Energy Security and Net Zero Committee Inquiry
Keeping the Power On: Our future energy technology mix

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The UCL Institute for Sustainable Resources' mission is to provide evidence, expertise and training to respond to climate change and support sustainable transitions for people and planet.

The UCL Energy Institute delivers world-leading learning, research and policy support on the challenges of climate change and energy security.

Across the team of authors there is a wide range of expertise including: energy security, the energy transition, energy innovation, social aspects of energy use, and energy markets. We also have specific expertise in energy modelling which has formed the basis of several of our answers to this inquiry. This includes the UK TIMES model, a comprehensive energy system model which has been developed between UCL and the Department for Energy Security and Net Zero (formerly BEIS).

We would be delighted to discuss this response, or any of our other work. Please contact Katherine.page@ucl.ac.uk

Summary

A theme of this inquiry was the focus on 'new' generation technology, rather than tried and true solutions and non-technology approaches to facilitating a green transition.

Primarily we note the lack of focus from the government on energy efficiency and demand reduction as key for energy security, meeting our climate targets, and creating an affordable future energy system. Technologies which improve household energy efficiency and reduce energy bills at a time of high cost of living, can also reduce the overall future demand on our energy system.

There are other important considerations that go beyond a focus on specific supply side technologies which will facilitate 'keeping the power on'. These include upgrading transmission infrastructure so we have a grid fit for our electric future, investing in long term energy storage to aid flexibility, and reforms to the electricity market which will pass on the significant savings from renewable generation to consumers. We must also ensure to invest in sustainable supply chains and build the resources and skills across the country to deliver change.

Evidence from modelling the energy system tells us that mature and low cost renewable technologies, specifically on and offshore wind and solar PV, will play a major role in the UK's net zero electricity system. They are comparatively quick to build, have abundant potential across the country and are now significantly lower cost than fossil generation or other low carbon alternatives, and so should be a target for accelerated deployment.

While it will take sustained effort, we can reach net zero quickly and affordably with accelerated development of key technologies, a renewed focus on demand reduction, and work to improve transmission and connection infrastructure.

1. Is the energy sector open enough to new generation technology?

In this answer we focus mainly on the electricity sector. This includes:

a) the physical electricity system, including generation, transformation and transmission infrastructure,
b) the different stakeholders that participate in energy related activities and take investment and regulation decisions, such as power generation companies, energy suppliers, system regulators and final consumers, and
c) the market and regulations that enable and promote the operation of the system.

The physical energy system is, in principle, technology agnostic. However, its current structure has developed through large, centralized thermal power stations, which makes it poorly adapted for integrating large volumes of variable, 'as-available' renewables.

Additionally, constraints in transmission capacity impede delivering surplus generation from areas with high wind capacity to zones of high demand. It is urgent to develop the transmission capacity to enhance renewables integration and to decrease and delay the need of investment in extra 'on-demand' generation. The system also remains poorly adapted to accommodate small-scale renewables, due to combinations of local network, transmission, and multiple planning obstacles.

With the UK being a liberalized energy market, investment decisions are based mostly on the business case behind each project for raising finance. As most 'new technologies' are capital intensive, and may involve greater risk, this requires access to cheap sources of finance, which depends on mitigating major financial risks. Specifically, without appropriate policies, the current market biases against renewables:

- Gas generators are 'self-hedged' against price volatility, since they set the electricity price[1] – if their input costs increase, so do their revenues from selling electricity;
- Whereas low carbon sources ("Inframarginal") have a fixed cost base but take on all the revenue volatility associated with gas (and hence electricity) price uncertainties.

Especially given this bias in the existing market, to support low carbon investment, policies that decrease revenue flows risk (in the case of more mature and tested technologies) or direct government grants (required mostly for less mature technologies) are important. Moreover, as investments require long-term certainty, a coherent and stable policy is required.

Long term storage technologies are particularly for balancing systems with high penetration of variable renewables. However, the purely market-based business case is exceptionally uncertain for these technologies, because they would only earn revenue by filling at times of surplus cheap generation and selling at times of shortage – both the frequency and scale of this price difference, projected to make an investment case, is intrinsically uncertain. Long term storage needs to be considered as a strategy investment in system security, resilience and facilitation of the low carbon transition. Currently there is no specific policy targeting requirements for the development of this sector.

