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TOWARDS A MORE DYNAMIC REGULATION FOR ENERGY NETWORKS

REPORT

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ABOUT CERRE

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EXECUTIVE SUMMARY

The nature of regulation

The overall direction of travel towards a net zero energy system has been clarified, at a high level, and has significant amounts of legislation behind it across Europe. However high levels of uncertainty remain in nearer term timings, the pathways that will end up being taken and the outturn difficulty of achieving a net zero energy system.

One way forward is for regulation to become more dynamic/responsive/adaptive in the face the challenges of net zero. This seems likely to exacerbate the current regulatory trade-offs. These exist between the need to **coordinate** across stakeholders, **motivate** regulated companies to respond appropriately and the **transactions costs** of regulation. They also exist between the **effectiveness** of regulatory incentives, **responsiveness** to new information and **coherence** between regulatory decisions.

Dynamic regulation emphasises that regulation is a repeated game where the regulator and the regulated companies face dynamic incentives to behave in certain ways which can be influenced by the nature and timing of regulation. **Responsive regulation** seeks to chart a middle way between completely fixed regulatory rules and *laissez-faire* regulation. **Adaptive regulation** emphasises the need to build future learning into the regulatory process. All of these 'dynamic' approaches to regulation emphasise the need for regulatory learning, from the past, in the present and into the future.

Potential changes to regulation

We explore potential areas where regulation could be changed in order to better cope with the uncertainty around net zero energy policies. These include potential changes to the nature of planning, uncertainty mechanisms, regulatory incentives, financing arrangements, stakeholder engagement, innovation processes and industry governance. We do this by asking both regulators and regulated companies for their views.

We observe that regulatory contexts vary across Europe and that several regulators, for example, in Great Britain and the Netherlands have recently consulted on the future of regulation under net zero.

Some regulatory jurisdictions are still lacking some of the basic elements of best practice incentive regulation, as demonstrated by Ofgem's RIIO, which emphasises that regulatory revenue (R) should depend on appropriate incentives (I), promotion of innovation (I) and the definition and incentivisation of a wider range of well-defined outputs (O). The evolution of regulation towards a more flexible system like RIIO should be considered beneficial. However, any best practice incentive regulation has to fit the specific context of industry structure, country size, demand mix and generation profile.

Electricity and gas face substantially different regulatory challenges. For electricity, there is a general expectation of expansion, but the required rate is subject to some uncertainty. For gas, there is a general expectation of significant decline in absolute volumes and in total connections, but large uncertainty around how fast this will occur and the extent to which biomethane or hydrogen or relaxations in net zero policies will slow the speed and extent of the decline.

Between distribution and transmission there are also some differences, particularly those relating to small distribution companies which will not be able to be as responsive or adaptive as larger distribution companies.

Governance issues for the energy sector are substantial. Integrated network planning between electricity and gas and between distribution and transmission is a work in progress. Network planning is still largely at the single company level, although this enables system integrated perspectives where different energy carriers are under a single system operator. This raises questions about overall industry governance and the role of the system operator and the role for reorganisations of network ownership to achieve net zero, e.g., via joint ownership of gas, electricity, and district heating assets.

Lessons from our questionnaires to regulators and regulated companies

We sent a detailed questionnaire to regulators and regulated companies to get a richer set of insights into their views on the need for changes to regulation.

Many of the points that the regulated companies make can be viewed as calls for the implementation of best practice regulation in their jurisdictions. These include, inter alia, having ex ante planning, appropriate uncertainty mechanisms, longer-term incentives, sufficient financing, effective stakeholder engagement, innovation funding mechanisms and promoting whole-system thinking.

The regulators do want to respond to company and other stakeholder concerns and some major changes are in train e.g., changes to governance arrangements (in the UK with the creation of the Future System Operator - FSO) and the nature of regulation (in Sweden via a move to TOTEX regulation from 2027). By contrast companies raise the issue of whether unbundling rules are preventing them from making system optimal investments within the current ownership structure.

Gas Transmission and Distribution companies (TSOs and DSOs) emphasise the need for regulation to be clarified with respect to heating generally and new gases. District heating and direct use of gas compete with each other but are often separately regulated or subject to quite different regulatory regimes. While hydrogen networks do not yet exist but could be significant in the future, competing with existing methane networks and with other sources of energy.

Regulated companies want more certainty as to government policy. However, regulators emphasise that they need to be responsive/adaptive to government policy. Regulators thus have to be realistic as to the extent to which they can offer multi-period guarantees on investment plans and build in re-evaluation points in line with the adaptive regulation framework we outline.

Lessons from outside Europe and other sectors

Finally, we look to non-European countries and other sectors for inspiration on ways forward for energy network regulation.

In Australia, 'New Reg' has instituted an **early engagement process** which attempts to bring together customers and electricity network companies in order to agree regulatory proposals.

In Scotland, WICS - the regulator of Scottish Water - has made use of a **Consumer Forum** to play a significant role in the price control review process.

In Singapore, the Singapore Autonomous Vehicle Initiative, has developed an **open platform** that allows authorities, research centres and think tanks, or industry companies to jointly run self-driving trials.

In England and Wales, the water regulator Ofwat, has adopted **adaptive planning** in its latest price control review. This approach involves the companies suggesting various decision points – over the next 25 years – when key investment decisions have to be taken to keep the company's long-term targets on track.

In Australia, major airports, are no longer subject to price controls, and the government has implemented a **system of price and quality monitoring.** This has resulted in airlines and airports agreeing on airport charges and quality of service levels, without the need for direct regulatory involvement.

RECOMMENDATIONS

The regulatory context matters so the specifics of what needs to be done will vary from jurisdiction to jurisdiction. However, net zero is such a demanding target that all jurisdictions will be required to adjust their energy network regulation to accommodate it.

The Nature of Regulation and the Regulatory Approach

Regulation needs to move beyond a static approach based on cost minimisation to efficiency to focusing on dynamic innovation led efficiency.

Regulation needs to become more responsive in the sense of combining regulatory rules and competition to achieve a balance between ex ante clarity and responsiveness to new information.

Regulation needs to be more adaptive in the sense that it explicitly builds in the need to acknowledge key points at which learning must explicitly be accounted for in regulation.

Learning is a common feature of the three attributes and should be a priority for the regulator of the net zero era. Learning from one price control period to the other, from the 'community of practice' around network companies, from third parties, from other regulators, from other sectors and jurisdictions, should all be encouraged.

There is a need for a 'learning' regulator who simultaneously looks to learn from the past, be responsive to stakeholders in the present and seeks to anticipate key future decision points.

Potential changes to regulation

Best practice network regulation goes a long way towards a more dynamic set-up. Thus, catching up with regulatory best practice should be a priority for all European regulators.

This, inter alia, involves having ex ante planning, appropriate uncertainty mechanisms, longer-term incentives, sufficient financing, effective stakeholder engagement, innovation funding mechanisms and promoting whole-system thinking.

On planning:

An individual price control review period should be explicitly set within a multi-period context of up to 25 years, with explicit recognition of when particularly significant decisions will be required. Company business plans should be framed in this context.

On uncertainty mechanisms:

Full use needs to be made of each of the five types: volume drivers, re-openers, pass-through mechanisms, indexation, and use-it-or-lose-it allowances. These fulfil different roles. The question is whether regulators are making appropriate use of these in the face of future uncertainty.

On regulatory incentives:

Regulators need to incentivise the outcomes they wish to see. These should include faster, cheaper network delivery and operation. TOTEX regulation can encourage non-capital intensive network solutions. In moving towards net zero appropriately defined outputs can encourage, inter alia, the roll out of hydrogen, biomethane, heat pumps, EV charging points.

On financing arrangements:

Regulated companies require adequate financing. A move towards a combination of taxpayer and customer funded networks, e.g. for hydrogen networks or electricity transmission lines, requires taxpayer funding to include an appropriate return which does not distort incentives between the two sources of funding.

On stakeholder engagement:

Stakeholder engagement can effectively reduce the role of the regulator in regulatory decision making. Regulators should set appropriate stakeholder engagement fora and experiment as to how to promote effective engagement, to the point that the regulator can leave certain regulatory decisions to the engagement process.

On innovation:

Regulators need to encourage innovation and make appropriate allowance for innovation funding. Offering 'Fast, Frank Feedback' to innovators on their technologies and business models is the minimum customers and innovators should expect.

On industry governance:

Net zero is an extreme policy challenge, hence industry governance needs to be reviewed with the objective of better coordinated decentralization of decisions.

Potential changes include:

The creation of separate system operator organisation that can make decisions free from accusations of bias towards certain types of assets.

The creation of new regional bodies to co-ordinate network planning at the sub-national level.

The reform of regulatory approaches from ex post to ex ante, from OPEX to TOTEX, from static to dynamic.

The reorganisation of asset ownership to merge gas and electricity assets, or to make gas and electricity network areas contiguous.

The explicit allocation of regulatory responsibilities for district heating and/or hydrogen networks to the current energy national regulatory agency (NRA).

The transfer of the ownership of network assets from or to the private sector to sharpen incentives, reorganise the industry or change incentives.

Unbundling rules which prevent network companies investing in certain technologies such as batteries, hydrogen and biomethane production facilities need to be reviewed.

With respect to transmission and distribution:
Regulators need to pay increasing attention to non-discrimination in regulatory treatment between transmission and distribution. This is because of the potential for distortion in meeting net zero between large transmission connected assets and distributed assets.

With respect to gas networks:
Gas networks need accelerated depreciation and increased regulatory allowances and more clarity as to their longer-term future, in particular adaptive regulation should be applied to future price controls making it clear when key decisions on their network future should be taken.

Gas TSOs and DSOs emphasise the need for regulation to be clarified with respect to heating generally and new gases.

Gas networks need regulatory barriers towards the roll out of hydrogen networks and hydrogen and biomethane production reduced.

For all network companies:
Lead times for new network investments need to be reduced. While planning can help establish a need for investment, it cannot deliver it alone. Reduction of lead times makes planning easier and reduces cost.

Lessons from other sectors and outside Europe
European energy networks can learn from other sectors and countries.

25-year adaptive planning has been adopted in the water sector in England and Wales.

An open innovation platform for the running of trials has been implemented in Singapore.

Periodic formal price controls have been replaced by regular monitoring of quality and prices for major Australian airports.

An early engagement process between customers and electricity network companies to agree regulatory proposals quickly has been put in place in Australia.

1. THE CONTEXT OF NETWORK REGULATION

1.1. Relevance

The net zero goals require significant upgrades and transformations of infrastructure, which will require massive investments. While investments in renewable capacities have ramped up, those in grid deployment and extension have been asymmetric, remaining constant at around $300 billion per year in the OECD – leading to more than 3000 GW of renewable projects in waiting grid connection queues (IEA, 2023). Additionally, these expansion projects ought to go hand in hand with the development of generation capacity and the electrification process.

Despite a steady increase in network investments in OECD countries, the pace needs to accelerate. Based on the estimation of the IEA, annual grid investments would need to almost double by 2030 - to more than $600 billion - to meet national climate targets (IEA, 2023).

However, the expansion and reinforcement of electricity networks translates into higher tariffs passed to consumers, which invariably raises social and economic concerns. While the structure of energy bills varies across geographies, an increase of distribution and transmission tariffs is always a sensitive matter leading to affordability debates, which spill over into political agendas.

For example, the electricity tariffs (distribution and transmission) across different European countries vary depending on the conditions and characteristics of energy systems, as well as on economic and social contexts. They range from €30-50/MWh (Greece and Romania) to €110-125/MWh (Ireland and Belgium). The share of network tariffs usually represents 20-30% of the overall energy bill, with the distribution tariff segment accounting for approximately 2/3 of this share (IEA, 2023).

1.2. How has regulation evolved since unbundling/liberalization and what challenges remain

The regulation of natural monopoly network companies has been evolving over time to match the challenges of unbundling and liberalisation in the energy utilities sector. Independent regulators need to continuously balance the interests of consumers and investors in the network companies (NC) to ensure a high-quality service at efficient prices while allowing for adequate returns. From an economic perspective, periodic regulatory reviews represent a repeated game with asymmetric information and uncertainty. Uncertainty affects both sides.

On one side, network companies (NC), as regulated entities, commit capital long term and are vulnerable to ex-post decisions from the regulator or policy maker that can affect their remuneration (Gilbert and Newbery, 1994). This can determine the size and type of investments they are comfortable committing in a time when getting adequate investment is key on the path to net zero.

On the other side, regulators have the goal to ensure NCs strive for efficiency and quality of service in a situation where they are not subject to conventional product competition. As managerial effort and

costs are not directly observable (especially with respect to innovation), the contract between the regulator and the utility is open to moral hazard (i.e., managerial effort is lower than presented) and adverse selection (true costs different than presented). The aim of the regulator is to set the rewards and penalties in a way that ensures allocative and technical efficiency. In the absence of competition, economic regulation attempts to ensure regulated entities behave in accordance with the possibility of higher returns in exchange for efficiency and quality, and lower returns otherwise (Jenkins, 2011).

In concrete terms, the fundamental objectives[1] of regulators are to ensure the interests of consumers are well represented and to determine natural monopolies with respect to:

- Efficient operational expenditures;
- Adequate investment;
- Quality of service.

While the objectives of networks companies are to:

- Pursue efficient investment and operational costs;
- Make the right financing and investment decisions to ensure adequate returns for shareholders;
- Maximise profits through meeting performance targets and responding to regulatory incentives.

For these to be achieved, NCs need to conduct the right amount of investments to meet future demand, keep operational costs under control, achieve the desirable level of service quality, while earning adequate returns. The information required to achieve this is not easily observable from outside the NC. This results in the possibility of the NC to engage in strategic behaviour to maximize its profits. There can be over or underinvestment, operational costs can be inflated or reduced below requirements, quality of service can be difficult to measure, while estimating the adequate return on capital for the NC can also obscured.

Various approaches and methods have been devised and implemented to deal with the information disadvantages of regulators toward the regulated entities. On the other side, protection for NCs from retroactive changes to regulation and policy or from events outside their control have also been a matter of concern – partially addressed through improvements to the regulatory contract. Ensuring that companies perform their functions for the system while extracting ***low but sufficient*** profits has long been the fundamental challenge of regulation (Jamasb and Pollitt, 2007; Joskow, 2014).

The 'cost of service' approach was the first and most basic form of regulation that attempted to use imperfect information on demand, costs, and firm viability to set network tariffs. It sets an ex-ante[2] limit on revenues, with minimal adjustments during periods and larger adjustments in subsequent periods based on revealed information. Obtaining the relevant information has been shown to be difficult, even under these static conditions (Joskow, 2014). Determining the parameters of the price

[1] There are ongoing discussions on including net zero within the remit of energy regulators
[2] In some regulatory regimes this process is replaced with an ex-post review

building blocks required significant approximation but was found to be broadly successful (Jamasb and Pollitt, 2007).

The next step has been to elicit efficiency improvements, attempting to recreate the incentives that would occur under competitive conditions. The price cap system, applied in Great Britain (RPI-X), ensured that tariffs were indexed with inflation (RPI), and, most importantly, adjusted by an efficiency improvement factor X. A profit-sharing mechanism was devised, so that the NCs could keep a part of the gains from efficiency improvements, particularly in operating expenditure (OPEX), which was believed to induce adequate managerial effort. Again, establishing the right starting point, determining X, the sharing mechanism, benchmarks and avoiding strategic behaviours have proven to be difficult but workable (Jamasb and Pollitt, 2007).

Box 1: What is RIIO?

Announced in 2010 and applied since 2013, RIIO was Ofgem's new method for setting price controls in electricity and gas distribution and transmission. RIIO stands for Revenue = Incentives + Innovation + Outputs. After significant consultation, Ofgem decided that the increased uncertainty brought about by decarbonization, decentralization and digitalization require a new approach to regulation. The most relevant changes that RIIO brought have been in setting incentives for investments and operational efficiency, most importantly the total expenditure (TOTEX) approach, in encouraging more innovation through dedicated allowances and establishing rewards and penalties for networks companies, linked to concrete outputs including customer satisfaction, reliability and availability, safety, connection terms, environmental impact, and social performance.

A further refinement of incentive regulation placed a greater emphasis on outputs and innovation, partly to prepare the system for decarbonisation. The aim was to partially recreate the conditions of dynamic (innovation oriented) competition in addition to static (price oriented) competition (Teece, 2011). In Great Britain, the RIIO formula (Revenue=Incentives + Innovation + Outputs) keeps many of the features of RPI-X but adds various adjustments of revenue, based on pre-defined outputs. The focus on outputs, together with the benchmarking based on total expenditure TOTEX, the sum of capital expenditure and operational expenditure (CAPEX+OPEX), aims to stimulate managerial effort toward goals such as reliability, safety, and customer satisfaction, while offering flexibility in terms of the methods and inputs used to achieve them. In the RIIO context, the NC is no longer incentivised to reduce only operational costs but gets to also share profits when obtaining savings from delaying or avoiding CAPEX. In a way, this approach also encourages the NC to pursue innovative technologies and practices to the extent that it helps them reach their target outputs associated with financial and reputational rewards.

Box 2: Totex regulation

The TOTEX approach replaces the established practice of having distinct treatment for capital (CAPEX) and operating expenditure (OPEX) for regulated energy networks. Traditionally, CAPEX earns the NC a regulated rate of return for the life of the asset while OPEX does not, making the former more

appealing. Under a TOTEX approach, NCs would be entrusted to use their knowledge advantage and optimize between CAPEX and OPEX, free from profit implications for the current or future regulatory period. The recent emphasis on TOTEX is driven by two primary factors. Firstly, a perception of a bias towards CAPEX by NCs prompted policy and regulatory interventions aimed at reducing the risk of excessive investment in physical network assets. Secondly, the evolving technological landscape has made less capital-intensive alternatives such as energy efficiency and digitalization increasingly viable for reliably matching supply and demand on the network. The approach is not without its risks and can be complex to manage. For instance, Frontier Economics discuss the need to assign a fixed capitalization rate and a corresponding fixed asset life to capitalized TOTEX. This introduces the risk of over or under-funding future capital investment requirements relative to a separate CAPEX and OPEX regime (Frontier Economics, 2018). However, In certain contexts, coupled with other regulatory features, a TOTEX approach can allow for greater flexibility and can better incentivize the right investments for net zero while keeping consumer bills in check (Rebane, Goldenberg and Posner, 2022).

To deal further with the adverse selection problem, RIIO also introduced an Information Quality Incentive, which varies in proportion to the positive difference between the companies' proposed business plan and the regulator's estimation (based on third party guidance). This is meant to encourage companies to reveal their true cost by allowing them a rate of return closer to the estimated cost of capital. This is a partial application of the menu of contracts approach whereby companies self-select into their cost category thanks to the differentiated incentive that matches the cost saving potential (Oxera, 2015; Jamasb, 2020).

RIIO also features an innovation stimulus package – including the network innovation competition – where NCs compete against each other for funding demonstration projects. This support for innovation has involved substantial regulatory expenditure allowances (up to 2.5% of revenue) for innovation, through a combination of competitive funding (via a network innovation competition) and non-competitive network innovation allowances. As we discussed in Anaya et al. (2022) this generous policy towards innovation allowances has propelled UK electricity distribution network companies to the top of global league tables on smart innovation[3]. However generous allowances have applied to both transmission and distribution and to electricity and gas.

