RP7 Efficiency Advice

The Northern Ireland Utility Regulator (UR)

24 November 2023

FINAL REPORT

Important notice

Contents

EXECUTIVE SUMMARY

We have assessed NIE Networks' efficiency of IMFT&I and NOCs, using our independently developed preferred set of models. The aim of our efficiency analysis is to provide insight to the UR for setting NIE Networks' efficiency targets for the RP7 price control review, running from 1 April 2025 to 31 March 2031.

For the efficiency analysis, we have relied on historical data only (2012-2021 data from Ofgem's RIIO-ED2 BPDTs and 2013-2022 data from UR's RP7 RIGs). To ensure comparability, and address differences in scope between GB DNOs and NIE Networks, we have conducted a comprehensive pre-modelling normalisation process, including regional wage adjustments.

We have rerun UR's RP6 final determination models, and have identified improvements to the RP6 final determination models. In particular, we have removed the time dummies, and did not retain the unit cost model (i.e., IMFT&I per customer) and more disaggregated models (CAI and BSC) from RP6. We have added a new IMFT&I model that does not use the %OHL driver, as this model passes the RESET test (i.e., model 2.3).

Table 1.1 summarises NIE Networks' efficiency scores according to our preferred set of models for RP7, including the upper quartile benchmark (UQ) and the catch up challenge (i.e., the difference between the upper quartile and NIE Networks' efficiency score). The score above 1 indicates inefficiency (i.e., less efficient than the industry average), and a score below 1 indicates efficiency.

We also show the upper quartile (UQ, i.e., 75th percentile) efficiency score of the industry, and the difference between NIE Networks' efficiency score and the UQ (i.e., the catch up challenge). NIE Networks' triangulated efficiency (equal weight on each model) score is -14% for IMFT&I, and -5% for NOCs (where a negative value shows performance better than the UQ). The results suggest that NIE Networks' historical IMFT&I costs are 14% more efficient than the UQ benchmark in the set of NIE Networks and GB DNOs.

Table 1.1: CEPA's preferred modelling results and NIE Networks catch-up challenge

	IMFT & I (inc. connection costs)			IMFT & I (exc. connection costs)			NOCs		
	Model 2.1	Model 2.2	Model 2.3	Model 2.1	Model 2.2	Model 2.3	Model 2.4	Model 2.5	Model 2.6
NIE Networks efficiency score	0.865	0.881	0.820	0.814	0.830	0.754	0.875	0.896	0.773
UQ	0.970	0.998	0.942	0.974	0.992	0.949	0.889	0.906	0.889
Catch-up challenge	-10%	-12%	-12%	-16%	-16%	-19%	-1%	-1%	-12%

Source: CEPA analysis

We have tested sensitivities to check the effect of our pre-modelling adjustments on NIE Networks' efficiency score, particularly:

- **Regional labour sensitivity:** In our core models, we applied a regional labour adjustment to 100% of labour costs for all companies, assuming that companies incur all their labour costs locally. To test the effect on efficiency, we tested the use of ED2 labour ratios for GB DNOs, whilst maintaining the application of regional labour to 100% of NIE Networks' labour costs. We conclude that this only has a minor impact on NIE Networks' efficiency score, resulting in an average catch up efficiency challenge of -13% for IMFT&I, and -5% for NOCs (instead of -14% and -5%, for IMFT&I and NOCs respectively).
- **Wayleaves sensitivity:** In our core models, we include wayleaves costs for all companies. We use this sensitivity to test the impact of the exclusion of wayleaves costs. We conclude that this has a larger impact on NIE Networks' efficiency score for IMFT&I than the the regional labour sensitivity, resulting in an average catch up efficiency challenge of -16% for IMFT&I, and -5% for NOCs (instead of -14% and -5%, for IMFT&I and NOCs respectively).

Overall, we consider that the modelling results show robust efficiency scores, and assumptions on pre-modelling adjustments do not materially affect our findings on efficiency.

Implications for RP7

At the RP6 review, UR found that NIE Networks was relatively inefficient compared to GB DNOs. However, while the result of the benchmarking analysis suggested a catch-up efficiency challenge of 2%, UR concluded that it was appropriate to set a final allowance without a catch-up efficiency challenge, to provide headroom for NIE Networks to resolve challenges as they arise.

The comparative benchmarking analysis for RP7 has not provided evidence for the imposition of a catch-up efficiency challenge, based on NIE Networks' historical expenditure. NIE Network is expecting a significant step up in expenditure for the next price control review. However, the assessment of the appropriate step up in expenditure is outside of the scope of this report.

1. INTRODUCTION

CEPA has prepared this report for the Northern Ireland Utility Regulator (UR) to inform the UR's assessment of the business plan submitted by Northern Ireland Electricity Networks Ltd (NIE Networks) for the price control period RP7, running from 1 April 2025 to 31 March 2031. Alongside its business plan in March 2023, NIE Networks submitted NERA's comparative benchmarking report on its proposed expenditure for the RP7 price control.

This paper presents the findings of CEPA's benchmarking analysis of NIE Networks historical expenditure compared to the GB distribution network operators (DNOs). This paper is one of the inputs that will inform the UR's proposal for the efficiency challenge for NIE Networks for the RP7 price control.

This report primarily focuses on NIE Network's operating expenditure (IMFT&I), which includes inspection, maintenance, faults, tree cutting and indirects. It also explores the use of total expenditure (totex) benchmarking, which combines NIE Networks' IMFT&I and capital expenditure (capex).

The rest of this report is structured as follows:

- Section 2 provides details on the data we have used and sets out our approach to pre-modelling adjustments.
- Section 3 sets out our methodology for benchmarking.
- Section 4 presents our preferred middle-up models and sensitivity analysis.
- Section 5 presents our totex results.

The appendices provide more detail on benchmarking approaches and on the results of the sensitivity analysis we carried out.

