The economics of energy service contracting

Steve Sorrell
SPRU (Science & Technology Policy Research)
Freeman Centre, University of Sussex
Falmer, Brighton, BN1 9QE
UK
s.r.sorrell@sussex.ac.uk

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Abstract

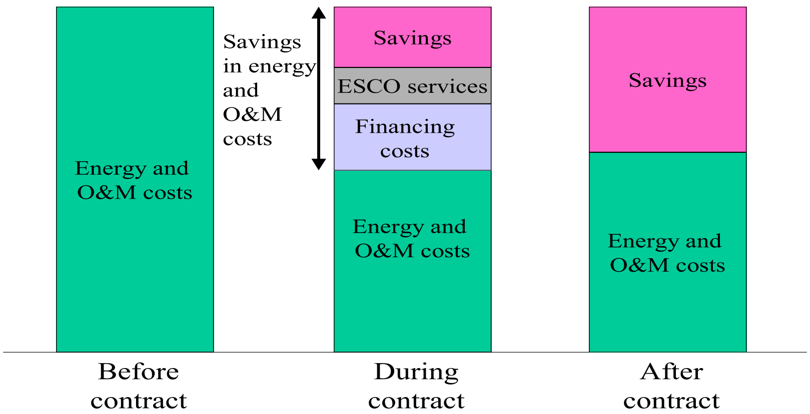
Energy service contracting can provide a cost-effective route to overcoming barriers to energy efficiency. Energy service contracts allow the client to reduce operating costs, transfer risk and concentrate attention on core activities. However, the energy services model may only be appropriate for a subset of energy services and energy using organisations. A challenge for both business strategy and public policy is to identify those situations in which energy service contracting is most likely to be appropriate and the conditions under which it is most likely to succeed.

Energy service contracting is a form of outsourcing. It will only be chosen where the expected reduction in the *production cost* of supplying energy services can more than offset the *transactions cost* of negotiating and managing the relationship with the energy service provider. Production costs will be determined by a combination of the physical characteristics of the energy system and the technical efficiency of the relevant organisational arrangements, including economies of scale and specialisation. Transaction costs, in turn, will be determined by the complexity of the energy service, the 'specificity' of the investments made by the contractor, the 'contestability' of the energy services market and the relevant legal, financial and regulatory rules. This paper develops these ideas into a general framework that may be used to assess the feasibility of energy service contracting in different circumstances. The framework leads to a number of hypotheses that are suitable for empirical test.

Introduction

A core theme in contemporary discussions of sustainability is the recasting of final demand in the economy as a collection of services rather than a collection of products (Jackson, 1996, ; Stahel, 1997). For example, consumers ultimately require mobility and cleaning rather than private cars and washing machines and there are ways of providing such services at lower environmental cost (James and Hopkinson, 2002). While the concept and practice of energy service contracting predates this contemporary discourse, it provides an important illustration of how the 'service model' may become a commercial reality.

In its most developed form, energy service contracting allows the client to minimise the total bill for the services that energy provides, (e.g. heating, lighting) through a single contract with an energy services provider. This contrasts with the traditional model in which energy consumers contract separately for each energy commodity and for different types of energy conversion equipment. Energy service companies (ESCOs) offer comprehensive contracts that include energy information and control systems, energy audits, installation, operation and maintenance of equipment, competitive finance, and fuel and electricity purchasing. These contracts allow the client to reduce energy costs, transfer risk and concentrate attention on core activities. The energy services model may provide an effective route for the diffusion of low carbon technologies and has the potential to develop into wider *carbon services*, including carbon offsetting, renewable energy purchasing and participation in emissions trading.



Source: FEMP (2001)

Figure 1. *Cash flows for an energy performance contract.*

While energy service contracting is endorsed for both business and environmental reasons (Hansen and Weisman, 1998, ; Bertoldi, Renzio et al., 2003), it has attracted little academic scrutiny. Most of the existing literature is from industry and government sources and makes little reference to economic theory.[1] The energy services model has important parallels with other forms of outsourcing and with the private financing of public sector infrastructure, but insights from studies into these topics have rarely been applied to the energy field. As a result, the determinants of the size and nature of the energy services market are poorly understood, as is its long-term potential. This makes it difficult to assess the potential contribution of energy service contracting to a low carbon economy or to assess whether a long-term transition from energy commodity to energy service supply is a realistic or a desirable goal.

This paper seeks to explain why energy service contracting is suitable for some energy services in some circumstances and not for others. It does so by developing a theoretical model of energy service contracting that draws upon ideas from Transaction Cost Economics (TCE). These ideas have been successfully tested in a number of applications (Shelanski and Klein, 1995, ; Reindfleisch and Heide, 1997) and appear particularly well suited to the outsourcing decision (Globerman and Vining, 1996). The model assumes that the primary objective of energy service contracting is to minimise the sum of the *production cost* of supplying energy services and the *transaction cost* of negotiating and managing the relationship with the energy service provider. The model is confined to energy service contracting in the industrial, commercial and public sector, which is where the market is most developed.

The paper is structured as follows. The next section explains the nature of an energy services contract and clarifies the terminology in common use. The following two sections introduce a framework for defining the scope and coverage of an energy services contract, and demonstrate that an individual contract can take a wide variety of forms. The paper then argues that cost minimisation is a necessary, if not sufficient motive for contracting and identifies the factors that contribute to such cost savings. The nature, origins and determinants of the transaction cost of contracting are examined, and the application of these to the energy service context is explored. The final section combines these insights to propose some testable hypotheses regarding where energy service contracting is most likely to be used.

The nature of an energy service contract

It is standard practice for organisations to use external companies to perform one or more activities related to the provision of energy services: for example, installing, commissioning, operating and maintaining equipment, purchasing energy commodities and identifying energy saving opportunities. But the conditions under which these activities can be classified as *energy service contracting* and the companies that provide them as *energy service companies* (ESCOs), is disputed. For example, the UK Energy Services Trade Association uses the term *contract energy management* (CEM) rather than energy service contracting and defines qualifying CEM companies as those that manage some aspects of their clients' energy use under a contract which transfers some of the risk from the client to the contractor (usually based on providing agreed 'service' levels).[2] This definition does not require the contractors to finance any investment, but does imply a long-term contract in which the contractor is accountable for equipment performance. In contrast, German and Austrian commentators frequently use the term *Third Party Financing* (TPF), which implies that the source of investment finance is the critical issue (Egger and Öhlinger, 2003).