To deal with deviations from the allowed business plans, due to new polices or changes in supply and demand within the five-year period, RIIO establishes a number of uncertainty mechanisms. Through volume drivers, indexations and reopeners, such as Net Zero, New Large Load, Medium Sized Investment Projects and others, NCs can apply for additional funding for qualifying projects. [4] While

[3] https://www.spgroup.com.sg/our-services/network/overview/smart-grid-index

[4] These re-opener processes are pre-defined and refer to investments outside the business plan, that meet certain thematic criteria (i.e., necessary for net zero, or new load, large transmission and others) and are required to follow certain process. More information on Ofgem re-opener mechanisms can be found at https://www.ofgem.gov.uk/publications/re-opener-guidance-and-application-requirements-document-version-3

they allow for a degree of flexibility, the process tends to be cumbersome and create some uncertainty as to the level of remuneration.

RIIO is 'widely regarded as the most comprehensive performance-based regulatory system developed to date' (Girouard, 2019) and has been pioneering in many ways, not least in the use of TOTEX (IEA, 2023, p. 61).However, even a state-of-the-art form of incentive regulation like RIIO may not be sufficient to encourage networks to enable decarbonization. At the same time, many countries are still far from models like RIIO and still have variations of the cost-of-service regulation since the start of liberalisation-deregulation-unbundling, even in Europe (Poudineh, Brandstätt and Billimoria, 2022).

Box 3: Uncertainty mechanisms[5]

As previously explained, price control periods in Great Britain are based on pre-determined allowances for network companies (NCs). Uncertainty mechanisms are meant to cover deviations from the scenarios established in the business plans submitted by NCs as a basis for the price control period. There are five such uncertainty mechanisms:

- Volume drivers are used to adjust allowances to reflect actual volumes of work versus forecasts, used in cases when costs are known but required volumes are uncertain.

- Reopener mechanisms are used to change allowances during a price control period, when the need and cost of a specific activity become more certain.

- Pass-through mechanisms that add to pre-determined allowances those costs over which NCs have limited control.

- Indexation to adjust for the evolution of general inflation of prices when it is different from what was forecasted.

- Use-it-or-lose-it (UIOLI) allowance meant to adjust allowances for certain work that has been identified, but costs and the exact nature of work are not yet known[6].

This continuous evolution in advanced regulatory regimes illustrates that regulation of utilities is challenging even in the absence of the significant shifts expected to occur as a result of the energy transition. Even ignoring the decarbonisation process, the challenges of regulation remain.

On the regulator side:

[5] https://www.ofgem.gov.uk/sites/default/files/docs/2020/12/final_determinations_-_core_document.pdf
[6] Some examples of UIOLI allowances in Great Britain include Net Zero and Re-opener Development, (NZRD) Worst Served Customers (WSC) or Vulnerability and Carbon Monoxide Allowance (VCMA).

- Regulation often is based on policy guidance from the government. This can potentially change dramatically with political cycles, affecting both planning processes and existing investments[7].
- Political interference with regulatory processes can undermine the credibility of regulatory arrangements, making long term commitments more costly.
- Retroactive changes to regulatory settlements can affect the remuneration of NCs and weaken the appetite for investments.
- Measuring the performance of NCs is difficult, indicators are imperfect and rely on NC themselves for inputs – some of which are subjective.
- The causal link between CAPEX and quality improvement is long and complex, determining what investments are truly necessary is challenging even with inside information, even more so from outside the organization.
- Benchmarking is difficult because NCs tend to be different enough for comparisons to be challenging. In the case of TSOs, benchmarking is even more difficult, as many jurisdictions only have one TSO and no comparison group.
- The regulator can be either captured by NC interests thus extracting more value from customers or by other interests that can gradually expropriate the NC, eliminating the incentives for long term performance.
- Setting the allowed capital costs in advance every three to five years is based on forecasts for customer and load growth, quality improvements, useful life of equipment, and information on each dimension is highly uncertain. Relying on third party consultants for a second opinion may not always be sufficient. The treatment of higher or lower than agreed CAPEX can be contentious.
- Reopening settlements can weaken incentives and credibility of regulation. Ex-post interventions reduce the reliability of ex-ante arrangements and are likely to affect NC behaviour to adapt to this possibility. This can also impact on the cost of capital given the higher risk. On the other hand, greater uncertainty in the system may require more frequent changes to business plans to accommodate unforeseen circumstances stemming from the energy transition.

On the NC side:

- NC can either increase operational costs in a wasteful manner or reduce them to the point that it affects the quality of service.
- NC can overinvest to increase the regulated asset base and benefit from the guaranteed rate of return or underinvest affecting long term reliability.
- NC can shift between OPEX and CAPEX to maximise returns, mainly to capitalise operational expenditure to appear more efficient by reducing OPEX and increasing CAPEX (and earning a rate of return on it).
- The regulatory cycle is a repeated game and NCs, not only regulators, can learn and adapt their behaviour to maximise profits.

[7] A recent ruling of the Court of Justice of the European Union (C-718/18) may have consequences on the extent to which governments can interfere within the activities of the regulator (Huhta, 2021). According to legal scholars, the ruling makes it even more difficult to clearly distinguish between 'general policy guidelines and matters that fall exclusively within the competence of the NRAs' (Huhta, 2021, p. 10)

- The regulator can become the "constituency" of NCs. Instead of focusing on customer needs, NCs can become fixated with meeting the (imperfect) KPIs imposed by regulation (e.g., prioritising cost saving at the expense of quality of service).

As has been shown, economic regulation in the energy sector has evolved to meet the various challenges arising from the nature of the sector. However, many issues remain even in the most experienced regulatory regimes. Net zero is likely to make some of these challenges even more significant.

1.2. Drivers of change and the uncertainty associated with net zero policies

The pathway to net zero in Europe is still subject to significant uncertainty in what concerns energy networks. Particularly on the roles of hydrogen and decarbonised gas versus electrification in heating and transport. At the same time, even the most conservative scenarios are likely to require massive investments in electricity grids. At the same time, having a view of the aggregate level of investments needed is not equivalent to knowing where and when those investments are going to be deployed, which keeps uncertainty high. Even more uncertain are the potentially significant investments in conversions to hydrogen (Chyong *et al.*, 2021). In addition, networks will have to incorporate new ways of working and potential innovation, to manage the increased penetration of DERs as well as new loads and harness the potential of digitalization. Overall, networks will remain a significant percentage of the final cost of energy. In this context, even efficient and justified costs are likely to be high, which means that the "traditional" principles and objectives of economic regulation will continue to be highly relevant, to ensure that customers will not end up supporting inefficient costs on their bills. Hence, on top of their traditional focus, regulators will have to be one step ahead of the evolutions in the sector and enable the transition to net zero while avoiding ballooning customer bills.

European energy and climate policy sets ambitious goals for both 2030 and 2050, which put great emphasis on an energy network which is capable of delivering them (Pollitt and Chyong, 2021). For electricity networks, there is the prospect of a significant increase in electricity demand (both in terms of power and energy) as transport, industry and heating are further electrified. In addition, there is the prospect of significantly increased demand for electricity to be used in the production of hydrogen, which then itself be used to further decarbonise hard to reach sectors. For gas networks, the future is highly uncertain as hydrogen, biomethane and electricity may all play a role in fulfilling the current demand they currently serve. Some networks – particularly for electricity and hydrogen - will face significant areas of growth, while other networks – particularly conventional methane – could face significant decline.

The range of potential outcomes under plausible pathways for individual networks is large. For instance, looking at Great Britain, NG ESO annually produces four *Future Energy Scenarios* for 2030 and 2050 (National Grid ESO, 2022). Electricity distribution networks deliver 90% more by 2050 (relative to 2021) in the least ambitious scenario and 145% more by 2050 in the most ambitious scenario; while interconnectors deliver net exports which vary by a factor of 2.8. Methane networks deliver c.35% less by 2050 in the most optimistic (for methane, not net zero) scenario and 97% less in

the least (National Grid ESO, 2022, p. 206): i.e., the difference between a significant network, still bigger than all but one in Europe are now, and near complete shutdown of the current methane network. Hydrogen networks deliver almost nothing by 2050 in the least optimistic and almost half of current methane demand (over 400 TWh) in the most optimistic scenario (National Grid ESO, 2022, p. 215). High hydrogen demand will also be associated with large amounts of electrolyser capacity (National Grid ESO, 2022, p. 11). A similar scenario could be identified for a CO_2 network, arising from the capture of CO_2 (CCS) from steam reformation of methane (to make blue hydrogen), bioenergy with CCS (to gain negative emissions) or conventional fossil fuel with CCS power production (Pollitt and Chyong, 2021).

In Germany, of 126 gas DSOs surveyed, 25% foresee hydrogen in their network by 2028, 31% by 2035 and 19% by 2040. On the end of methane supply, 9% of DSOs see it before 2032, 13% before 2035, 32% before 2040 and 37% before 2045 (H2Vorort, 2022). The differences are significant even within a single country which can probably explained by the government's strategy that foresees a "hydrogen backbone network" and different points in time when hydrogen will be available for certain regions.

Across Europe, national gas networks are at very different starting levels of significance for space heating[8]:

- Only five (including the UK, Netherlands and Italy) serve 55% plus of households;
- Five (including France and Germany) serve between 30% and 55% of households;
- 14 serve between 5% and 30% (e.g., Ireland and Switzerland); and
- Six serve less than 5% of households (e.g., Norway and Cyprus).

This suggests very different outcomes for gas networks are likely across Europe because starting points are so different. In addition, there are several studies at the European level comparing full electrification scenarios with various combinations of low-carbon gases that point out that the least-cost solutions may differ significantly from country to country with different technologies playing different roles, especially in heating (Guidehouse, 2022; Corporate Value Associates, 2023).

Another point of difference between countries that may generate some uncertainty is the role of district heating and the relationship with the regulated segments of electricity and gas. Currently, district heating is significant in countries like Germany, France, the Nordics, Poland and Bulgaria, and much smaller in Spain, Italy or Portugal (European Commission, 2022). With some notable exceptions (Estonia, Sweden, Luxembourg, Lithuania), the district heating systems are largely run on fossil fuels and are likely to undergo transformations in the near future (European Commission, 2022). Coordination will be required between electricity and gas networks on one hand, and district heating

[8] Across the EU-27 only around 40% of households are connected to the gas network, but less use gas for heating. See https://acer.europa.eu/en/Gas/Documents/ACER_FACT-SHEETS_2021-07_02.pdf. For country totals we consider EU-27 + Norway + UK + Switzerland. For data on spacing heating shares: for EU-27 see Eurostat (nrg_d_hhq); for Switzerland see https://www.swissinfo.ch/eng/business/some-58--of-swiss-buildings-heated-with-fossil-fuels/47958720; for UK see https://www.statista.com/statistics/426988/united-kingdom-uk-heating-methods/

networks on the others, to ensure optimal decarbonization of heating and cooling and avoid redundancy, unfair treatment, or misaligned incentives. This adds to the task of regulators and whole-system planners.

For transmission networks, there are similar large ranges of potential outcomes. CERRE Net zero modelling of the decarbonisation of the whole European energy system (Chyong *et al.*, 2021; Pollitt and Chyong, 2021), suggests that large amounts of offshore and onshore wind and solar should be significant in the overall energy mix by 2050 if net zero is to be achieved. In this world, electricity trading across borders increases significantly, but gas trading (due to rising local production via the use of hydrogen and biomethane and declining demand) declines. This suggests very different potential outcomes for electricity and gas transmission. However, the rise of an international trade in green or blue hydrogen may somewhat offset this. To some extent, the relative costs of the different technologies on which net zero depends will still determine which energy sources are favoured.

In Germany, for example, the government presented draft legislation in May 2023 accommodating the creation of a core hydrogen network of pipelines by 2032. There are ongoing consultations with industrial users and the networks companies on the exact routes, the split between conversions versus newly build pipelines, and funding mechanisms, particularly on ways to treat the uncertainty of actual demand. [9]

In Italy, a significant role in preparing grids for the energy transition may be played by the Recovery and Resilience plan – the country being, together with Spain, the top beneficiary of such funds by volume. Italy's plan includes €3.91 billion in investments into grids, including reinforcement of stations, digitalisation, and resilience to climate change. The way this interacts with the regulatory revenue of network companies and the implications for tariffs may be different from other countries that are not beneficiaries of significant amounts of EU grants. [10]

France, on the other hand, sees a significant role for biomethane from crop residues and other agricultural or urban waste in gas decarbonization. Currently, there are 540 sites injecting biomethane into the French gas grid, generating the equivalent of 9211 GWh/year. [11] The Government set a target of 10% renewable gas in the grids by 2030, with some estimates seeing the potential to be even higher – between 12 and 20% of current natural gas consumption (Malet, Pellerin and Nesme, 2023).

An example of uncertainty playing out in a relatively short period of time comes from the Netherlands. According to a study by Kiwa, the ambitious and sudden electrification plan in the Netherlands was confronted with severe practical difficulties (Kiwa, 2022). In 2018, due to numerous issues and the complex process surrounding gas extraction activities in the Groningen province, the Dutch Government opted for an accelerated plan for the phase-out of gas and an increased pace of

[9] https://www.bmwk.de/Redaktion/DE/Pressemitteilungen/2023/05/20230524-bundeskabinett-beschliesst-gesetzentwurf-zur-schaffung-eines-wasserstoff-kernnetzes.html; https://fnb-gas.de/en/hydrogen-core-network/;
[10] https://www.governo.it/sites/governo.it/files/PNRR.pdf
[11] https://www.grdf.fr/institutionnel/actualite/dossiers/biomethane-biogaz/unites-injection-gaz-vert

electrification. All-electric solutions have been prioritised, despite the grid having limitations in accommodating electric heat pumps, especially in densely populated areas. Customers in rural areas mostly opted for decentralized renewable solutions (e.g., solar, wind), leading to similar network challenges as the grid faced technical barriers. At the same time, electricity consumption increased, driven by electric vehicles (EVs), heating and cooking, as well as the increasing adoption of electric solutions in industrial sectors. Consequently, an increasing number of potential new users (mainly business) were unable to apply for new connections. As decentralized electric generation ramped up – also as a solution to these challenges – congestion-management decisions had to be implemented. This led electricity DSOs to prohibit new connections and even disconnect consumers at certain times. In this context, expanding and upgrading the electrical grid can be both expensive and, given Europe's general permitting limitations and lead times, also result in long waiting times for end-users.

This illustrates the uncertainty on how exactly net zero will be achieved both within and between countries. In addition, there remains uncertainty about whether the push towards net zero will continue to be supported by overall policy. The Covid-19 Pandemic (of 2020 and 2021) and the Russia-Ukraine War (from February 2022) shows how events and the need to prioritise energy security and affordability can affect well-intentioned plans to continue to push towards net zero, at least within the current regulatory period. The UK[12] has seen pressure to slow the rollout of electric vehicles, with the ending of sales of new fossil fuel vehicles pushed back to 2035 (from 2030). Germany has encountered domestic political resistance to the rapid roll out of heat pumps to replace gas boilers, with a popular backlash against the 'heat hammer'.[13] The reality of the high political cost of sustaining the ambitious pathway to net zero is becoming clearer, even as the undoubted political benefits of advancing climate policy have been bolstered by the Russia-Ukraine War.

Uncertainty on the path to net zero is to a large extent unavoidable. This is because of the wide range of potential choices and the uncharted nature of the territory that networks are moving into. While uncertainty might be expected to reduce over time as choices are made and outcomes realised, uncertainties will be something that NRAs and regulated companies will have to live with. However, this means that the regulatory system (which includes both NRAs, energy ministries and the general legislative framework) and regulated companies need to be better prepared to manage the uncertainty they face, and that the system should be better designed to limit the negative impact of uncertainty on consumers and investors.

All these evolutions are likely to require regulation that is more 'dynamic'. In this context, dynamic regulation efficiently incorporates information gathered through repeated interactions – i.e. over previous regulatory cycles (Agrell and Bogetoft, 2003) and focuses more on incentives for investment and innovation for meeting future needs of the system than on optimizing the existing system (Bauer and Bohlin, 2008).

[12] https://www.gov.uk/government/speeches/pm-speech-on-net-zero-20-september-2023#:~:text=This%20country%20is%20proud%20to,eases%20the%20burdens%20on%20families.
[13] https://energypost.eu/germany-to-ramp-up-the-decarbonisation-of-buildings-heating-from-jan-1st-2024-how/

However, dynamic regulation raises the issue of who decides when to reopen regulatory settlements and approve additional expenditure (or, indeed, that planned expenditure will not be necessary). While the possibility of reopening regulatory settlements exists in current systems of regulation, the question is whether current approaches are sufficient.[14] Great Britain (GB) has recently announced the creation of a Future System Operator (FSO) who will have more strategic oversight of network development and hence might be a position to approve the financing of individual projects (especially for energy transmission). GB has also reopened the possibility of regional system operation (first suggested in Helm (2017)) to combine the operation of gas and electricity at transmission and distribution levels on a regional basis in an effort to improve energy optimisation at a more local level.[15] Thus, governance arrangements around networks are important and should be given due consideration. Governance arrangements could be at the local level for municipalities who want to advance decarbonisation, at regional level for optimizing larger areas and especially agglomerations, or at the supranational level for international transmission projects.

Dynamic regulation might consider different approaches to old and new assets in terms of rates of return or the assessment of efficient levels of costs. It might also treat first of a kind and established asset investments differently. The Western HVDC Link[16] connected the transmission system in Scotland with England's with a 422 km offshore transmission cable rated at 2.25 GW. This was the first offshore transmission investment using the sea to site what was an investment within the national transmission system of its kind in the world. The project was delivered late due to technical reasons, but substantial conventional regulatory late delivery penalties were applied. According to anecdotal evidence, this apparently strongly disincentivised the TSO from taking further first of kind major investment risks, which have greater led to technical and delay risks, with associated generator penalties. This example suggests the potential role for higher rates of return or better risk sharing on riskier investments.

Other regulatory issues that arise in the context of high uncertainty about the growth or contraction of network demand include: the need to vary depreciation rates (e.g., in cases of gas network growth and contraction); the role of subsidy vs customer-financed network assets, especially where networks need to build ahead of demand (which could be the case for offshore, highway electrification, hydrogen or CO_2 networks); the need to define more clearly the rights of network users and who and when networks can be utilised; and issues in how network charging methodologies should be evolved.

Conventional regulation already involves built-in flexibility mechanisms to respond to rising demand at certain points in the network (e.g., load-related capex expenditure allowances and formulae for triggering network upgrades). There are usually explicit conditions on what triggers reopening of regulatory settlements (e.g., new major investments or storm damage). As reopenings could be triggered more often in the future by the NRA, regulatory entities and political stakeholders should

[14] For example the TURPE6 regulation for electricity networks, covering the period 2021-24 was reopened in January 2023.
[15] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1066720/future-system-operator-consultation-govt-response.pdf
[16] https://www.spenergynetworks.co.uk/pages/western_hvdc_link.aspx

consider the restrictions around such reopenings (in order not to undermine the ex-ante incentives and invite gaming).

It is worth acknowledging that dynamic regulation is easier said than done. The price control review may be conservative and relatively inflexible, but it also serves to protect companies and their rates of return from short-term market and political pressure as part of the regulatory balancing act we noted above. More responsive regulation may hence have unwelcome side-effects for investors, as well as the potential for higher incentivisation.

Across Europe, more dynamic regulation might imply different regulatory settlements for different types of network companies. One could imagine that larger network companies might require more dynamic regulation than (some) smaller network companies. Individually differentiated regulation can potentially occur within a jurisdiction with similar network companies. For instance, Ofgem has experimented with 'fast track' approaches to the regulation of certain network companies who could produce more credible price control business plans in the past.[17]

1.3. The regulatory trilemma and implications of net zero

There are multiple, equally valid goals that regulation must pursue, and some may be conflicting with others. This is valid even without decarbonization, with the latter only adding to the complexity.