2. DATA USED AND APPROACH TO PRE-MODELLING ADJUSTMENTS

In this section, we briefly discuss:

- input data for our analysis – in terms of the cost elements of NIE Networks' business plan submission; suitable comparators, and the time period; and
- our approach to pre-modelling adjustments, which ensures that NIE Networks' is compared on a like-for-like basis with its comparators.

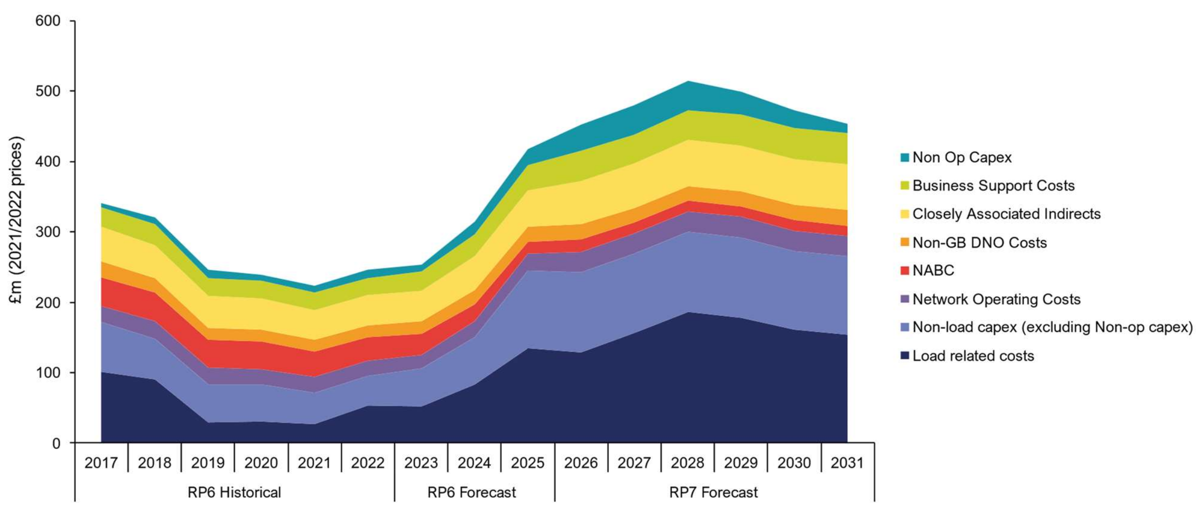
2.1. DATA USED FOR EFFICIENCY ANALYSIS

2.1.1. Overview of NIE Networks' business plan submission

NIE Network submitted its business plan in March 2023, including the Regulatory Instructions and Guidance (RIGs) containing data on NIE Networks' historical expenditure and forecast costs.

Figure 2.1 summarises NIE Networks' historical expenditure up to 2022, forecast expenditure for the remaining of RP6 (to March 2025), and forecast expenditure over the RP7 price control (April 2025 – March 2031).[1] It illustrates a fall in historical expenditure over the early part of RP6 up until 2021. Actual expenditure then increased from 2021 to 2022, with further expenditure increases forecasted year-on-year until 2028. These increases include significant year-on-year increases in the final years of RP6 and early years of RP7. NIE Networks primarily attributes this step-change in expenditure to the investment required to support the delivery of Northern Ireland's net-zero commitments.

Figure 2.1: NIE Networks' historical and forecast distribution expenditure across RP6 and RP7



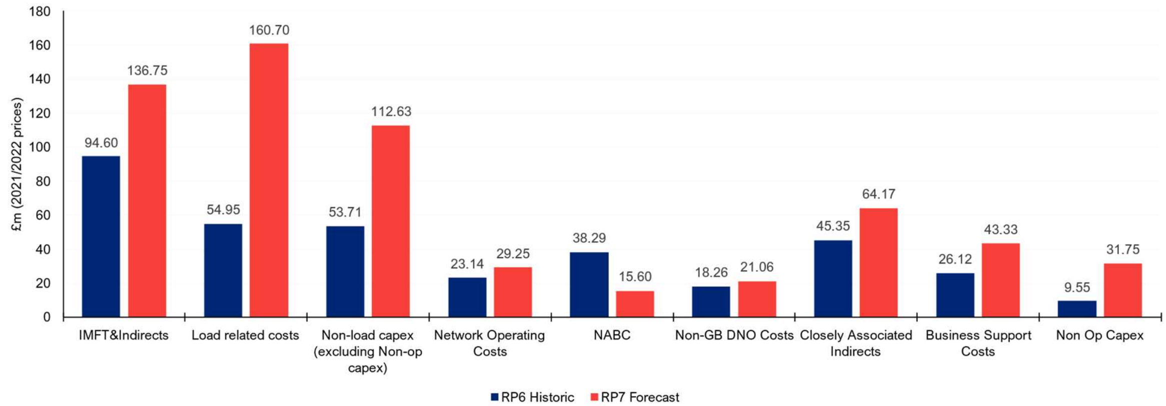
Source: CEPA analysis of NIE Networks data

Figure 2.1Figure 2.2 compares actual annual average expenditure by cost activity in RP6 with forecasted annual averages across RP7 (i.e., the step-up needed according to NIE Networks compared to its current spending). With the exception of non-activity-based costs (NABC), annual expenditure for all categories is forecast to be higher in RP7 when compared to the actual costs incurred in RP6. The three categories with the largest forecast £ million

[1] This figure includes distribution costs and LV 110kV transmission costs as this is deemed comparable to the GB distribution system (see Section 2.2.2)

increases are Load related costs (from £54.95 million to £160.70 million), Non-load capex (excluding Non-op capex (from £53.71 million to £112.63 million), and IMFT & Indirects (from £94.60 million to £136.70 million).