More generation is not the only way to meet demand in times of low variable renewable generation. This neglects the potential of demand side actions and technologies that could shift demand and provide the required system flexibility, decreasing the need for on-demand generation. In this regard, it is important to create policies that stimulate the involvement of energy suppliers and especially final consumers in the operation of the energy system by providing incentives for demand flexibility.

[1] https://www.ucl.ac.uk/bartlett/sustainable/sites/bartlett_sustainable/files/the_role_of_natural_gas_in_electricity_prices_in_europe_updated_may_2023.pdf

2. Does the Government sufficiently support development of innovative energy infrastructure?

Innovation within the whole energy system can have long term impact on achieving our combined climate, energy security and social targets. In general, the UK government now devotes significant resources to supporting energy innovation – through research, development and demonstration programmes and through support for technology deployment. Whilst more support would help to accelerate development and deployment, there are also important questions about the balance of spending between technologies (see response to Q5) – and between technology stages.

Supporting innovation to help meet net zero across the whole UK (and global) energy system should include a wide set of innovative approaches to solving complex and interconnected problems. These include supporting innovative behaviours, companies, community organisations or approaches, local and regional governance structures, as well as innovative technology and businesses.

This recognizes that while some innovations are technological, many others may be social.
Innovation support in the UK and many other countries tends to focus on supply side technologies rather than on technologies for reducing demand. While ensuring the future supply system is fit for purpose is essential, the size and complexity of this system is dependent on the level of end-use service required (our combined energy use). Changes to the overall amount of energy required are social and governance based in nature. Innovation here is as essential as technology related innovation programmes.

Some of the authors of this response have separately written a report for the Department for Energy Security and Net Zero as part of a consultancy project 'Energy Innovation Portfolio Evaluation'. The report responded to a government question on the potential use of quantitative methods and modelling for assessing the UK benefits of investments under the Net Zero Innovation Portfolio (NZIP) programme. Evaluating the impact of R&D funding programmes has previously used a variety of methods, including interviewing experts to generate data for analysis. However, it is important to recognise that participants can be biased, and either over-conservative or over-confident in attributing benefit to a given policy.

Salient points from this report include the following:

- By narrowing the focus on particular technologies or innovation causal pathways the evaluation may ignore or undervalue wider programme benefits. Such benefits could include technology spillovers, skills development, network formation, market influence etc. Taking a holistic whole energy system based view of what innovation means is important to understanding its potential benefits.
- This is important because innovation objectives are not independent from policy objectives. A quantified review that showed that a given innovation policy was not providing 'value for money' in a narrow definition would lead to changing or removing this policy – notwithstanding any of its unquantified wider benefits.
- Finally, innovation does not take place in a vacuum and the UK does not operate in isolation from the international community. Assessing innovation support assumes that we understand what the state of the system would have been without it – and this state is not static in the absence of UK policy. It is also not straightforward, in a globally connected science and energy system, to attribute changes in particular technology to a UK policy.

3. Is the Governments plan for energy security sufficiently long term?

The government's most recent strategy for energy security is set out in *Powering Up Britain*[2], published in March 2023. It is an update to the *British Energy Security Strategy*[3] which was published in the wake of the Russian invasion of Ukraine. Before commenting on whether the government has got their strategy right, including whether it is long-term enough, it is important to remind ourselves what energy security means. The International Energy Agency defines it as 'the uninterrupted availability of energy sources at an affordable price'[4].

Strategies to achieve energy security are both complex and contested[5]. They include shorter-term strategies to ensure affordability (e.g. the provision of help to households as through the Energy Bills Support Scheme), and longer term strategies to shift us away from high cost and/or unreliable energy sources (such as the broader strategy to increase investment in low carbon electricity technologies and carriers such as renewables, nuclear power and green hydrogen).

It is often tempting to assume that resources that are domestic are more secure than sources of energy from other countries. There are three key reasons why this might not be the case. First, domestic resources might be inherently limited. For example, the UK imports around half of the gas it needs because production in the North Sea is declining. Second, other countries might be able to produce energy more cheaply – so importing some of the energy we need can be part of a strategy to keep costs down. Third, resources that are apparently 'domestic' often depend on international supply chains for technologies and/or the minerals used to manufacture them. This applies to most energy technologies.

