Efficient and service oriented infrastructure operation; the role of the Energy Efficiency Directive in driving change towards multi-utility service companies

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Keywords

Energy Efficiency Directive (EED), governance, policy implementation, transition management, institutions

Abstract

Infrastructure operation can be described as separate utility systems provisioning unconstrained demand, with higher throughput corresponding to higher profits. In contrast, an efficiency perspective would prioritize coordinated infrastructure operation focused on essential service delivery at the lowest possible resource use. We investigate how to accelerate the adoption of alternative infrastructure operation configurations which are: centred on the end-user and their demand for services; concerned with implementing resource efficiency improvements; and consider multiple infrastructure streams. We call these alternative modes of operation Multi-Utility Service Companies (MUSCos).

Market and system failures that arise in privatised utility systems present barriers to the adoption of MUSCos. This paper categorises these barriers and investigates the extent to which the European Energy Efficiency Directive (EED) overcomes them. The EED is analysed because energy is required to deliver the majority of household infrastructure services and as a result energy policy will have influence over the related infrastructure systems.

Our research finds that the EED could increase adoption of service-oriented contracts in the public sector, potentially resulting in spillover to the domestic and commercial sector. However, without changes to accounting practices, financial instruments and standardisation of contracts, investment risks and transaction costs would remain high and it is unlikely that this spillover would occur. In addition, the continued fragmentation of policy and cross-sector information asymmetries augments existing barriers to more integrated infrastructure operation.

We describe additional measures that might overcome these weaknesses; including measures to reduce contractual barriers and risks in the domestic sector, provide more appropriate financing and accounting arrangements and more explicitly address the interconnectivity of infrastructure systems in future policy.

Introduction

Our physical infrastructure – the system of energy, transport, digital information, water, waste and flood protection assets – is a means to an end; it is built, maintained and expanded in order to enable the functioning of society and the economy. In turn, however, the technical building blocks of infrastructure and its geographic layout determine, to quite a large extent, the level and composition of a society's resource demand, creating lock-in to certain types of resource dependency and uses (Unruh, 2000). Perhaps more surprisingly, physical infrastructure also shapes the institutional and social organisation of a society, through a historical process of change and evolution described as "co-evolution" (Foxon, 2011). This implies that changing infrastructure operation necessarily involves larger social and institutional shifts as well as technical improvements that are currently considered when scenarios of future infrastructure are described.

The present form of infrastructure operation can be described as separate utility supply systems provisioning unconstrained demand, with higher throughput volumes corresponding to larger economic revenue. There is often little incentive for end-user savings, for example in the UK, the majority of water and waste services are unmetered. This is risky and ultimately unsustainable because unlimited growth in demand means unlimited pressures on ecosystems and natural resources; at a time when we are already well beyond our planetary safe operating space Rockstrom et al., 2009). From the perspective of societal resilience and security of supply, a system which understands and manages demand is much more secure than one of unlimited dependence on external, most often imported and sometimes scarce, inputs (Foresight, 2011).

Technically, a large demand for resources is often a symptom of systemic inefficiencies, since modern technologies in almost every domain enable the same standard of service delivery at drastically lowered consumption levels (Cullen et al., 2011). For example more than 60 % of UK domestic energy costs result from space heating (DECC 2012a) yet if a building is perfectly sealed and insulated, a constant temperature can be maintained without the addition of heat. Since the 1970s, spurred by the oil crisis, research on energy use has demonstrated huge potential for efficient "win-win" technological improvements or behaviour changes that would result in joint resource and cost saving (Lovins 1985). This type of joint economic and technology analysis is now commonplace when considering carbon mitigation options (abatement cost curves, or MAC curves)(McKinsey, 2010), and has been applied to water (2030 Water Resources Group, 2009) and other resource streams measures such as waste reduction (Beaumont and Tinch, 2004).

When such studies are conducted, what is surprising is not just the existence of many diverse win-win, or "no regrets," resource efficient technologies or behaviours, but the magnitude of the macro-economic costs that their adoption would save. In addition, there is a great deal of potential for resource efficiency improvements at the end-user side, which is currently under exploited. This in turn begs the question: if such cost-saving technologies and resource efficiencies exist, why are they not implemented as part of the business-as-usual incentives of market economies? Even if existing actors don't immediately grasp the benefits of new technologies or behaviours, surely new successful enterprises could be established on the basis of these large cost savings. However, no matter the resource stream, application or bundle of resource efficiency measures under consideration, the adoption of many win-win solutions always lags far behind their estimated potential (Cullen et al., 2011). A new approach is needed to accelerate adoption of resource efficient technologies and behaviours.