Figure 2.2: NIE Networks' annual average expenditure per distribution cost activity across RP6 (historic) and RP7 (forecast)



Source: CEPA analysis of NIE Networks data

2.1.2. Comparators for benchmaking

In line with the approach adopted for RP5 and RP6 we have identified GB DNOs as the most suitable comparators to NIE Networks Therefore, our analysis encompasses 15 companies (14 GB DNOs alongside NIE Networks).

To ensure comparability, and address differences in scope between GB DNOs and NIE Networks, we have conducted a comprehensive pre-modelling normalisation process, which we discuss further in Section 2.2.

2.1.3. Historical and forecast data

NIE Networks submitted 10 years of historical outturn cost and volume data, covering 2013-2022, and nine years of forecast data, covering 2023-2031. Ofgem provided us with the GB DNOs Business Plan Data Tables (BPDT) submissions for RIIO-ED2, providing 11 years of historical data and 7 years of forecast data. A summary of the available dataset is presented in Table 2.1 below.

Table 2.1: Summary of available dataset

Company	Companies	Historical data	Forecast data
NIE Networks	1	2013-2022 10 years	2023-2031 9 years
GB DNOs	14	2011-2021 11 years	2022-2028 7 years

Source: CEPA analysis

Like NIE Networks (see Figure 2.1), the GB DNOs are forecasting significant growth in expenditure linked to network investment to support the transition to net zero. This creates the potential for a 'structural break' between historical data and forecast data, which could mean that benchmarking using historical data only may fail to explain important trends in expenditure in RP7.

However, using forecast data relies on consistent assumptions being used to build up the forecasts; otherwise, forecast data may result in inaccurate relationships between costs and cost drivers. The consistency of assumptions is particularly challenging when considering that:

- GB DNO forecasts were informed by the Future Energy Scenarios (FES), which outlines different pathways to form a picture of how GB might reach net zero. NIE Networks relied on different forecasting assumptions/future scenarios.
- The step up in expenditure comes at a different point in time for NIE Networks compared to the GB DNOs.
- The GB price control (RIIO-ED2) and NIE Networks' price control (RP7) start at a different point in time. GB DNOs are expecting a significant step up at the start of the RIIO-ED2 price control (i.e., 2023), while RP7 starts in 2026.
- The step up in expenditure also comes at a different point in time for NIE Networks compared to the GB DNOs. This is a result of price controls starting at different points in time, and GB DNOs and NIE Networks operating in different jurisdictions with different expectations regarding the pace of electrification,
- There are different Uncertainty Mechanisms (UMs) in the price control framework in GB and Northern Ireland, which makes it more challenging to be confident that baseline spending is sufficiently comparable.

Conducting benchmarking analysis between different jurisdictions is a complex process, due to differences in regulatory framework and assumptions underpinning forecast costs. So, on balance, we considered it would be more appropriate to use historical data only. We considered that using forecast data would add additional complexity, which could result in benchmarking analysis that is not on a sufficiently comparable basis. This differs to Ofgem's RIIO-ED2 approach, which relied on a combination of historical and forecast data for networks – but did not have to consider any cross-jurisdictional issues.

2.1.4. Sample period and balanced panel

Our econometric models exclude 2011 from the dataset, to ensure a balanced panel with 10 years of historical observations for both NIE Networks and the GB DNOs. This results in 140 historical observations from comparators being utilised in our benchmarking analysis, out of a total of 154. Because including additional observations in the dataset may increase the explanatory power of the model, we have tested the sensitivity of including 2011 values.

2.2. Pre-modelling adjustments

NIE Networks and GB DNOs have differences in costs incurred that are outside of the control of the companies. These costs include differences in regional wage pressures (e.g., LPN is operating is a high wage area while NIE Networks is operating in a low wage area), scope of activities undertaken and the types of costs incurred. For instance, NIE Networks undertakes metering activities, while in GB metering activities are not within the scope of distribution companies.

In the subsections below, we discuss each of the following topics in turn:

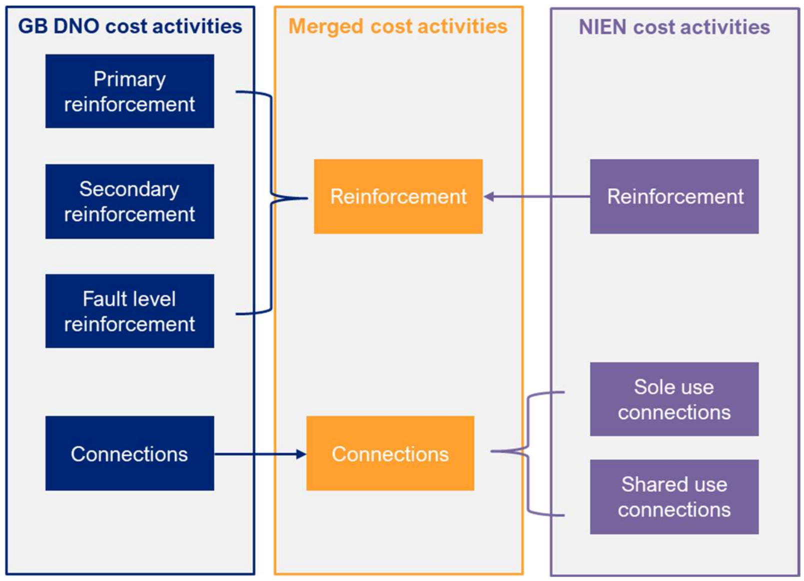
- **Differences in scope:** we allocate costs and volumes from NIE Networks' transmission business for 110kV assets to the distribution side of the business based on an allocation given by NIE Networks.
- **Cost exclusions:** we have followed Ofgem's RIIO-ED2 approach to cost exclusions.
- **Re-allocation of non-op capex:** we have reallocated non-op capex vehicle and property costs to CAI and BSC, respectively.
- **Other regional factors**: we have used Ofgem's RIIO-ED2 regional factors for our analysis in RP7. We have made no equivalent adjustments for NIE Networks, matching our approach in RP6.
- **Wayleaves:** we have excluded wayleaves costs from both NIE networks' and GB DNOs costs.
- **Connection costs:** we relied on both pre-allocation and post-allocation models.