Using a general approach, Eskesen (2021) adapts the framework from Bogetoft and Olesen (2004) grouping together the objectives of contract design into three categories:

- Coordination
- Motivation
- Transaction cost

Coordination covers production and risk. For production the aim is to align customers' preferences and the NCs production possibilities. To achieve that, the regulator either mandates interaction with customers, or indirectly establishes outputs relevant for customers as the basis for penalties and rewards, or both. In the case of risk, the regulator aims to reduce total risk and to expose the NC to the optimal amount of risk, not least, in the case of energy, for keeping the cost of capital low.

Motivation includes participation, effort, and investment. The regulator needs to ensure the minimum benefit for the NC is secured to ensure participation and needs to deal with adverse selection and moral hazard issues on costs and effort for efficiency. On investment, the goal is to find solutions to the hold-up and horizon problems which may inhibit taking a long-term perspective with respect to capital expenditures.

[17] https://www.ofgem.gov.uk/sites/default/files/docs/2014/02/fast-track_decision_letter.pdf

Finally, the **transaction costs** of entering into the contract and monitoring and enforcing need to be kept at reasonable levels. Information costs for gathering market data, facilitating customer engagement, evaluating performance and compliance cannot be infinite.

Eskesen (2021) demonstrates that these three objectives of contract design are subject to trade-offs, by looking at regulatory arrangements at Copenhagen Airport, Scottish Water, Danish electricity regulation, and Ofgem's RIIO. Increasing coordination, for example, as in the case of the Customer Forum of Scottish Water, comes at the expense of higher transaction costs. The context of the NC – what issues and challenges are more salient in a country at a given point in time – is what determines a focus on one of the objectives at the expense of another. This can be relevant for the discussion on the energy transition, as certain countries with advanced regulatory regimes may have to prioritise coordination of production and risk to generate the right behaviours that will accommodate the energy transition, and perhaps reduce the emphasis on others such as effort for efficiency improvement.

The wider literature on regulation, stemming from the legal and public policy tradition, discusses a **regulatory trilemma of effectiveness, responsiveness and coherence** (Teubner, 1998; Parker and Braithwaite, 2005). It is argued that any regulation can either i) fall to irrelevance; ii) lead to disintegration on the social area surrounding the intervention or iii) lead to disintegration effects on the regulation itself. In concrete terms, **effectiveness** assesses the extent to which the regulated entities comply with the regulation, looking at the cost of compliance, creative adaptation, and loopholes. **Responsiveness**, on the other hand, is the ability of regulation to maintain desirable social practices that form the core of the regulated activity's functioning and contribution to welfare. Regulation that is too effective can introduce rigid rules and objectives that divert actors away from positive behaviours such as voluntary responsibility and cooperation and toward token compliance. This can inhibit positive self-regulation, incentive led market behaviours and co-regulation revealing private information. Finally, regulation that is responsive may fail at achieving **coherence**. By paying too much heed to existing and different social norms and behaviours, one may reduce the consistency and predictability of the regulatory regime, failing at upholding some of the most relevant principles of regulation, such as equal treatment and fairness.

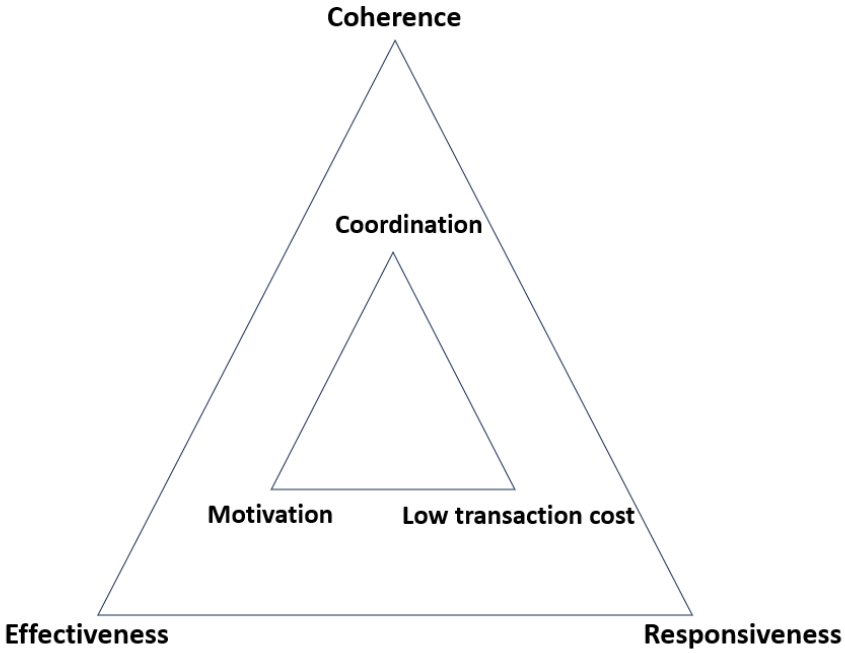


Figure 1: Two trilemmas of regulation

Within the wider trilemma of regulation, in economic regulation on energy, we can speak of an **energy regulatory trilemma** – ensuring a balance between **coordination**, **motivation** and **transaction costs** (Eskesen, 2021), as illustrated in Fig.1. A regulator with a social focus will pursue all three objectives but will face trade-offs. Moving closer to one objective means moving away from at least one of the other two. For example, coordinating and linking the preferences of customers and stakeholders, on one hand, and the capabilities of network companies, on the other, is highly desirable – being the reasoning behind negotiated settlements. But this comes at the expense of higher (potentially prohibitively) transaction costs. One can imagine the costs of deliberation – even assuming no agency problems – as being difficult to bear for the system. Another trade-off is between the coordination of risk and motivation. For example, reducing risk by fixing compensation will decouple remuneration from managerial effort. On the other hand, linking compensation to outcomes exposes the NC to risk related to achieving the outcomes. While regulators try to distinguish controllable versus uncontrollable costs and outputs, avoiding reward or punishment for events outside the companies' control, ensuring enough motivation may require exposure to more risk of wrongful reward/punishment. Another example relates to the length of regulatory periods – longer periods may enable longer term perspective in business plans but may reduce the ability of the regulator to respond to the information revealing properties of price reviews. On the other hand, shorter periods may increase coordination but reduce motivation for network companies to start projects that bear fruit beyond a few years.

Shifting between one or other of the objectives according to particular circumstances has always been challenging for regulators but decarbonisation is likely to make it more difficult and consequential.
To be more specific, regulators with a social welfare mandate continuously face a great number of trade-offs.

The regulators want:

- Managerial effort for low operational cost **but** not at the expense of quality of service;
- Sufficient investment **but** not overinvestment at fixed rate of return;
- To avoid overinvestment **but** provide incentives for anticipatory investment when needed;
- Credible ex-ante price controls to keep costs to consumers in check **but** also flexibility to amend when needs change;
- Stability and certainty for investors to keep cost of capital low **but** flexibility to adapt to new circumstances;
- Effective control of costs through detailed planning and monitoring **but** keeping complexity and enforcement cost manageable;
- To get representative pools of stakeholders and customers involved **but** keeping transaction costs low;
- Encourage and reward innovation **but** avoid wasteful innovation using customer money;
- Encourage competition between NCs **but** also get them to coordinate and share information.

Decarbonisation will exacerbate some of them in the following ways:

- The need for anticipatory investment becomes more significant but the exact amount that will be required is not known (otherwise it would not be anticipatory). Even when the amount may be known, the spatial allocation and prioritisation may still be uncertain. Hence, a greater level of uncertainty and a greater potential for overinvestment will have to be tolerated. These can only be reduced by higher transactions costs or with a higher tolerance of incoherence by being highly selective in what anticipatory investment is allowed.
- The credibility of ex-ante controls can be undermined by the frequent use of reopeners, needed to adapt to changing circumstances.
- The risks associated with ex-post rulings – which may affect remuneration of assets outside of the plan – may translate into higher cost of capital demanded by investors.
- As decentralisation continues, more numerous and diverse stakeholders may emerge but the cost of managing them, ensuring they are truly representative and informed enough to make choices on complex issues will be high.
- Innovation may become more consequential but the temptation to reward only the one that is successful will discourage future attempts, while too much freedom may induce wasteful innovation spend.
- The nature of these trade-offs is incomplete. A willingness to incur higher transaction costs may not be enough to reduce the impact on coordination and motivation of net zero. Similarly, attempts to limit responsiveness may not be enough to prevent emerging incoherence and ineffectiveness of regulation under net zero. Regulators will be faced with rising coordination, motivation and transaction costs problems simultaneously. At the same time as experiencing increasing demands to be responsive and accusations of incoherence and ineffectiveness.

1.4. Dynamic/responsive/adaptive regulation

Regulators and policy makers around Europe are reviewing the extent to which the current toolkit resulting from years of successive attempts at achieving cost effectiveness are fit to face the challenge of net zero. While this concerns mostly the mechanics of incentive regulation – adapting the price setting process to induce more and sometimes anticipatory investment under uncertainty – the approach to regulation may also need some reflection. Currently, a certain adversarial culture is the norm around Europe – whereby regulators mainly use reward and punishment to determine certain behaviour from NCs, with courts being used regularly to settle differences of perspective regarding the implementation of various rules. Given the increased uncertainty, the higher need for collaboration, stakeholder engagement, and whole system thinking, perhaps a revised culture around regulation is also warranted.

In this sub-section we explore three attributes – dynamism, responsiveness, and adaptiveness - that regulation may need to enhance in order to keep up with the changes required by net zero. What these three-attribute share is an element of learning in time: learning from one iteration to another, learning to switch back and forth between rules and guidance, and learning to incorporate elements of change as the context warrants (see Fig.2).

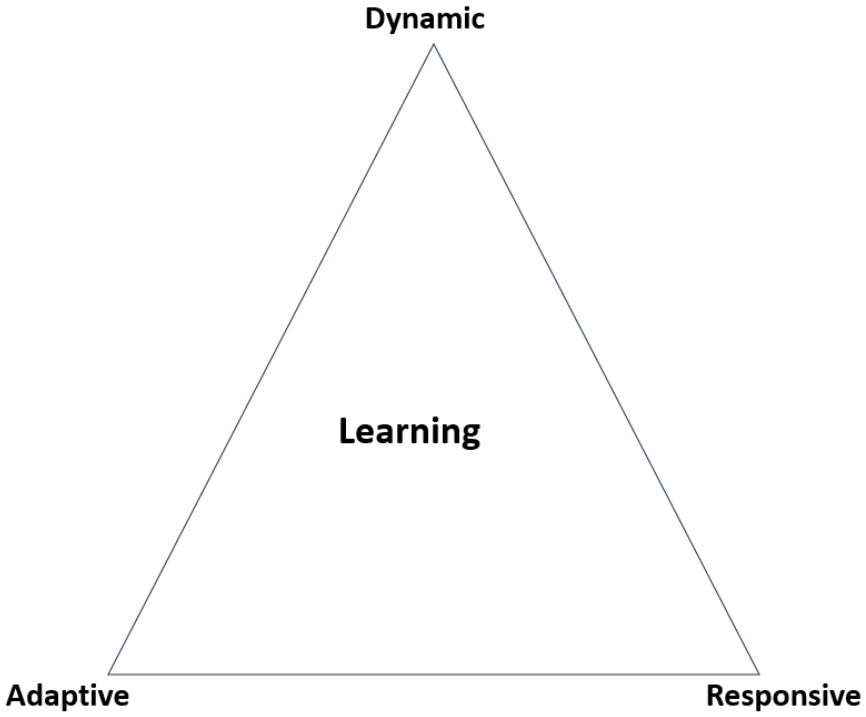


Figure 2: Attributes of regulation

Dynamic regulation is defined by two features. First, it is regulation that efficiently incorporates information gathered through repeated interactions – i.e. over previous regulatory cycles (Agrell and Bogetoft, 2003). Second, it is regulation that focuses more on incentives for investment and innovation for meeting future needs of the system than on optimizing the existing system (Bauer and Bohlin, 2008). Both properties have been explored in the literature.

The first feature is based are on the Vogelsang-Finsinger model (Vogelsang and Finsinger, 1979). This model deals with the issues of information asymmetries by incentivising the NC to reveal its true costs over the course of several regulatory periods. After the first period, the observed outputs and costs are used to determine the prices of the next. Over time, the NC reveals relevant information that helps the regulator identify the optimal prices. Sappington (1980) shows that even under this type of dynamic regulation, strategic behaviour is possible, as NCs can misrepresent costs in the first period or engage in wasteful management, including "pure waste, inefficient factor utilization, excessive research and development, and overinvestment in demand-increasing expenditures to increase long term profits" (Sappington, 1980, p. 360). The dynamic aspect consists of the possibility of repeated periods that allow for information to be extracted by the regulator. The extent to which regulation can change ex-post based on revealed information is likely to induce strategic behaviour from the NC. A variety of potential solutions are advanced in the literature, including an incremental surplus subsidy (Sappington and Sibley, 1988), a menu of contracts to induce self-selection by low cost and high cost firms (Laffont and Tirole, 1986), but all are vulnerable to strategic behaviour (Joskow, 2014). We consider an expanded scope of learning from the repeated cycles, going beyond the private information revealed by NC on its true cost. Learning and adjustment can include new technology applications and innovative organization models and practices.

The second feature of dynamism can be understood in contrast to what Bauer and Bohlin (2008) describe as 'static' or 'comparative static' regulation. Static regulation takes technological and economic conditions as given and attempts to minimize cost. Comparative static regulation acknowledges technological change but focuses on updating the regulatory tools to incorporate them. By contrast, dynamic regulation aims at encouraging the NC to pursue investment and innovation, accepting uncertainty which moves it away from equilibrium as inherent to dynamic processes (Bauer and Bohlin, 2008).

Another attribute regulators may want to enhance is responsiveness. Responsive regulation moves away from the exclusive use of reward and punishment as determinants of behaviour and encourages stakeholder participation and the perpetuation of positive social norms around the regulated activity. **Responsive regulation** is an approach that attempts to find a middle ground between two extremes: regulation relying solely on strict reward/punishment, on one hand, and *laissez-faire*/self-regulation on the other. Ayres and Braithwaite (1995) argue that a whole range of options lie between these extremes and the act of regulation should excel at understanding the context well enough to judge what regulatory approach is suitable and to be flexible about changing it over time. Responsive regulation thus looks more like an art, relying on the experience and good judgement of the regulator to understand the activity well enough to know when to switch back and forth between rules and guidance. Their regulation pyramid ranks possible interventions in ascending order of coerciveness from the least costly – dialogue and persuasion to the most costly - penalty and reward. The act of regulation should always start at the base of the pyramid and move up and down according to context. To avoid exclusive relationships between the regulators and NCs and possible collusion, the involvement of third parties – customers and citizens is presented as a condition for responsive regulation in the long run. Elements of responsive regulation can be seen in the energy sector,

particularly the new emphasis on stakeholder engagement. On the other hand, the regulation of natural monopolies is based on the assumption that social outcomes would be suboptimal, should operators be allowed to dictate quantities and prices. In setting the price caps, outputs and incentives, regulation attempts to mimic the pressures of a competitive market and determine NC to behave in a way that leads to efficiency, managerial effort, and innovation. Responsive regulation may be more suited to non-economic regulation, such as various forms of compliance, where engagement from the regulators and third parties can be preferred to automatic punishment. But even under economic regulation, one can see the case for more responsive regulation. Currently, regulation is based mainly on ever increasing sophistication in setting the rewards and punishments and measuring outputs and performance standards. This can, at times, be seen as leaving little room for NCs to bring their contribution and use their sector experience in defining and pursuing desirable outcomes. Finding the right balance and adjusting it as needed is the task of the responsive regulator.

Regulators may also need to become more adaptive. In contexts affected by uncertainty, as described throughout this paper, adaptive regulation (or adaptiveness) also deals with a trade off by finding the middle ground between giving enough stability and visibility for NCs and implementing change when it is needed. **Adaptive regulation** is another concept born from the agenda of regulatory reform that aims to improve learning in the system and avoid mis-regulation (Bennear and Wiener, 2019). It seeks to find a middle ground between regulation that stays fixed for long periods of time and regulation that constantly changes. The standard regulatory process follows a series of steps, considering options, negotiating with REs, drafting the preferred option, consulting stakeholders, and publishing the final determination. This process has its merits, as it gives periods of stability to NCs and allows them to perform their activities within the set framework. But circumstances change and for some sectors, change occurs more frequently, which can render the established regulation obsolete – leading to under or over supply of certain technologies, for example. In such cases, faster incorporation of new information into rule-making is necessary. To achieve that, adaptive regulation replaces big one-time decisions with a series of partial sequential decisions based on pre-determined indicators. Triggering each of these partial decision processes can be planned or unplanned, automatic or discretionary, depending on the particularities of the regulated sector. Adaptive regulation comes with advantages such as flexibility and agility, but also with costs including perception of instability, less trust in made decisions (including rewards and penalties) and higher information costs. A more adaptive approach may be most suitable in sectors where fundamental, yet uncertain changes are expected, and experimentation is required. Both electricity and gas would fit this description.

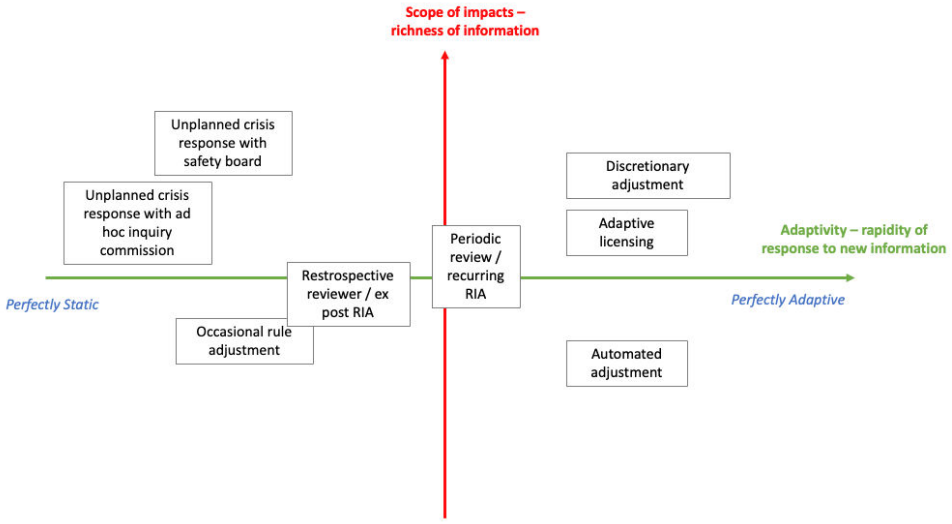


Figure 3: Adaptive regulation

Source: Based on Bennear and Weiner (2019, p. 15)

What the three attributes have in common is the role of learning. This learning can arise from one period to another to enforce dynamic efficiency, from the 'community of practice' around NCs for greater responsiveness, or from outside perspectives and third parties on the 'known unknowns' for more adaptive regulation. Looking at the time dimension, being "dynamic", as discussed in the literature, implies backward-looking learning, while "responsive" refers to learning in real-time. "Adaptive", on the other hand, is forward-looking learning. We represent this in Figure 4.