In the last decade, researchers from the fields of Industrial Ecology and Sustainable Consumption & Production have put forward proposals aiming to circumvent or resolve many of the barriers to efficiency described above, gathered under the title of "performance economy" or "functional economy" (Mont and Tukker, 2006; Stahel, 2010; Steinberger et al., 2009). These ideas require a fundamental shift: away from selling products or metered quantities of utility, and towards selling "services": which can be defined as the ultimate goal of the product or utility purchase. When applied to infrastructure this would mean that the utility company (selling units of utility such as electricity, gas or water) is replaced by a utility service company (which sells the ultimate service provided by the infrastructure, such as thermal comfort, illumination or motive power).

Utility service companies have only been studied in the energy sector (Energy Service Companies (ESCo)). Several studies have investigated the international status (Vine, 2005) and the future potential of ESCos (Hannon et al., in press; Westling, 2003), as well as the European situation, diversity of contract types and economics of service companies (Bertoldi et al., 2006; Marino et al., 2010; Sorrell, 2007). All of the studies agree on the beneficial nature of ESCo operation for the implementation of energy and cost-efficient technologies (including the reduction of initial investment costs and transfer of risk). However, they also agree on the huge obstacles to mainstreaming the ESCo business model, from regulation to lack of information and training to risk sharing. Left to the market, the adoption of these business models has lagged behind expectations, however, there is little work investigating how governance could help to overcome these obstacles or support the transfer of the energy service model to other infrastructures.

In parallel to this, there is increased interest in the risks and opportunities presented by the increasing interconnectivity and interdependence of our infrastructure systems. This interconnectivity occurs at the physical, operational and digital level (CST, 2009a; Hall et al, 2012; Rinaldi et al., 2001). Physical interdependence is well illustrated in the water and energy systems: water and wastewater treatment plants place a significant burden on the energy system, and are becoming more energy intensive as water quality standards become increasingly stringent (CST, 2009a). Conversely, there is a great deal of potential to generate energy within water and wastewater facilities (for, example through anaerobic digestion of sewage sludge and the use of hydro turbines) and support the energy system. Interconnectivity is also important at the end-user level – for example the use of hot water, which accounts for 5.5 per cent of UK household energy use (Defra, 2008). A reduction in hot water use would not only contribute to reductions in water consumption but also to a reduction in energy consumption. The UK government commissioned research to investigate the contribution of UK infrastructure interdependencies to economic growth (Frontier Economics, 2012) and the Infrastructure Transition Research Consortium will develop new methods for analysing performance, risks and interdependencies of UK infrastructure (Hall et al., 2012). While most of this work is focussed on analysing challenges and opportunities of physical infrastructure interconnections within the supply system, little emphasis has been placed on integration of infrastructure at the end user or on integration in operation and governance.

The work presented in this paper has been conducted as part of the EPSRC funded project, Land of the Multi-Utility Service Companies (Land of the MUSCos). Land of the MUSCos investigates how we might accelerate the adoption of alternative infrastructure operation configurations which are: centred on the end-user and their demand for services; concerned with implementing resource efficiency improvements; and take into account multiple utility streams simultaneously. The project considers MUSCo adoption in the UK but many of the finding will be relevant in the EU and beyond.