Energy security often gets reduced to 'security of supply'. In other words, discussions and policies have a tendency to focus on the security of energy sources. They often neglect the role of secure supply chains and network infrastructure - and the role of energy demand – in strengthening energy security. As Winston Churchill famously observed in the early 20th Century[6], diversification of energy sources and supply chains is a very important energy security strategy to avoid over-dependence on particular countries or supply routes. Reducing energy demand, for example through household energy efficiency, can make a significant difference to household bills – and therefore improve energy affordability, especially at times of high prices.

The government's strategy set out in *Powering Up Britain* is an improvement over the *British Energy Security Strategy*. Whilst it talks about increasing energy independence, the revised strategy recognises the interconnected and international nature of energy markets, technologies and resources. However, it has three significant flaws:

- First, it continues the tendency to focus the most on security of supply and is not ambitious enough on measures to reduce demand and lower the exposure of households and businesses to high prices. The new target to reduce demand from industry and households by 2030 is welcome, but the practical policy mechanisms, funding and incentives to meet this target – and go beyond it – are inadequate.
- Second, it is too long-term. Ambitious plans for non-fossil technologies are set out such as floating offshore wind, nuclear power and green hydrogen. But these plans often focus on technologies that might not deliver until the 2030s and beyond. There is not enough complementary action to deploy the cheapest non-fossil technologies available now over the next few years. The quicker the UK can deploy technologies such as solar and wind, the more impact this will have on our dependence on fossil fuels.

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[2] https://www.gov.uk/government/publications/powering-up-britain
[3] https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy
[4] https://www.iea.org/topics/energy-security
[5] Mitchell, C., Watson, J. and Whiting, J. (eds) (2013) New Challenges in Energy Security: The UK in a Multipolar World. Palgrave Macmillan.
[6] Yergin, D. (2006) Ensuring Energy Security. *Foreign Affairs* March/April 2006.

Current policies effectively rule out onshore wind deployment in England and Wales, one of the cheapest electricity generation technologies.

- Third there is not enough emphasis on measures to increase the resilience of our energy system including measures to ensure sufficient diversity of technologies, sources of energy and minerals and supply routes. The strategy contains no analysis of the current levels of diversity and resilience of the UK energy system – so it is hard for the government and other stakeholders to assess where our vulnerabilities lie, and to monitor the impact of implementation. This also includes energy storage. Whilst battery storage is being deployed very quickly, action on longer-term storage (e.g. of gas) is not taken seriously enough.

Finally, the more recent confirmation by the government that it wishes to prioritise new oil and gas licensing raises serious questions about its commitment to a security strategy that is compatible with international action on climate change. New licensing could slow down the rate of decline of UK oil and gas production. However, it is unlikely to have a significant impact on affordability for households and businesses because prices of these fuels are set through international markets.

4. **What current technologies could usefully be deployed at scale to deliver better energy security in the UK?**

Some current technologies are already being deployed at scale, and could contribute to improved UK energy security by lowering bills and reducing the need for fossil fuels. The rapid growth of offshore wind and solar deployment over the past decade are two examples. The deployment of these technologies has helped the UK get to a position where well over 50% of our electricity comes from non-fossil fuel sources.

With respect to priorities for further technology deployment at scale, UK energy security could be further strengthened in three main ways:

- A step change in programmes to **improve energy efficiency and reduce demand**. This particularly applies to the range of technologies that can deliver significant improvements in household energy efficiency – and help to reduce energy bills. Until the early 2010s, the UK was deploying well over a million energy efficiency measures a year. A switch to policies that are far less effective led to a collapse in levels of activity from 2013[7]. This needs to be reversed as a matter of urgency, though effective and large-scale programmes. These programmes should also integrate much stronger measures to support a move away from gas for heating, with a particular focus on accelerating the deployment of heat pumps. The UK is currently lagging behind most other European countries in heat pump installations[8], including countries that have also depended on gas for heating in the past. This is due to a lack of installers and independent advice for households, and the relatively high cost – especially where consequential changes are required to heating systems.
- Stronger deployment of technologies to **improve energy system resilience and flexibility**, including storage. As electricity becomes more important across the economy – including for transport and heating – the resilience of the grid becomes ever more crucial. Whilst electricity storage technologies are now being deployed at scale, investments in the grid[9] and incentives for companies who can help to balance more complex electricity systems remain inadequate. In addition to investment in electricity infrastructure, the UK also needs to take gas infrastructure more seriously. There have been long and inconclusive debates about the low level of gas storage in the UK. Whilst it would be expensive, there is a case for increasing the capacity of storage.