- **Regional labour adjustments:** we have applied regional labour adjustments to 100% of labour costs for GB DNOs and NIE Networks, assuming that companies incur all their labour locally.

2.2.1. Data mapping

To ensure a comparable dataset across all companies we identified cost categories in GB DNOs that are comparable to NIE Networks' cost base, and therefore suitable for benchmarking. Figure 2.3 shows an example of our data mapping and merging exercise. After identifying comparable cost categories, we have applied pre-modelling adjustments to ensure NIE networks' efficiency analysis is undertaken on a comparable basis.

Figure 2.3: Overview of CEPA's approach to mapping cost activities



2.2.2. Differences in scope

The two main differences in scope relate to the voltage level of assets that NIE networks and GB DNOs are responsible for, and to metering activities.

For NIE Networks, 110kV and 275kV assets are held in the transmission business. GB DNOs operate up to 132kV, apart from the Scottish DNOs which only operate up to 66kV. To account for these differences, we allocate costs and volumes from NIE Networks' transmission business for 110kV assets to the distribution side of the business based on an allocation given by NIE Networks.

NIE Networks incurs costs associated with metering, whereas GB DNOs do not undertake metering activities. To account for this difference, we excluded metering costs from NIE Networks' dataset, and indirect costs associated with metering.

2.2.3. Cost exclusions

To create a comparable dataset across companies, we excluded costs that:

- are incurred by a single, or small number of DNOs;
- were not adequately explained by Ofgem's ED2 models; and
- are not comparable across DNOs.

This includes for example 'atypical' one-off costs that are unrepresentative of business-as-usual activity, as these costs are not comparable across DNOs.

We have followed Ofgem's ED2 approach (as shown in Table 2.2) for cost exclusions on the GB side and applied these exclusions to NIE Networks where relevant. We also excluded ETR tree cutting costs from the dataset. Some GB DNOs do not incur these costs and NIE Networks incurred very minimal costs attributable to ETR 132 tree cutting. Hence, we considered that these costs are not comparable for benchmarking purposes.

As we did not receive a Transmission Cost and Volume reporting workbook split into LV (110kV) and HV (275kV) transmission costs, we had to make the following assumptions:

- We have not excluded any transmission costs related to ETR 132 and BT21CN costs. Distribution costs in these categories are close to zero, so this assumption is unlikely to have a material impact on efficiency.
- For severe weather, we estimated average LV transmission costs from 2013-2016 using data submitted as part of the RP6 business plan. We assume that these costs are carried forward into RP7.

Table 2.2: Approach to cost exclusion

Cost area	Rationale	Approach for NIEN
RIIO-ED2 exclusions		
Transmission Connection Point (TCP) Charges	Pass through cost	No costs reported
Quality of Service (QoS)	Not adequately explained by driver	No costs reported
Physical Security	Not adequately explained by driver	No costs reported
Rising and Lateral Mains (RLM)	Not adequately explained by driver	No costs reported
BT 21st Century (BT21CN)	Most DNOs have finished this programme of work and there are no costs forecast for RIIO-ED2.	Costs removed from Operational IT&T
Worst Served Customers	Not adequately explained by driver	No costs reported
Streetworks	Not adequately explained by driver	No costs reported
Green Recovery	Separately assessed	No costs reported
Cyber Security	Significant change in the equivalent level of costs between the RIIO-ED1 and RIIO-ED2 periods.	No costs reported
Severe Weather 1 in 20	Outside of DNO control	Costs removed from faults
Other exclusions		
ETR 132 tree cutting costs[2]	Not all GB DNOs incur these, and NIE Networks incur minimal costs.	Costs removed from Tree Cutting

2.2.4. Re-allocations of non-op capex

Non-op capex includes costs for purchasing vehicles and office property. However, companies can make decisions to lease or buy vehicles, and to rent or buy office spaces. These decisions have implications for the opex and capex allocations. While NIE Networks leases all its vehicles, approaches across GB DNOs differ, with a mixture of leasing and buying. This difference in approach affects relative opex and capex allocations across comparators, so it is

[2] ETR 132 tree cutting is Tree cutting activity carried out to establish compliance with Engineering Technical Recommendation (ETR 132) where such resilience cutting has not been undertaken previously.

important that vehicle and transport expenditure is compared on a like-for-like basis. We adopted a similar approach to Ofgem at RIIO-ED1 and RIIO-ED2 and include DNO non-op capex spending related to vehicles in Closely Associated Indirects (CAI). GB DNOs report Vehicles & Transport non-op capex as a separate cost activity, so this expenditure is grouped with CAI. NIEN do not report Vehicles & Transport non-op capex. We propose to take a similar approach to RP6, and perform a cost reallocation in line with the approach described in the box below.

Similarly, to Vehicles & Transport, there is a differing approach to purchasing and renting office spaces in GB and for NIE Networks. Because of this, we reallocated Property Management non-operational capex to Business Support Costs (BSC). For GB DNOs, this is done using Property Management non-operational capex, which is grouped with BSC in our Data Mapping exercise. As NIE Networks do not report Property Management non-operational capex, we take a similar approach to RP6, and perform a cost reallocation in line with the approach described in the box below.

Approach to reallocation of non-op capex

NIEN provided the UR with a breakdown of non-op capex into Vehicles & Transport, Property Management, IT & Telecoms and Small Tools & Equipment for 2013-2016, and 2018-2023. For these years, we reallocated Vehicles & Transport and Property Management costs away from non-op capex towards CAI and BSC costs respectively, as for GB DNOs.