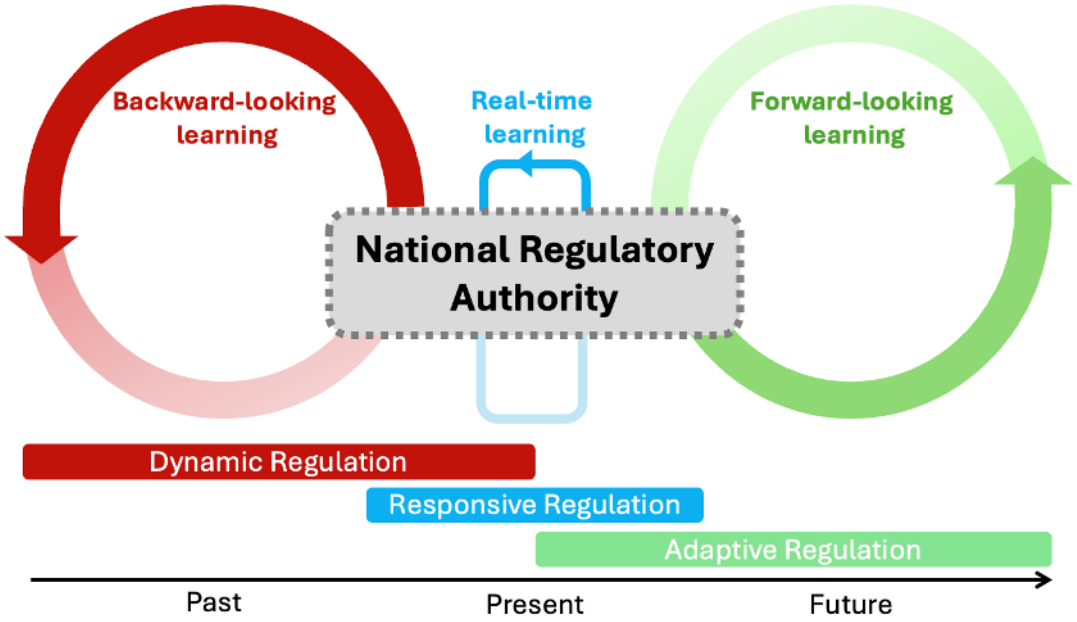


Figure 4: Learning and the time dimension

No matter the source or the time dimension, NRAs will have to gather and process much more information. Additional consultation, periodic reviews of the adequacy of regulation and the state of

the art, as well as experience from other sectors and jurisdictions, will help regulation keep up with the challenges of net zero.

All regulatory regimes have three attributes to varying degrees. However, net zero may require improvements under all three categories– dynamic, responsive, and adaptive. We would advocate the need for a 'learning' regulator who focuses on learning from the past, being responsive to stakeholders in the present and anticipating key future decision points. Such a regulator would be taking advantage of the type of learning identified in the three categories of regulation we discuss.

2. POSSIBLE CHANGES NEEDED TO REGULATION UNDER NET ZERO POLICIES

2.1. The components of regulation that may need to change under net zero

To be able to face the challenges of net zero, economic regulation will need to consider a number of changes.

Firstly, there may be a need for changing the mandate of regulatory authorities. For example, in October 2023, the UK Government adopted changes to the Energy Bill adding a statutory responsibility for Ofgem to support the Government in achieving net zero by 2050. [18] Ofgem will thus continue to have the duty to defend the interests of current and future consumers, but instead of simply "reducing greenhouse gases emissions in electricity and gas supply", the regulator will explicitly support the objectives of the Climate Change Act, specifically net zero by 2050. Whether this will have significant concrete implications for regulation remains to be seen, but the signal is clear – in addition to its existing mandate of ensuring enough investment, quality of service while minimizing cost, the regulator must ensure that networks are contributing to net zero. At the same time, there are also limits to what can be achieved through economic regulation of networks. Fundamental choices – such as the role of hydrogen in heating or electric transport – are still within the remit of policy makers. Regulation would need to ensure the objectives are being enabled at reasonable cost and in due time, but policy, particularly toward technologies that are not currently commercially viable, will continue being the main driver.

Secondly, it may require changes in some of the main components of regulation, which we detail below. This list of 7 areas of change is generated from our reading of the responses to the Ofgem consultation on the future of regulation from 2026, which we discuss in more detail later. While they are relevant for the UK context, we believe they reflect universal challenges of economic regulation for the decarbonization era, despite not having the same exact immediate implications in actual regulation. Whether these changes amount to a fundamental shift of approach or mere adjustments of exiting systems is difficult to establish.

On **planning [1]**, regulators can ask networks companies for business plans for a specific period of time, which are subsequently negotiated and then settled[19]. These form the basis of the revenue cap and are meant to be stable. Given the increased uncertainty already experienced in recent regulatory periods, reopening the settlements will become more frequent, which will both require time and regulatory resources, and undermine the revenue cap. The business planning will likely need better elements of adaptation while keeping enough certainty for the system to prepare. In addition, the changing balance between anticipatory investments versus just-in-time upgrades of the grid will also impact planning.

[18] Ofgem welcomes Energy Act getting Royal Assent | Ofgem
[19] In some regulatory regimes, this process is replaced by an ex-post review

Relatedly, **uncertainty mechanisms [2]** will need improvement. At present, reopening mechanisms are seen as burdensome even in the most advanced regulatory regimes. In addition, they cover pre-determined elements (such as cyber-resilience, net zero pre-construction work) which means they are not fit for "unknown unknowns" – which may become more relevant as the resultant of various new evolutions associated with the transition.

Incentives [3] based regulation will also need to be adapted. Currently, profit sharing (whether based on OPEX or TOTEX) may induce NCs to focus on short-term measures and less about outcome beyond the regulatory period. At a time when long term thinking is more important than ever, regulators will need to find ways to reconcile short-term action with long term development plans. In some circumstances, for large transmission projects, competitive procurement mechanisms may be more effective in achieving efficient costs than incentive regulation. In addition, the outputs (the "O" in RIIO) – which crate incentives for NC across regulatory period, could better adapted for decarbonisation. Equally, incentives between transmission and distribution need to harmonise where these are distortionary. A relevant case was when Great Britain introduced capacity markets and this lead to an unexpected and unwelcome rush of diesel generators connecting at the distribution level because they received additional payments unavailable at the transmission level (Lockwood, 2017).

The large investment needed together with the higher uncertainty will have an impact on **financing [4]** conditions. The extent to which uncertainty mechanisms will affect regulated revenues (via ex-post rulings that may not lead to adequate remuneration) may increase the cost of capital (in addition to the higher interest rate scenario already in place). Also, the possibility of stranded assets – particularly on the gas side – may have an influence on the cost of capital. In addition, the sheer amount of investments needed translating into upfront outlays could require involvement from regulators. Third-party finance – in some EU countries via grants and low-interest loans programs such as the RRF – may play a significant role. Regulators will need to enable the integration of such funding mechanisms with remuneration models of network companies, ensuring they do not distort incentives and allow for full cost recovery for NCs.

The emergence of DERs but also the high stakes of net zero will mean that networks companies will have to deal with a larger and more diverse set of **stakeholders [5]**. As they are the ones footing the bill, their preferences should be the basis of economic regulation. Yet, consultation with consumers and other stakeholders is not trivial. The complexity of the subject matter will likely require delegation of responsibilities to specialised parties – which may make it difficult to insulate genuine public interest from competing corporate interests. Also, stakeholders are not a homogenous group - ensuring adequate representation, including of certain vulnerable groups, may need new structures which may involve potentially significant costs.

Funding and adopting technological and business model **innovation [6]** is more valuable than ever. As initial costs will impact consumer bills and some innovation will unavoidably fail, ensuring abundant yet effective funding will be challenging. Also, with network companies being at different technological

and operational levels across Europe, concentrating innovation in specialised clusters and encouraging learning across network companies may be needed to avoid duplication and optimize costs.

At the **governance [7]** level, there may be several directions of potential change needed. Firstly, regulators may need explicit mandates to enable net zero. While policy and primary legislation will continue to drive the most relevant decisions, providing them with an extended authority may be required for regulators to adopt the far-reaching measures necessary for net zero. Secondly, the existing separation in time and scope between gas and electricity, distribution and transmission regulatory periods may not be conducive to **whole system** thinking and optimisation. Centralised longer-term plans may need to feed into the actual business plans and having this activity carried out by an independent actor – such as the Future System Operator in the UK (see Box 1) - can have certain advantages dependent on the incentivization of such an independent actor and other institutional arrangements. Thirdly, whole energy thinking will be also needed at the local level – the emergence of DERs may increase heterogeneity across regions, requiring locally adapted coordination. This can be achieved through existing entities – for example by separating the system operation function from network operation at DSOs and encouraging collaboration across energy vectors but can also imply the creation of new regional organisations.

Box 4: The UK FSO

As a result of the review of GB's energy market and ensuing consultations, a new entity has been proposed, tasked with taking over the system operation function from the electricity TSO, separating it from network operation. The Government proposed in 2021 the creation of FSO – e new entity that would carry out this task but would also act as an impartial advisor and coordinator for the energy system and ensure a whole system perspective that optimises across energy carriers with a long-term planning perspective. The FSO (recently given the name: National Energy System Operator – NESO[20]) will be a public corporation funded through price controls regulated by Ofgem. [21] The FSO can be seen as a key pillar of tripartite governance system for a net zero energy system, working in collaboration with the Ministry of Energy and Climate (Department of Energy Security and Net Zero) and the independent regulatory agency (Ofgem). The FSO started consultations[22] in 2023 on the Centralised Strategic Network Plan at transmission level, which, together with the Regional System Planners at the distribution level, would ensure a whole system approach.

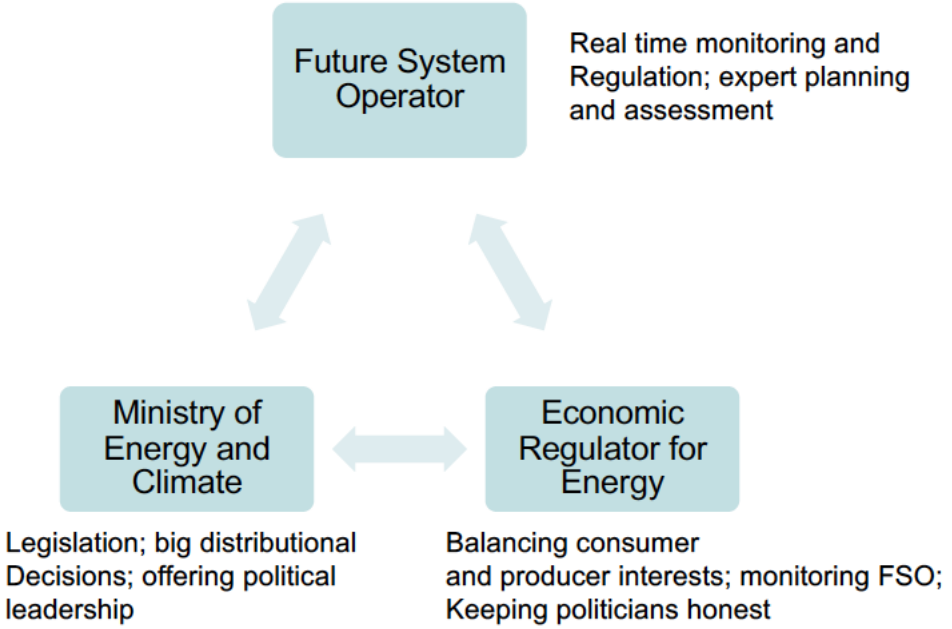


Figure 5: The Future Energy Governance Triangle

[20] https://www.nationalgrideso.com/news/eso-announces-name-forthcoming-future-system-operator
[21] https://www.ofgem.gov.uk/energy-policy-and-regulation/policy-and-regulatory-programmes/future-system-operation-fso#:~:text=Future%20System%20Operation%20(FSO)%20%7C%20Ofgem
[22] https://www.ofgem.gov.uk/publications/ofgem-kickstarts-conversation-future-energy-price-controls-funding-pave-way-net-zero

2.2. Regulation contexts vary across Europe

Regulatory regimes as well as energy networks across Europe are at different stages either in network regulation, or in their net zero journey, or both. While some jurisdictions have decades-long experience with economic regulation in fully liberalised systems, others may face different challenges or opt for different approaches. In the UK, Ofgem is assessing the possibility of upgrading RIIO – one of the most complex regulatory regimes in operation. Italy is also trialling similar approach as RIIO, with a TOTEX based incentive for its smart meter rollout (Bovera, Delfanti and Fumagalli, 2020). Portugal has also implemented a TOTEX approach since 2022 (ACER, 2023). Finland. Slovenia and Spain feature significant innovation allowances for electricity DSOs. In other countries, regulators may not have the capacity, nor the need, for such resource-intensive regulatory regimes (Joskow, 2014). Where the challenges are different – for example power systems are almost fully decarbonised (e.g., Sweden) or quality improvements and refurbishments are more relevant and regulatory resources less available (Romania, Bulgaria) the focus may be elsewhere, and rightly so. This means that a common blueprint for how regulation needs to change in Europe is unlikely to be identified. Some systems may need to refine or even move beyond RIIO, others may be gradually moving toward RIIO, while others may define different approaches to economic regulation that delivers decarbonisation. This gives rise to a key role of the EU regulatory agency, ACER, and the Council of European Energy Regulators (CEER) in spreading good regulatory practice and supporting regulatory initiatives to improve the operation of regulation in smaller, new or less developed regulatory systems. These institutions can work with ENTSO-E, ENTSO-G, and the EU-DSO Entity in spreading good practice with respect to planning, innovation, and stakeholder engagement among regulated network companies.

For example, in some regulatory systems there may be a more recent adoption of ex-ante incentive regulation (Sweden), less emphasis on outputs (Germany), or particular OPEX saving incentives that exclude labour costs (Romania) (Black, Harman and Moselle, 2009; CEER, 2023). Some countries may worry about the potential of redundant innovation spending while others may have no innovation incentive for network companies. In some countries, the involvement of stakeholders may be significant, while in others, there may be no articulate consumer or civil society body involved in the regulation of grids.

The focus of this report is on the most advanced regulatory regimes within the most ambitious net zero policy settings. However, we also wish to draw lessons that are relevant for other countries as well, which are likely to run into similar challenges in the near future.

A summary of the differences in regulation across European countries in terms of incentive-based regulation, innovation allowances and the use of outputs is presented in Table 1. The information is based on reports by CEER and ACER (ACER, 2023; CEER, 2023). The majority of countries use a variety of incentive regulation with revenue caps and broadly similar approaches to establishing the regulatory asset base (RAB), the weighted average cost of capital (WACC), depreciation and other key drivers. OPEX saving incentives are also prevalent throughout Europe. However, innovation allowances and the use of outputs are less frequent, with only a few countries having implemented such schemes and mostly in the case of electricity DSOs.

	Electricity DSO	Electricity TSO	Gas DSO	Gas TSO
Incentive regulation	23	18	19	18
TOTEX approach	8	8	5	5
Innovation incentive	GB, Finland, Ireland, Slovenia, Spain	GB, Finland, Slovenia, Spain	GB, Ireland, Northern Ireland	GB, Finland, Slovenia, Ireland, Spain
Outputs incentives	Germany, GB Sweden, Norway	GB	GB, Ireland, Northern Ireland	GB

(*out of 33 countries surveyed)[23] Source: ACER (2023); CEER (2023).

Table 1: Key features of regulatory regimes in Europe

As can be seen, network regulation differs across European countries, as each jurisdiction tackles its unique challenges. Within the overall similar rules on setting revenue caps, RABs and WACCs, there are numerous variations. Only a few countries have adopted more advanced regulatory features such as TOTEX approaches, innovation allowances and outputs linked to remuneration. As net zero is likely to play out in specific ways across Europe, the regulatory tools may also differ. At the same time, the increased uncertainty and urgency of the transition will likely require changes in the regulatory process that go beyond the use of specific tools.

2.3. Differences across energy carriers, network levels, network functions and network companies

While this discussion examined regulation in general, there may be a need to examine potential differences between regulatory regimes by energy carrier, by voltage/pressure level, by function and by country.

Electricity and gas

The difference between carriers may require different approaches. For electricity the uncertainty revolves around how much demand will increase, whether this will happen mostly through increases

[23] As defined by CEER, all EU Member States plus Albania, Georgia, Great Britain, Iceland, Montenegro, Northern Ireland, North Macedonia, Norway, and Ukraine.

in load or also in terms of energy, and how many new applications networks will have to accommodate (heating, local balancing of DERs, communities, etc) and the volume of self-consumption in the future. For gas, the uncertainty is more about how drastic the demand reduction will turn out to be, the possible need of decommissioning, ensuring safe operations until then, and the role played by hydrogen and biomethane. On the latter, a further complication is generated by the relationship between households and industrial consumers. If industry moves faster toward decarbonization, preferring one option, it may influence residential consumers in the vicinity, who can also transition faster, impacting the rest of the existing grid. While the differences are relevant, most of the net zero adjustment of the regulatory components and objective discussed above, is unlikely to be significantly different from electricity. Planning will also need to be adaptive, uncertainty mechanisms related to hydrogen conversions will need to be more effective, long-term incentives will be just as valid. The particularity of decommissioning gas assets (where decided), the option of reducing depreciation times before decommissioning, and the possibility of stranded assets may have impact on financing (Cross-Call *et al.*, 2018). Also, the innovation need may not be as wide-ranging as in electricity. If the gas grid is going out of use in the long-term, the usefulness of an efficiency benchmark needs to be questioned. Instead reducing investments and agreeing on increasing OPEX (for more maintenance of aging assets) might be considered as a way forward.

Considering both carriers in planning and attempting optimization between them seems to be more relevant as a need for change in the regulatory approach than the difference between them. Governance structures, acting on the basis of political decisions, which can credibly include both energy carriers in long term national planning while accounting for differences in local context are going to be crucial.

Illustrating the difference in perspectives between electricity and gas, in 2023, gas network companies have announced their intention to leave the UK Energy Networks Association, the main industry body representing grid companies in the country[24]. The gas companies stated that their interests would be better served by leaving the organization.

A relevant case is the interaction between gas regulation and the creation of a hydrogen market in Europe, discussed in Banet (2023). To foster the development of hydrogen and renewable gases, regulation will require a level of dynamism – not only regarding parameters (ratchets or uncertainty mechanisms) but market models and fundamental regulatory principles. Currently, there seems to be an assumption that methane (existing natural gas, current and future biomethane injections) and hydrogen will represent parallel infrastructure development processes (Chyong *et al.*, 2021; Banet, 2023). While developing an entirely new sector (hydrogen) may require a different approach from simply managing or improving an existing one (biomethane), a convergence or at least an element of common planning is likely desirable, particularly in the context where whole system approaches are believed to be key for managing an optimal transition process. Also, the options for hydrogen, for example in landlocked countries with insufficient capacity, will be greatly impacted by the choices of

[24] ENA membership – Energy Networks Association (ENA)

their neighbours that may or may not develop and connect import routes. This also impacts governance – establishing the entities in charge with developing and enforcing network codes (e.g., ENTSO-G) but also to market models, such as the level of unbundling, which may need to adapt to the stage of development, particularly in hydrogen. In addition, given the level of uncertainty and different starting points across member states, there may be a case for balancing between harmonisation and flexibility to adapt to local needs. One cannot expect a fledgling market like hydrogen to have the same level of regulatory harmonisation across states as an established market like electricity. On the other hand, allowing network companies, particularly smaller ones, to play active roles across carriers, while maintaining sound competition practices, may also be required. At the same time, ensuring there is not an unfair difference between competition regimes in electricity and gas networks will be important. For example, negotiated third party access may be possible for hydrogen but not for electricity. All these elements illustrate the challenges of dynamic regulation in gas grids and the differences from electricity.

