finally there is a real risk of unproductive regional competition.

The Future Power System Architectures project identified 35 functions required to transform the UK electricity system and tackle the energy trilemma, grouped within 7 areas. The 7 functional areas are:

1 – Flexibility/responding to charge

2 – Changing mix

3 – Aligned financial incentives

4 – New entrants

5 – Active management

6 – Emergencies

7 – Coordination across vectors

A Regional System Architect function could facilitate all of these functions to a certain extent, and could arguably facilitate new functions in flexibility, new entrants and co-ordination across vectors more effectively than a centralised approach.

The energy sector not only needs innovation it needs rapid innovation in a risk averse sector with a small number of powerful present incumbents. Could a bottom up Regional System Architect enable communities and cities to take managed risks and learn and innovate much more rapidly? This would also require BEIS and Ofgem to loosen regulatory rules to allow this innovation and to allow a whole systems approach to be explored.

iv. The System Architect as policy maker

The Future Power System Architectures project has a technical focus, and sees the System Architect as managing the complexity of the evolving electricity system architecture in the public interest, on behalf of Government, with a role of implementing policy rather than making policy. This policy implementation but not policy formation is much like the regulator role.

We go beyond the FPSA (electrical only) policy implementation role.

We propose that a fully independent System Architect function could provide a framework for energy system strategy development (in addition to implementation), that is both coherent and clear but also flexible enough to nurture and enable bottom up initiatives to thrive. Therefore, the System Architect has a role in influencing and forming policy, as well as implementation.

So let us consider the DSO function for a moment. There is a discussion in the UK energy sector around moving from a Distribution Network Operator (DNO) model to a DSO model (Scottish Power Networks 2016), thereby merging responsibility for asset management with asset planning, design and operation. In particular, the UK DNO is typically an entity which owns and operates the distribution network, but which does not undertake the system balancing role of a system operator (Baringa Partners LLP 2016). Moving to a DSO model, with responsibility for balancing at the distribution level, could be seen as a way of the present incumbents ensuring greater control of their asset base, or it could be seen as a way of creating a market by which communities and bottom up initiatives can get access to the retail price of electricity and earn additional revenue from providing services to the DSO. This bundling of operation and asset management is in conflict with the proposed System Architect model. We propose a system whereby asset management and asset operation are separate. The DSO concept could also be seen as paradoxical when compared to the concurrent shift of separating the system operator function from the UK TSO to create a network only operator at the transmission level.

5. Summary

The authors have proposed a System Architect for the UK. The proposal is for a System Architect which takes a long term, non-political, non-commercially based view of energy industry and system strategy. The System Architect can be flexible to enable bottom up initiatives as well as top down UK system overview.

The proposed System Architect is to have a role within policy making as well as policy implementation. This raises issues of governance and transparency. There is a need to ensure that a System Architect has some accountability and legitimacy. The Centre for Energy Systems Integration is interested in the current energy system policy formation processes, and the ways in which these provide accountability, transparency and legitimacy, so that a governance approach for the System Architect may be proposed.

The top down manifestation of the System Architect idea could include the SO function working alongside organisations such as the ESC, the National Infrastructure Commission and NGOs such as National Energy Action. A key question is whether a national level System Architect of this nature could coexist with a number of regional bottom up System Architects. The Centre for Energy Systems Integration is interested in investigating this.

What is clear, arising out of consideration of the UK's long term energy future, is that whole systems thinking is complex. It enables more options, considering for example shared storage and shared assets. It also enables longer term thinking, and an approach which approaches the energy trilemma in a holistic way. Decision making will be more complex, however, needing an interdisciplinary approach and greater co-ordination. It also means that leaving things to the market is difficult.

However, the benefits of a System Architect approach which embraces whole systems thinking have a value to the sector as we move forward. These benefits include improved whole system efficiency, increased asset utilisation, increased utilisation of renewable energy, improved system reliability, improved system flexibility, and decision making appropriate to geography/vector. Without the role, we risk a fragmented, costly and ultimately ineffective energy system which fails to deliver a low-carbon modern energy system to UK industry and society.

6. References

Baringa Partners LLP. 2016. "Viewpoint. The future role of network operators: The emerging active DSO model. GB experience and its relevance to the pending European market redesign." In.

BEIS. 2017. "Statement on the Future of Electricity System Operation." In. London: BEIS.

Committee on Climate Change. 2015. "The Fifth Carbon Budget. The next step towards a low carbon economy." In. London: Committee on Climate Change.

de Bruijne, M, and M van Eeten. 2007. 'Systems that should have failed: critical infrastructure protection in an institutionally fragmented environment', *Journal of Contingencies and Crisis Management*, 15: 18-29.

Department of Energy and Climate Change. 2010. "2050 pathways analysis (URN 10D/764)." In. London: The Stationary Office.

Dodds, P.E., I. Keppo, and N. Strachan. 2015. 'Characterising the Evolution of Energy System Models Using Model Archaeology', *Environ. Model Assess.,*, 20: 83-102.

Hawker, G. S., K. R. W. Bell, and S. Gill. 2016. "Capacity markets and the EU target model – a Great Britain case study." In *CIGRE*, 1-15. Paris: e-CIGRÉ.

HM Government. 2008. "Climate Change Act 2008: Elizabeth II. Chapter 27." In. London: The Stationary Office.

HM Treasury. 2010. "National Infrastructure Plan 2010." In, edited by HM Treasury, 48. London: HM Treasury.

House of Lords Science and Technology Select Committee. 2015. "The Resilience of the Electricity System." In, edited by House of Lords, 110. London: The Stationary Office Limited.

IET. 2014. "Britain's Power System The case for a System Architect." In. London: IET.

"Future Power System Architecture (2016). A report commissioned by the Department of Energy & Climate Change.2 Main Report. Energy Policy." In. Stevenage: IET.

Institute of Civil Engineers. 2014. "The State of the Nation: Infrastructure 2014." In.

Jonas, Andrew E. G., Aidan H. While, and David C. Gibbs. 2010. 'Managing Infrastructural and Service Demands in New Economic Spaces: The New Territorial Politics of Collective Provision', *Regional Studies*, 44: 183-200.

Lockwood, M 2014. 'New Thinking Blog: The Belly Of A (System) Architect', University of Exeter Accessed 09/06/17. http://projects.exeter.ac.uk/igov/the-belly-of-a-system-architect/.

Lockwood, M., and C Mitchell. 2017. "Ofgem Call for Evidence on Future arrangements for the electricity system operator: its role and structure: Submission from Matthew Lockwood and Catherine Mitchell, Energy Policy Group, University of Exeter." In. Penryn: University of Exeter

Newbery, D. 2016. 'Missing money and missing markets: Reliability, capacity auctions and interconnectors', *Energy Policy*, 94: 401-10.

Ofgem. 2017. "Future arrangements for the electricity system operator: its role and structure." In. London: Ofgem.

Scottish Power Networks. 2016. "SPEN DSO Vision." In.

Taylor, P. 2014. 'We need an independent architect to redesign the UK energy industr', *The Guardian*.

Taylor, P. 2015. "Policy Note 1. Batteries included: Electrical energy storage for the grid." In. Newcastle: Newcastle University.

The Institute of Engineering and Technology, and Energy Systems Catapult. 2017. "Future Power System Architecture Project 2: Policy Briefing Paper." In. London.

Traustason, A.D., and H. Þ. Hilmarsson. 2016. "ICELAND – UK INTERCONNECTOR: IS PROPER POLITICAL RISK MITIGATION POSSIBLE? ." In *Fifth International Scientific Conference on Project Management in the Baltic Countries*. Riga, University of Latvia.