For 2017, we were provided with total non-op capex. We estimated the percentage of non-op capex related to Vehicle & Transport and Property Management by averaging the percentage of these costs in 2016 and 2018, and reallocated this percentage away from non-op capex to the relevant category.

Cost exclusions that affect non-op capex are likely relevant to the Vehicles & Transport and Property Management costs that we reallocated to CAI and BSC. In the absence of sufficiently disaggregated information, we assumed that the exclusions affecting non-op capex are proportionately applied to these reallocated costs also, in line with the percentages outlined above. For example, indirect costs associated with connections are reallocated from non-op capex to connection costs. We reapply this reallocation proportionately to CAI and BSC due to the reallocation of non-op capex to CAI and BSC.

2.2.5. Company specific factors

To ensure that cost benchmarking is carried out on a comparable basis, Ofgem excluded costs where companies have provided sufficient evidence that they incur higher efficient costs due to the inherent nature of their network(s). The following special factors were used by Ofgem to exclude costs in RIIO-ED2:[3]

- LPN: (i) nature of streets (i.e., additional costs incurred due to complexity of excavation and reinstating services in and around London which is deemed unique to their network) and (ii) network-specific factors, such as confined space and tunnel costs and congestion charges.
- SSEH: additional costs that arise from serving islands, including more use of helicopters, submarine cables and remote generation.
- SPMW: the interconnected, or meshed, configuration of SPEN’s Manweb network resulted in additional operation, maintenance and modernisation costs
- SPN: network-specific factors, such as confined space and tunnel costs and congestion charges.

We have used these same regional factors for our analysis in RP7. We have made no equivalent adjustments for NIE Networks, matching our approach in RP6.

[3] Ofgem (2022), RIIO-ED2 Final Determinations Core Methodology Document, p.225.

2.2.6. Wayleaves

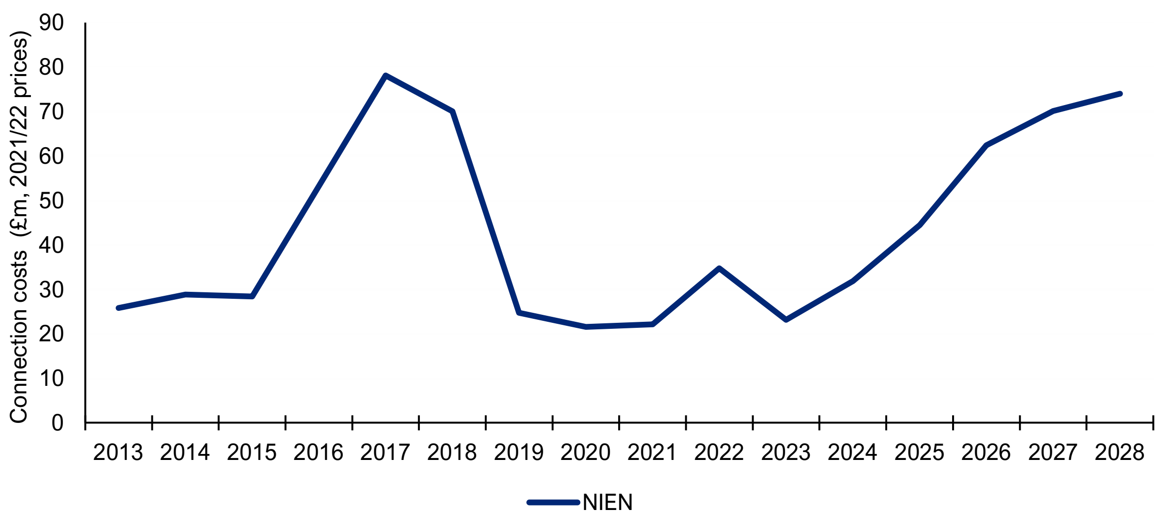
Wayleave payments are associated with the cost of rent payments to landowners to cover the financial impact of having equipment on the landowners' land, or having to access so that the network company can reach its equipment.[4] NIE Networks and their advisers argue that wayleaves costs are not comparable between GB and NIE Networks, and therefore should be excluded from the comparative benchmarking analysis. It argues that because of the higher share of overhead lines compared to other DNOs, NIE Networks incurs higher wayleaves costs.

The CC in RP5 included wayleaves in IMFT & Indirect analysis as they considered them comparable. We consider that wayleave payments can be captured within the models by including percentage of overhead line length (OHL) for each company. Additionally, wayleaves are partially captured by network length, as companies with a large network length are usually associated with a high percentage of OHL. Therefore, no pre-modelling adjustment is made for wayleaves.

2.2.7. Connection costs

Every year a proportion of IMFT&I costs are allocated to connections for NIE Networks and the GB DNOs. Connection costs are treated outside of the price control as connection costs are funded through customer connection charges. However, NIE Networks historically has been allocating a relatively high proportion of indirect costs to connections. Figure 2.4 shows that NIE Networks' connection costs are very variable over time. In contrast, the average connection cost for GB DNOs is much more stable over time. We have not seen any clear rationale for the variation in the connection costs for NIE Networks over time.

Figure 2.4: NIE Networks' connection costs



Source: CEPA analysis

The benchmarking can be run using pre-allocation approach or a post-allocation approach (i.e., before and after re-allocation of connections-related indirects). Table 2.3 summarises the advantages and disadvantages of the two approaches.

[4] Ofgem(2022), RIIO-ED2 Business Plan Data Template – Glossary, p.231

Table 2.3: Advantages and disadvantages of pre- and post-allocation models

	Pre-allocation models	*Post-allocation models*
Advantages	Does not allocate costs between activities which reduces the risk of distortions in the modelling. Does not create any perverse incentive to inefficiently allocate indirect costs to connections.	Focuses the analysis on regulated costs.
Disadvantages	Requires post-modelling adjustment, increasing the number of regulatory decisions.	Requires allocation of costs between connections and other activities, which could introduce distortions in the modelling. Requires policing of the costs allocated between activities.