Transmission and distribution

The differences in the regulatory approach for transmission may stem from the scale of investments needed, the possibility to separate (insulate) projects and the cross-boundary infrastructure needs. To some extent, transmission already benefits from more adaptive regulation in some jurisdictions, such as the UK. There, the role of allowances settled outside of price controls has been significant for large transmission projects (such as offshore transmission links to windfarms, international interconnectors, and bootstrap projects). The challenges of scaling up large transmission infrastructure to meet (let alone anticipate) to connect regions with high renewable potential with load centres have been outside the scope of economic regulation. The cases of Germany or Sweden, but many other European countries illustrate issues around permitting, environmental impact, property regimes, rather than investment. For both electricity and gas, there may be significant cross-border dimensions to investment plans. The high voltage (including HVDC) interconnectors are already present, in execution or planned across Western Europe. In the case of gas, there may be a continental market for pipeline hydrogen to connect the most favourable production locations with large consumers. The financing regimes will almost certainly be outside price control periods, using a variety of instruments such as competitive bidding and direct subsidies (including from grants in EU countries).

System operation versus network operation in electricity

The system operation function, particularly for TSOs, but increasingly for DSOs, is becoming more relevant because of net zero. In addition to balancing and settling the system, facilitating competition in the market and governing over network codes, the system operator (SO) function is increasingly needed to support whole system outcomes and foster competition in networks themselves. Traditionally having the two functions in one firm created a link between network planning and operation, synergies and knowledge exchange as well as chances to rotate personnel between functions. However, when the system and network operation functions are under the same organisation, the SO may be tempted to deviate from optimality in favour of solutions that generate higher returns for the network business. Also, the regulation needed to sharpen the incentives for SO is fundamentally different from the case of capital-intensive networks. For these reasons, in the UK,

for example, the National Grid SO has been legally separated from the network operation activity.[25] This may become a relevant discussion in other jurisdictions as well, particularly where TSOs are privately (or foreign) owned. Different ownership models have been tried in several countries, both with advantages and drawbacks. The right model for the net zero challenge is likely to depend on the particularities of a country or region (Haney and Pollitt, 2013).

At the distribution level, with the emergence of DERs, the role of system operation is also expected to increase, including procurement of active and reactive power, increased reverse flow points with TSO and potential for optimisation. DSOs (e.g., UKPN) have begun to experiment with the creation of separate system operator functions within the overall business[26],

At the same time, there may be significant synergies from having system and network operation functions under the same entity – including from a human resources perspective. In addition, it is unclear whether creating new entities and potentially increasing complexity will pay off in terms of mitigating the potential conflict of interest. Whether or not the effort to separate the two functions is worth the effort is likely to depend on context.

Differences between network companies

There are also significant differences between NCs, in terms of size, ownership model and age of assets. GB, for example, features a small number of fairly large DSO areas some of which are owned by the same groups. Sweden has 170 DSOs[27], many of which of are rather small in terms of points of connection but large in terms of area covered. The type of regulation – particularly on issues of innovation – may be inherently different between a system dominated by larger DSOs that one with higher fragmentation. It may even be the case that within the same country, larger and smaller DSOs may require different types of incentive regulation, tailored to their particular structures.

Another source of difference is the ownership model. Privatised investor-owned DSOs are likely to respond differently to incentives than state or municipally owned ones. The design of regulation must take this difference into account and use the appropriate toolbox to determine the desired changes, in this case enabling net zero.

Finally, some DSOs, particularly in Eastern Europe, are still in a catch-up phase in terms of quality of service, having been affected by periods of underinvestment and thus facing different types of challenges – such as interruptions or even oversized but poorly maintained networks. It may be the case that incentive regulation fit for net zero will need to consider such particularities as well.

[25] https://www.ofgem.gov.uk/publications/future-arrangements-electricity-system-operator-its-role-and-structure

[26] See : https://dso.ukpowernetworks.co.uk/#:~:text=The%20Distribution%20System%20Operator%20(DSO)%20has%20three%20main%20roles%3A&text=Using%20data%20and%20insights%20to,centring%20local%20authorities%27%20decarbonisation%20plans.

[27] https://ei.se/ei-in-english/electricity

To sum up, the changes to regulation needed for net zero are not going to be the same across jurisdictions or NCs. The differences between energy carriers, the network level, size, ownership, and physical state of the network, are all going to require adapted approaches.

2.4. The case of GB – the Ofgem consultations

The UK started a review of economic regulation in 2022 with the aim of updating its principles to face new challenges, particularly net zero (DBEIS, 2022). Ofgem, the Great Britain energy regulator, issued an open letter on future of the price controls from 2026 (in September 2022)[28] which explicitly asks this and related questions. The context is a discussion whether Great Britain's regulatory regime for networks based on RIIO – Revenue = Incentives + Innovation + Outputs – and itself a development of RPI-X incentive regulation remains fit for purpose. Ofgem raised the following questions, inter alia:

1. Should there be a continued use of periodic price control?
2. Is there an alternative to the current ex-ante price control regime?
3. Is there scope for greater stakeholder participation in the regulation of networks?
4. Is it possible to have an ex-post regulatory regime?

The 41 responses from stakeholders, including the NC themselves alongside industry bodies, consumers groups or research organisations, seem to converge on a number of themes.

First, the RIIO framework is seen positively, in terms of generating the correct incentives, achieving efficiency improvements, and enabling innovation and stakeholder participation. Most respondents argue that a shift away from ex-ante period reviews would be detrimental, potentially increasing the cost of capital and wasting the potential for improvement.

Second, there seems to be a consensus over the need to reform some of the existing instruments that could help deliver net zero. Specifically, the reopeners and uncertainty mechanisms are seen as too complex and time consuming. Most operators call for simplified processes and many argue in favour of differentiated approaches with a baseline of simple business-as-usual investments based on a light touch regulation complemented by more complex net zero oriented investments.

Thirdly, on a governance level, there seems to be a need for regional system planners, as well as Distribution System Operators (legally separated from DNOs), to better reflect the differences that may emerge from different local contexts. These new structures would need to coordinate with the Future System Operator to ensure a whole system approach, which optimises various among energy vectors, according to long term centralised plans but adapted to local realities.

[28] https://www.ofgem.gov.uk/publications/open-letter-future-systems-and-network-regulation

Fourthly, on stakeholder engagement, there is a concern that there is "stakeholder fatigue", that commercial interests are hard to distinguish from genuine public interest and that the complexity of regulation makes proper consultation difficult. Negotiated settlements are seen as less applicable to energy than to other regulated sectors due to the significant complexity.

Other relevant themes include the need of anticipatory investments, the need for careful balance of flexibility with stability to avoid higher uncertainty and increased cost of capital and calls for moving away from a short term least cost mindset to a broader and longer term for cost benefit analysis including wider benefits for decarbonisation.

One observation that can be made about current regulatory regimes is that they often, but not always, treat electricity distribution, electricity transmission, gas transmission and gas distribution in a similar way in terms of the way the regulatory system sets their financial incentives.[29] However, the uncertainties with respect to them are fundamentally different (as discussed above) and vary widely between countries. Considering whether there is a need for more divergence between them would seem to be important.

The case of the UK transmission, which gets a relatively different regulatory treatment, can be of interest. For electricity, a significant portion of revenue is set through allowances outside of the price control period. Many investments are set through reopener mechanisms like Strategic Wider Works[30] and Large Onshore Transmission Investment.[31] In addition, the Accelerated Strategic Transmission Investment (ASTI)[32] framework, which streamlines regulatory approvals and funding processes, has been an example of the increased need of centralisation particularly for large transmission lines required for connecting renewable energy plants. The framework is outside the scope of the price control period, by-passes competition and tries to carefully engineer the rewards and penalties to encourage both timely delivery and value for money. While this is possible in transmission, where there are fewer operators and the need is already demonstrated, the case for a similar approach for distribution is probably less compelling at this point.

A follow-up consultation[33] was initiated in March 2023 that reflected on the initial responses and proposed a number of options to deal with the identified issues that regulation needs to tackle to enable net zero. These issues are summarized as follows: changes to the location of electricity generation, increased electricity demand, decline of natural gas demand, the importance of demand side flexibility and energy storage, as well as uncertainties in the depth and speed of elements of the transition, geopolitical considerations.

[29] Most European countries have combined gas and electricity regulators: see https://www.ceer.eu/eer_about/members#
[30] https://www.ofgem.gov.uk/publications/strategic-wider-works-faq
[31] https://www.ofgem.gov.uk/publications/large-onshore-transmission-investments-loti-re-opener-guidance
[32] https://www.ofgem.gov.uk/publications/decision-accelerating-onshore-electricity-transmission-investment
[33] https://www.ofgem.gov.uk/sites/default/files/2023-03/Consultation%20on%20frameworks%20for%20future%20systems%20and%20network%20regulation.pdf

Ofgem also presented three archetypes that propose different solutions to the fundamental questions of what investments are needed, how to ensure they are done at efficient costs and how to monitor their performance.

The archetypes are Plan and Deliver, Ex-ante Incentive Regulation and Freedom and Accountability. Plan and Deliver involves performing the need assessment and strategic functions outside the NC and using competitive procurement to ensure delivery at least cost. The planning would involve cooperation between several layers of administration from central to local, as well as numerous other stakeholders. This would seek to find broad consensus, a whole system perspective, but also enough granularity to establish the anticipatory investment needs and then procure them from the market. This approach has been in use for the ASTI program in electricity transmission in GB. The concerns are related to the high information needs and the far from perfect record of competitive procurement processes.

Ex-ante Incentive Regulation is seen as a modified version of RIIO with the adaptations required for accelerating the net zero process. The need assessment and planning are performed by the NC, scrutinized, modified, and approved by the regulator, who then establishes mechanisms to ensure the delivery of the plan is efficient. The potential adjustments to the existing system are related to reducing the regulatory burden, for example by having a simplified methodology for recurring business- as-usual activities, allowing for greater scrutiny for the transformative or anticipatory part of the plan. Other elements of change can come from the definition of outputs, making them simpler and more in tune with net zero.

Freedom and Accountability is a variant of ex-post regulation. NCs would be given more leeway in establishing and delivering the needed investments, passing the costs through to consumers, with regulators verifying ex-post whether the costs were prudent and fitting with pre-established net zero objectives. NC would thus no longer need to provide detailed investment plans but instead would have to meet consumer needs as they see fit, as long as the outputs defined by the regulator are met. Monitoring becomes more relevant, as regulators ensure NCs do not earn more than their cost of capital. Bonuses and penalties can be used to further incentivise NCs to pursue efficient costs.

2.5. Other jurisdictions are also considering the regulatory implications of net zero

The UK is not the only country or jurisdiction undergoing a review process on how to better align incentive regulation with the requirements of net zero. The Netherlands has launched a similar exercise with some of the results presented in 2023. The energy system in The Netherlands has been experiencing challenges in recent years, particularly due to significant grid congestion. The increased penetration of renewable energy, decentralised PV, and the increase in demand due to electrification of heat and transport, resulted in difficulties for grid operators. Managing congestion and delays in connection for generators (large and small) and consumers (residential and industrial) have become challenging. In 2023, the Dutch government and market regulator have started a process of reflection and consultation aimed at finding the most effective way to improve incentives for grid operators to

reinforce grids in a manner that responds to the demands of the market.[34] Since 2017 and operationalised in the current regulatory period (2022-2026), regulation intended to tilt incentives slightly away from efficiency and toward greater investment. The current model is a price cap with the use of international and local benchmarking. For TSO, the investment focus is operationalised through an annual CAPEX true-up for large investments and an ex-post review. For DSOs, there is a price cap with efficiency incentives based on national benchmarks, plus a renewable energy mechanism meant to correct possible mismatch in the energy-based adjustments (renewables may add capacity not necessarily kWhs). To further examine potential improvements to the regulatory regime and meet the challenges of net zero, (Brunekreeft, 2023) looks at the merits of various base models with additional items. The latter include bonus malus schemes for congestion and connection times, TOTEX efficiency sharing and rate of return adders (Brunekreeft, 2023). The NRA also commissioned an international study to weigh the options that the Netherlands can explore to adjust incentive regulation with the imperatives of net zero (DNV, 2023)

[34] https://www.acm.nl/en/publications/acm-starts-preparations-new-regulatory-period-system-operators

3. THE VIEWS OF PRACTITIONERS

To get a better grasp on the challenges faced by regulators and NCs, but also on the solutions they envisage to the various trade-offs described above, the chapter collects and presents the arguments put forward by practitioners.

3.1. Methodology

Based on the discussions in section 1.4, we compiled a questionnaire to be addressed to practitioners in the field. The questionnaire is the basis for in-depth discussions with selected practitioners. The research strategy is qualitative, attempting to collect detailed information from a few respondents, rather than pursuing large number of responses. To ensure the conclusions are representative of various regulatory contexts, the target group will be regulators and NCs that will cover transmission and distribution, electricity and gas, and different socio-economic profiles, with countries spanning from Northern, Southern, to Central and Eastern Europe, both EU and non-EU.

The questionnaire is structured based on the seven regulatory components identified in chapter one as being the most relevant for the challenges of net zero.

These are:
[1] Planning
[2] Uncertainty mechanisms
[3] Incentive regulation
[4] Financing conditions
[5] Stakeholders
[6] Innovation
[7] Governance / whole system

For each of these areas, a brief description is provided, and respondents are asked to give a score from 1 (least relevant) to 5 (most relevant). They are then asked to provide their reflection on each during online interviews with the research team. The questionnaire is available in Annex 1.

3.2. Overview of results

The interviews aimed to capture the perspectives of a diverse group of stakeholders across Europe, including regulators and operators, DSO and TSO actors, from both the electricity and gas sectors (Fig. 4). A variety of regulatory contexts have been sought by the inclusion of West, South, North and East European countries.

Figure 6: Countries covered through the interviews and questionnaires

We have responses from 4 regulators and 9 network companies. The average scores of regulators, on one side, and DSO and TSO operators, on the other, show interesting differences in ranking the drivers that will shape the future of regulation. While National Regulatory Agencies (NRAs) are focusing first on aspects related to incentive schemes, governance, and uncertainty mechanisms, operators are more concerned about planning (especially gas operators, with high long-term uncertainty), financing options for investments, and then incentives.

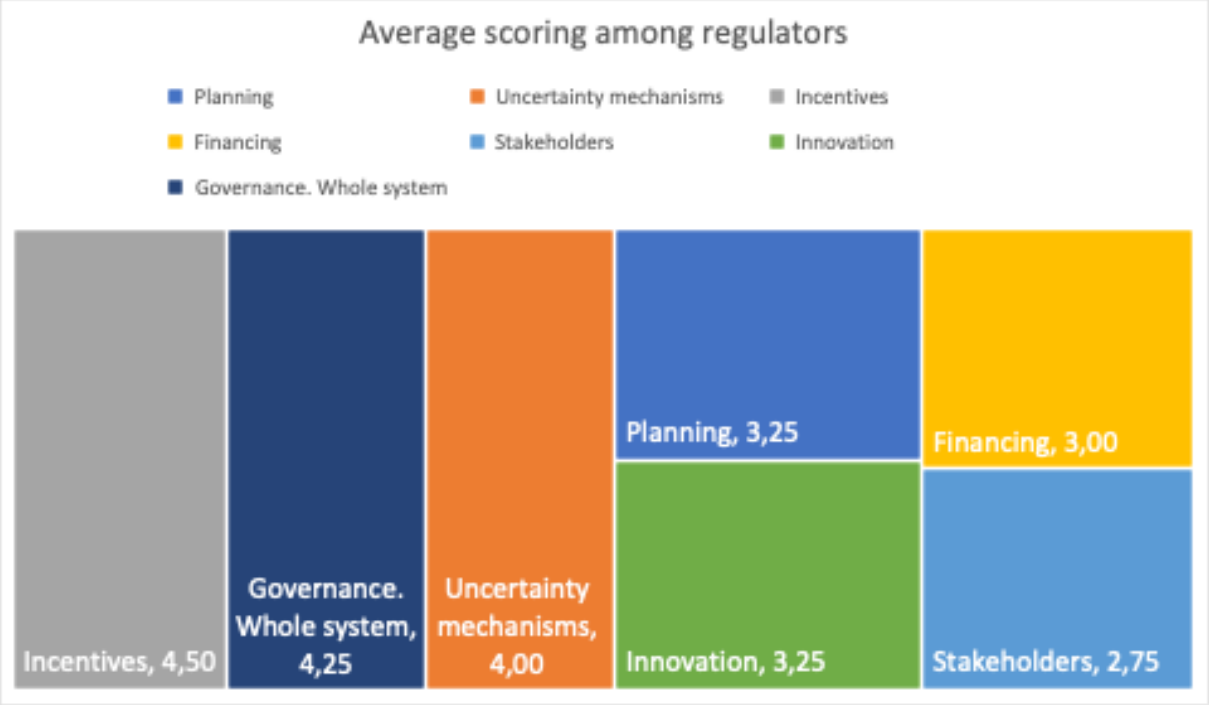


Figure 7: Average scores among regulators

Interestingly, while acknowledging the importance of all stakeholder categories being involved in the transition process, both operators and regulators have scored lowest in this dimension. Also, with average scores of 3 and 3.25, innovation doesn't seem to be a priority for companies and regulatory bodies, respectively.

In a different, more granular representation of the scoring - split by entity type and vector – additional elements are highlighted. On average, operators managing both electricity and gas portfolios, as well as administrators of electricity-only networks, are less concerned about planning, once again highlighting the rather predictable pathways for electricity grids. Similar trends can be observed for uncertainty mechanisms, where gas-only operators have lower predictability in development plans. Perhaps for these reasons, aspects related to governance – therefore to coordination roles and the emerging win-sets between regional and local authorities – are of higher concern for gas operators. Stakeholders also seem to represent a more significant contributing factor for the future of regulation for gas operators (including the ones operating both vectors), in comparison with electricity-only entities.

In what follows: ED = electricity distribution only; GD= gas distribution only; ET= electricity transmission only; GT= gas transmission only; GD = gas distribution only; EGD = electricity and gas distribution.

