Engineering for Energy

A proposal for governance of the energy system

An IESIS strategy document

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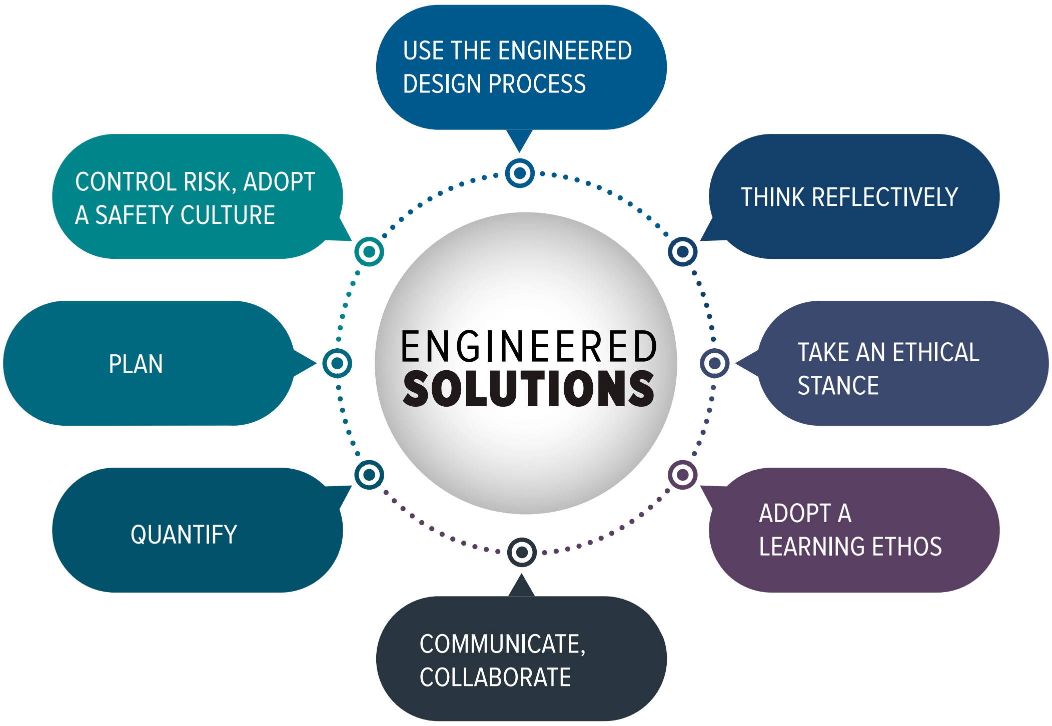
Written by the IESIS Energy Strategy Group



PROBLEM SOLVING STRATEGIES FROM *TO ENGINEER*

Contents

For background information to the paper see: www.iesis.org/efore

The opinions expressed in this paper may not be held by all members of IESIS.

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1 Executive summary

The interconnected nature of energy issues makes it essential to adopt a whole system approach when planning for energy (Sections 3 and 6). Since ensuring the electricity system is fit for purpose is the core issue in energy planning, the main focus of this paper is on the electricity system.

A National Energy Authority, should be appointed to ensure the provision of fit for purpose energy infrastructure. The paper explains why such an authority is needed (Sections 4 and 5), how it may structured (Section 7) and provides evidence that it can be highly successful in its operation (Section 4). The creation of the Authority does not imply nationalisation of the electricity industry or that there would be no competition among participants.

A parliamentary commission should be appointed to establish how the Authority should be constituted.

Figure 1 summarises the recommendations made in the paper.

2 Introduction

The United Kingdom Government and the Scottish Government have set targets for reduction in CO_2 emissions and progress has been made in this respect. However, without proper analysis of their effects, changes to the electricity system can result in cost escalation, increased incidence of power cuts and prolonged reinstatement of supply. Such events can have serious social and economic consequences.

When proposing an action to reduce CO_2 emissions, a government must seek answers to a range of important questions including: 'What will it cost?', 'How will it affect security of supply and security of operation of the electricity system?', 'By how much will CO_2 emissions be reduced?'. Such questions can only be satisfactorily answered by using results from a 'system model' which is capable of predicting system behaviour, and takes account of the interactions among the competing objectives.

The electricity system is being partially planned - for example, the use of renewable generation is being promoted by means of subsidies and auctions and new nuclear generation is given price guarantees. Our recommendation is that it should be fully planned.

The paper explains why the use of engineered planning is essential, and how it may be implemented, as well as providing evidence that such planning can be successful. It focuses on the electricity system and uses the introduction of wind and solar generation as an example of why a system approach is needed for energy planning. The paper does not (a) make any recommendations about what types and proportions of generation types should be used in the electricity system or (b) discuss the range of strategies being used, or proposed, for the energy system.

The electricity system is unlike conventional enterprises which are market driven. It needs to be fully planned due to two special characteristics. First, it needs to be viewed as a single entity, an integrated system where change in one part can have significant effects on the overall behaviour (Section 4). Second, computational technology (Section 6) is available and can be used to predict the interactions among the parts. Market signals cannot compete with use of information derived from this technology; however, the introduction of a fully planned system can involve competition among participants.

Planning should be carried out by a national body (Section 7) using professional engineering methodology which has proven effectiveness for electricity planning. Nearly 100 years ago a case was presented to the UK Parliament that, in order to reduce electricity prices, a national grid should be created and the sizes of generators should increase. Independent bodies were appointed to make plans for the system and to implement them - with very successful outcomes (Section 4).