The energy service market is most established in the United States, where the term *performance contracting* is employed (Singer, 2002). This is defined as providing 'energy savings' to a customer for a fee, the level of which depends upon the amount of energy saved (WEEA, 1999). ESCOs

1. Useful publications include Hansen and Weisman (1998), Bertoldi (eds) (1993) and Singer (2002)
2. http://esta.kiwi.co.uk/

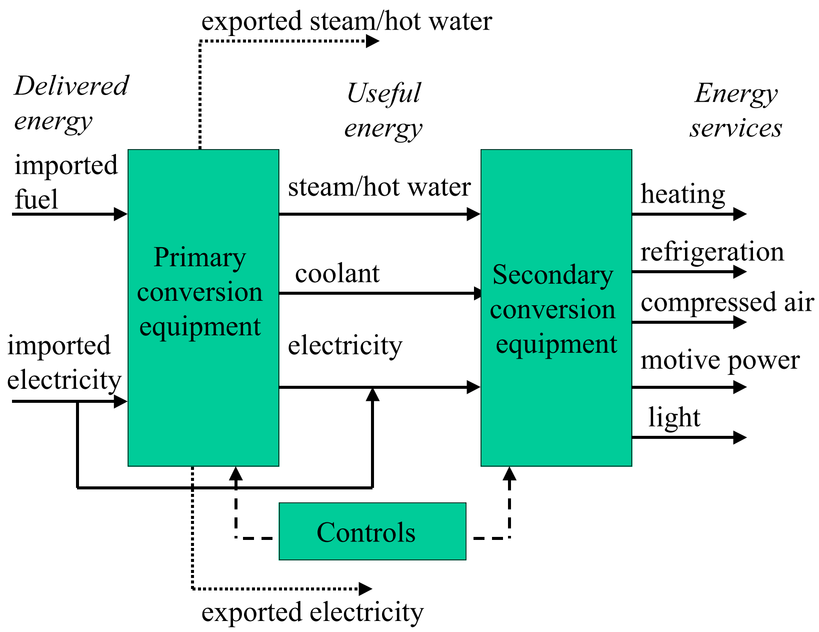


Figure 2. *Final energy, useful energy and energy services within a single customer site.*

are then defined as companies that provide performance contracting as a core part of their business (Goldman, Hopper et al., 2005, 3). Performance contracts typically involve investment in energy conversion equipment, but differ from turnkey projects since the contractor has a long-term responsibility for equipment performance, coupled with an incentive to improve performance. Similarly, performance contracts typically involve energy audits, but differ from energy consulting since the contractor is paid for the results achieved. Since payment is in proportion to the amount of energy saved, performance contracts require the establishment of baselines for energy use, together with ongoing monitoring and verification (Kats, Rosenfeld et al., 1997).

Figure 1, which is taken from the US Federal Energy Management Programme (2001), illustrates the financial logic of a performance contract. The investment in energy conversion, distribution and control equipment lowers the production cost of supplying energy services – where the latter includes the cost of purchasing energy commodities and the operation and maintenance costs of the equipment. These savings are used to cover the financing cost of the investment, with the remainder being shared between the ESCO and the client. The contractor has an incentive to maximise savings during the lifetime of the contract, while the client is guaranteed a minimum level of savings. When the contract comes to an end, all the savings go to the client.

The scope of an energy service contract

The US performance contracting market is concentrated in the public sector and is focused on improving the overall energy efficiency of buildings (Goldman, Hopper et al., 2005).[3] In contrast, the UK CEM and German TPF market is concentrated in the private sector and is focused on improving the efficiency of steam, hot water and electricity supply within industry (Helle, 1997). The differences between the two may be illustrated with the help of Figure 2, which shows the energy flows within a general customer site. Here, *delivered energy* represents energy commodities such as coal, gas and electricity, which are traded through conventional energy markets. Primary conversion equipment, such as boilers and CHP converts the delivered energy into various forms of *useful energy,* such as steam, hot water and coolant. In turn, secondary conversion equipment such as radiators, motors and drives converts the useful energy into final energy services, such as space heating, motive power and light. Electronic controls are standard for both types of conversion equipment and frequently link the two.

This framework allows the *scope* of an energy service contract to be defined in terms of its overall coverage of both useful energy streams and final energy services. In general, a contract will cover one or more streams of useful energy, and/or one or more types of final energy service. At one extreme, a contract could cover a single useful energy stream or a single final energy service, while at the other extreme a contract could cover all the useful energy streams and all the final energy services for an entire site.

Many of the UK CEM and German TPF contracts focus solely on the primary conversion equipment, such as boilers and CHP.[4] Hence they cover one or more streams of useful energy, but do not cover secondary conversion equipment and final energy services. Such contracts may be termed *supply* contracts since payment is typically on the basis of a specified per-unit price for the useful energy supplied,

3. A comprehensive review by Goldman et al (2005) found a total of 771 projects in the public sector with a total project cost of $1 677 Billion. In contrast, there were only 309 projects in the private sector with a total project cost of $260 Billion.
4. Frost and Sullivan estimated that performance contracting represented only 5% of the market for 'contract energy management' in Europe, with the remainder being supply contracting.

Table 1. Three approaches to energy service contracting.

	Supply contracting	End-use contracting	Performance contracting
Energy focus	Useful energy	Energy services	Delivered energy
Sectoral focus	Industry	Industry	Public and commercial buildings
Example technologies	Boilers, CHP, refrigeration, compressed air, industrial gases	Motors and drives, compressed air, lighting	Boilers, CHP, refrigeration, compressed air; HVAC, heat recovery, lighting, motors and drives, building fabric.
Contract scope	Narrow	Narrow	Wide
Typical basis of payment	Per unit cost of useful energy.	Per unit cost of energy service	Reduction in delivered energy demand compared to baseline
Providers	Boiler/CHP vendors; ESCOs	Equipment vendors; engineering firms	ESCOs
Production cost savings	Medium	Medium	High
Transaction costs	Low	Medium	High

Source: Based on (Ramesohl and Dudda, 2001)

which is lower than the pre-contract supply cost.[5] The contract revenues must cover the post-contract cost of supply together with the transaction costs incurred by the contractor, while still providing an acceptable return on investment. The contract provisions normally include indexing to the relevant fuel and electricity prices, together with minimum standards for supply quality and availability. The contractor has an incentive to maximise the technical efficiency and minimise the O&M costs of the relevant primary conversion equipment, which in turn will reduce the demand for delivered energy. However, the contractor is unlikely to guarantee a reduction in delivered energy consumption since she lacks control over both the efficiency of secondary conversion equipment and the demand for final energy services. Hence, if the scope of the contract is confined to primary conversion equipment, supply contracts are likely to be the norm.