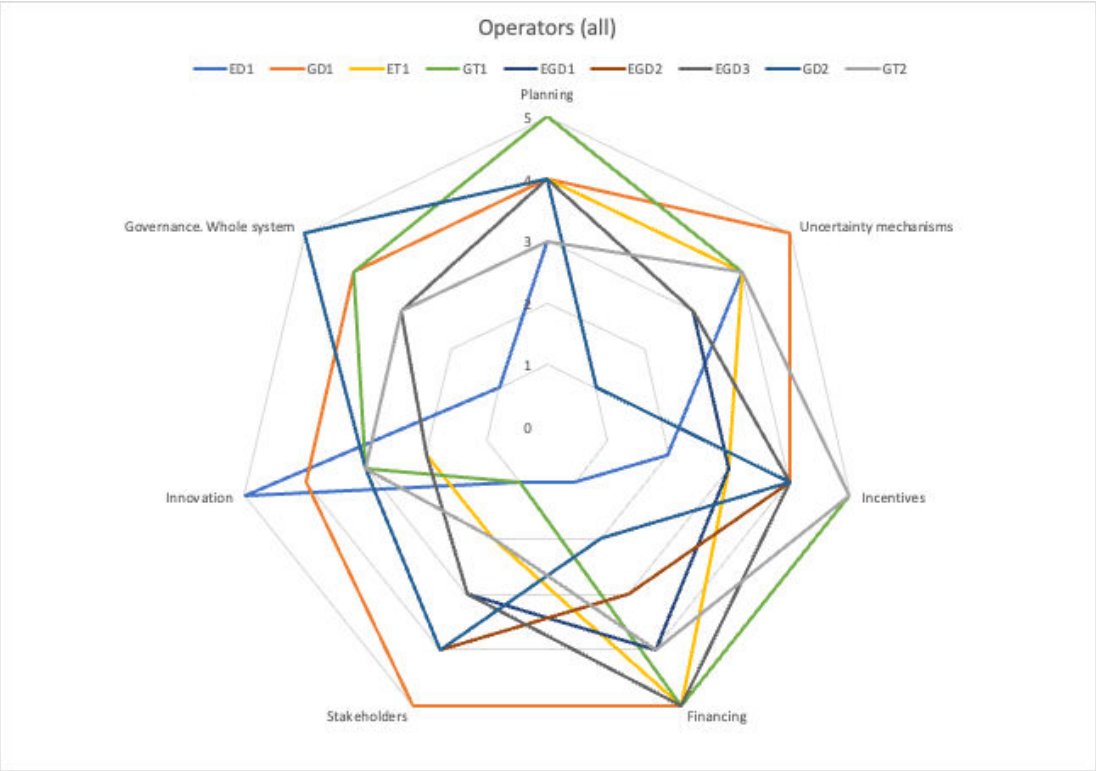
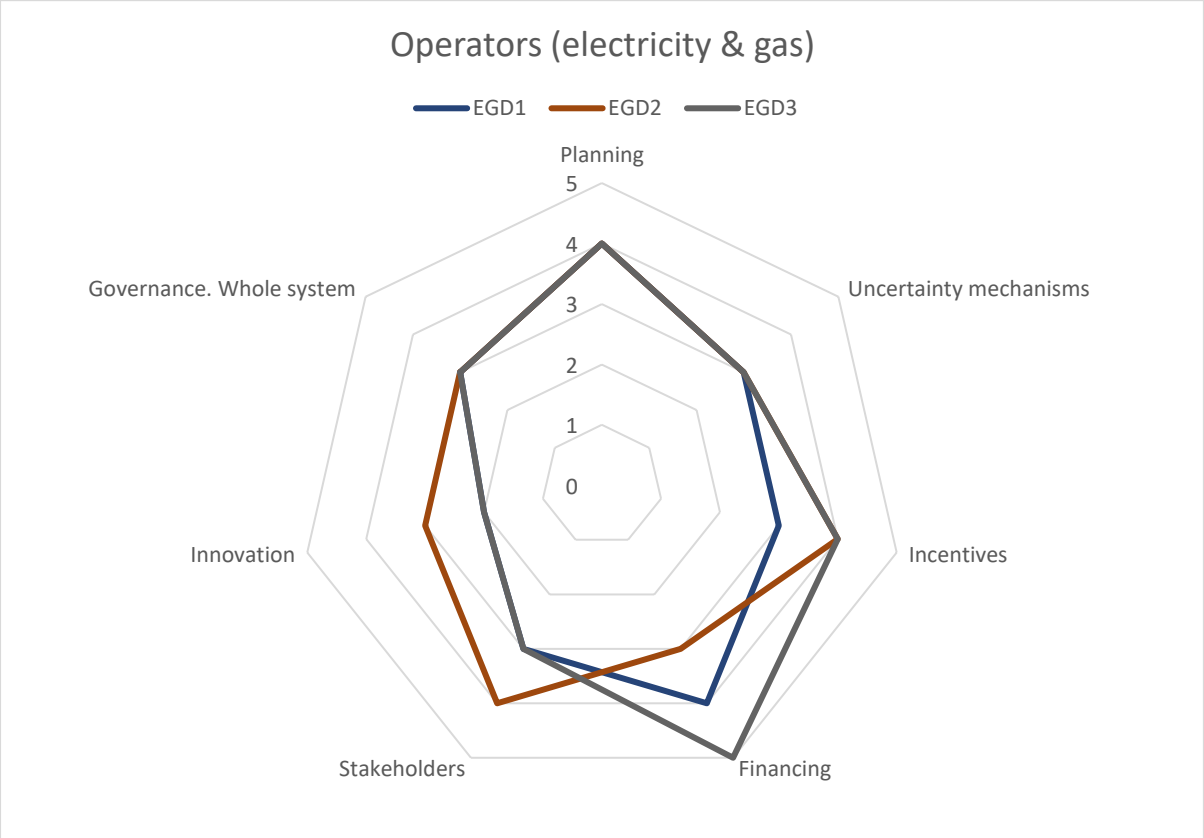
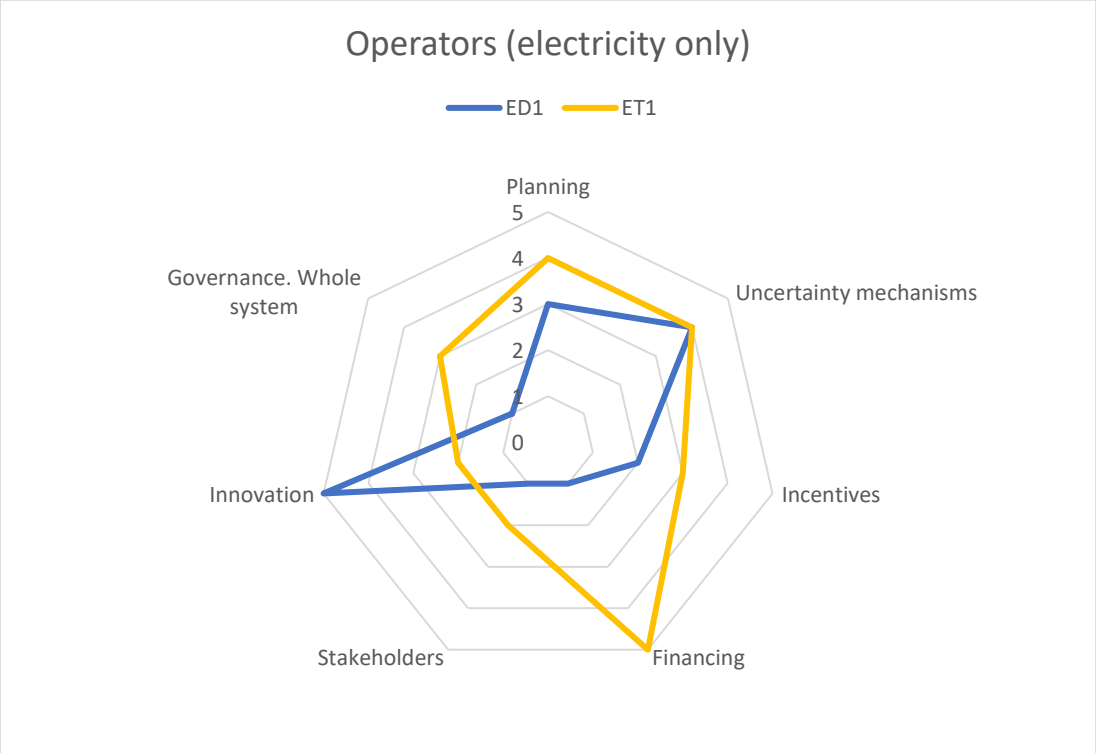


Figure 8: Average scores among operators





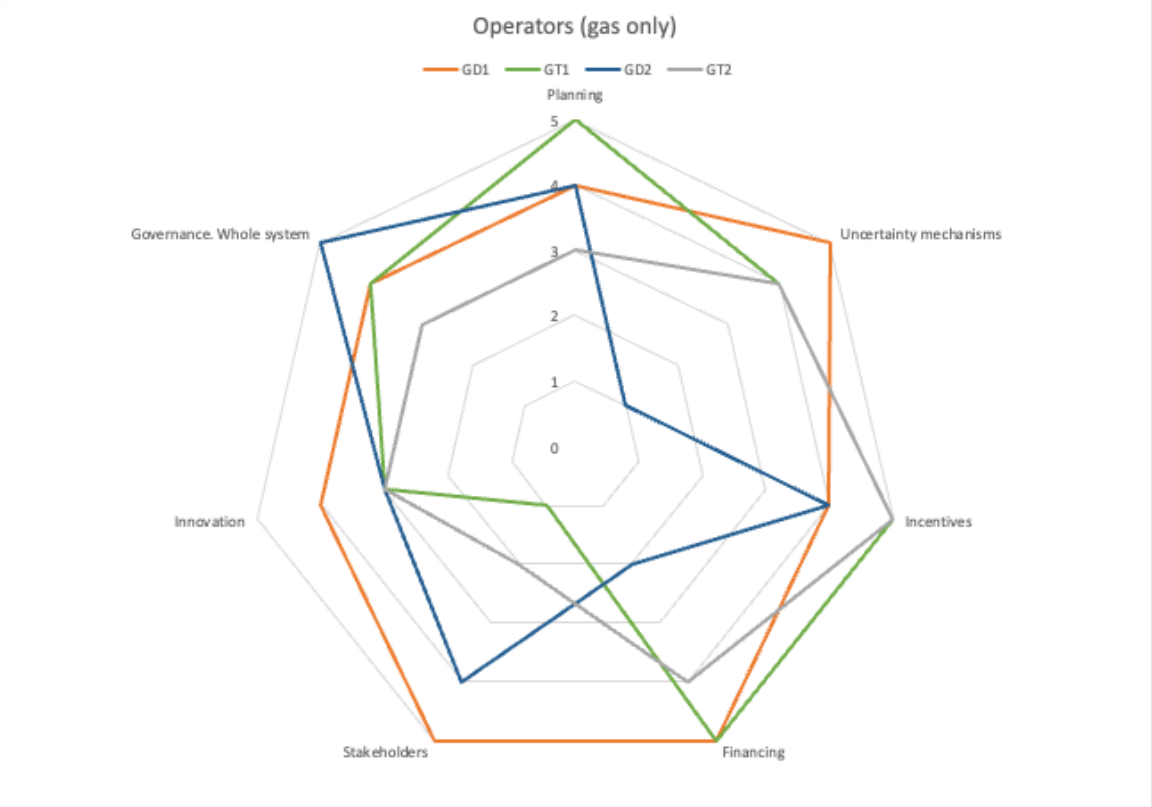


Figure 9: Scores split by operator group

3.3. The view of regulators

3.3.1. Planning

Encouraging adaptive planning is seen as a possible way forward by respondents. One way to pursue this is by implementing organizational changes in the regulator itself. Adopting new ways of working, including agile approaches, improving the use of data, streamlining processes and faster feedback times can all contribute to regulation that quicker to adapt to changing circumstances.

On a technical level, advanced modelling approaches including connectivity models, digital twins and forecasting tools are considered. If successful, these new approaches may improve network and scenario planning, contingency analysis as well as business plans.

Some NRAs state that the challenges of net zero require another layer of centralization to enable planning that goes beyond the remit of the NRA or the NC. Such a centralized planning function would, on one hand, identify the scale and location of required building, decommissioning, and repurposing, and on the other, ensure that the required resource and capabilities are available to deliver.

The greater use of data and digitalization is also mentioned as a driver for better planning by NRAs. The overall goal is to help NRAs to access the right data at the right time to be able to incorporate it in faster decisions for adjustment.

A significant challenge mentioned by NRA is dealing with anticipatory investments. Some of the practical tools used to determine the cost benefit analysis of a given investment program require rich data that may not be available in the case of demand that is not yet available. NRAs acknowledge that updates to some of their practices will be needed to accommodate the anticipatory investments that the system is likely to need.

3.3.2. Uncertainty mechanisms

The management of uncertainty differs across regulators but follows a number of principles. In regulatory regimes based on ex-ante allowances, incremental improvements are seen as relatively simple on the Business As Usual (BAU) mechanisms like volume drivers, pass-through of uncontrollable costs and indexation. For reopeners, some complexity is seen as unavoidable, however, given their likely increased use, materiality thresholds and estimating the likely administrative burden should be taken into account in their design and implementation.

One regulator, helpfully, points out that uncertainty mechanisms take at least five different forms: volume drivers, re-openers, pass-through mechanisms, indexation, and use-it-or-lose-it allowances. Thus, when revenue adjusts to volume, inflation, and pass-through costs (e.g., energy costs for gas compressor stations) these are natural adjusters for ex ante uncertainty. Use-or-lose it allowances for certain types of expenditure (such as R+D or repairs) also adjust for uncertainty. Re-openers are only one form of uncertainty mechanism, which usually involves large information requirements on

regulated companies. The question is whether each of these mechanisms is currently being used appropriately by regulators.

Another approach considered by a regulator is to set up a 'light-touch' mid-term review of the price-control period to examine the changes in demand and its implications, without changing fundamental parameters such as return on capital or OPEX benchmarks.

One regulator is planning to adapt to the potential future changes coming from the policy level by setting up a dedicated uncertainty mechanism, using a ring-fenced level of funding to enable the flexibility needed to meet the goals of new energy strategies.

3.3.3. Incentives

Adjusting incentives for NCs to ensure that their short-term actions contribute to long-term goals is a universally shared objective, but there are few readily available solutions with proven results. To some extent, better planning and embedding of shorter-term business plans in longer term development strategies should ensure some degree of alignment.

Some NRAs discussed their experience with ex-post regulation and the difficulty of setting cost efficiency incentives. In addition, they mentioned that NCs and NRAs sometimes have to resort to legal action to settle differences in interpretation of incentive regulations. Somewhat surprisingly this can occur in jurisdictions with reputations for more stakeholder collaboration and/or with publicly owned enterprises. Private ownership of networks might make regulators less likely to attempt to appropriate owners returns and also lead companies to make rational trade-offs between shorter- and longer-term returns.

Some NRAs already use a TOTEX approach to incentive regulation, others are still contemplating the implications of moving beyond the separation of OPEX and CAPEX incentives.

While agreeing that the time has come to move beyond static cost efficiency as the sole principle of regulation, NRAs underline the fact that monopolies are inherently interesting in capturing more rents than optimal and that regulation will continue to be vigilant about that while trying to modernize and adjust to the net zero challenges. Some NRAs pointed out that past experiences of NCs extracting excessive rents and under-delivering have led to some degree of risk aversion from the part of the regulator who is under pressure from the public to ensure value for money.

Some NRAs point out that lack of progress in some instances, particularly on large transmission projects, is more due to issues related to permitting rather than lack of incentives. Since permitting is often not within the remit of NRAs, but mostly local and other central authorities, having more incentives will not necessarily lead to more investment.

NRAs also recognize the difference between NCs, their capabilities and risk appetite. Sometimes NCs react differently to the same incentives, which should be taken into account when designing them. In

addition, the issue of ownership is presented as relevant. NCs can be large and investor owned, state owned or owned by small municipalities or communities. Incentive regulation may play out differently depending on the nature of ownership, with privately owned firms responding more to positive incentives to action.

3.3.4. Financing

Specifically on gas, some NRAs mention some approaches to dealing with the likely decline in the number of users and volumes while ensuring the current gas network is well maintained and safely operated. Options include adjusting depreciation rates and regulatory asset lives, and reopeners.

3.3.5. Stakeholders

NRAs have different ways of managing stakeholders and organizing consultations. One way is to segment by user type, domestic, small business, and large business. To the extent that such stakeholders are increasingly affected by regulatory decisions over time, NRAs also recognize that net zero regulation will require greater stakeholder engagement.

To manage the information cost and heterogeneity of stakeholders, one regulator is planning to establish a scale for project costs and provide additional information on larger projects, enabling stakeholders to consider their merits. Various forms of stakeholder participation are explored including consultations, advisory councils, roadshows, research projects, and partnerships.

3.3.6. Innovation

In jurisdictions with existing innovation schemes – including Great Britain – NRAs focus more on improvements and adoption. An additional area of interest is the involvement of third-party innovation in areas under the control of NCs.

In GB, Ofgem started the Strategic Innovation Fund for key innovations to enable a cost effective and decarbonized energy system. The funding available is £450 million until 2026 (from 2021). Recent projects include scaling hydrogen in a cost-effective way and driving flexibility in networks to meet demand.

Another common practice in advanced regulatory regimes is the regulatory sandbox. NRAs in GB and Germany have adopted such approaches that suspend certain rules to trial certain technologies or model that could potentially benefit customers while reducing the risk of non-compliance. Ofgem uses two approaches to this end:

- The Fast, Frank Feedback offering advice to innovators to navigate the sector and understand the regulatory implications of their innovations.
- Innovation Link, with Ofgem offering support for trials of new products, services, methodologies, or business models. Innovators can range from start-ups, large businesses, public and NGOs.

The first of these is particularly important since most innovation in electricity and gas sectors will fail to achieve sufficient scale to actually impact consumers' bills or quality of service. Most innovation has no chance of becoming significant for consumers and it is good if innovators understand why this is the case earlier, rather than later.

Other approaches to innovation pursued by one NRA include flexibility mechanisms that release additional funding for innovation projects as they are identified, risk sharing of overspending in innovation projects, and recycling unused funds and directing them to innovation projects. All three approaches are meant to encourage a sustained innovation activity.

3.3.7. Governance / Whole system thinking

NRAs agree on the greater need for oversight and coordination among different actors: policy, system operation, regulation, network development across energy carriers, at centralized but also local levels. In GB, for example, Ofgem is one of the entities that will work with the new FSO to perform the coordination roles required by net zero (see above for details). Other NRAs recognized the need for centralization.

Including the achievement of net zero within the mandate of NRAs has been mentioned as relevant by some NRAs while others underlined that political commitment can be sufficient if credible, without official changes in mandate.

To enable a greater whole system approach, Ofgem after a consultation process, decided on a way forward on system governance[35]. It aims to achieve better planning and coordination at regional and local levels. This is meant to accommodate developments including increased local generation, deployment of public EV charging and the new heating solutions, which are likely to evolve in a heterogenous way from one area to another.

Ofgem is also considering the introduction of regional system planners to feed into distribution level investment plans. These regional planners would align regional realities with national security and net zero requirements and thus develop sub-regional plans that contribute to those greater objectives in a locally optimized way. Sweden has been considering the case for a separate System Operator in electricity but has recently decided not to implement this for now. Other NRAs do not acknowledge the increasingly relevant regional heterogeneity layer.

[35] https://www.ofgem.gov.uk/publications/decision-future-local-energy-institutions-and-governance

Some regulators are considering changes to license conditions to ensure they are conducive to whole-system thinking and coordination across actors within the increasingly complex system.

3.3.8. Differences between Transmission and Distribution

NRAs do not see a fundamental difference in the regulatory approach between Transmission and Distribution. However, certain schemes such as Accelerated Strategic Transmission Investments[36] are dedicated to Transmission simply because of investments of that scale and potential for separation from other assets are specific to that network level.

3.4. The view of network companies

3.4.1. Planning

With regard to planning, one can detect different perspectives between transmission and distribution and between electricity and gas.

For electricity transmission, NCs showed a clear preference for considering anticipatory investments, particularly for the offshore transmission grid and prospective connections to offshore wind farms. Also, they emphasize that the planning approach should aim at achieving optimal resilience for the entire power system, considering various scenarios rather than focusing on minimizing costs in a base scenario.

At the DSO level, some NCs argue that a degree of uncertainty will be unavoidable irrespective of how accurate planning will be. While planning may get better at predicting aggregate volumes of investments and works needed for a given period of time, their exact location is not entirely predictable. As deployment of technologies will be a matter of decentralized decision from households, communities and businesses, DSOs will have to be reactive to such evolutions. Therefore, DSOs may need to be allowed some degree of freedom in localizing investments, including the anticipatory ones.

Gas NCs recommend more granularity and a bottom-up approach to planning, due to the increased differences between local contexts. The role of hydrogen, LNG, biomethane, may be very different from one place to another, depending on the extent of the existing methane network and the availability of hydrogen and biomethane.