The need to reduce CO2 emissions has dominated the provision of new generation facilities since 2005.

There is a developing trend that energy is supplied under contract e.g. for renewable generation, new nuclear and for generation to meet peak demand.

System costs need to be estimated and economic viability needs to be assessed using information from a system model. (Section 6)

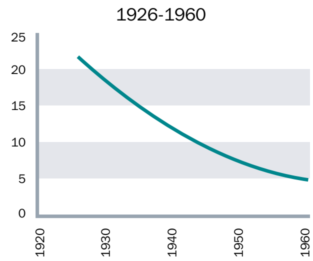
Key objectives for the electricity system:

- Low CO_2 emissions
- Secure - for supply and operation
- Low price

Market mechanisms will not adequately control the risks related to these common good issues. information from a system model needs to be used.

Cost can be very successfully controlled by engineered planning

Under engineered planning 1926 to 1960, the price of electricity in real terms reduced by a factor of 3.5 (Section 4).



The way forward
The present method of providing new electricity generation facilities needs to be taken to its logical conclusion - that all generation be subject to contracts based on engineered planning via a National Authority. The historical record shows that such planning can be very successful.
All government actions that relate to energy should be part of the planned approach.

FIGURE 1 Summary of the arguments made in the paper

3 Engineered planning

Reference 1 provides a summary of how professional engineers achieve successful outcomes in situations of complex uncertainty. Key principles in relation to the arguments made in the present paper include:

- **Do not jump to conclusions**
  Withhold judgement until it is time to make a decision. Carry out option analysis where, if appropriate, a wide range of situations are considered. Develop information about the options and compare them against all objectives and constraints. If no clear winner emerges from the options, use balanced judgement in making a decision.
- **Use a range of strategies to control risk**
  Significant increases in energy costs can lead to fuel poverty and economic decline. Electricity blackouts can result in deaths and civil disturbance - reference 2. Such major risks should be controlled using the most advanced methods available.
- **Quantify**
  Quantify the parameters to be used in decision making. The behaviour and cost of an electricity system can be satisfactorily predicted using computational methods. Also since it is data rich, probability analysis can be successfully used in risk analysis.

Engineered planning would incorporate whole-system, whole-life, holistic approaches. For the electricity system this implies:

- *Whole-system*: The energy system comprises parts that work together rather than compete. It needs to be treated as a single entity operating within a wider energy system.
- *Whole-life*: Electricity system assets need to be assessed on much longer timescales i.e. 25 - 60 years, than is normal for most assets.
- *Holistic*: All relevant issues including security of supply, security of operation, cost, emissions reduction and other environmental issues need to be addressed.

4 Understanding the electricity system

Creation of the National Grid

Prior to the 1926 Electricity (Supply) Act, the electricity system comprised a large number of providers all operating separately - reference 3. Each operator generally had to provide backup supply when its main plant was not generating. This was a major contributing factor to the high cost of electricity at that time.

The creation of the National Grid transformed how electricity was generated and supplied. It allowed for the connection of larger, more efficient generation units and for each generator to become part of an interconnected system. This brought down prices and improved reliability for all electricity customers. It also meant that it was no longer practical to build generators without assessing their effect on the system.

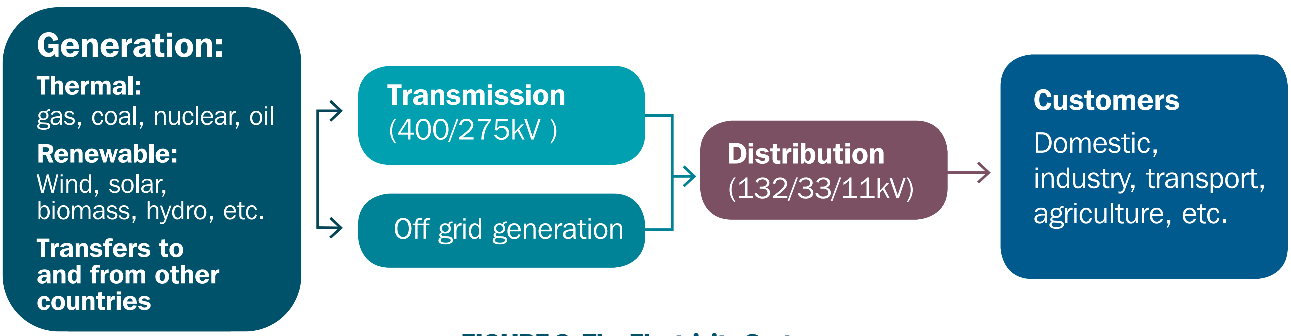


FIGURE 2 The Electricity System

Use of computational technology

Like weather forecasting (Box 1), the electricity system is dependent on computational technology (Section 6) for the achievement of its goals. In operational time-scales The National Grid Company carries carry out continuous on-line security assessments to ensure the system is compliant with the Operational Security Standards at all times and may constrain generation on or off to maintain network security and stability.

Like the wings of an aircraft (Box 2, page 8), the parts of an electricity system are interdependent. Making a change to one part can have important effects throughout the system. If these interactions are not considered when making system modifications, an electricity system can become unstable and fail.

These two features, interdependence of the parts and dependence on computational technology, come together when changes to the system are needed. The technology provides the means of assessing the interdependence. Therefore proposed changes to the electricity system must be based on use of the most advanced computational technology rather than on market signals. Box 3 (page 10) explains this in relation to the closure of a power station.