In contrast to European practice, most US *performance* contracts include both primary and secondary conversion equipment and often seek to be comprehensive in their scope. Payment here can be on a variety of terms, but is usually linked to either a reduction in the demand for delivered energy or a reduction in the total cost of supplying the relevant types of final energy service, compared in each case to a specified baseline level. The former approach allows for savings in the energy purchase costs incurred by the customer, while latter approach allows for additional savings such as the elimination of outside maintenance contracts. In both cases, the contract will include minimum standards for the availability and quality of final energy services, such as specified illumination levels for office lighting. The contract will also include indexing provisions for fuel and electricity prices, together with adjustment procedures to allow for factors outside the contractor's control, such as weather conditions or building occupancy. Provided the quality standards are met, the contractor may reduce costs by reducing the demand for individual energy services - for example, by improving lighting controls so that lights are switched off when a room is unoccupied.

This general framework also points to a third type of energy service contract, which is focused solely on one or more final energy services. For example, motor equipment vendors are increasingly providing ancillary equipment such as controls, sensors and variable speed drives, together with associated service packages such as financing, commissioning, installation, servicing and remote monitoring (Neal Elliot, 2002). Payment for these *end-use* contracts can be on the basis of a specified per-unit price for the energy service, which gives the contractor an incentive to minimise the per-unit cost of supply.[6] Since several of the factors that influence these costs are outside the contractor's control (e.g. energy prices), the contract must again include appropriate indexing and adjustment provisions.

Since each of the above approaches can link payments to equipment performance within the framework of a long-term contract, each may be classified as a type of energy service contract. And since the potential for reducing the production costs of supplying energy services may be expected to increase with the scope of the contract, performance contracts that maximise scope may be seen as the preferred solution ('total energy management'). As argued below, however, consideration of the transaction costs of contracting will modify this conclusion.

The differences between these three approaches are summarised in Table 1. While in principle the distinction is clear, in practice contracts can take a variety of hybrid and intermediate forms. For example, heat supply contracts often include secondary conversion equipment and controls; performance contracts may begin with a single energy service (e.g. lighting only) and expand over time; and all contracts may extend beyond energy to include water supply, wastewater disposal and wider facilities services such as security and telecommunications.

5. It is common to use a fixed charge to meet capital and O&M costs together with a variable charge for fuel and consumables.
6. For example, E.ON Ultra Air offers contracts for compressed air services, including design, installation, finance, operation and maintenance. Supply is priced in _/m3, declining with volume, with electricity costs paid for separately.

Table 2. Key considerations within an energy service contract.

Area	Issues
New equipment	Specification; selection; cost; responsibility for installation and commissioning.
Maintenance	Division of responsibilities, monitoring
Operation	Division of responsibilities, monitoring; coordination
Equipment ownership	Rights during and after contract; buyback provisions
Calculation of energy savings	Baseline energy consumption and operating conditions; assumptions; formulae; adjustment for factors beyond the contractor's control
Service standards	Acceptable parameters for temperature, lighting, air exchange and other factors
Monitoring and verification	Protocols and standards for monitoring and verifying energy consumption and savings
Pricing and payment provisions	Fixed and variable components of pricing; guarantees to customer; division of savings
Adjustment to external changes	Adjustment to inflation, changes in energy prices and other factors
Other	Provisions for backup service in event of malfunction; insurance; dispute resolution; provisions for early termination; penalties for contract breach; exit strategies etc.

Source: Based on Hansen and Weisman (1998)

The coverage of an energy services contract

In the above framework, a contract may be defined as 'covering' a particular useful energy stream or final energy service if the contractor is responsible for one or more *activities* for one or more of the *technologies* that are required to supply that stream or service. The relevant activities include design, finance, purchase, installation, commissioning, refurbishment, insurance, operation, maintenance and control. The relevant technologies include the conversion, distribution and control equipment, but also any additional equipment that may contribute to the supply of that service. For example, heating and lighting are provided actively by the conversion of delivered energy carriers, but also passively by sunlight mediated through building structures and orientation. So here the relevant technologies include building fabric, thermal insulation and glazing, and these may also be covered by the energy services contract. In increasingly liberalised energy markets, it also common for contracts to include fuel and electricity purchasing.

In general, for an individual useful energy stream or final energy service, a contract will cover one or more of the relevant technologies and one or more of the relevant activities. A contract would have full coverage of a particular useful energy stream or final energy service if the contractor were fully responsible for all these activities for all of the relevant technologies. In contrast, a contract would have partial coverage if the responsibility were shared between the contractor and the client. While in principle the contract coverage could vary between different streams and services, in practice it is likely to be fairly uniform.

As with contract scope, the potential for reducing the production costs of supplying energy services may be expected to increase with contract coverage. Indeed, a minimum coverage is necessary if a contractor is to be held accountable for equipment performance. But again, maximising contract coverage may not be the optimum solution when transaction costs are taken into account.

The coverage of a contract will largely determine the division of responsibilities, property rights, incentives and risks between the client and contractor, and these must be carefully designed and monitored if both parties are to benefit. Table 2 lists some of the factors to be taken into account when developing such a contract.

The motives for an energy service contract

Energy service contracting is a specialised form of outsourcing and has much in common with other outsourcing contracts, such as those for security, buildings maintenance, telecommunications and information technology. All of these have experienced substantial market growth since the late 1980s and the latter in particular has become a multi-billion dollar industry (Lacity and Willcocks, 1998). There is now a wealth of literature on the economics of such arrangements, including theoretical models, detailed case studies and quantitative surveys incorporating formal hypothesis tests.[7] Surprisingly, these ideas have not been applied to the energy service market.

The primary motive for outsourcing is to reduce the costs of supplying a particular commodity or service, and there is good evidence that substantial cost reductions can be achieved (Domberger and Jensen, 1996). The most comprehensive evidence of the specific benefits of energy service outsourcing comes from a survey of the US market by Goldman *et al* (2005), who found a median benefit-cost ratio of 1.6 for public-sector energy service contracts and 2.1 for private sector contracts.[8] Interviews with UK ESCOs suggest a broader range of client motivations, including productivity and comfort improvements, compliance with health, safety and environmental regulations and replacement of unreliable or obsolete equipment.[9] However, many of these can be properly regarded as financial benefits (albeit difficult to quantify) and hence should be allowed for in the cost-benefit calculus.

Studies such as Goldman *et al* (2005) focus on the production costs of supplying energy services, as embodied for ex-

7. Papers on the economics of outsourcing include (Poppo and Zenger, 2002) (Aubert, Rivard et al., 1996) and (Wang, 2002). Papers on the economics of private finance for public infrastructure include (Grout, 1997) and (Parker and Hartley, 2003). Hirschheim et al (2002) provide a useful overview on the outsourcing literature for information services.
8. Using discount rates of 7% for public sector projects and 10% for projects in the the private sector.
9. The author conducted ten interviews with representatives from UK ESCOs in the summer of 2004.

ample in the contract price for useful energy. This includes the energy, operation, maintenance and financing costs, but neglects the transaction costs of negotiating and monitoring the relationship with the energy service provider. In some circumstances, these transaction costs may outweigh the savings in production costs and hence make energy service contracts unviable. But while these transaction costs are difficult to quantify, their determinants are well established and should be taken into account by the client when making the outsourcing decision. Contractors should also take these factors into account and will not bid for projects where the transaction costs are too high. The following sections examine the determinants of production and transaction costs in more detail, drawing in particular on the framework proposed by Globerman and Vining (1996).