This paper focuses in particular on the role that the recent Energy Efficiency Directive (EED) plays in the transition to widespread adoption of MUSCos. The EED has been selected for analysis because energy is required to deliver the majority of household infrastructure services and as a result energy policy

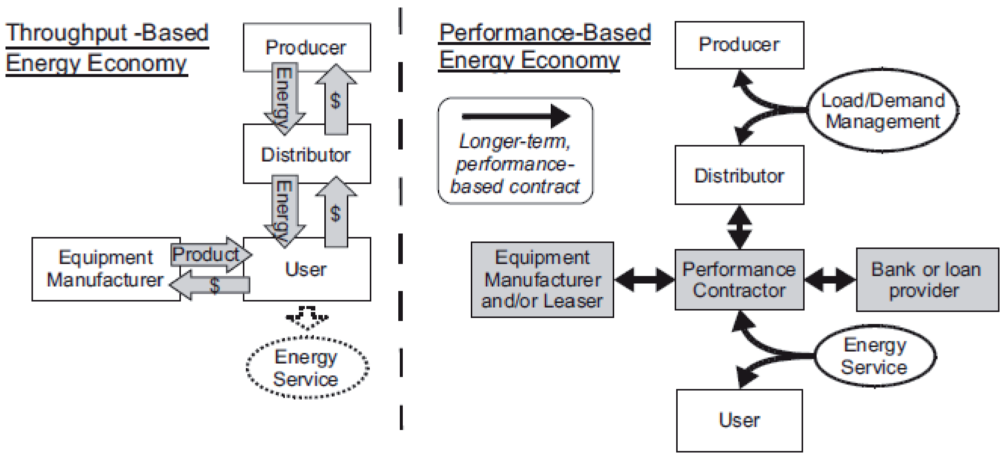

Figure 1. Schematic diagram of traditional vs performance-based incentive structure (Steinberger et al., 2009).

will have influence over the infrastructure systems required to deliver these services. We begin by describing in more detail why service and performance contracts and more integration of operation would lead to more resource efficient and resilient infrastructure. We then describe key barriers, identified through a literature review, to a more service and performance-oriented, integrated mode of operation. The role of energy efficiency governance in overcoming these barriers and accelerating transition to MUSCos is then addressed and exemplified with the EU's Energy Efficiency Directive. We present a review of the extent to which the EED could overcome the barriers identified in the literature review. We conclude with a discussion of the priority areas for future policy.

Multi-Utility Service Companies

The overarching purpose of seeking to accelerate the adoption of MUSCos is the potential step-change in resource efficiency that could be delivered; the MUSCo itself is a means to an end. We define a MUSCo as a means of operating infrastructure which displays the characteristics of service and performance-orientation and integrated "multi" utility delivery with the overarching aim to reduce resource consumption. However, we do not suggest this is the only solution to the efficiency gap described above, but that it is one of a suite of measures required to deliver a more resource efficient and resilient infrastructure system. We define and describe the two core characteristics of a MUSCo in more detail below.

SERVICE & PERFORMANCE-ORIENTED INFRASTRUCTURE

The notion of service and performance-orientation of infrastructure operation builds on the concept of the performance economy or functional economy, which has been applied in detail to the servitization of products (Stahel, 2010). At the product level, the term "Product Service System" is often used to describe new commercial arrangements where a service is sold rather than a product (Mont and Tukker, 2006) . A typical example would be a car-sharing service, as opposed to traditional car ownership. Beyond the raw materials saved by sharing one car between several users, the high level of maintenance and variety of models lead to higher efficiency at each use. Famous examples of companies providing product service systems are Xerox copy machines, Michelin truck tires, Hilti construction tools and Rolls Royce turbines. Generally, product service systems are based on leasing arrangements, where the user defines the level and type of service they will require, and the seller then proposes technically appropriate solutions. By allowing freedom from traditional ownership models, the lifetime of consumer products can be extended, the leased products taken back for remanufacturing at the most optimal time, and higher levels of efficiency along the supply and use chain can be achieved (Stahel, 2010.

At the infrastructure level, an established example of performance contracting is ESCos, which serve their customers by guaranteeing durably lower energy bills whilst maintaining the services provided by energy supplied (Sorrell, 2007). ESCos can take many forms (public, private, part of traditional utility companies, or completely separate), but by definition their profits must be made mostly through the energy savings of their customers. ESCos thus have an incentive structure opposite to that of traditional energy supply companies: they benefit from the lowered energy use of their clients, rather than from their increased consumption (see Figure 1 for a schematic comparison). The ESCo business model thus relies on more than a simple meter for electricity or gas: the basis of the energy contract is no longer the volume of consumption, but a guaranteed provision of energy service provided at a lower level of energy consumption. This performance-based relationship could be applied to other infrastructure services, which often rely on more than one infrastructure system (for example cleanliness depend on energy and water) requiring a more integrated approach to operation.