Government action and the electricity market

In the years prior to 1990, electricity was supplied to all customers at tariffs that were established by Regional Boards. The cost of generation was minimised daily using the Total System Cost Method to decide which plant would be cheapest to use.

Now, private firms generate electricity and suppliers sell to customers. The suppliers bid for energy from the generators in a spot market or can make contracts directly with the generators.

Some of the generators are also suppliers; they can sell their own generation to customers and can also bid in the market. Customers seek to keep down the price that they pay by changing supplier.

Consistent with free market principles, the Government expects private companies to make proposals as to what plant is built and where is it is to be built. Such use of market signals is proving to be inconsistent with other objectives.

For example, in order to meet CO_2 emissions reduction targets, licences are being granted for non-market compatible projects such as: (a) renewable energy projects that are subsidised or are given price guarantees based on auctions and (b) a nuclear power project has been given guaranteed levels of payment for energy.

The 2013 Energy Act made provision for a Capacity Market where firms bid for contracts to supply power at times of peak demand. The amount of capacity to be contracted is based on results from a system model - rather than on market signals.

The National Grid Company also prepares an annual Future Energy Scenarios (FES) document - reference 4. This is based on the results from a system model to predict the efficacy of a range of scenarios for electricity generation.

We propose that the use of information from a system model (Section 6) for deciding on changes to the electricity system be developed to its logical conclusion: all decisions should be based on such information rather than on market signals.

Section 5 explains why modelling at the system level is needed in relation to the introduction of intermittent renewable generation.

The FES approach should be extended to involve a wider range of options. This system would optimise the use of generation plant and transmission taking account of cost and the needs for power, energy, system stability, emissions reduction, etc. (Box 3, page 10).

BOX 1 Weather forecasting – computational technology in action

The accuracy of weather forecasting for a few days ahead has improved dramatically in recent years. At the core of weather forecasting is the use of computational technology that includes:

- Use of computational models i.e. mathematical models of the atmosphere, that seek to predict how the weather will change.
- Use of data to assess and improve the accuracy of these model.

This technology is being constantly developed by the UK Met Office.

Security

An electricity system can develop faults that can cause a blackout i.e. the system can fail to provide supply over an area or, in extreme cases, the whole system can close down. Such failures happen. Reference 2 describes the record of blackouts in North America over several decades. In 2012, a blackout in India resulted in over 300 million people not having a supply of electricity.

System failures tend to be caused by a combination of events such as demand being greater than supply and operational faults. The types of plant in the system and the locations of the facilities are important in relation to security. In particular, closure of thermal generators results in a significant loss of system inertia, an important feature in preventing system instability. In Box 3 (page 10) the closure of the Eggborough coal-fired station is discussed. All UK coal-fired generating stations are expected to close by 2025.

Coal-fired and gas-fired generators are important in restoring electricity supply after a system failure i.e. for black start. Wind generators can only have a very limited role in such situations and nuclear generators cannot be quickly restarted. The time to restore supply in Scotland is now estimated in days - several days - rather than in hours. A lengthy delay would have severe negative consequences - the supply of food, water, heat, money, petrol would be compromised; there would be limited communications. The situation would be nightmarish.

It is reasonable to ask the question: ‘We have not had system planning since 1990; after 28 years, the system still operates well with very few breakdowns. Does that not show that market signals work?’. Although the probability of failure has been increasing, a combination of events to cause a major failure has, fortunately, not occurred.

The likelihood of system failure and the time to restore electricity supply is therefore increasing at a time when society and business have become fully dependent on it. The risks will continue to increase unless action is taken to control them. The solution to the problem is the coordinated future planning of the energy supply capacity and plant mix.

BOX 2 The wing of an aircraft engineering design in action

Main functions of aircraft wings include:

- They provide aerodynamic lift that allows the aircraft to fly.
- They support engines - in many cases.
- They act as fuel tanks.

Decisions about the features of the wings involves a design process that includes computational technology in aerodynamics, structural mechanics, fluid mechanics, etc. It is not possible to design the aircraft safely without using such technology.

The functions of the wings are inter-dependent. For example, suppose it was decided to adapt an existing aircraft for shorter flights. It is obvious that one should not make the wings smaller because they need to contain less fuel without ensuring that the aerodynamic properties are not compromised or that the wings would still safely support the engines.

Historic prices for electricity

It is important to take a historical view of the situation[3].

Prices 1921 to 1990

Figure 3, based on data from a government source, shows the price of electricity for all GB users from 1921 to 1990 in real terms with 1990 as the base year.

The 1926 Electricity Supply Act allowed for the appointment of Electricity Commissioners who planned the system and a Central Electricity Board that implemented the plan. Between 1926 and 1947 the generators were owned by private companies and by municipalities. In 1947 the electricity system was nationalised.

Figure 3 shows that between 1926 and 1960, the price of electricity reduced by a factor of 3.5. Strategies that contributed to this decrease included:

1. Savings in costs for response and reserve through having a system that was interconnected via the National Grid
2. Improvement in the design of the coal fired generators including increases in the sizes, pressure and temperature of the turbo-generators. This improved their efficiency and lowered the cost of production.
3. On a long-term planning horizon, use of a system model allowed optimum arrangements for generation and transmission to be identified.
4. Data from monitoring of performance of the system and its parts informed decisions about changes to the system.