The production costs of an energy services contract

Each stream of useful energy at a site will have an associated in-house production cost, as will each energy service. The extent to which an energy service contract can lower these costs for a particular stream or service will depend in part upon the characteristics of the relevant technologies, including the technical potential for improved conversion and distribution efficiency (whether through refurbishment or replacement) and the scope for efficiency improvements through improved operation, maintenance and control. While this potential is fixed by the nature of the technology, the extent to which it is actually realised will depend upon the organisational differences between in-house production and contracting. There are three main reasons why ESCOs may able to achieve greater savings (Globerman and Vining, 1996, 579):

- *Economies of scale:* Since their energy costs are often small in both absolute terms and as a proportion of total costs, many client organisations lack the scale to manage energy efficiently. For example, energy management is often allocated to a single, time-constrained facilities manager who combines inadequate skills and training with multiple responsibilities (Sorrell, Schleich et al., 2004). In contrast, ESCOs that specialise in energy management and contract with multiple clients have the potential to achieve considerable scale economies. For example, ESCOs may be able to obtain bulk discounts on energy purchasing by having a single supply contract to cover multiple client sites. Similarly, ESCOs may have greater access to information, skilled labour and managerial expertise in the relevant areas and may leverage these benefits by having individual staff serve a number of clients. Such staff should be able to develop and apply specialist skills that would not be feasible within the client organisations and to rapidly disseminate learning benefits between different clients.
- *Economies of scope*: Related to insufficient scale, it is possible that client organisations will face diseconomies of scope in attempting to manage multiple activities (Globerman and Vining, 1996, 579). For example, a hard-pressed facilities manager may be able to devote only a fraction of his time to energy managment. Outsourcing may therefore allow managerial staff to concentrate attention on 'core competences' and more strategic issues.
- *Market incentives*: If energy is managed in-house, the relevant staff will be shielded from the incentives of market competition and senior management may lack adequate monitoring and/or benchmarks to assess staff productivity. The result may be 'X- inefficiency' (Leibenstein, 1966) or 'monopolistic' pricing of energy services above the marginal cost of supply. By introducing competitive bidding for these services, such inefficiencies may be reduced.

In general, we would expect the ESCOs' advantage in terms of scale economies to be inversely related to the *size* of the client, as measured by the production cost of supplying energy services. While smaller clients will lack both staff and technical resources, larger clients may have dedicated and competent in-house energy management. Similarly, we would expect the ESCOs' advantage in terms of economies of scope to be inversely related to the *energy intensity* of the client, as measured by the proportion of total costs accounted for by the supply of energy services. Energy management is likely to be neglected when it forms only a fraction of total costs, but is likely to form a core competence of energy intensive organisations. But in all cases, energy service contracting has an advantage in bringing the discipline of market incentives.

The transaction costs of an energy services contract

THE NATURE OF TRANSACTION COSTS

The concept of transaction costs was introduced by Coase (1937) and later formalised by Williamson (1985). The term transaction refers to the transfer of goods, services or property rights, whether externally within markets or internally within organisations (Furubotn and Richter, 1997). There will be costs associated with such transfers, including the legal, administrative, information gathering and other costs associated with searching for partners, negotiating and writing contracts, monitoring performance, negotiating changes to contracts when unforeseen circumstances arise, enforcing promises, resolving disputes and so on (Table 3).

Transaction costs are claimed to result from two features of human behaviour: *bounded rationality* and *opportunism*. Bounded rationality implies that individuals seek to make rational decisions, but are limited by both cognitive capacity and incomplete information. Since they do not have the capacity to foresee every contingency that might arise, any contracts they engage in will be 'incomplete' in that they will not specify the actions to be taken in all circumstances. Opportunism refers to '…the incomplete or distorted disclosure of information, especially to calculated efforts to mislead, distort, disguise, obfuscate or otherwise confuse' (Williamson, 1985, p. 47-48). Since bounded rationality and incomplete information prevent fully effective monitoring of contractual behaviour, there is always the risk that the other party will act opportunistically - for example, by claiming that cost reductions result from performance improvements, when their real origin lies elsewhere.

Table 3. Types of transaction costs.

Type		Examples
Market (external)	Search and information costs	Searching for parties with whom to contract; communicating; gathering information about price and quality.
	Bargaining and decision costs	Bargaining and negotiating costs; time and legal advice; costs of making any information gathered usable; compensation paid to advisers; cost of reaching decisions.
	Supervision and enforcement costs	Monitoring contract terms; measuring product/service quality; measuring the valuable attributes of what is being exchanged; protecting rights; enforcing contractual provisions.
Organisational (internal)	Establishing organisations	Costs of setting up, maintaining or changing and organisational design, including incentive design, information technology, public relations, lobbying, etc.
	Running organisations	Costs of decision-making, monitoring the execution of orders, measuring the performance of workers, agency costs, costs of information management etc.

Source: Based on Furubotn and Richter (1997, p. 43-47)

Williamson claims that market, organisational and contractual arrangements are chosen to minimise transaction costs – or more specifically '…to economise on bounded rationality while at the same time safeguarding against the hazards of opportunism' (Williamson, 1985, p. 32). TCE locates these so-called *governance structures* on a spectrum, with spot markets at one end and hierarchical organisations at the other. Market structures provide powerful incentives for exploiting profit opportunities and allow quick adaptation to changing circumstances, but expose parties to the risk of opportunistic behaviour when investment in 'specific assets' is required (see below). In contrast, hierarchies reduce the scope for opportunistic behaviour but provide weaker incentives to maximise profits and lead to additional bureaucratic costs. In between these two idealised forms are contractual relationships of increasing duration and complexity, together with hybrid forms such as joint ventures and 'partnering'. Energy service contracting represents a shift from a hierarchical form of organisation to a more market-based form.

Transaction costs may be incurred both prior or during contract negotiation (ex-ante) and subsequently during contract execution (ex post). The latter may usually be anticipated and allowed for during the negotiating stage - for example the costs involved in monitoring contract compliance. Hence, the proposition that transaction costs explain the choice of governance structure implies that the relevant transaction costs are uncertain – they include costs that are estimated at the time of making a decision (Masten, 1993). If the actual transaction costs turn out to be different from those anticipated, the chosen governance structure may be sub-optimal. Market forces may eliminate sub-optimal governance structures over time, but these processes may be slow.