Source: CEPA analysis

NIE Networks and its advisers argued that the benchmarking analysis should be conducted excluding all connection costs, i.e., on post-allocation basis only. They argue that connection activities in Northern Ireland historically have not been contestable, while the market for new connections in GB was contestable in some areas. They argue that the data on the indirect connection costs come from the same source (i.e., NIE Networks' RIGs) as the data for any other cost exclusion, and therefore it is unclear why there is greater uncertainty around connection costs compared to any other exclusion.

In RP6, UR triangulated between pre- and post-allocation modelling (50% weight on both approaches). Given the advantages and disadvantages of the two approaches, we consider that the RP6 approach (i.e., applying 50% weight on both options) remains appropriate. We therefore provide results to the UR for both pre-allocation and post-allocation models.

2.2.8. Regional labour adjustment

The GB DNOs and NIE Networks may experience differences in their operating costs due to regional differences in the operating environment of the company that are outside their control. Adjustments for regional wage differentials are used by regulators (e.g., Ofgem in RIIO-ED2) to increase the comparability of data. The rationale for this adjustment is that wages vary across regions, and thus the cost of labour for companies that employ workers locally will also vary.

Aligned with the RP6 and Ofgem's RIIO-ED2 approach, we have made a regional wage adjustment (RWA) to GB DNOs' and NIE Networks' labour costs to account for these regional differences. We have used Annual Survey of Hours and Earnings (ASHE) data published by the Office of National Statistics (ONS) which reports wage estimates for different regions and different job types. Table 2.4 shows the regional wage indices we have applied to each companies' labour share. Appendix A discusses the method for calculating regional wage adjustments in more detail.

Table 2.4: DNOs and NIE Networks' Regional Wage index

Company	Wage index
ENWL	0.96
NPGN	0.93
NPGY	0.94
WMID	0.95
EMID	0.95
SWales	0.94
SWest	0.94
LPN	1.19
SPN	1.06
EPN	1.03
SPD	1.00
SPMW	0.95
SSEH	1.00
SSES	1.03
NIEN	0.89

Source: CEPA analysis

This section discusses the main differences between NIE Networks' and CEPA's proposed approach, which are::

- **Method of averaging:** for calculating the indices, there are two steps involved that can be applied in a different order. You can first average regional wages across cost categories using occupational weights[5], and then divide the regional average wage by the UK average wage to obtain regional labour cost indices (or vice versa).
- **Proportion of locally incurred labour costs:** this decision is based on the premise that some costs can be located outside of NIEN/GB DNO's operational area, e.g., call centres. To account for this, in RIIO-ED2 Ofgem only normalises locally incurred costs by using a fixed percentage split between costs incurred inside and outside of a GB DNO's operational area.

Method of averaging

To calculate the regional wage index that represents relative differences between DNOs, there is a choice to make in which order to apply the occupational weights (i.e., combining the relevant wage estimates from different occupations using RIIO-ED2 occupational weights), and to compare the regional ASHE data with the UK average. We have tested two different methods for calculating RWAs:

- Approach 1 calculates the ratio of wage estimates between the region in question and the UK first, before applying the occupational weights (as per Ofgem's assumptions at RIIO-ED2).
- Approach 2 applies the occupational weights first, before calculating the ratio of wage estimates between the region in question and the UK.

Approach 2 was used for the RP6 RWA calculation and for RIIO-ED2.[6] Weighting the relevant ASHE occupations together using occupational weights before taking the ratio between the region and the UK (i.e., Approach 2) essentially calculates the average hourly wage for a DNO-type company in each region (in each year) and then compares it to the rest of the UK. We consider it remains appropriate to use the same approach for RP7.

[5] The RWA should reflect the types of work undertaken by electricity network companies. Occupational weights are calculated using DNO's full time equivalents (FTEs) job categories relative to its total FTEs to obtain the industry average occupational weight, which reflects occupations that are relevant for a typical network company.

[6] CEPA (2017), Regional Wage Adjustments, p.15

Proportion of locally incurred labour

Some costs do not necessarily have to be sourced within the region the DNO operates. At RIIO-ED1 and RIIO-ED2 Ofgem only applies the regional labour adjustment to the percentage of labour costs that it assumes needs to be done locally (e.g., repairs and maintenance activities). Ofgem assumed that these shares are 0% for business support costs, 40% for CAI and non-op capex, and 88% for all other areas. At RP6, the UR placed a 75% weight on models that do not adjust for the proportion of labour that needs to be co-located with the network (i.e., adjust all costs for regional wage differences) and 25% weight on models that used the RIIO-ED1 local labour assumptions.

In a report provided as part of its RP7 submission, NIE Networks' advisers claim that an assumption that all labour must be sourced locally for all networks would bias the efficiency assessment in favour of companies operating in high-cost areas at the expense of those operating in low-cost areas, such as Northern Ireland. Therefore, NIE Networks and their advisers have relied on Ofgem's local labour assumptions for the efficiency modelling.

For the RP7 efficiency modelling, we considered three approaches to the application of locally incurred labour:

- 1) Apply no local labour adjustment to NIE Networks' and GB labour costs (assuming 100% of labour is sourced locally).
- 2) Apply Ofgem's RIIO-ED1 and RIIO-ED2 local labour adjustment to all cost categories for GB companies only (i.e., assuming GB companies source a portion of their labour outside of their region). Apply no local labour adjustment to NIE Networks' labour costs (assuming 100% of labour is sourced locally).
- 3) Apply Ofgem's RIIO-ED1 and RIIO-ED2 local labour adjustment to all cost categories (i.e., assuming all companies source a portion of their labour outside of their region).