INTEGRATED INFRASTRUCTURE OPERATION

Infrastructure is becoming more integrated physically (for example, the relationships between energy and water described above), operationally (for example, infrastructure is owned by one party but under the oversight of other organisations) and digitally (for example, the reliance of managed motorways on ICT to manage traffic flows). This leads to risks as one system becomes more vulnerable to cascading failures from other systems (Rinaldi et al., 2001; Zimmerman and Restrepo, 2006). Importantly, operating infrastructure systems in silos leads to "financial and operational inefficiencies, a poorer service to cit-

Table 1. Overview of services provided, related technology categories involved and infrastructure interdependencies.

Service	Technology categories involved	Infrastructure affected			
		Energy	Water	Transp.	Com.
Ambient temperature /thermal comfort	Insulation, heating, cooling, ventilation	✓			(✓)
Illumination	Day illumination, artificial lighting,	✓			(✓)
Industrial process heat and motive power	Heat and physical process appliances	✓			
Hygiene, food & drink preparation (sustenance), hot industrial process water	Water, cleaning, and kitchen appliances	✓	✓		(✓)
Irrigation, cold industrial process water	Water appliances		✓		
Entertainment & communication	Entertainment and communication appliances	✓			✓
Mobility (i.e. personal access to work, education, shopping, and daily leisure, carriage of freight)	Different modes of transport: road (cars, lorries, buses, motorcycles), rail, ship, and human-powered transport; and virtual access modes: tele-working, online education & shopping	✓		✓	(✓)

izens and businesses, and unintended negative consequences" (CST, 2009b).

This inefficiency becomes particularly apparent when one considers infrastructure services at the end user; one service may rely on many infrastructure systems. Optimisation becomes extremely challenging when these systems are operated individually. Table 1 provides an illustration of the interdependence of infrastructure systems at the end-user level (i.e. individual households and industry) from a service perspective. The table does not include interconnectivity upstream of the end-user, for example the energy required to produce cold water. At a glance five different service types could be separated regarding the infrastructure streams affected. Ambient temperature, illumination and industrial process heat and motive power is solely provided through the energy infrastructure, and irrigation and industrial process water only affect the water sector. In between the two hygiene and food and drink preparation requires a combination of energy and water infrastructures. Entertainment and communication requires energy besides the communication infrastructure. Mobility is provided through the transport and energy infrastructure and additionally might include communication when virtual access modes are considered. This highlights the importance of energy policy for infrastructure operation since energy infrastructure is involved in almost all service provision at the end-user level. Furthermore communication might enhance efficiency gains in other infrastructure stream and therefore serve as an enabling technology.

The individual operation of infrastructure systems is currently amplified by fractured governance[1] systems, which have not evolved uniformly across utility streams and rarely take interconnectedness into account (Hall et al., 2012). The governance arrangements have evolved in response to the changes within of the individual utility systems and thus exhibit dramatic differences between sectors. Governance continues to be implemented in sector-specific silos – synergies and interdependencies are largely ignored and opportunities for cost and resource savings are missed. For example, schemes designed to reduce end-use of energy, such as building regulations; for example the Green Deal (DECC 2012b) and the Energy Company Obligation (ECO) (UK Parliament, 2012) don't address the end use of water. This could actively deter MUSCo proliferation by incentivising action in one infrastructure system and precluding more integrated approaches to efficiency.

Barriers to MUSCos

There are no MUSCos according to our definition in operation in Europe; therefore, there is no empirical evidence relating to the principal barriers to their adoption. Instead, in this section we investigate the barriers to the two characteristics of MUSCos; service and performance orientation and integrated delivery.

SERVICE AND PERFORMANCE-ORIENTED INFRASTRUCTURE

A review of literature related to infrastructure services has been undertaken to identify the principal barriers to adoption of service and performance-oriented operation. This is predominantly drawn from the Energy Service literature, owing to the lack of literature on other infrastructure services. The barriers identified are summarised in Table 2[2].

The review identified a number of factors that increased the risk to investors (high investment costs, high transaction costs,

1.We define governance as "the use of institutions, structures of authority and even collaboration to allocate resources and coordinate or control activity in society or the economy." (Bell, 2002). It is not limited to the actions of national governments but includes the policy developed and implemented by a complex network of non-state actors at international and sub-national levels (Smith, Stirling, & Berkhout, 2005).