Transaction costs also represent both real and opportunity costs (Masten, Meehan et al., 1989, ; Reindfleisch and Heide, 1997). For example, negotiating changes to a contract in response to external changes represents a real cost, while failure to adapt effectively to those changes represents an opportunity cost. Both may influence the choice of governance structure and the subsequent performance of that structure (e.g. the success of the contract).

FACTORS INFLUENCING TRANSACTION COSTS

Transaction costs will be incurred in negotiating an energy service contract and in monitoring contract performance. The size of these costs can be expected to vary with the nature of the outsourced services, the scope and coverage of the contract, the terms of the contract and various features of the external environment. TCE reduces this complexity to a small number of relevant variables, which are claimed to explain the choice of governance structure in a wide variety of situations. Hence, by identifying the relative magnitude of these variables for different types of energy service, the feasibility of contracting that service may be assessed. The three most important variables are *asset specificity*, *environmental uncertainty* and *behavioural uncertainty*:[10]

- *Asset specificity* refers to the value of physical, human and other assets outside of a particular relationship – such as an energy services contract. An asset is specific if it makes a necessary contribution to the production of a good or service and has much lower value in alternative uses (Klein, Crawford et al., 1978). For example, an ESCO that invests in a CHP scheme located within a separately owned chemical plant has limited bargaining power should the plant owners demand a lower price for the heat, since there is no other market for the heat (the 'hold-up' problem). Similarly, the investment by a contractor in understanding a particular client's organisational procedures represents a sunk cost that cannot be recovered if the contract is terminated. Transactions that require either party to invest in specific assets increase the potential for opportunism. To protect such assets, simple market relationships are likely to be replaced by alternative forms of governance that provide safeguards to mitigate such risks, such as long-term contracts or unified ownership.
- *Environmental uncertainty* refers to unanticipated changes in the circumstances surrounding a transaction. In the context of energy service contracting, this could include, for example, unanticipated changes in the occupancy of buildings, the mix of products being produced, the price of energy commodities or the relevant environmental regulations. These changes may have their origin either

10. Williamson also emphasises a fourth variable: the frequency of the transaction (Williamson, 1985). However, the importance of this has rarely been explored within empirical research.

within the client organisation or externally and must be anticipated and allowed for during contract negotiation if disputes are to be avoided. If unanticipated, they may necessitate changes to the contract during execution. Environmental uncertainty leads to additional bargaining and negotiating costs for the transacting parties, both before and after contract completion.

- *Behavioural uncertainty* results from the difficulties in monitoring and measuring the contractual compliance and performance of the other party to a contract. Monitoring is costly but inadequate monitoring leaves one party vulnerable to opportunistic behaviour by the other. For example, contractors will have an incentive to 'cut corners' to the detriment of quality if they believe that their actions will go undetected by the client and if they have no long-term responsibility for equipment performance (Sorrell, Schleich et al., 2004). Hence, behavioural uncertainty leads to monitoring, supervision and enforcement costs, together with the risk of productivity losses through opportunism.

Table 4, adapted from Reindfleisch and Heide (1997), summarises how each of these variables contributes to transaction costs. In brief, asset specificity creates a *safeguarding* problem, environmental uncertainty creates an *adaptation* problem and behavioural uncertainty creates a *measurement* problem. Each leads to direct or opportunity costs, both prior to contract signature (ex ante) and during contract execution (ex post).

Globerman and Vining (1996) have simplified the TCE framework by grouping environmental and behavioural uncertainty under the single heading of *complexity* – defined as the degree of difficulty in defining and monitoring the terms and conditions of the transaction. Greater complexity should increase the cost and difficulty of performance monitoring and thereby increase the probability that parties will behave opportunistically (behavioural uncertainty). Greater complexity should also increase the cost and difficulty of specifying contract terms, as well as the vulnerability of the transaction to changes in internal and external circumstances (environmental uncertainty). The nature of the transaction may then be described by only two variables: *asset specificity* and *complexity*.

The following section examines how asset specificity and complexity apply to energy service contracting.

The internal influences on an energy services contract

ASSET SPECIFICITY

Since energy service contracting requires the contractor to invest in specific assets, it becomes vulnerable to opportunism by the client. To safeguard these investments, the contractor may seek suitable protection clauses or add a risk premium to the contract price. If the risk is too great, contracting will not take place.

Energy service contracts necessarily involve investment in *site* specific assets. Physical equipment is located on the client site and typically has limited resale or scrap value. While some supply projects may export electricity or heat or both, most projects rely on continuing energy service demand from within the client site and hence on both the economic viability of the client and the stability of end-use demand. Uncertainty over either will undermine the potential for contracting. If the site has a rental value it is possible that energy service demand may continue following a change in ownership, but this is likely to require contract renegotiation.

Table 4. Three determinants of transaction costs.

	Asset specificity	Environmental uncertainty	Behavioural uncertainty
Nature of governance problem	Safeguarding investments	Adapting to changed circumstances	Evaluating performance
Origin	Vulnerability to exploitation of specific assets due to opportunistic behaviour of other party.	Difficulty in specifying and modifying contract terms to accommodate changed circumstances	Difficulty in assessing the performance and contractual compliance of exchange partners.
Behavioural antecedents	Opportunism	Bounded rationality	Bounded rationality and opportunism
Energy service example	Contractor may need to spend time learning the operating procedures of the client - this knowledge is not transferable.	Contractor may find that the demand for energy services has dropped, owing to changes in product demand.	Client may find it difficult to determine actual energy savings, and to assess whether these are due to the contractor or other factors.
Direct transaction costs	Costs of crafting safeguards within contracts (ex ante) Threat of hold-ups (ex-post)	Communication, negotiation and coordination costs (both ex ante and ex post)	Screening and selection costs (ex ante) Measurement costs (ex post)
Opportunity costs	Failure to invest in productive assets	Failure to adapt, or maladaptation	Failure to identify appropriate partners (ex-ante) Productivity losses through effort adjustments (ex post)

Source: Adapted from Reindfleisch and Heide (1997).

Table 5. Financing investments within energy service contracts.

Client finances investment through debt or lease	ESCO finances investment through debt or lease
Client has separate contracts with ESCO and finance company	Client has single contract with ESCO ESCO has seperate contract with finance company
Asset appears on customer's balance sheet	Asset appears on ESCOs balance sheet
ESCO assumes performance risk	ESCO assumes both performance and credit risk
Lower cost of capital	Higher cost of capital
Higher proportion of energy cost savings to customer	Lower proportion of energy cost savings to customer
Lower proportion of energy cost savings to ESCO	Higher proportion of energy cost savings to ESCO
Increases debt-equity ratio for customer	Increases debt-equity ratio for ESCO

Source: Based on (Singer, 2002)

Energy service contracts may also involve *physical* asset specificity. All projects will require investment in data gathering and auditing, some will require specialised equipment, and many will require design and engineering to meet specific physical constraints and technical requirements. Performance contracts in particular require a detailed and costly 'investment greater audit' (IGA), which generates information that the client could opportunistically use to implement the energy saving projects itself. To mitigate this risk, US performance contractors first conduct a feasibility study and then make a proposal that is subject to the outcome of an IGA. The proposal usually stipulates that client must pay the full costs of the IGA if it chooses not to take up the contract (Singer, 2002).