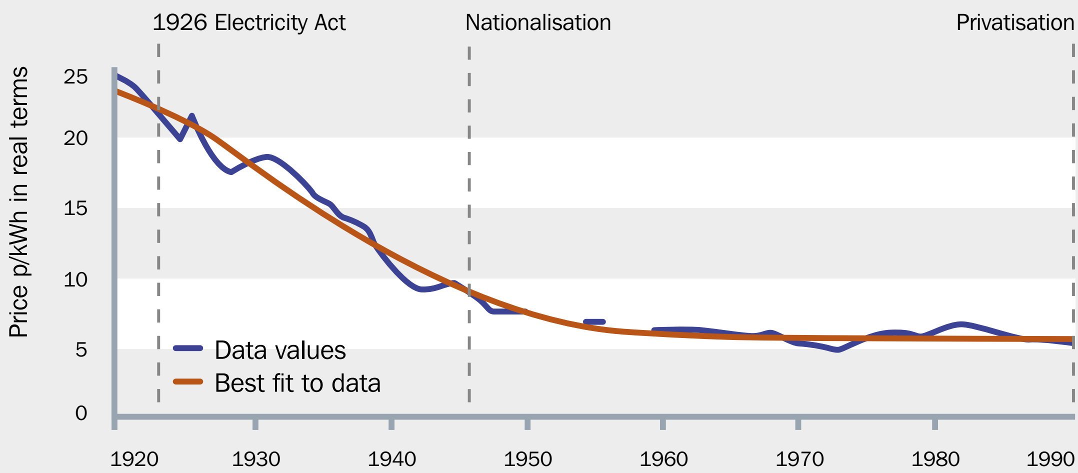


FIGURE 3 GB electricity prices for all users 1921-1990 in real terms (1990 base year)

For sources of data and calculations see reference 5.

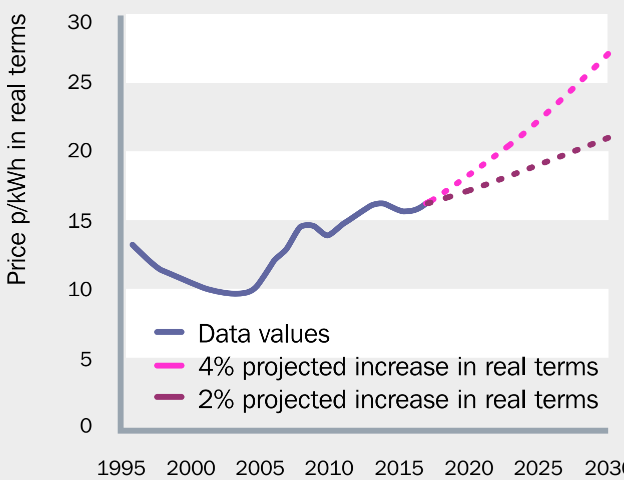


FIGURE 4 GB domestic electricity prices 1996 to 2017 (2017 base year) plus projections to 2030

For sources of data and calculations see reference 5.

See the 'Intro' worksheet in reference 5 for further discussion of the reasons for changes in price during this period.

Between 1960 and 1990, Figure 3 indicates that the price of electricity (a) did not change much in real terms as compared with the previous decades but (b) did vary both up and down during that 30 year period. The reasons for these variations are not clear. During the period there was a great deal of investment in the development of nuclear power which is likely to have caused upward pressure on price. At an operational level the use of the Total System Cost Method sought to minimise the price on a daily basis.

Prices 1996 to 2017

Figure 4 shows the price of GB domestic electricity from 1996 to 2017 in real terms with 2017 as the base year. Also included are projections to 2030.

The available data does not allow a continuous record of price converted to a single base year to be produced. It is very important to note that the prices in Figure 4 cannot be compared directly with those in Figure 3 because (a) they do not represent the same metric and (b) they are based on different base years for the definition of real price. The diagrams should be used for trend analysis. Further analysis of the data and the trends are included in the 'Intro' Worksheet of reference 5.

In the early 1990s, the UK Government lifted an embargo on the use of gas for baseload electricity generation resulting in a 'dash for gas'. This is likely to have been a contributing factor to the reduction in price up to 2004.

The increase in price from 2004 is likely to have been mainly due to the introduction of renewable energy generation. From 2004 to 2017 the increase was at an average rate of 4% p.a. compound. Figure 4 shows in pink the prices from 2017 to 2030 if this rate of increase were maintained. The measure of the rate of increase is very sensitive to the span of years chosen to define it. Starting with the year with the lowest price (2004) is logical but a very different value is found if the start year is 2008. As an example, the projection with a 2% p.a. compound increase is shown on Figure 4.

Summary

Figure 3 shows that prices can reduce significantly in an electricity system which is subject to engineered planning. Figure 4 shows that prices can reduce in a privatised system.

In order to understand which approach is likely to give the better result, we need to look at how cost may have been reduced, as the data does not provide this answer.

Of the four strategies used in engineered planning listed above, only Item 2, improvements in the design of the generation plant, would be addressed in a market context. The other strategies require the use of a system model which requires a planned approach. While we do not have data about the relative importance of the strategies, it was considered at the time (1926-1990) that the use of the system model was an important factor in controlling cost.

The significant investment in generation and transmission facilities to reduce CO_2 emissions is likely to be an important factor in the increase in price of electricity in recent years.