2. International accounting rules: In the case of an operating lease the annual contracting fee needs to be booked as revenue while the unbilled receivables are reduced. This operation in the balance sheet can have a negative impact on the credit rating. In the case of a financial lease, the total revenue needs to be booked at the end of the project and therefore annual booking is not allowed. In this case, the ESCO needs to finance the VAT for the whole duration of the project (Marino, Bertoldi and Resezzy, 2010).

Table 2. Principal barriers to service oriented infrastructure operation (based on Hall et al., 2012; Marino et al., 2010; Sorrell, 2007 and Hannon et al., in press).

Barrier	Notes
Accounting	International accounting rules (IFRS) can have a negative effect on credit rating or VAT financing. Profits delivered over the medium to long-term.
Financing	Access to financing – lending is asset based and banks are cautious about cash-flow based lending. Disconnect between guaranteed savings and access to finance. Availability and appropriate forms. Potentially high initial investment costs so proposition appears high risk.
Procurement	Excessive tendering requirements puts off smaller companies (many ESCos are small). Public bodies failing to account for lifetime costs. Principal agent problem – landlords own property but would not benefit from savings.
Contracts	Lack of flexibility. Length of commitment. Lack of standardisation – time consuming to develop. Complex contracts. Require collaboration. Unstable consumers and demand driven by external factors.
Monitoring and verification	Unavailability of energy consumption data to produce baselines. Complex definition/specification and verification of service delivered.
Awareness and trust	Few examples outside industry and public sector. Poor levels of awareness and knowledge of service-oriented offers. Mistrust of consumers and little experience of service contracts.
Scale	Risks dispersed and difficult to manage. Inappropriate scale for financing. Reverse economies of scale – out competed by incumbents.
Governance	Perverse incentives, such as cross-subsidised energy prices. Lack of specific regulatory framework or accreditation schemes for service contracts. Poor future regulatory stability. Regulation to improve competition in monopoly sectors prevents appropriate length of contracts. Regulation prevents generation of revenue from sources other than utility throughput (for example UK Water Industry).

Table 3. Principal barriers to integrated infrastructure operation (based on CST, 2009a; Frontier Economics, 2012; Hall et al., 2012).

Barrier	Notes
Governance	Inappropriate incentives. Regulation in silos prevents cross-utility operation, accounting and investment. Strategic planning in national policy is fragmented.
Decision making processes	Decision making processes are locked into consideration of separate infrastructure operation by business practices, planning process and regulation. Poor information sharing.
Co-ordination	Information asymmetries can lead to market failures when one party has more information about the nature of an activity or risk than another party. Integration between systems requires co-ordination over time and scale, which implies significant changes in business planning and operation.
Cost externalities	One infrastructure system may affect another without any need for the cost and benefits of that impact to be taken into account.
Evidence	There is limited quantification of the risks and benefits of infrastructure integration, which makes action difficult.

lack of ability to secure long-term contracts, scale of project, and uncertainty over government incentives); increased risk to end-users (contractual flexibility, verification of savings, poor awareness and knowledge) and structural barriers (revenue generation, competition regulation).

INTEGRATED INFRASTRUCTURE OPERATION

A separate review of literature related to infrastructure integration was undertaken to identify the principal barriers to integrated infrastructure operation. This is predominantly related to integration upstream of the end-user, owing to the lack of literature addressing integration at the end-user. The barriers identified are summarised in Table 3.

The review identified that a lack of evidence of risks and opportunities was contributing to segregation of infrastructure systems and compounding ineffective regulation, decision making and costing of the effects of infrastructure interconnectivity.

The contribution of the Energy Efficiency Directive to overcoming barriers to MUSCos

Infrastructure provides a public good; therefore, the services it delivers need to be reliable, at a sufficient level of quality and quantity, and offer value for money. Governance, usually in the form of regulation and policy intervention, is needed to correct the market and system failures that would arise in a purely privatised utility system, many of which contribute to the barriers identified above. For example, the market does not deliver the required investment into infrastructure development as a result of scale of investment required and the long pay-back periods and most often indirect benefit to private entities (Hall et al., 2012). Non-traditional technologies and business models (for example ESCOs) are often under-represented as a result of market imperfections, such as information asymmetries and monopolistic competition (Hall et al., 2012). Governance is required to encourage investment and innovation that would not be delivered by the market alone, therefore it has a key role in accelerating the adoption of MUSCos.