The extent to which energy service contracts involve *human* asset specificity – such as specialised knowledge of technical requirements - will depend in part on the nature of the technology. Many energy conversion, distribution and control technologies may be considered *generic*, as they are suitable for use in a wide variety of applications (e.g. lighting, motors, boilers, CHP, HVAC equipment). While specialised knowledge may be required for these technologies, this can be readily transferred between clients. In other cases, the knowledge will be specific to individual industrial processes (e.g. brewing) or sectors (e.g. oil refining). While specialised engineering firms may have competence in these areas, and may conceivably offer 'performance-related' contracts (Neal Elliot, 2002), the technologies are likely to fall outside the expertise of a traditional ESCO and hence are unlikely to be included within a comprehensive performance contract.

ESCOs will seek to protect specific assets through increasing contract duration or requiring compensation for contract termination. But longer contracts may limit the client's ability to replace the contractor, to negotiate better terms, or to adapt to changing conditions. Formulaic adjustment mechanisms may help adaptation but are more costly to negotiate, while more flexible adjustment mechanisms may increase the scope for opportunism during the negotiation process. Contract duration will also depend on the size and rate of return of the relevant investments – for example, lighting projects may pay back within three years while insulation projects take longer.

Specific assets also make the ESCO vulnerable to financing risk. If the ESCO finances the investments, it takes on the risk of repaying the debt should the customer go out of business. To compensate for this increased risk, ESCOs will require higher returns for these contracts, which will make the savings less attractive for clients.[11] In contrast, if the client finances the investment, the ESCO will only take on the equipment performance risk (Table 5).[12] Since this is a more effective mechanism to safeguard the contractor's investment, it tends to be more common in the US (Goldman, Hopper et al., 2005). For similar reasons, performance contracts have achieved greater penetration in the US public sector, since here the credit risk is low and long-term viability is more assured.

COMPLEXITY

Complexity is defined here as the degree of difficulty in specifying and monitoring the terms and conditions of a contract to supply a particular useful energy stream or final energy service (Globerman and Vining, 1996, 579). At one extreme, a contract to purchase energy commodities on behalf of a client would be relatively straightforward, since the price and quality of these commodities can be very easily defined and verified.[13] At the other extreme, a contract to supply comprehensive energy services to a commercial building would be relatively complex, since a variety of environmental conditions (e.g. illumination levels, air flow) would need to be agreed and monitored.

Greater complexity has four consequences (Globerman and Vining, 1996, 579). First, it makes it more costly to specify and negotiate contract terms. Clients, for example, may need to hire consultants to help them define appropriate service standards and comfort conditions. Second, it makes it more costly to establish and operate monitoring systems, to determine whether those terms have been met. Sub-metering of hot water flow from a boiler, for example, may be cheaper and easier than monitoring temperature, humidity

11. This approach also increases the ratio of loan to equity finance for the ESCO, which may increase its cost of capital. Modigliani and Miller (1958) argued that the cost of capital should be independent of the level of 'gearing', but both theoretical arguments (Mclaney, 1994, p. 273) and real-world practice suggest otherwise.
12. In this case, the ESCO can help to arrange the finance and can guarantee that the energy savings will provide the cash flow to repay the loan – thereby providing the client with access to lower cost finance.
13. The UK Energy Consortium, for example, purchases gas and electricity for several UK universities, who benefit from the economies of scale provided by the Consortium and their specialised knowledge of UK energy markets.

and airflow within a large building. Third, the availability, cost and quality of the service is more likely to be influenced by various internal and external factors, such as changes in weather conditions, occupancy patterns, passive heat generation and occupant/user behaviour. Poor adaptation to these changes may reduce cost savings or undermine service quality, while adequate adaptation may necessitate additional modifications to contract terms. Finally, greater complexity increases the information asymmetry between the client and the contractor, which should increase the scope for opportunism. For example, a contractor may blame cost increases on unavoidable external influences, but greater complexity makes it harder for the client to verify this claim. If the energy services market is competitive, opportunism during contract negotiation may be attenuated by the risk of competitors offering more attractive bids. But once the contract is signed, the client is more vulnerable to opportunistic behaviour since there may be significant costs associated with terminating the contract and either replacing the contractor or taking the service back in-house. Interviews with potential UK clients suggest that the expectation of opportunistic behaviour is a major obstacle to the acceptance of energy service contracts:

> *"It is extremely difficult to prove that a CEM company isn't doing what they could be doing. If your building goes down, they could blame you.…Unless the university is extremely careful in the way that the contracts are written, they could lose a lot of money. Most CEM contracts look good on the surface until you see the hidden extras. Legally the ESCO will comply, but will try their darndest to get the most money out of it they can."*[14]

The transaction costs associated with negotiation, specification and monitoring will be shared between the client and contractor: for example, the contractor may pay for the installation, operation and maintenance of the relevant energy information systems. But whoever bears these costs; they will lower the probability of outsourcing by reducing the net savings.

In general, the complexity associated with supplying a useful energy stream should be less than that associated with supplying a final energy service. Transaction costs will be less when equipment performance is defined by technical and easily quantifiable factors, but the move from supply to performance contracting should increase both the number of factors influencing equipment performance and the proportion that are under user/occupant control (Helle, 1997). Complexity may also vary significantly from one energy service to another.

There need not be a correlation between asset specificity and complexity. For example, a contract to maintain building environmental conditions is likely to be complex, but need not involve 'human specific' investments since the relevant technologies (e.g. building energy management systems) are generic. In contrast, technologies such as wort boiling are specific to an individual sector (brewing), but are not necessarily complex. However, energy service contracting will be most problematic when asset specificity and complexity are combined.

The external influences on an energy services contract

The costs and risks posed by transaction complexity and asset specificity will be modified by two external factors: the *contestability* of the energy services market and the *institutional context*.

CONTESTABILITY

If there is limited competition in the market for energy services, a contractor may behave opportunistically by pricing bids above the cost of supply (Globerman and Vining, 1996, 580). However, if the market is competitive, contract prices should be bid down to an efficient level. In a similar manner, limited competition may create a greater incentive for contractors to behave opportunistically during contract execution, since it is more difficult to find an acceptable replacement. But if the market is competitive, the incentive to 'cheat' will be offset by the risk of losing the contract, either prematurely or at the point of renewal. Hence, by reducing the risk of contractor opportunism, greater competition in the energy services market should reduce transaction costs for the client.