[7] Climate Change Committee (2023) Progress in Reducing Emissions: 2023 Report to Parliament. London: CCC, p149.
[8] Financial Times 'The humble heat pump blows a green wave across Europe' 7th August 2023.
[9] Winser, N. (2023) Electricity Networks Commissioner's principle areas of recommendation. Recommendations to the DESNZ Secretary of State; https://www.gov.uk/government/publications/accelerating-electricity-transmission-network-deployment-electricity-network-commissioners-recommendations

- Increased incentives for the deployment of **non-fossil electricity generation**, especially renewables. This includes meaningful planning reforms to remove the de-facto moratorium on one of the cheapest forms of generation – onshore wind. The government is right to have ambitious targets for renewable energy deployment, but these targets are not matched by the incentives on offer (e.g. through Contracts for Difference auctions) or investment in grid infrastructure. In addition to improving these incentives, reforms to the electricity market need to be implemented so that households and businesses can benefit from cheap renewable electricity.

5. Are there technologies that have not been able to develop their potential and should be abandoned?

We agree with the premise of this question. A medium sized economy such as the UK does not have the financial and other resources to support all low carbon technologies at scale. It is therefore essential for government to carry out regular reviews of technologies that receive public funding, and to identify clear priorities.

Such priorities should be based on clear criteria including:

- The potential of technologies to contribute to the rapid decarbonization of our energy system, whilst also helping to meet other policy goals;
- The potential for future cost reductions that could be realized through public funding – whether this funding is for research, development and demonstration (R,D&D) or for deployment (e.g. through mechanisms such as Contracts for Difference); and
- The scope for UK leadership and economic benefits from the development, manufacture and deployment of these technologies.

The government has been conducting such reviews for over a decade. This initially took the form of a set of Technology Innovation Needs Assessments (TINAs) in the early 2010s[10]. A more recent process was commissioned by BEIS, and published as an Energy Innovation Needs Assessment (EINA) in 2019[11]. The latter process resulted in a more focused set of priorities, and was commissioned to inform decisions on allocating the government's energy innovation funding programme.

We think government should continue to conduct regular reviews of its priorities at least once every five years. The scope should be widened from the recent EINA review so that future reviews cover all public support – including support to technology deployment as well as support via R,D&D programmes. If there are technologies that are not developing as quickly as expected, this does not necessarily mean that they should be abandoned altogether. But it might mean that support is reduced and focused more on R,D&D. This would mean that more expensive deployment support could be prioritized for those technologies that have significant short or medium-term potential.

6. What energy generation mix will get us to net zero the quickest in the most affordable way?

It is now widely recognised that mature and low cost renewable technologies, specifically on and offshore wind and solar PV, will play a major role in the UK's net zero emissions electricity system. This is because they are deployed at scale today, are comparatively quick to build, have abundant potential across the country and are now significantly lower cost than fossil generation or other low carbon alternatives. Given

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[10] A summary and links to TINA reports can be found on the Carbon Trust website: https://www.carbontrust.com/our-work-and-impact/guides-reports-and-tools/tinas-examining-the-potential-of-low-carbon-technologies

[11] Vivid Economics et al (2019) Energy Innovation Needs Assessment: Overview Report. Report commissioned by BEIS; https://www.gov.uk/government/publications/energy-innovation-needs-assessments

their high costs and long build times, new large nuclear plants are unlikely to play a significant role in the medium-term, and particularly in delivering net zero power by 2035[12].