Overall, we consider that it is difficult to pinpoint the total proportion of labour that can realistically be procured outside of the operating area by DNOs. The extent to which companies are incentivised to procure labour outside of its region is likely to be asymmetric. For instance, DNOs operating in the London area experience relatively high wages, so have larger incentives to source labour outside of their operating area. NIE Networks operates in the lowest wage area across Northern Ireland and GB (see Table 2.4). Therefore, NIE Networks has limited incentives to source their labour outside of its own region. We therefore consider it inappropriate to apply Ofgem's local labour adjustment to NIE Networks' labour costs (i.e., Option 3). While we recognise that a company in a high wage area has higher incentives to source outside the area it is operating in (e.g., LPN operating in London), this incentive is asymmetric across companies. Therefore, it is difficult to pinpoint the asymmetric effect of incentives to source outside of the operating area.

Additionally, we aimed to replicate the work Ofgem undertook to develop its data adjustments at RIIO-ED1 and RIIO-ED2. However, we were unable to find the exact source of Ofgem's assumptions with regards to its local labour adjustment. As a result, we were unable to duplicate Ofgem's analysis that would have supported us when assessing the suitability of the adjustment for Northern Ireland. Therefore, we have not applied a local labour adjustment to NIE Networks' and GB labour costs, assuming 100% of labour is sourced locally (i.e., Option 1). We report the results of a sensitivity using Option 2 for the local labour adjustment.

3. BENCHMARKING METHODOLOGY

In this section we present our approach to developing and assessing econometric models This builds on the methods CEPA established for RP6 and the models that the UR used for the RP6 final determination.

The main elements are:

- Identifying the model selection criteria used to assess models.
- Determining which statistical tests are appropriate for assessing the robustness of the models.
- Setting out the level of cost aggregation (i.e., the dependent variables).
- Setting out the appropriate cost drivers/explanatory variables to be included in the models.

3.1. CEPA's RP7 selection criteria

Our aim is to develop a robust set of models to assess NIE Networks' historical performance. We started by rerunning the RP6 final determination models, using updated data. As part of the process, we sought to improve these models by testing various options for cost aggregations, relevant drivers and the functional form.

Figure 3.1 lists the assessment criteria we used to guide the model development and assessment process by testing the logic, reliability, transparency and robustness of different model specifications. These are in line with the model selection criteria CEPA previously used when advising Ofwat at PR24 and Ofgem at RIIO-GD2 and RIIO-ED2.

Figure 3.1: Model assessment criteria

Table 3.1

Economic/technical rationale	• Do the model specifications and results have a clear economic/technical rationale? • Are the selected explanatory variables consistent with an engineering view? • Are the stated coefficients consistent with a priori expectations of magnitude and signs of estimated coefficients?
Robustness	• How does the model perform against the statistical tests (see Table 3.1 below)? • Is the model sensitive to the underlying assumptions? We test this through sensitivity analysis such as removing one year of data or removing outlier companies (e.g., LPN and NIE Networks).
Transparency	• Is the data used and results transparent and easy to interpret? • Is the model understandable and intuitive? This should consider an appropriate balance between simplicity and complexity if complexity brings a significant improvement in the performance of the model.
Data requirements	• Is the data used in the model available to all stakeholders? • How reliable is the available data used in the model?
Consistency with regulatory objectives and policy	• Is the model consistent with and does it create incentives that align with regulatory objectives? • Does the model create perverse incentives or distort companies' behaviour? • Does the model rely on exogenous cost drivers that are outside of company control?

3.1.1. Statistical and robustness tests

A clear set of evaluation criteria helps to objectively demonstrate whether model results are suitably robust and valid for the purposes of informing or setting cost baselines as part of the price review. To assess model robustness, we use a range of statistical tests drawing from CEPA's previous work for Ofwat at PR24 and Ofgem at RIIO-GD2 and RIIO-ED2. Ideally, the final models selected would pass all model evaluation criteria and tests that they are submitted to. However, setting such a high standard would make it very difficult to develop models at all. We therefore categorise the importance of the statistical and robustness tests as follows:

- **High:** Tests and criteria that when failed would raise serious concerns about using a model.
- **Medium:** Tests and criteria that, when failed, would raise some concerns about using the model but the model could be used with caution if it passes other tests.
- **Low:** Tests and criteria that, when failed, would raise relatively limited concerns about using the model.

Table 3.1: Statistical tests

Importance	Test	Rationale
High	Goodness of fit (adjusted R^2)	If a model fails to explain a substantial share of the variation in costs of the industry, it would be inappropriate to use it for the estimation of the costs going forward
	Statistical significance of individual parameters (t-test)	If one or more of the coefficients in the model fails this test, we cannot rule out that the relationship being identified between the cost driver and costs under consideration is spurious (i.e. the coefficient could be zero). Parameters could fail this test because there is no relationship between the cost driver and the costs but also due to limitations in the data or multicollinearity.[7]
Medium	RESET test	This tests whether there are non-linearities in the data that have not been captured adequately by the estimated model. Failing this test may indicate that the data could be better fitted using a different shape (e.g. quadratic). However, this is not to say that a linear assumption is automatically wrong but that other options should be explored. If alternative specifications using non-linear terms in the model do not yield satisfactory results, then the failure of the RESET test on its own may not be a valid justification to dismiss a model. This is particularly the case if the model offers useful information from an economic or engineering perspective.
	Chow test	To use a panel data estimation method, we need to assume that the coefficients being estimated are stable over time. If this assumption fails, panel data analysis may not be appropriate. This can be tested with the Chow test. The Chow test tests for a breaking point, breaking the sample into two (or more) groups (e.g., pre RP6). We have tested for the presence of a structural break at the start of the RP6 price control, by including an RP6-dummy and interacting this with each driver. We then conduct a joint significance test for the dummy interactions with all independent variables.[8] If the test fails, potential remedies include truncating the dataset or including pre-RP6 dummy/interaction terms in the model.
Low	Heteroskedasticity	If a model fails the heteroskedasticity test, it means that the variance of the errors is not equal for all observations. It typically occurs when the variation in the residuals is very different over time. We assign low level of importance to this test, as we use clustered robust standard errors to control for potential heteroskedasticity. Therefore, the model can still be used if it fails the test, as failure does not affect the robustness of the model.
	Normality	The test for normality is used to assess whether the residuals are normally distributed. Failure of this test affects statistical inference. However, this does not introduce a bias in the estimated coefficients. We therefore apply a low level of importance to this test.
	Breusch-Pagan LM test	Test of pooled OLS versus RE. If the models fail this test, the effects are like the ones discussed above for heteroskedasticity i.e., the results are still robust, but they do not achieve all the positive properties that are normally associated with an OLS estimate. Failure of the test would provide an indication that random effects is preferred over Pooled OLS estimation.