The effect of intermittent generation on the cost of electricity is discussed in Section 5.

BOX 3 Closure of the Eggborough generating station

In February 2018 it was announced that the 2GW Eggborough (Yorkshire) coal-fired generating station would be closed in September 2018. Reasons for the closure include: (a) coal fired generation attracts the highest levels of carbon tax, (b) coal fired generation is the last to be called on to produce power to the grid resulting in low productivity, (c) the station failed to be given a contract in a capacity auction. In short, it is not financially viable.

Eggborough contributed to the electricity system by providing:

- energy to the system when needed
- power at times of peak demand
- features that keep the system stable such as inertia and reactive power
- support for a black start situations
- a store of energy in the form of coal in the coal store

The capacity auctions focus only on the second of these provisions. They allow the award of contracts to provide power at lowest cost at times when demand is approaching the limit of the generation capacity. This seems to be a sensible approach but it neglects the interdependence of the features of the system exemplified by the above list. The five functions (and other requirements) need to be satisfied at optimum cost. This can only be achieved by making use of information from a system model.

Use of such information would allow risk in decisions about plant closures to be fully assessed.

5 Understanding wind and solar energy production

The demand for electricity varies throughout every day. For example, in winter mornings, the demand can increase from 30GW to 40GW over a period of three hours. To match such changes, the system has to have generation that is *flexible*, i.e. that can be called in when needed at the required power levels, and *reliable*, i.e. it must have a high likelihood of being available when needed. It follows from the information given in Box 4 that wind and solar generation are neither reliable nor flexible.

A range of control strategies, e.g. extra generation, storage and demand management, can be used to maintain flexibility and reliability. This results in extra cost on the system – known as 'integration cost'. With low proportions of intermittent generation, the integration costs are low but as the proportion increases, they may rise steeply.

It is essential that these costs are taken into account. The integration costs and the efficacy of the control strategies must be assessed at a system level.

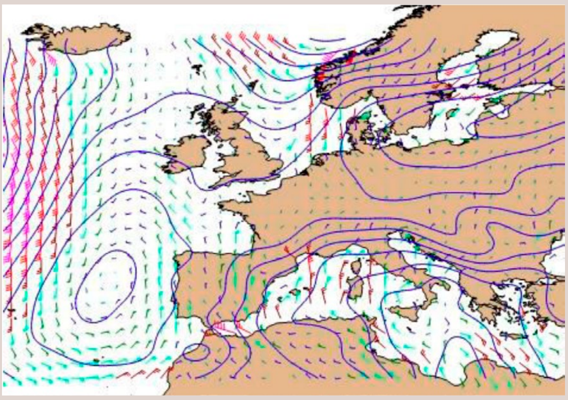
BOX 4 The intermittency of wind and solar energy production

The diagram shows weather data for February 6, 2012. The contour lines are isobars, lines of equal atmospheric pressure. Over the whole of Western Europe the isobars are very widely spaced indicating low wind velocities.

The arrows or 'barbs' point in the wind directions and the relative wind velocities are indicated by the lengths and colours of the barbs. In the diagram, the barbs are very small over most of Western Europe. The level of production from the wind generators would have been very low on that date in 2012.

It is not an uncommon occurrence and it can happen in winter when the temperatures are low and demand for electricity is high.

At night there is no solar energy therefore the electricity system has to cater for situations where very little wind energy or solar energy is available.



6 System Modelling

A suite of models referred to here as a 'system model' - Figure 5 - should be used to predict the behaviour of the energy system. It is implied that such system modelling would incorporate the most advanced methods which are available and the most appropriate level of detail in the data.

This computational technology includes:

- Simulation of behaviour: technical models, economic models
- Quantified risk analysis
- Data analysis

Such technology is being developed and used by a range of institutions including the National Grid Company.

In addition to the use of computational technology, pilot testing of proposals may be used

Modelling for the electricity system

A system model simulates the behaviour of the electricity system using:

- Detailed performance data for generation, transmission and distribution assets
- Time series data for demand

Output from the model would include:

- Estimates of the risk that demand will fail to be met (security of supply)
- Estimates of the risk that the system will become unstable (security of operation)
- Estimates of the cost of production
- Estimates of the performance and cost of strategies for CO_2 emission reduction

Cost predictions

The price of electricity is rising significantly faster than the rate of inflation (Section 4). It is essential to know why it is rising and to make predictions of what the likely changes in cost, and hence price, may be in the future.

In modelling the performance of the electricity system, cost estimates should be based on whole system, whole life analysis. This can be achieved using the Total System Cost Method (TSC) which takes account of all the costs paid for by customers for generation, transmission and distribution. The model uses time series data for demand and generation, data about the construction cost, the operational costs, the decommissioning costs and the operational performance for each component of the system.

Behaviour of every item in the system which affects the cost should be taken into account in the model. For example, the efficiency of thermal generators operating in a cycling mode to satisfy the standards for the Grid Code would be modelled. This behaviour affects the integration costs of intermittent generation.

Output from the TSC would give estimates of the overall cost of electricity. To assess the extra cost or cost savings of a change to the system, the model would be run with and without the change.

Modelling for the energy system

Information from a system model should be used to assess the feasibility and viability of all energy issues that the Government seeks to address. Some of these issues are noted below.