In practice, limited competition may not be a problem, provided that the market is *contestable* – that is, new suppliers are able to enter at relatively low cost (Baumol, Panzar et al., 1982, ; Globerman and Vining, 1996). But if bidding for a specific contract involves substantial costs (e.g. acquiring client-specific knowledge), the incumbent contractor will have an advantage and contestability will be reduced. Contestability may therefore depend on the scope, coverage and terms of the individual contract and may be expected to vary between different countries, sectors, organisations, and contracts.

The European energy service market is smaller, more concentrated and less competitive than in the US, and is further split by functional specialisation. For example, UK companies specialising in supply contracts for industry (e.g. ELYO Industrial, Dalkia Utilities, MCL) rarely compete with those specialising in performance contracts for buildings (e.g. Cofatec, Johnson Controls, United Utilities), with the result that there is only a handful of competitors within each market segment.[15] In principle, market growth should encourage competition, which (by lowering transaction costs) should encourage further market growth, but this 'virtuous circle' has yet to be established in many Member States.

Market competitiveness is not the only inhibitor of opportunism. Contractor reputation is very important, particularly among potential clients within the same sector, since 'bad experience' stories can haunt companies for years.[16] Opportunism may also be mitigated by clients retaining the capa-

14. From one of 45 interviews with energy managment staff, undertaken by the author in 1999 (Sorrell, Schleich et al., 2004).
15. 5 The CEM Group of the Energy Systems Trade Association has 13 members, of which only 9 are active in the market.
16. One interviewee pointed to experience with an ESCO in a neighbouring hospital: "...It was a disaster. They were questioning every piece of work...All the work that was normally done by direct labour was treated as additional to what was specified in the contract. Hence it required more money. Also, the hospital lost some of its best engineering staff...I don't think you can get round this by writing the contract in a better way. It is a question of attitude as well. You can only be so prescriptive in a contract..."

bility to bring the relevant energy services back in-house ('back sourcing'), or by owning the relevant equipment (specific assets) and by leasing these to the contractor, thereby making it easier to change contractors if necessary (Globerman and Vining, 1996, 580).

INSTITUTIONAL CONTEXT:

Transaction costs will also depend upon various features of the legal, financial and regulatory context, such as public procurement legislation, the availability of project finance and the existence or otherwise of specific initiatives to encourage contracting. For example, the effectiveness with which the legal system establishes, maintains, protects and enforces contractual obligations will affect the viability of the contracting approach (North, 1990).

Some features of the institutional context may actively *inhibit* contracting. For example, despite its apparent synergies with the energy service model, relatively few ESCOs have used the UK government's Private Finance Initiative (PFI) to contract with otherwise attractive public sector organisations. The reasons include the unnecessary risk and cost of PFI bidding procedures, coupled with incentives for clients to use off-balance sheet financing.

Institutional factors that may actively *encourage* contracting include:

- *Information*: Clients will incur transaction costs in understanding and identifying the opportunities available. These may be reduced through publicly funded information programmes and demonstration schemes.
- *Procurement*: Transaction costs may be lowered by standardised tendering and procurement procedures and measures to reduce risk. The success of performance contracting in the US public sector owes much to such initiatives at both federal and state level.
- *Accreditation*: Accreditation and certification of ESCOs may reduce the risk of opportunism, enhance ESCOs reputation and give assurance to clients that standards will be maintained.
- *Monitoring and verification protocols*: Standardised protocols for monitoring and verification may reduce costs for both client and contractor, reduce the risk of opportunism and lower the cost of capital by increasing investor confidence (Kats, Rosenfeld et al., 1997).
- *Model contracts:* Standardised contracts may reduce transaction costs for the client by making it easier to compare and evaluate bids, increasing trust and reducing the scope for opportunism. For example, the US trade association is developing a standard language for key contract provisions, (Bertoldi, Renzio et al., 2003)
- *Consultancy*: Clients may benefit from expert assistance in establishing baseline data, defining contract scope, assessing bids and negotiating with contractors. Public funding for this would reduce transaction costs.
- *Employment protection*: Clients may be discouraged by staff and union opposition to outsourcing. This threat may be partially mitigated by the introduction of employment protection regulations.

While measures such as these have been widely advocated and appear to have been successful in some instances (Bertoldi, Renzio et al., 2003), evidence on their aggregate costs and benefits is limited.

The choice of an energy services contract

This theoretical framework leads to six hypotheses. First, energy service contracting is more (less) likely to be used for *client organisations* where:

- the ESCO has a greater (smaller) advantage in economies of scale (relates to 'size' of client);
- the ESCO has a greater (smaller) advantage in economies of scope (relates to 'energy intensity' of client);

Second, energy service contracting is more (less) likely to be used for *energy services* where where:

- the specificity of the assets required to provide the service are smaller (greater);
- the complexity of the energy service is smaller (greater);

Third, energy service contracting is more (less) likely to be used in market/institutional *contexts* where:

- the contestability of the energy service market is greater (smaller);
- the institutional framework within the country is more (less) conducive to contracting.

Measures could be developed for each of these constructs and the hypotheses could be tested through a postal survey of ESCO clients. Here, we simply use the hypotheses to provides a stylised indication of the potential suitability of contracting for different types of organisation (Table 6), energy service (Table 7) and market/institutional context (Table 8). In each table, it is assumed that contracting is more likely when both of the relevant variables act in its favour, and less likely when both act against. In practice, there will be interactions between the variables in each pair - the most important being that transaction costs more likely to inhibit contracting for 'smaller' clients, since the offsetting savings in production costs are also smaller (this is reflected in Table 6). Hence, the extension of contracting to smaller sites is likely to require bundling of sites within multi-site contracts.

A potential client will need to take all these factors into account by when choosing, *whether* to use energy service contracting, and if so *which* energy streams and services to outsource (contract scope) together with *which* technologies and activities (contract coverage). As argued above, energy service contracting is not an either-or decision, but a continuum of options. The minimum requirement for choosing contracting is that the clients' share of the production cost savings are greater than the transaction costs it incurs. The same must apply to the contractor if a contract is to be viable.

Table 6. Suitability of energy service contracting for different types of organisation.

Size of energy bill	Energy Intensity		
	Low	Medium	High
Small	*	*	**
Medium	***	****	***
Large	****	**	*

Table 7. Suitability of energy service contracting for different types of energy service.

Asset Specificity	Complexity		
	Low	Medium	High
Low	*****	****	***
Medium	****	***	***
High	***	**	*

Table 8. Suitability of energy service contracting for different types of market/institutional context.