Therefore, achieving net zero power will require a rapid and sustained push to build more renewable infrastructure and transform the country from sourcing around 30% of its electricity from wind and solar today to 70% or more by the mid 2030s. Potential pathways for the transition of the UK's power system, produced by UCL using the UK TIMES whole energy system model, are shown in Figure 1, which is taken from a recent Centre for Research on Energy Demand Solutions report.[13]

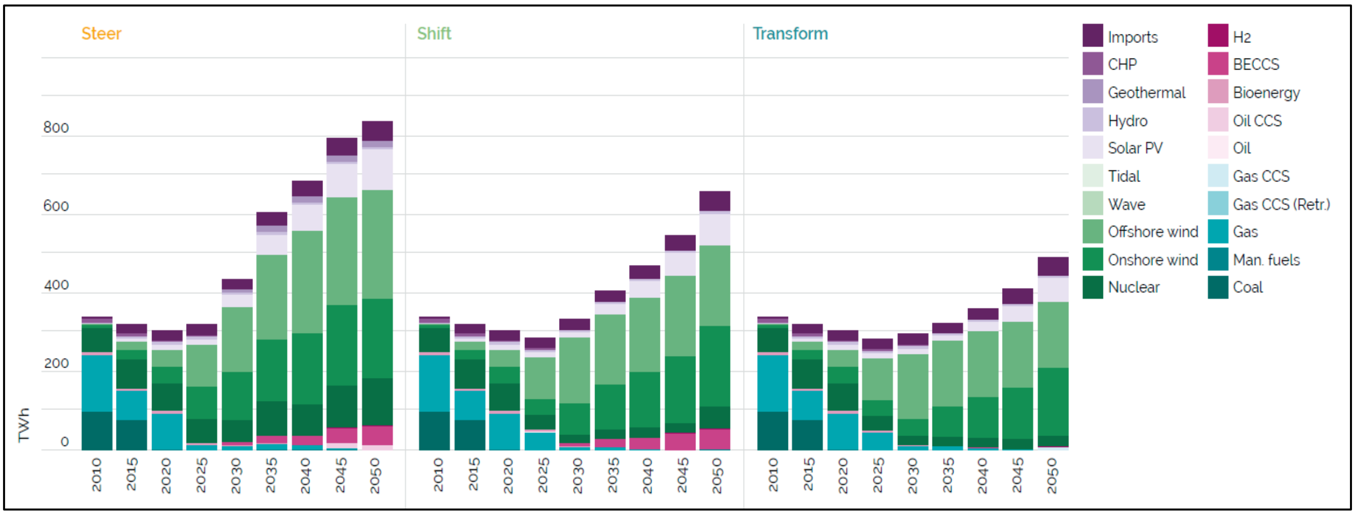

Figure 1:Power generation by scenario 'Steer', 'Shift' or 'Transform', 2010–2050.

Delivering this renewable transition will critically depend both on the timely construction and connection of new generation infrastructure to the network and the contemporaneous deployment of a full suite of key technologies to increase system flexibility and enable renewable integration.

The majority of these technologies are cost effective today and have already been deployed at scale, i.e. interconnection to other countries, reinforcing the transmission system, short duration storage (e.g. batteries) as well as options to provide essential ancillary services like system inertia. Indeed, batteries are only expected to become more affordable going forward. Low carbon dispatchable generation fuelled by hydrogen is increasingly seen as a complement to variable renewables by some stakeholders[14]. Additionally, long duration energy storage using hydrogen has been identified as important for renewables integration by academia[15], the CCC[16] and Government[17], with the former study showing such storage can lower system costs by as much as 21%. Utilisation of this storage route would allow the UK to, among other things, fuel its own dispatchable low carbon generation, further enhancing energy security. Given the appropriate policy support, long-term hydrogen storage is expected to mature quickly as the most promising and affordable option relies on hydrogen storage in salt caverns, a practice which is at scale today though not for energy applications.