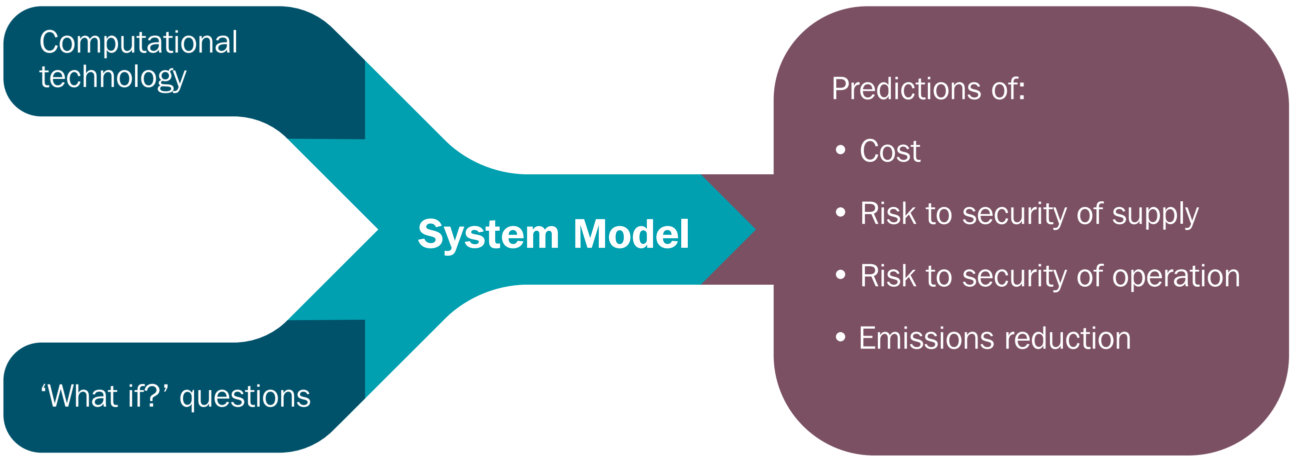


FIGURE 5 System Model

Electrification of transport

Figure 6 shows the proportions of UK CO_2 emissions in 2017. It is clear from this diagram that reducing emissions for transport should be a major objective. If the main strategy for doing this is electrification, then the degree to which the electricity system is decarbonised is a critical issue. This illustrates the pressing need to take a system view in planning for energy.

Electrification of domestic energy use

The same problem in reducing emissions as for electrification of transport would arise if domestic gas were replaced by electricity.

In 2018 the cost per unit of energy from electricity is more than 4 times that for gas. Use of off-peak tariffs and improvements in efficiencies would reduce this factor but those who convert to electricity for domestic heating are likely to have significant increases in their running costs and would also have capital charges for changing from a gas boiler to an electricity heater with hot water storage. Alleviation of the resulting fuel poverty would need to be part of the plan.

Gas supply

During the cold snowy weather in February 2018, gas supplies were running low. For electricity generation, coal fired power stations were made to work at full capacity and use of gas for electricity generation was throttled back. Contractually agreed cuts were made in supply to industrial users. It was evident that more gas storage capacity was needed. The need for a whole system approach for decisions about gas supply is evident

CO_2 emissions auditing

A system model (Section 6) should provide information about whole-life carbon footprints of all proposals.