Institutional context	Contestability of energy services market	
	Low	High
Unfavourable	*	**
Favourable	**	***

Summary

An assessment of the market potential for energy service contracting requires a better understanding of the underlying economics than has been achieved to date. This paper presents a general framework for understanding the contracting decision that identifies the determinants of production cost savings, together with the determinants of the transaction costs associated with establishing and monitoring those contracts. The framework is suitable for empirical test and may be elaborated to assess the suitability of contracting for particular sectors and services.

The model suggests that, while energy service contracting may have an important role to play in a low carbon economy, a wholesale shift from commodity to service supply is unlikely to be either feasible or desirable. Contracting may only be appropriate for a subset of energy services within a subset of organisations, and is particularly unsuitable for final energy services at small sites and process-specific energy uses at large sites. Despite the attention given to comprehensive performance contracting, more limited forms of supply and end-use contracting may often be more appropriate. Hence, while institutional reforms may encourage energy service contracting, this should only form part of a broader strategy for achieving a low carbon economy.

References

Aubert, B.A., S. Rivard and M. Patry (1996), "A transaction cost approach to outsourcing behaviour: some empirical evidence", *Information and Management*, 30, 51-64.

Baumol, W.J, J.C Panzar and R.D. Willig (1982), *Contestable markets and the theory of industrial structure*, Harcourt Brace Jovanovitch, San Diego.

Bertoldi, P., M. Renzio, J. Adnot and E. Vine (2003), "How EU ESCOs are behaving and how to create a real ESCO market?" ECEEE 2003 Study – Time to turn down energy demand, France, European Council for a Energy Efficient Economy.

Coase, R.H. (1937), "The nature of the firm", *The nature of the firm: Origins, evolution and development*, O. E. Williamson and S. G. Winter (Ed.(^(Eds.), Oxford University Press, Oxford, 18-33.

Domberger, S. and P. Jensen (1996), "Contracting out by the public sector: theory, evidence, prospects", *Oxford Review of Economic Policy*, 13(4), 67-78.

Egger, C. and C. Öhlinger (2003), "Building up a market for Third Party Financing in Upper Austria", ECEEE Summer Study, Mandelieu, France, European Council for a Energy Efficient Economy.

FEMP (2001), *Super Energy Saving Performance Contracts*, Federal Energy Management Programme, US Department of Energy, Office of Energy Efficiency and Renewable Energy, Washington D.C.

Furubotn, E.G. and R. Richter (1997), *Institutions and Economic Theory: The Contribution of the New Institutional Economics*, University of Michigan Press, Ann Arbor.

Globerman, S. and A. R. Vining (1996), "A framework for evaluating the government contracting-out decision with an application to information technology", *Public Administration Review*, 56(6), 577-584.

Goldman, C. A., N. C. Hopper and J. G. Osborn (2005), "Review of US ESCO industry market trends: an empirical analysis of project data", *Energy Policy*, 33(3), 387-405.

Grout, P.A. (1997), "The economics of the Private Finance Initiative", *Oxford Review of Economic Policy*, 13(4), 53-66.

Hansen, S.J. and J.C. Weisman (1998), *Performance contracting: expanding horizons*, Fairmont Press Inc., Lilburn.

Helle, C. (1997), "On energy efficiency-related product strategies—illustrated and analysed using contracting approaches in Germany as an example", *Utilities Policy*, 6(1), 75-85.

Jackson, T. (1996), *Material Concerns: Pollution, Profit and Quality of Life*, Routledge, London & New York.

Kats, G.H., A.H. Rosenfeld and S.A. McGaraghan (1997), "Energy efficiency as a Commodity: The Emergence of a Secondary Market for Efficiency Savings in Commercial Buildings", ECEEE Summer Study, France, European Council for an Energy Efficient Economy.

Klein, B., R.G. Crawford and n A.A. Alchian (1978), "Vertical Integration, Appropriable Rents and the Competitive Contracting Process", *Journal of Law and Economics*, 21(2), 297-326.

Lacity, M. and L. Willcocks (1998), *Strategic Sourcing of Information Systems*, Wiley, Chichester.

Leibenstein, H. (1966), 'Allocative Efficiency vs. 'X-Efficiency'', *American Economic Review*, 56(June), 392-415.

Masten, S. E., J.W. Meehan and E. A. Synder (1989), "Vertical integration in the US auto industry: a note on the influence of transaction specific assets", *Journal of Law, Economics and Organisation*, 7(Spring), 1-25.

Masten, S.E. (1993), 'Transaction costs, mistakes and performance: assessing the importance of governance', *Managerial and Decision Economics*, 14, 119-129.

Neal Elliot, R. (2002), *Vendors as industrial energy service providers*, American Council for and Energy Efficient Economy, Washington.

North, D.C. (1990), *Institutions, Institutional Change and Economic Performance*, Cambridge University Press, Cambridge.

Parker, D. and K. Hartley (2003), 'Transaction costs, relational contracting and public-private partnerships: a case study of UK defence', *Journal of Purchasing and Supply Management*, 9(3), 97-108.

Poppo, L. and T. Zenger (2002), 'Do formal contracts and relational governance function as substitutes or complements?' *Strategic Management Journal*, 23, 707-725.

Ramesohl, S. and C. Dudda (2001), 'Barriers to energy service contracting and the role of standardised measurement and verification schemes as a tool to remove them', Proceedings of the 2001 ECEEE Summer Study, Mandelieu, France, Europ. Council for an Energy-Efficient Economy.

Reindfleisch, A. and J.B. Heide (1997), 'Transaction cost analysis: past, present and future applications', *Journal of Marketing*, 61(4), 30-54.

Shelanski, H. A. and P. G. Klein (1995), 'Empirical research in transaction cost economics: a review and assessment', *Journal of Law, Economics and Organisation*, 11(2), 335-361.

Singer, T. (2002), *IEA DSM Task X - Performance Contracting - Country Report: United States*, International Energy Agency, Paris.

Sorrell, S., J. Schleich, E. O'Malley and S. Scott (2004), *The Economics of Energy Efficiency: Barriers to Cost-Effective Investment*, Edward Elgar, Cheltenham.

Stahel, W. R. (1997), 'The service economy: wealth without resource consumption?' *Philosophical Transactions A, Royal Society*, 355, 1309 - 1319.

Wang, E.T.G. (2002), 'Transaction attributes and software outsourcing success: an empirical investigation of transaction costs theory', *Information Systems Journal*, 12, 153-181.

WEEA (1999), *Briefing Paper on Energy Services Companies with Directory of Active Companies*, Washington, World Energy Efficiency Association.

Williamson, O.E. (1985), *The Economic Institutions of Capitalism*, Free Press, New York.