Also, they call for planning to be better connected to other large-scale policy efforts. For example, they argue, the Renovation Wave[37] in the EU may generate significant demand reductions, and planning should reflect that in order to avoid overinvestments.

[36] https://www.ofgem.gov.uk/publications/decision-accelerating-onshore-electricity-transmission-investment
[37] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en

Some NCs also draw attention to the need for planning to take into consideration extreme whether events, which are becoming more frequent and are affecting assets. Incorporating climate adaptation and resilience in planning becomes more relevant.

What is common to all responses is the understandable need for clear long term policy signals to enable effective planning and execution of large infrastructure projects.

3.4.2. Uncertainty mechanisms

The trade-off between thorough ex-ante planning and the management of uncertainty is widely acknowledged by respondents. The need to ensure that the complexity of procedures around reopeners is managed to keep transaction costs low is also emphasized, yet few answers suggest how this could actually be achieved in practice.

Focusing on 'big ticket' items like volumes, inflation and other 'known unknowns' when setting up predefined rules for reopeners is seen as a general solution (reflecting good practice in automatic uncertainty mechanisms already).

Some NCs argue that on the electricity side investment needs are so high that NRAs should not worry about overinvestment and allow NCs to use 'common sense' including on anticipatory investment.

On the gas side, NCs, both in more and less sophisticated regulatory regimes, are concerned with the inherently higher uncertainty compared to electricity. In countries with a high reliance on woody biomass, where people demand extensions of the gas grids to upgrade their houses and enjoy greater comfort, the uncertainty around gas boilers and the future of the gas grid is likely going to lead to uncoordinated and potentially inefficient investments that will need to be accounted for.

3.4.3. Incentives

NCs argue that regulation should focus more on long-term results – even as far as 2050 – and move beyond short-term cost reduction as the main regulatory goal. Also, they demand better coordination between incentive design and national energy policy objectives.

The issue of covering stranded assets costs is a matter of concern for gas NCs, which is easily understandable, but also for power NCs. For the former, the issue is related to the potential reduction in volumes as countries may mandate switching to other forms of heating. For the latter, investments are sometimes required in anticipation of special projects – a large offshore wind farm or a large electrolyzer - which may or may not materialize, making the new infrastructure vulnerable to becoming stranded. Enough consideration should be given to situations when these developments fail to become reality.

Some NCs raise the issue of insufficient incentives for investment. They underline the fact that underinvestment can be even more costly for the system than overinvestment, as grids may quickly become the bottleneck in the deployment of low-emissions and potentially lower cost technologies,

thus making the high-emissions status quo last longer. Regulated companies want incentives to build ahead of need and to reduce lead times. The two of these go together in the sense that if lead times could be reduced, then there would be less need to build ahead of needs.

NCs also mention the aspect of OPEX saving incentives which, in their opinion, should have some realistic limits. As network operation adjusts to the realities of the transition to net zero, the trajectory of OPEX savings cannot be left unchanged. It may be the case that OPEX actually needs to increase for NCs to be able to perform the extra tasks and keep up with the pace of change in their grids.

Some NCs also consider that certain benefits brought to the system cannot be reflected in tariffs and should be incentivized differently, potentially through direct subsidies. Others emphasize the need for more jurisdictions to have a TOTEX approach and to move beyond the narrow differentiation between physical and digital investments.

Other NCs operating in less experienced regulatory regimes point out that incentives for innovation are not really in place, as the focus of NRAs is solely on conventional investment and improving the quality of service at the lowest cost. This illustrates the relevance of regulatory contexts, as there are still countries in Europe that experience lengthy outages, technical and commercial losses, as well as high rates of poverty (including energy poverty). In their case, the demonstrated improvements of innovation are perceived to be relatively small, which places conventional investments much higher on the priority list.

For example, the Grenoble municipality in France decided to privilege district heating instead of gas or electricity, to connect every new or renovated building to district heating no matter the cost or problems caused to gas infrastructure company. The local gas distributor is very small and the impact on the tariff was a +40% increase in local distribution tariff.

3.4.4. Financing

Some respondents argued in favour of differentiated WACCs by types of assets and their associated risks, including stranded assets. The role of regulation in securing long-term debt is also mentioned.

The recent interest rate hikes are also a matter of concern for respondents who argue that regulated rates of return need to be adjusted accordingly to maintain the attractiveness of NCs for investors. Investors' confidence, it is argued, is highly dependent on the NRAs agility in reacting and adjusting to unfavourable changes. Greater confidence then translates into lower financing costs in the long run and the reverse is true when NRAs do not show willingness to adapt.

On the issue of third-party finance and the interaction with remuneration, NCs argue for clear separation between the streams, to ensure the incentives are not weakened. Some call for incentives for managing project financed from third parties (such as EU funded projects) which involve operational costs that should be at least neutralized but preferably remunerated. Some NCs in

countries that have high allocations of EU funding argued that third-party financing could make higher levels of investments possible in a short period of time while limiting the impact in consumer bills.

Moreover, third-party finance runs the risk of turning NCs is procurement agents which may reduce their incentives to build and deploy their capabilities in network development and optimization.

3.4.5. Stakeholders

NCs recognize the importance of stakeholder engagement and argue in favour of more structure in this process. Defining who are the stakeholders and how they ensure representation is seen as highly relevant.

Some NCs argue that stakeholders are demanding faster progress than the NRAs are prepared to foster and consider greater engagement as key for determining regulation to create dynamic incentives for greater investment and innovation. They believe that NRAs strict and inflexible mandates make them somewhat disconnected from and slow to react to the expectations of stakeholders. More effective consultation would be needed to tackle this issue. A moderated, inclusive, and structured dialogue is believed to be needed for greater coordination between the needs of consumers, capabilities of NCs and decisions of the NRAs.

Some voices are much harder to be heard, according to some NCs. Getting involved more behind the meter and being more decentralized will be key to ensuring inclusivity. At the same time, regulation needs to make consumer aware that they are entitled to receive a share of the benefit they bring to the system but also to pay for costs they create.

3.4.6. Innovation

The issue of innovation appears high on the priority list for many NCs. In jurisdictions where there are no dedicated innovation allowances, NCs are arguing for the introduction of such schemes.
An interesting suggestion is that of the regulatory treatment of Intellectual Property rights. What party can claim ownership of the rights will depend on the financing arrangements for these innovation schemes and may have a strong impact on the incentives to pursue projects of innovation generation and adoption.

3.4.7. Governance / whole systems thinking

Surveyed NCs do not support the separation of the System Operation function from Network Operation by creating different entities. They argue that the benefits of synergies between the two functions outweigh the costs of the potential conflict of interest. Some argue instead for strengthening the system operation function at DSOs, especially those that also operate high voltage grids. Greater coordination between the DSO and TSO is recommended, but separating entities is not seen as a necessary step.

Several NCs mention whole system approaches as crucial to avoid incoherence for example between the development of district heating, which is regulated differently, and gas and electricity. It is argued that greater coordination across carriers would avoid redundancies and potential losses for NCs that can also affect customers.

Some surveyed NCs contend that an explicit net zero mandate would help NRAs move beyond narrow cost efficiency objectives and toward more ambition in getting greater investments into the grids. This would also protect them from potential legal action.

Some NCs agree that local realities are becoming more heterogeneous as different technologies are deployed at different rates to match the specificities of certain regions. Maintaining a strong link between the local level and the centralized whole-system planning level is becoming increasingly relevant. This may also have implications for smaller NCs and regulation overall – it may be the case that setting a unified regulatory regime valid for all NCs in all contexts is no longer possible.

Gas NCs argue that whole system approaches will be crucial for optimization. As gas provides for relatively simple storage capacity, using it to cover peaks may be decisive for the right utilization of renewable sources. They also point to the potential for biomethane which may differ widely from country to country but will require a coordinated approach to ensure the grids are well maintained to accommodate it. In addition, they point out the value of relying on several energy carriers in having system resilience, even beyond short term optimization.

Gas NCs also emphasize the need for a bottom-up approach, arguing that 'transition happens at the local level'. The differences between a place with an existing gas grid and high potential for biomethane and one where heat pumps are already in use should be well accounted for in the approach to regulation. Gas NCs point out that they could do more to promote new gases if unbundling rules were relaxed, allowing them to invest in early-stage hydrogen or biomethane production facilities.

The whole system approach should be across the value chain, not only across carriers, or central and local levels. Some NCs consider that the silo approach in generation, transmission, distribution, and use is not conducive to the kinds of optimization processes required for net zero.

Differences in TSO – DSO Perspectives

DSOs make the point that regulators do seem to apply different approaches to them than to TSOs. DSOs suggest that NRAs are more forgiving of transmission company mistakes and apply lighter standards to proof on approval of new investments. Regulators in turn say that DSO regulation is easier because of the availability of comparators.

Investments prevented by regulatory barriers

Regulated companies – particularly electricity DSOs and gas DSOs and TSOs - raise the issue of whether unbundling rules are standing in the way of whole system thinking and cost minimisation. Batteries can increase network capacity and initial hydrogen and biomethane production facilities might best be supported by network companies.

3.5. Reflections on survey results

1. Many of the points that the regulated companies make can be viewed as calls for the implementation of best practice regulation in their jurisdictions. These include, inter alia, having ex ante planning, appropriate uncertainty mechanisms, longer-term incentives, sufficient financing, effective stakeholder engagement, innovation funding mechanisms and promoting whole-system thinking.

2. Beyond suggesting changes to regulation in line with best practice, companies have more of a 'show us what you are proposing, and we will tell you whether we like it' approach to changes to regulation. This is perhaps not surprising, but it does suggest that the onus in suggesting changes to regulation lies with NRAs, governments, and other stakeholders (such as academics!).

3. The regulators do want to respond to company and other stakeholder concerns and some major changes are in train e.g. changes to governance arrangements (in the UK with the creation of the FSO) and the nature of regulation (in Sweden moving to totex regulation from 2027). Some company comments indicate that overall system planning functions and individual asset ownership must be clearly separated. By contrast companies raise the issue of whether unbundling rules are preventing them from making system optimal investments within the current ownership structure.

4. Gas TSOs and DSOs emphasise the need for regulation to be clarified with respect to heating generally and new gases. District heating and direct use of gas compete with each other but are often separately regulated. While hydrogen networks do not yet exist but could be significant in the future, competing with existing methane networks and with other sources of energy.

5. Regulators emphasise that they need to be responsive/adaptive to government policy. Regulators thus have to be realistic as to the extent to which they can offer multi-period guarantees on investment plans and build in re-evaluation points in line with the adaptive regulation framework we outline. While many stakeholders (especially regulated companies) want more certainty as to government policy, the extent to which this can be clarified on a multi-period basis, across multiple electoral cycles, is limited.

6. Regulated companies point out that direct taxpayer funding for network investment needs to have the same incentives as regulator approved customer funded investments. They discuss how this can be done in different jurisdictions including allowing them to earn a return if added to the asset

base and allowances for profits and operating costs (not just directly incurred costs). Regulators and governments need to be concerned about incentives to efficiently minimise combined taxpayer and customer funded investments in the same way they have been about opex – capex trade-offs.

4. WHAT CAN BE LEARNED FROM OTHER JURISDICTIONS OR SECTORS?

This section describes case studies relevant to the subject matter of this report – regulatory improvements to face new societal or economic challenges. Cases cover both European and non-European jurisdictions and energy and non-energy regulation. Each case has been chosen because it represents a good example of an attempt to make monopoly network regulation more dynamic/responsive/adaptive in the face of an uncertain long-term future affected by net zero climate policy.

Each case study will be relevant to one or more of the components of regulation discussed above.

[1] Planning
[2] Uncertainty mechanisms
[3] Incentive regulation
[4] Financing conditions
[5] Stakeholders
[6] Innovation
[7] Governance / whole system

4.1. 'New Reg' Australia

In Australia, a need for increasing sector engagement as well as to identify opportunities for regulatory innovation have led to a join initiative, established in 2018[38] - between the Australian Energy Regulator (AER), the Energy Networks Australia (ENA) and the Energy Consumers Australia (ECA) - called 'New Reg'. The aim of this common platform is to ensure that both network business activities and regulatory policies are driven by customers' preferences, and that these preferences are better reflected in regulatory proposals.

The initiators' objective was to switch from the conventional practice of the regulatory process to a Customer Forum, which negotiates details of various regulatory proposals. The Forum does not represent any personal interests, instead it needs to run independent research and customer engagement activities, to ensure the representation of all customers. To do so, the representatives –

[38] New Reg | Australian Energy Regulator (aer.gov.au)

who need to have relevant skills and experience for these roles - are selected to represent both households' interests, as well as those of business consumers (small and industrial).

The 'New Reg' process has two main components[39]:

- The development of the regulatory proposal through an Early Engagement Process – this entails the extension of the current consumer involvement to "a point where the network business reaches agreement (or otherwise) on some or all aspects of the regulatory proposal".
- The assessment of the regulatory proposal by the AER – taking into account agreement between consumers and the network through the Early Engagement Process, "with the reasoning and evidence for this agreement" to be included in the Engagement Report.

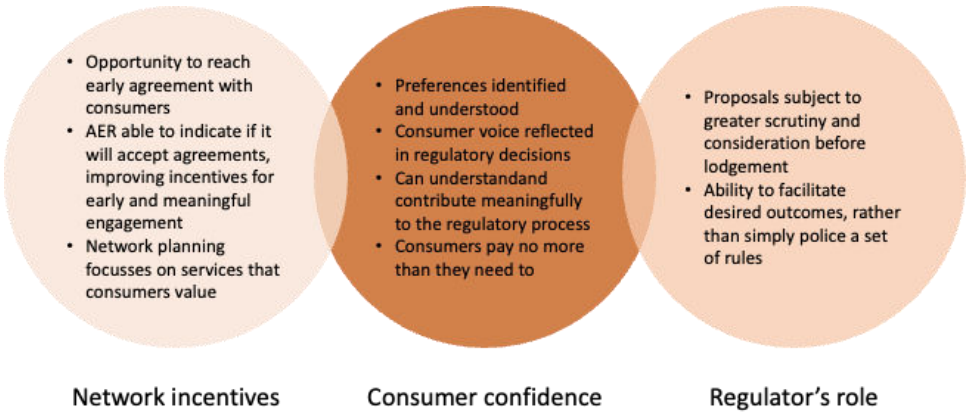


Figure 10: Opportunities to improve the regulatory review process Source: Australian Energy Regulator[40]

A first trial for the newly established New Reg was the development of AusNet Sevices regulatory proposal for the 2021-2025 period, which led to a very high engagement process between stakeholders.[41]

Building on the lessons learned from this first trial, the Australian Energy Regulator has developed a comprehensive Handbook aimed at highlighting the findings of these engagement efforts. It helps network operators to develop proposals which are endorsed by customers, through various

[39] NewReg Directions Paper - Towards Consumer-Centric Energy Network Regulation - March 2018.pdf (aer.gov.au)
[40] https://www.aer.gov.au/system/files/CEPA%20New%20Reg%20Final%20Evaluation%20Report.pdf
[41] https://www.aer.gov.au/networks-pipelines/new-reg/ausnet-services-trial

engagement options[42]. According to AER, genuine engagement will also improve the understanding and, therefore, the trust relations between operators and consumers.

The Handbook sets the regulator's expectations on how network operators need to engage with their customers, as well as how this engagement must be reflected in their investment proposals. Moreover, the document also sets expectations for various element that tend to significantly impact customers, such as CAPEX and OPEX levels, depreciation, or tariff structure statements.

The Australian Energy Regulator also introduced – through this Handbook – the "early signal pathway", an alternative process that allow operators to engage earlier with the regulator and to receive earlier formal feedback on regulatory details about their upcoming proposals.

4.2. Scottish Water

The Scotland water utility – Scottish Water – introduced a Customer Forum (CF) as early as 2011. Scottish Water is a government owned utility. Its mandate evolved from simply representing customers in relation to both the utility and Water Industry Commission for Scotland (WICS) to playing a significant role in the price control review process. The first business plan adopted based on input from the Customer Forum was in 2014 and the performance has been considered satisfactory (Littlechild, 2014). The motivation behind introducing the CF stemmed from anticipation regarding approaching limits to efficiency gains, the economic situation after the financial crisis and the greater need for legitimacy of bills, in the eyes of customers. Thus, in a context of relatively high customer satisfaction, increased efficiency, and declining tariffs, WICSs chose to act pre-emptively and intensify customer involvement in potentially consequential decision making that was about to follow. The CF consisted of eight members plus a chairman, including one representative of SW. All members were jointly appointed by the three parties – WICS, SW and customers. A larger consumer association – Consumer Focus Scotland – could nominate five members, but agreement would be needed from all parties for the appointment. The different representation of residential and business customers was also ensured. The composition of the Forum turned out to be of mostly prominent former office holders, members of various boards, representatives of academia and former regulators. While some members had previous experience in the water sector, most of them did not. The first duty of the CF was to conduct research on the willingness to pay and other preferences of customers. The information collected revealed a low level of awareness among the public on the value of water bills. As the CF was mandated with representing the public in setting price control, the limited public knowledge of and low priority given to water bills was seen as a significant challenge.

The CF was also given a role in the implementation of a regulatory innovation adopted by WICS – financial tramlines. These represented a series of lower, intermediary, and upper thresholds, regarding certain financial ratios, which determined different regulatory action. For example, if the actual number would be below some intermediary threshold but above the lower limit, a reward would be

42 https://www.aer.gov.au/system/files/Better%20Reset%20Handbook%20-%20December%202021.pdf

offered to SW. If the intermediary threshold would be reached, the matter would become a point of discussion with the CF. If the resulting discussions would not lead to improvement, the WICS would enact the necessary adjustments and potential penalties. The graduality of this approach was also meant to protect the CF from facing too much responsibility.

Following repeated interaction, and not without friction, the CF ended up with an expanded mandate that included input in the business plan and price control settlement for 2015-2021. The involvement resulted in a number of elements being introduced such as updated customer satisfaction measurement methodologies, new incentives linked to those actual measures as well as network tariffs for the period. The final determination of WICS broadly reflected the agreement reached between SW and the CF. The role of CF is seen to be meaningful and positive. While it is hard to establish how much influence it had over the 'hard' components of regulation like the rate of return or capex, the more intense involvement brought more scrutiny into otherwise technical processes and determined SW to produce more explicit and "friendly" argumentation around key regulatory parameters. The CF in Scotland served as inspiration for other UK regulators in other sectors and regions on how to elicit more interaction between customers, utilities, and regulators.

4.3. Anticipatory regulation – Singapore Autonomous Vehicle Initiative

In 2014, the Singapore Autonomous Vehicle Initiative (SAVI) was launched, which aimed to research the autonomous vehicle transportation sector and test-bedding. It created a cross-industry committee – which included both public and private representatives – in an attempt to better anticipate and integrate autonomous vehicles after the Land Transport Authority agreed to more flexible testing of these solutions.[43]

The initiative developed an open platform that allows authorities, research centres and think tanks, or industry companies to jointly run self-driving trials, to test various scenarios and solutions. As a result, it attracted the attention of multiple foreign investors into the sector.

In 2016, an AV piloted by 'nuTonomy' collided with a lorry, leading to an immediate investigation of the accident. Once the safety concerns were addressed, the pilot project was resumed, showcasing the authorities' mission to strike a balance between eliminating and minimising risks, while seeking innovative solutions, in a partnership with private operators and the communities.

Researchers argue that although Singapore has addressed short-term AV risks, medium and long-term regulatory challenges remain, e.g. behavioural changes in AVs due to deep learning, cyber-attacks, and workforce disruptions (Tan and Taeihagh, 2021). To this end, the regulatory designs for medium and long term are similar to the electricity/gas frameworks, as they also embed high uncertainty that can deviate from baseline scenarios.