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12 https://www.ft.com/content/c4bf95e2-6868-448d-bfca-5871dd2fb492?desktop=true&segmentId=d8d3e364-5197-20eb-17cf-2437841d178a#myft:notification:instant-email:content
13 https://low-energy.creds.ac.uk/the-report/
14 https://www.theccc.org.uk/2023/03/09/a-reliable-secure-and-decarbonised-power-system-by-2035-is-possible-but-not-at-this-pace-of-delivery/
15 https://www.sciencedirect.com/science/article/pii/S0360544222023325
16 https://www.theccc.org.uk/2023/03/09/a-reliable-secure-and-decarbonised-power-system-by-2035-is-possible-but-not-at-this-pace-of-delivery/
17 https://www.gov.uk/government/publications/benefits-of-long-duration-electricity-storage

A crucial and often overlooked aspect of delivering a highly renewable power system is electricity demand. The transition to net zero is expected to result in demand for electricity growing substantially over the next few decades as heat pumps are deployed at scale in buildings and electric vehicles replace those driven by internal combustion engines. Much of this demand will also be coupled to the weather which, combined with a predominantly weather dependent supply of electricity, means that unlocking demand as a variable of the transition, and not just fixed, becomes important.

From an operability perspective, demand flexibility, e.g. shifting demand away from peak periods, is well understood to lower the total system cost, i.e. the cost of building and operating the system, because it can better align when renewables produce with when demand occurs. Schemes to incentivise behaviour that supports demand flexibility can also make electricity more affordable for consumers. Furthermore, recent work has demonstrated the sizable benefits of policy interventions to reduce energy demand across the whole energy system[18]. Figure 1 shows three potential pathways to a net zero emissions UK electricity system, with progressively greater ambition to reduce demand for electricity from left to right. Lower demand, due to, for example, improved building insulation or fewer car journeys, directly results in a smaller electricity system in annual generation and capacity terms and so less infrastructure needing to be built. This contributes to the speed of the transition, and its feasibility, and makes it more affordable due to substantial capital and operational cost savings.

In summary, the quickest and most affordable route to net zero power is through: i) a rapid scaling of low cost and mature technologies, ii) focused policy support to enhance system flexibility and iii) perhaps most crucial of all, efforts to reduce electricity demand and, where possible, make is more flexible.

7. **Are the energy solutions universal across the UK or are there regional and local approaches on fuel and energy?**

Significant electrification of the energy system, for example heat in buildings and road transport, is now well understood to be the least cost pathway to reach net zero.

Weather dependent renewables, i.e. on and offshore wind and solar PV, will underpin this transition. Research has shown that the most cost effective way to deploy this infrastructure is in a spatially diverse manner to leverage the best resource quality and different timings of production (that is, different weather in different locations at the same time)[19]. This means siting wind farms in the windiest locations but also distributing their deployment throughout the windiest parts of the UK and its exclusive economic zone (the area of sea surrounding the UK over which the country has jurisdiction). Figure 2 shows an example of a spatially diverse deployment for onshore wind capacity in a low carbon power system as designed by UCL's highRES model.

[18] https://low-energy.creds.ac.uk/the-report/
[19] https://www.sciencedirect.com/science/article/pii/S0306261918309966

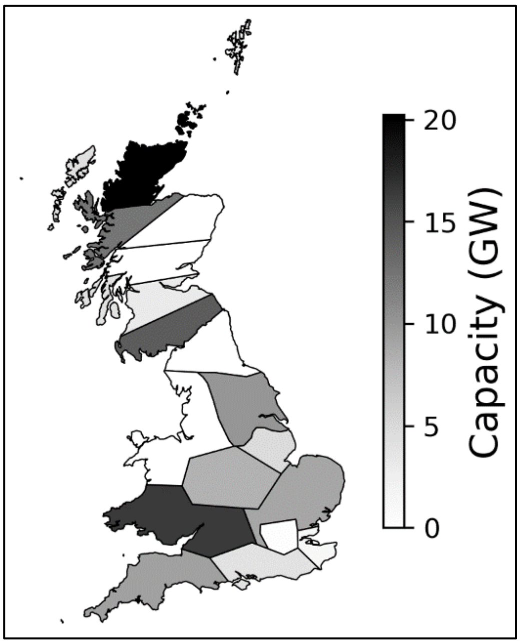

Figure 2: Installed onshore wind capacity in a low carbon GB power system (source: https://ieeexplore.ieee.org/document/9085902)

To enable a highly renewable system, it is vital that new renewable infrastructure is connected to the network in a timely manner and new network capacity is built out to move electricity from where it is generated (e.g. Scotland) to where it is demanded (e.g. the Midlands and the South East of England). A transition to a net zero power system will see the regional patterns of supply and demand becoming much more important and needing to be managed by a long-term strategic roadmap to support adequate system development.