There has been a plethora of recent directives and strategies relating to resource efficiency, which, in effect, seek to achieve the same aim as MUSCos; to reduce absolute resource consumption, without reducing the service delivered (for example, the EU 20-20-20 targets, Roadmap to a Resource Efficient Europe (European Commission 2011), the Energy Efficiency Directive (European Commission 2012)). These policy instruments have the potential to affect the barriers described above both positively and negatively. Energy policy, in particular, has significant potential to affect the adoption of MUSCos as a result of its promotion of infrastructure services (ESCo) and the fact that energy is involved in the majority of infrastructure services. As a result, we have undertaken a detailed review of the EU's Energy Efficiency Directive (EED) (European Commission, 2012) to identify the extent to which it addresses and is likely to overcome the barriers identified above. We present our findings in the sections below for the two characteristics of MUSCos.

SERVICE AND PERFORMANCE-ORIENTATION

The EED has made provision for significant advancements on the promotion of service oriented infrastructure operation. It specifically addresses measures to increase the adoption of 'energy performance contracting[3]' and the contribution of 'energy service providers[4]' to energy efficiency. The measures defined to encourage adoption of energy service provision and energy performance contracting have been evaluated to determine the extent to which they could overcome barriers to wider infrastructure service-oriented contracts.

Accounting: The Directive makes explicit reference to removing accounting barriers to service companies (paragraph 48 of introduction) and Member States will be required to report on progress towards removing regulatory barriers in their National Energy Efficiency Action Plans. It goes on to state in Article 15 (8) that "Member states shall ensure that national energy regulatory authorities encourage demand side resources, such as demand response, to participate alongside supply in wholesale and retail markets", which implies that barriers to generation of revenue from alternative sources should be removed if this article is implemented effectively. It is not clear to what extent this will help to overcome international accounting rules that affect credit ratings.

Financing: Loan guarantees to foster energy performance contracting are specifically mentioned in paragraph 52 of the introduction as a means to overcoming barriers to the availability of financing. Article 12 requires Member States to take appropriate measures to promote and facilitate efficient use of energy generally, which include fiscal incentives and access to finance, grants or subsidies. More specifically, Article 18 requires Member States to promote the energy services market *disseminating information* on financial instruments, incentives, grants and loans to support energy efficiency projects. There is no requirement to support appropriate forms of financing specifically for service contract.

Procurement: Article 6 (3) *Encourages* public bodies to "assess the possibility of concluding long-term energy performance contracts that provide long term energy savings". It does not provide any provision for changing procurement processes to assess lifetime costs or address procurement in landlord-tenant arrangements.

Contracts: A major advancement of the EED is its promotion of model contracts; paragraph 47 of the introduction recognises the vital role they will play in stimulating demand for and the supply of energy services. Article 18 reiterates this point requiring Member States to provide model contracts for the public sector, including a specific Annex (XIII) outlining the minimum items to be included in energy performance contracts with the public sector. However, this requirement does not extend beyond the public sector to the domestic sector, which is where transaction costs are higher still (Sorrell, 2007).

Monitoring and verification: Article 8 of the EED requires Member States to *promote* the availability of energy audits and specifically states that the findings of these audits must be available to energy service providers. This could improve the baseline data making initial requirement description more straightforward. However, there is no reference to measures that might improve the quantification and verification of savings.

Awareness and trust: The EED recognises the importance of transparency in developing the market for energy services. Article 12 specifically addresses consumer information and empowering, requiring Member States to "take appropriate measures to promote and facilitate an efficient use of energy". And in relation to energy services requires them to disseminate information on the energy service contracts, financial instruments, incentives, grants and loans specifically relevant to "energy efficiency service projects". It also requires Member States to make publicly available lists of available energy service providers. This could go some way towards increasing awareness in and trust of service contracts.