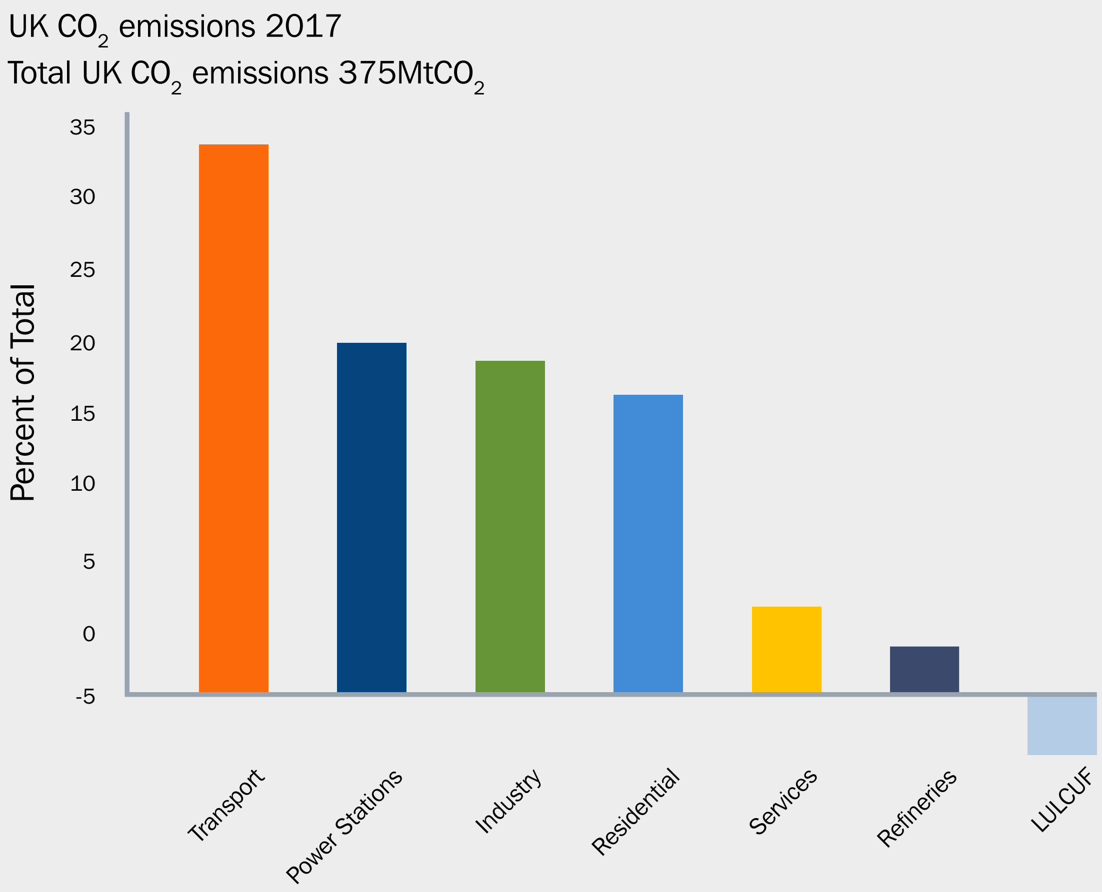


FIGURE 6 Proportions of UK CO_2 emissions in 2017

Notes:
This diagram is based on data extracted from:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/666256/Annex-b-carbon-dioxide-emissions-by-source.xls Reference scenario worksheet, Carbon dioxide emissions by source.
LULUCF is: land use, land use change and forestry

7 A National Energy Authority

The system needs to be planned by a national body which operates without commercial bias. An intuitive reaction to this statement is to conclude that government interference in the electricity market is the problem, not the solution. However, Figure 3 shows that prices for electricity can significantly decrease in a system planned by a national body.

The system as privatised in 1990, also had a very good record for reliability.

This planning for electricity production and supply was successful because it was engineered (Section 3). The electricity system is a big technical beast that can only be tamed by using engineering methodology.

Governance

Critical issues in governance are responsibility, authority and accountability.

Figure 7 shows options for governance of the electricity system. Free market implies that decisions about types of generation plant and where they should be built are based on proposals made by commercial companies. With tight regulation, proposals for new generation facilities are based on a national plan supported by information from a system model. The GB electricity system has moved towards the tight regulation approach but the predictive power of system modelling is not being fully utilised. The Longannet coal fired power station in Scotland was closed in 2016, well before assessments of the impact of its closure had been completed. Transmission is being upgraded before detailed decisions about the siting of generation facilities have been made.

We recommend that a not-for-profit National Energy Authority (NEA) be established. It should have the following attributes:

1. It will have statutory powers that will allow it to work for the common good.
2. All involved must work together to seek to achieve the goals for energy taking appropriate account of the risks.
3. A whole-system, whole-life, holistic approach would be used (Section 3). All the consequences of introducing changes are assessed.
4. The most advanced technologies should be applied in the drive to achieve the goals for the system.
5. The staff of the Authority must have the necessary range of high level competence - technical competence, financial competence and especially competence in power system engineering. The staff should, as far as is practical, be free from political and commercial constraints. Where expertise is not available within the organisation, it should be procured from other sources.
6. The Authority should draw up long term and short term plans for situations where the Government seeks to make changes to energy production or use. For the electricity system, it should have powers to determine the types of plant that are to be built, where they are to be built and when they are to be commissioned.
7. The operation of the Authority should, with the exception of issues that relate to national security, be transparent to the public. Data should be made available so as that members of the public can carry out studies independently of the Authority. Such contributions should be welcomed as having potential to help to achieve the system goals. Before major decisions are made, public consultations should be held about proposals.
8. The line and boundaries of responsibility for all functions of the electricity system should be clearly defined.
9. The Energy Authority must have authority to ensure that plans are implemented. Reference 6 describes an arrangement whereby this may be achieved.
10. The Authority should assess innovative proposals and seek to ensure that innovations will be related to perceived needs.
11. It should operate under an audited quality management system to seek to ensure that the objectives are being competently addressed.

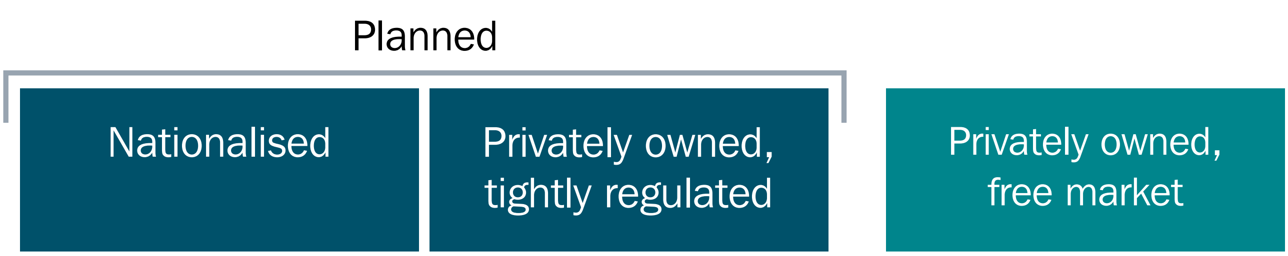


FIGURE 7 Governance of the electricity system

The recommendation in the October 2017 Cost of Energy Review - reference 7 that the Electricity System Operator should be a not-for-profit body is in line with the concept of a National Energy Authority as outlined above.