[43] https://media.nesta.org.uk/documents/working_model_for_anticipatory_regulation_0.pdf

This example shows how political determination, the capacity to develop robust policy, the existence of public-private dialogues and partnerships, or cross-departmental collaboration can lead to a successful regulatory environment for innovation. However, the same experts highlighted some relatively unique conditions leading to this success, such as the country's compact size, the existing political structure, and the high public acceptance of administration policies. For these reasons, replication of these best practices may pose both geographical and sectorial limits.

4.4. Ofwat – adaptive regulation

Ofwat, the water regulator in England and Wales, has chosen adaptive pathways planning for its latest price control (PR 24). Faced with the implications of climate change for the water sector, the need for investments and the cost-of-living crisis, Ofwat required that NCs adopt an adaptive pathways method to their business plans in order to prepare to meet the challenges of the future. The business plans are meant to cover five years but need to be presented within 25 years strategies, emphasizing the ways in which each period contributed to the long-term goals. Each company needs to define a core pathway for 25 years, describing the most likely scenario. They also need to present relevant indicators and thresholds for triggering alternative pathways that deviate from the core. The NCs need to assign reasonable probabilities as to when a threshold may be reached based on the available information and the likely changes needed to their business plans.

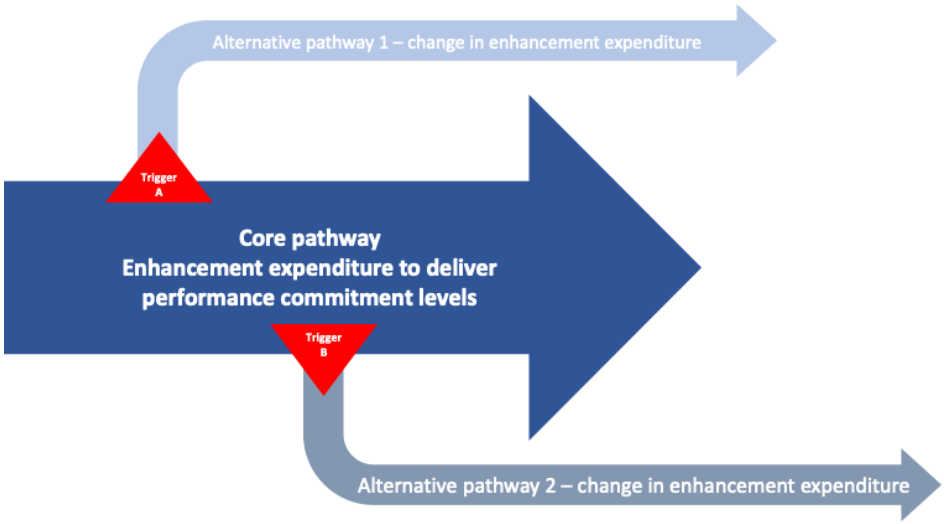


Figure 11: Ofwat adaptive planning
Source: Ofwat (2021, p.18)[44]

Ofwat aims to "secure the needs of current and future customers, in a way which delivers value to customers, the environment and wider society over the long term", therefore distinguishing its role as

[44] https://www.ofwat.gov.uk/wp-content/uploads/2021/11/PR24-and-beyond-Long-term-delivery-strategies-and-common-reference-scenarios.pdf

an enforcer of sustainable water supply.[45] To deliver this desiderate, a shift to long-term adaptive planning is needed. For these reasons, the regulatory framework ought to ensure that companies do not delay appropriate investment in the short term, which in turn would be beneficial for future customers.

Therefore, the long-term delivery strategy of business operators should set the long-term outcomes that the company wants to deliver. Therefore, it needs to include:

- all the planning frameworks and statutory environment programmes;
- planned enhancement activities that are outside of these frameworks (factoring in forecast performance improvements from base expenditure);
- the integration of these elements in a broader 25-year framework;
- Use the short-term strategy (5 year) to form the business plan (figure 7 below).

Long-term strategies should consist of five main parts (figure below), supported by data (costs, outcomes, bill impacts) and argumentations on how the operators' strategies have been informed by customer preferences.

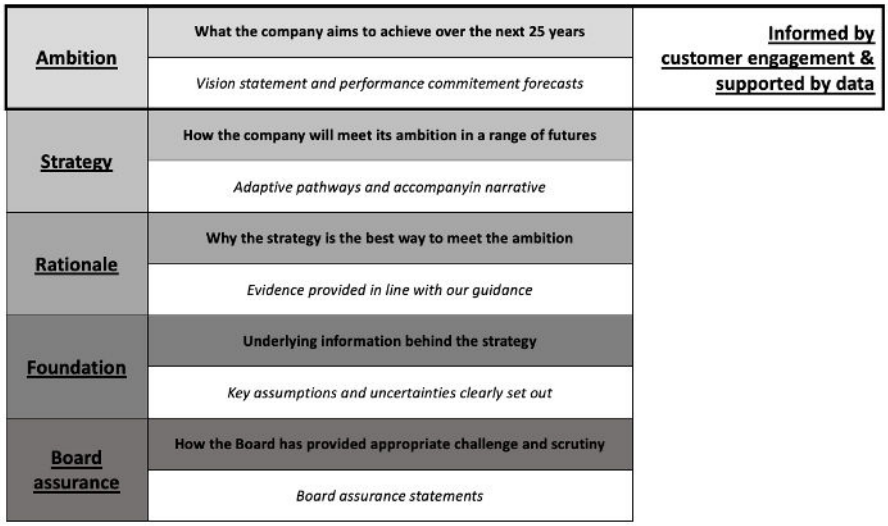


Figure 12: Structure of a long-term delivery strategy
Source: Ofwat (2022, p.6)

The long-term delivery strategy is based on adaptive planning. The process evaluates what activities will be dependent on what circumstances and what are the needs based on these alternative scenarios, which ensures that decisions are taken when they are needed, while minimising the risk of stranded

[45] https://www.ofwat.gov.uk/publication/pr24-and-beyond-final-guidance-on-long-term-delivery-strategies/

assets. This approach sets various decision points - indicating when decisions have to be taken to keep the company's objective on track (figure 8 below) - which lead to different deviation pathways.

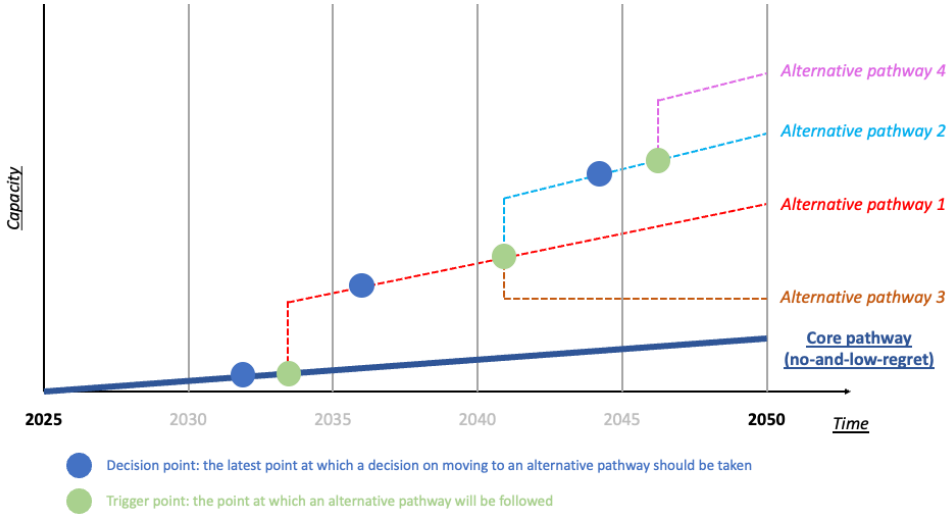


Figure 13: Example core and alternative adaptive pathways
Source: Ofwat (2022, p.7)

Scenario analysis is a critical part of adaptive, therefore companies are required to test the set of core and alternative pathways to deliver the company's ambition.

While this case study showcases relevant elements for electricity and gas regulatory frameworks, there are limits of comparison with the water utilities. First, the level of uncertainty in the water sector is lower than the electricity/gas grids, making scenario analyses more accurate. Second, the electrification process makes basically gas-fired applications (e.g., heating, cooking) find a substitute product, an impossible transition for water users. Third, the decentralised, self-generation electricity (and the pace of this transformation) makes the electricity grids difficult to compare to water infrastructure. Fourth, a relative increase of water tariffs would still represent a low absolute value, making end-users less interested in actively addressing their consumption patterns/behaviours.

4.5. The Australian Airport Regulation

In most cases, airport prices were set on a cost-based system, including in the case of countries owning and operating these facilities. The price capping system emerged in the UK in 1986, when the UK Civil

Aviation Authority (CAA) followed the mechanism used for other utility companies, which had price caps (Adler *et al.*, 2015).

From 1997 to 2022, the Australian Government privatized 23 airports with 99-year leases, including eight general aviation airports. Eleven out of twelve largest airports (Sydney was excluded) had prices caps, which allowed for pass-through necessary new investment costs.

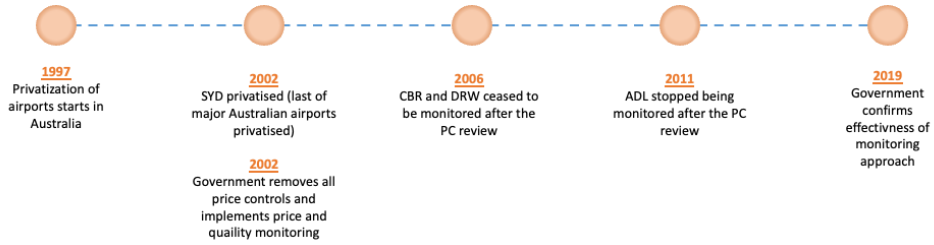


Figure 14: Timeline of actions in Australian airports

Source: ACI Europe (2021, p.11).

(Airports: SYD – Sydney, CBR – Canberra, DRW – Darwin, ADL – Adelaide; PC – Productivity Commission)[46]

The price cap was meant to be a temporary measure, which would need evaluation after a 5-year period by the Australian Competition and Consumer Commission (ACCC). To ensure objective evaluation, the Productivity Commission (PC) was tasked with the review. Following a multi-staged process – and following the Productivity Commission's recommendations – the Government eliminated price control and implemented a system of price and quality monitoring.[47]

According to industry associations – both from Australia and abroad, that evaluated this case study – the removal of prices caps brought several benefits, including AUD15 billion in investments between 2002 and 2018, two-thirds of which focused on aeronautical assets, leading to a growth in passengers, from 76 million in 2002 to 159 million in 2018. This is an illustration of how a formerly regulated network monopoly could move beyond conventional price control.

A key element of this process is the fact that airlines can represent ultimate customers effectively and ensure that any stakeholder engagement process balances customer and producer interests. Well-informed customer representatives with strong incentives to balance price and quality trade-offs can deliver beneficial outcomes without the need for formal regulation. Of course, both producers and consumers can still appeal to the responsible government body but have a vested interest in settling

[46] https://www.aci-europe.org/downloads/resources/Lessons%20For%20Europe%20From%20Australia%20-%20The%20Review%20Of%20Australian%20Airport%20Economic%20Regulation.pdf

[47] https://www.aci-europe.org/downloads/resources/Lessons%20For%20Europe%20From%20Australia%20-%20The%20Review%20Of%20Australian%20Airport%20Economic%20Regulation.pdf

rather than opening the regulatory process up to additional external scrutiny which may not improve on their negotiated outcome.

The direct applicability of this to electricity and gas networks is somewhat limited by the fact that energy retailers are not subject to the same competitive pressures as individual airlines at a given airport, especially where transit traffic is significant and very price sensitive. However, the potential to learn lessons from the evolution of regulation at airports under uncertainty and with strong cost-quality trade-offs is clear.

5. CONCLUDING REMARKS

In this report we set out to examine the implications of the transition to a net zero energy system for regulatory regimes in electricity and gas across Europe, arguing that regulation will need to become more dynamic.

To do so, we re-examined the evolution of economic regulation, as it moved from simpler rate of return models, toward cost-focused incentive regulation and, more recently, toward adding outputs and innovation as specific objectives in the context of strengthening environmental objectives.

We also revisited the inherent trade-offs of economic regulation, stemming from the asymmetry of information, the difficulty of measuring outputs, and the long causal chain between investments and quality of service, among others. In addition, we presented the challenges faced by network companies and investors who are sometimes subjected to significant changes in key policies and regulations affecting their long-term plans and remuneration. We argued that, on top of the existing inherent problems of regulation, net zero may add additional ones, mostly due to uncertainty in the actual path and pace of decarbonization, increased investment needs, the unknown contribution of certain technologies, such as low carbon gases, and the need for pursuing and adopting innovation at an unprecedented scale.

We also introduced into the net zero context, two regulatory trilemmas. Two sets of trade-offs that affect regulation. The first includes effectiveness, coherence, and responsiveness. The second involves coordination, motivation, and low transaction costs. We show for each of the trilemmas, action that increase any two objectives are detrimental to the third. We also discuss the difficult balancing act that regulators need to perform on a continuous basis to attain all goals to an acceptable extent.

We also put forward three attributes of regulation that could make the net zero processes more effective: dynamic, adaptive, and responsive.

Dynamism captures the need to move beyond static cost-based efficiency toward innovation-inducing long-term incentives. Responsive regulation moves back and forth, as needed for each regulatory challenge, between two ends of a spectrum: pure reward and punishment on one end, and self-regulation on the other.

Finally, adaptive regulation embraces uncertainty by preparing scenarios and setting up change drivers and thresholds (e.g., a certain percentage of EV penetration) to ensure faster response to evolutions that may be somewhat predictable.

We argue that all three attributes have a key element in common - learning. Taking the three attributes together we argue for a ‘learning’ regulator who looks to learn from the past, learn from stakeholders in the present and anticipate key future learning points. Regulators who need to navigate the increased

uncertainty, the technological advancements, the innovations stemming from outside the network companies, and the diversity of stakeholders' interests will need to be able to learn faster and incorporate new information swiftly into regulatory decisions.

Next, we substantiated the uncertainty surrounding net zero by showcasing the differences between scenarios within countries (Great Britain) and between countries (Germany, France, Italy, and the Netherlands) with respect to key drivers of energy system transformation, including the role of hydrogen, biomethane, electrification of consumptions, offshore wind, gas grid uses, and others. We then discussed two cases where the regulatory regime is under a process of potential revision, Great Britain, and the Netherlands. Based on the 41 responses to the consultation launched by Ofgem in 2022 on the future of regulation for net zero, we identified seven regulatory components that may require reflection and reform: planning, uncertainty mechanisms, incentives, financing, innovation, stakeholders, and governance/whole system thinking. We then discussed the variation in economic contexts and energy systems between European countries, carriers (electricity and gas), and network level (transmission and distribution), acknowledging that the regulatory regimes may face different challenges and have different tools to address them.

We then presented the results of a questionnaire and in-depth interviews with key industry stakeholders. We included representatives of both electricity and gas, transmission and distribution networks companies, regulators, as well as a diverse geographical scope with countries in the West, North, South and East of Europe. The results illustrated the concerns of practitioners, who are calling for better planning, whole system coordination, smoother uncertainty mechanisms and better aligned short- and long-term incentives.

Finally, to showcase the different facets of the net zero challenges, we presented a number of case studies from other jurisdictions (Australia, Singapore) and sectors (water, autonomous vehicles). They illustrate different approaches to similar problems, including uncertainty, ensuring stakeholder involvement, and adaptability to change. The cases demonstrate the practical importance of the three attributes of regulation and offer lessons for European energy regulators to learn from regulatory experiences outside of energy and outside of Europe.

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ANNEX 1 - QUESTIONNAIRE

This upcoming CERRE report will study whether current European network regulations – based on periodic price control reviews conducted every 3-5 years – are fit for purpose in the net zero era. Specifically, it seeks to investigate if a more dynamic form of regulation is required, which addresses and acknowledges the uncertain environment we are in and the implications of the level of ambition which European climate policy has set. The aim of the project is to consider whether and how network regulation might evolve to better achieve net zero.

To face the challenges of net zero, economic regulation will need to consider a number of changes. There may be a need for changing the mandate of regulatory authorities. It may also require changes in some of the main components of regulation. Whether these changes amount to a fundamental shift of approach or mere adjustments of exiting systems is difficult to establish.

In this context, based on our initial research, we have identified seven components of regulation where we expect significant change to occur as decarbonisation accelerates.

	COMPONENT	DEFINITION	Score (1-5)
1	**Planning**	• Business planning may need greater flexibility to adapt to unforeseen changes in the network (surge in consumption due to EV charging or electric heating, DER integration, conversion to hydrogen, decommissioning of certain gas networks, etc).	
2	**Uncertainty mechanisms**	• With more sources of uncertainty, reopener processes will have improved while keeping the ex-ante price cap principle credible.	
3	**Incentives**	• Incentive mechanisms may need to change to encourage more long-term, system-wide thinking to enable decarbonization.	
4	**Financing**	• With increased uncertainty, the cost of capital may increase or may need to be differentiated. • Other sources of finance – grants, subsidies – may be channeled to strategic projects with no impact in tariffs.	
5	**Stakeholders**	• More diverse stakeholders (e.g. DERs) will need to be included but coordination and representativeness will be the challenge.	
6	**Innovation**	• More DSO but also third-party innovation spending and adoption will be required but spending will need to be kept under control.	

7	**Governance** **Whole system**	• More coordination and central guidance will be needed. • Regulatory agencies may have explicit net zero mandates. • Regional and local realities may grow increasingly heterogenous requiring local planning. • Whole system optimization across energy vectors will be needed. • System operation may become more relevant for DSOs (in addition to network operation).	
8	?	?	
9	?	?	

Questions

Based on the THREE top-scoring components from above, the questionnaire will focus on what you identify as the main changing factors. For all the following questions, we encourage you to refer to specific examples of best practices, changes you would consider necessary, and cases that can be relevant for learning (positive or negative).

1. **Planning**
   - How can regulation encourage more adaptive planning?
2. **Uncertainty mechanisms**
   - How can regulation better balance between ex-ante planning and effective uncertainty mechanisms?
   - How could the complexity of implementation be reduced?
3. **Incentives**
   - How can incentive regulation change to encourage more long-term thinking in investment and operational costs?
4. **Financing**
   - How can uncertainty be managed to reduce the cost of capital impact?
   - How can you integrate third-party financing (e.g., EU grants, other subsidies) into network remuneration models?
5. **Stakeholders**
   - How can stakeholders be more involved in economic regulation? Which stakeholders?
   - How can stakeholders be involved while minimising participation cost and complexity?
6. **Innovation**
   - How can regulation incentivise effective innovation spending and adoption from network companies?

7. Governance/Whole system thinking?

- What are the barriers to whole system thinking, and how can they be removed? Should there be an entity planning and coordinating a whole system approach?
- How can regulation encourage whole system thinking and optimise across energy vectors? Is this falling under the NRA's mission (net zero)?
- How can regulation better adapt to local contexts? Are there missing local regulatory institutions?

8. For Regulatory Authorities (electricity and gas) only:

- How do TSOs' and DSOs' perspectives on how price controls differ, and what does this mean for regulators?

OR

8. For Business operators (electricity and gas) only:

- Are there cases of investments or innovation adoption where you believed that there was a positive cost-benefit analysis, but regulation prevented it from happening? Where was the bottleneck/barrier? What should change in the regulation framework for projects like that to be implemented?
- Do you have good regulatory practices in other jurisdictions or sectors?

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