Scale: There is only one statement relating to the barrier associated with the challenge of appropriate scale of contracts and finance; in paragraph 52 of the introduction stating that financing facilities could be "linked to programmes of agencies which will aggregate and assess the quality of energy saving projects, provide technical assistance, promote the energy services market and the to generate consumer demand for energy services". There are no specific clauses or requirements to enact this aggregation function.

3. Defined in the EED as "a contractual arrangement between the beneficiary and the provider of an energy efficiency improvement measure, verified and monitored during the whole term of the contract, where investments (work, supply or service) in that measure are paid for in relation to a contractually agreed energy performance criterion, such as financial savings".

4. Defined in the EED as "a natural or legal person who deliver energy services [the physical benefit, utility or good derived from a combination of energy with energy-efficient technology or with action, which may include the operations, maintenance and control necessary to deliver the service, which is delivered on the basis of a contract and in normal circumstances has proven to result in verifiable and measurable or estimable energy efficiency improvements] or any other energy efficiency measure in the final customer's facility or premises".

Governance: The EED recognises the need for an integrated approach to energy efficiency (in paragraph 45) and the need to "identify and remove regulatory … barriers to the use of energy performance contracting …". There are some specific issues identified; in Article 7 (7) allows obligated parties to count savings from energy service contracts to count towards Energy Efficiency Obligation schemes; Member States are required to ensure national energy regulatory authorities encourage demand response; Article 19 requires Member States to "evaluate and if necessary take appropriate measures to remove regulatory and non-regulatory barriers to energy efficiency".

In summary, the EED specifically addresses participation of demand-side management in the wholesale electricity market, fiscal incentives to reduce the risk of investment in energy efficiency technologies, model contracts in the public sector, energy audits to improve monitoring of baseline conditions, dissemination of examples and providers or energy services and removal of regulatory barriers to energy performance contracting. However, it does not address international accounting rules, financing specific to energy services, lifetime cost assessment of energy contracts, verification of savings or aggregation of small contracts or model contracts for domestic or commercial users to reduce transaction costs.

INTEGRATED INFRASTRUCTURE OPERATION

The EED is, of course, focussed on the energy system and efficiency improvements therein. However, measures contained within the EED have been assessed to identify the potential to overcome or augment the disconnection in infrastructure operation and regulation by prioritising energy over other infrastructure systems.

Governance: The EED does consider infrastructure integration, to some extent, through its promotion of cogeneration of electricity, heat and hot water. There are two articles (14 and 15), which aim to encourage new high efficiency cogeneration and reduce the regulatory barriers associated with connection to the grid. Article 9 (3) also provides a mechanism for allocating costs for heat and hot water produced by cogeneration, which could provide a demonstrator that could lead the way to overcome the barriers of price regulation and cross-sector accounting. However, the Directive places a great deal of emphasis on providing and marketing incentives, loans and grants specifically for energy efficiency, which could distract from a more integrated approach to resource efficiency.

Decision making processes: are addressed to some extent in the EED by Article 6 (1), which states that central government should "purchase only products, services and buildings with high energy-efficiency performance, insofar that it is consistent with … wider sustainability …". And that energy audits might be undertaken as part of a broader environmental audit. However retrofitting targets set out in Article 5 are specifically for energy performance, which misses the opportunity to undertake a wider energy efficiency-driven retrofit and could drive retrofit decisions to focus on individual infrastructure systems.

Co-ordination: is encouraged to some extent in the directive, by Article 6 on procurement, Article 8 on energy audits and Articles 14 and 15 on cogeneration. However, there are some significant opportunities for co-ordination missed, in particular, the targets for retrofitting, as discussed above.

There are no articles or requirements that would specifically improve the evidence base relating to the risks and benefits of infrastructure integration or address the challenge of unaccounted cost externalities.

In summary, the EED could help overcome barriers to integration by encouraging the cogeneration of electricity, heat and hot water and encouraging consideration of wider sustainability in energy audits and energy service procurement. However, it could amplify barriers by focussing on energy incentives, audits and marketing and setting retrofitting targets for energy alone, which could detracting from efficiency across systems.