That the NEA needs to have authority to implement proposals is evidenced by the situation that pertained for electricity planning during the period 1919 to 1926[3]. The 1919 Electricity Act allowed for the creation of a body that was charged with taking a system view of electricity production but the Act did not grant the necessary authority to fully implement recommendations. The creation of the National Grid was delayed until amendments to the Act in 1926 assigned the needed authority.

An example of a (trans-national) body that addresses security is the North American Electric Reliability Corporation which imposes strict standards for Security of Supply and Security of Operation over the whole of the USA, Canada and parts of Mexico. The need for such an organisation was prompted by serious failures over a number of years[2]. The experiences of these failures and the methods being used to avoid them in North America should be carefully considered when defining the constitution of the NEA.

The proposed arrangements for governance can be introduced without significant financial implications.

BOX 5 The Energy System as national infrastructure

Because private toll roads had proved to be unsatisfactory, the Local Government Act of 1888 gave responsibility for the provision and maintenance of main roads to county councils and municipal councils. We now also have national planning for motorways and major roads. As a result of this planning, the UK road system well serves the needs of users.

This is achieved by bodies such as the Department of Highways, Transport Scotland, etc.

As with roads, a system approach for energy provision requires planning that is controlled by a government body. The successful methods used by government in carrying out infrastructure planning should be taken into account when defining the constitution of the National Energy Authority.

8 Risk

UK Government energy policy is resulting in changes that are intended to reduce the likelihood that CO_2 emissions will affect climate. The Government's stated intention of seeking to ensure that other risks are adequately controlled is not being backed up by adequate action.

Actions taken by Government in relation to energy planning can result in events such as:

- **Electricity blackouts and longer times to recover from them.** Such events lead to deaths, severe societal and industrial disruption, civil disturbance, loss of production.
- **Increased energy costs** leading to increase in poverty and damage to the economy.

The consequences of these events are severely negative and the likelihood of their occurrence is increasing because:

- The continuing closure of reliable and flexible electricity generators (mainly coal fired) and replacement of them with generators that are neither reliable nor flexible (wind and solar) is causing increases in security risks (Section 4).
- The introduction of new types of generation without carrying out estimates of cost based on best practice methods, means that the risk of cost escalation is not being adequately assessed.

We call on the Government to act in the best interests of the people that it represents by using engineering methodology in its planning for energy.

9 Conclusion

Logic and evidence point to a conclusion that government planning for energy should be based on professional engineering methodology. The logic is that it is only by the use of such methodology that the risks of failing to meet energy objectives can be controlled (Section 8). The evidence includes the positive achievement of national planning for electricity in the past (Section 4), and the success of national planning in other areas of infrastructure (Box 5, page 16).

The planning should be carried out by a National Energy Authority (Section 7), appointed to seek to ensure the provision of fit for purpose energy infrastructure.

As a matter of urgency, a parliamentary commission should be appointed to establish how the Authority should be constituted.

Finally, it is instructive to read the acceptance speech (reference 8) of Sir Donald Miller, a leading power systems engineer, after he was inducted to the Scottish Engineering Hall of Fame in 2015.

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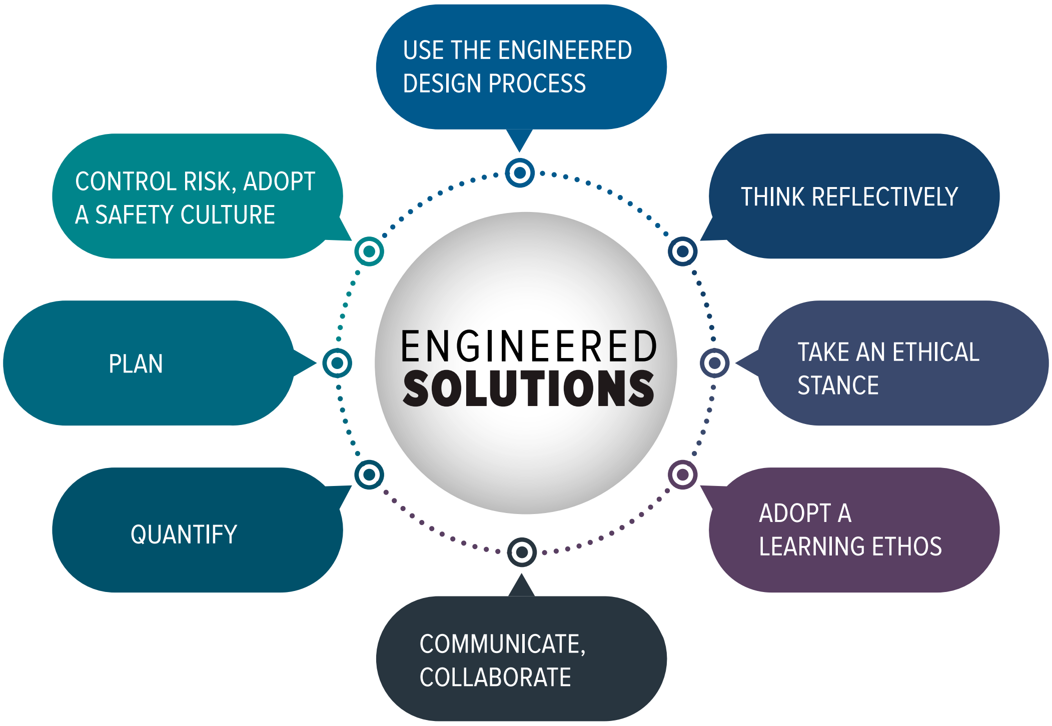

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