Discussion

Despite its focus on the energy system, the EED goes a long way towards encouraging service-oriented infrastructure operation and has the potential to prepare the way for service-based contracts in other infrastructure systems. The EED provides some of the strongest instruments for energy efficiency to date, including a series of quantitative target, energy-efficient retrofitting and provision of financing and grants for energy efficiency. It also specifically addresses service contracts through measures to raise awareness of service contracts and service providers. Its requirement to provide model contracts could drastically reduce transaction costs associated with contract establishment in the public sector.

However, some crucial barriers will not be addressed if it is transposed into national policy in its current form. This is particularly the case for barriers associated with financing and accounting; including international accounting rules, accounting by lenders, development and provision of appropriate forms of finance, and profit timescales.

The EED does little to reduce the risks and transaction costs associated with domestic and commercial service and performance-oriented contracts. Some of the instruments with most potential to address contractual barriers, such as long-term contracts and model contracts, are only applied to the public sector. This omits the huge opportunities for efficiency saving in the domestic and commercial sectors where there are perhaps more significant barriers to MUSCo adoption (Sorrell, 2007). This is compounded by the fact that there are no specific instruments that would improve the definition and specification of energy services for verification and no instruments designed to improve aggregation or 'bundling' of contracts with smaller end-users.

There are few provisions to exploit opportunities for efficiency from a more integrated approach to infrastructure operation. Some of the strongest measures in the Directive (the quantitative targets for reductions in energy consumption and energy-specific retrofitting on central government property) have the potential to discourage integration in infrastructure operation by putting too much focus on one sector.

In addition, there is no proposal to remove the barrier created by regulation, intended to increase competition in utility supply, which prevents utility providers from committing customers to long contract. This is also the case for the target for retrofitting, which only applied to central government. This excludes opportunities in local government and domestic buildings.

Some outstanding issues that would help strengthen the role of the EED in accelerating the adoption of MUSCos include:

- Removing regulation to prevent long term contracts in the domestic sector;
- Introducing standard or model contracts in the domestic and commercial sectors;
- Developing financing arrangements which are appropriate to service contracts and reduce high initial investment requirements;
- Provide detailed support on the definition and specification of services to support development and verification of contracts;
- Encourage the development of coherent and integrated strategies across infrastructure systems;
- Provide guidance and incentives for aggregation of small-scale contracts to reduce transaction costs in the domestic and commercial sectors;
- Explicitly recognise the interconnectivity of infrastructure during the development of future Directives.

Conclusions

MUSCos have the potential to contribute to improvements in the resource efficiency of infrastructure systems and to overcome the efficiency gap observed in current resource efficiency policy. However, there are numerous barriers to the realisation of service-oriented, integrated infrastructure operation. The widespread adoption of MUSCos is unlikely to come about if left entirely to the market; governance must intervene to overcome the market barriers and remove obstructive policy and regulation.

In this paper we have investigated the extent to which the Energy Efficiency Directive could begin to reduce barriers to MUSCo adoption. The review found that the EED could be very effective at increasing adoption of service-oriented contracts in the public sector through measures legislating building retrofit and reducing contractual barriers. This could increase the energy service sector's capacity to deliver service contracts and reduce mistrust of service contracts, potentially resulting in spillover of service contracts to the domestic and commercial sector. However, without changes to accounting practices and appropriate financing arrangements investment risks would remain high. In combination with a lack of measures to reduce the risk and costs of administering small-scale contracts it is unlikely that this spillover would occur in reality.

In addition, the continued fragmentation of European and National strategy and cross-sector information asymmetries[5] augments the existing governance barriers to more integrated operation of infrastructure which prevents the exploitation of cross-sector efficiency opportunities.

We have described a series of additional measures we consider to be necessary to overcome these weaknesses. These include measures to reduce contractual barriers and risks in the domestic sector, provide more appropriate financing and accounting arrangements and more explicitly address the interconnectivity of infrastructure systems in future policy.

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5. For example it is disproportionately harder to justify investment in low carbon technology to the end user in the water sector than in the energy sector. Users of water are generally unaware of the benefits of low carbon technologies in relation to supply of clean water. This can prevent investment in these technologies and constrain opportunities to generate energy on water company property.

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Acknowledgements

The authors gratefully acknowledge the support of the UK Engineering and Physical Sciences Research Council who funded this work (grant number EP/J00555X/1). Thanks also to Catherine Bale and an anonymous reviewer for their insightful comments on drafts of this paper.