3.2. Estimation technique

We have used pooled ordinary least squares (POLS) for all regressions. POLS is commonly used by regulators for econometric benchmarking, and was used by UR in RP6 and NIE Networks and its advisers in RP7. We use cluster robust standard errors when estimating the standard error of coefficients. This helps control systematic differences in the variance of the error term between companies and is useful in a POLS context that otherwise does not take account of the fact that the sample is made from multiple cross-sections.

We have tested Cobb Douglas and squared functional forms. Cobb Douglas (i.e., log-log regressions) allows the regression results to be interpreted as elasticities, and squared terms allows for cost elasticities to vary across companies.

3.3. Level of cost aggregation

For the RP6 price control, the UR used different levels of aggregation, including four middle-up models (three IMFT&I models and one NOCs model), and two bottom-up models (BSC and CAI). For the RP7 price control, we have explored the same middle-up and bottom-up levels of aggregation. Additionally, we have also explored a tree-cutting model, which is also used by Ofgem in the RIIO-ED2 price control.

CEPA considered the use of totex models not to be appropriate for efficiency modelling for the RP6 price control, due to the limited capital expenditure (capex) timeseries.[9] As we have a longer historical capex timeseries available for the RP7 price control, we also explore the use of totex models for efficiency assessment alongside UR's RP6 middle-up (i.e., IMFT&I and NOCs) and disaggregated models (i.e., BSC and CAI).

Table 3.2 summarises advantages and disadvantages of a totex modelling approach, both generally and in the specific RP7 context.

Table 3.2 Advantages and disadvantages of totex modelling

Advantages	Disadvantages
General	
• Avoids cherry picking. • Allows operators to trade-off different areas of expenditure to find the most efficient mix, i.e. higher incentive for cost reduction. • Intends to equalize incentives to spend capex and opex (i.e. addresses capex bias)	• Requires having a high level of confidence that models used and data set used is robust. • Risk of drawing incorrect conclusions on efficiency when comparing firms with very different investment requirements, e.g., separate net zero targets causing different pace of investment

Source: CEPA

[7] Multicollinearity is a statistical concept where several independent variables in a model are correlated. Multicollinearity among independent variables will result in less reliable statistical inference.

[8] Wooldridge (2009), Introductory Econometrics, 5h edition, p.453.

[9] CEPA (2017), RP6 EFFICIENCY ADVICE, p.10.

We explore totex models that are closely aligned with Ofgem's RIIO-ED2 approach[10], which used the following totex modelling approaches alongside disaggregated modelling[11]:

- Model 1 (2016-2028) – a bottom-up model that regresses totex on a bottom-up CSV, which aggregates all cost drivers used in Ofgem's activity-level analysis into a single composite driver (i.e., consisting of MEAV; customer numbers; faults driver; peak demand; capacity released; length OHL; total network length; and spans affected ONI driver). The model includes an ED2 time dummy to control for the step up in expenditure expected in the next price control period
- Model 2 (2016-2028) regresses totex on the top-down CSV, the ED2 time dummy, and capacity released, which aims to capture the impact of LCT uptake on the network. The top-down CSV reflects high level drivers of DNOs totex (i.e., MEAV, network length, customer numbers and peak demand).
- Model 3 (2022-2028) regresses totex on the top-down CSV (as in Model 2) and a Composite Low Carbon Technology (LCT) variable which captures the cumulative number of heat pumps (HPs) and cumulative number of (EVs).

The cost categories included in each level of aggregation are described in more detail in Appendix C.

3.4. Cost drivers for model development

Table 3.3 below outlines the various drivers we considered for the RP7 model specifications.

[10] Ofgem (2022), RIIO-ED2 Final Determinations Core Methodology, p.238

[11] Ofgem used a range of benchmarking approaches, including econometric benchmarking, unit cost analysis and qualitative assessment to determine efficient allowances for each activity separately.

Table 3.3: List of drivers that we have considered for the RP7 model specifications

Driver	Rationale
Scale	
Middle up (MU) CSV	50% weight to network length, a 25% weight to customer numbers, and a 25% weight to units distribute.
Network length	Costs should be related to the length of network that they serve. Network length captures scale and sparsity but may not capture the complexity of the network.
Units distributed	The amount of electricity that is being distributed through the network on an annual basis captures scale and network penetration but may not capture the complexity of the network.
Peak demand	Networks are primarily designed to meet the level of peak demand rather than annual volume of units distributed.
MEAV	MEAV reflects the scale and composition of a network based on its replacement costs.
Customer numbers	Costs should be driven by the number of customers they serve. A network is operated, maintained and reinforced to meet its customer requirements. Customer numbers capture scale but may not fully reflect the complexity of the network.
Updated RIIO-ED1 bottom-up CSV	A composite scale variable (CSV), which aggregates cost drivers used in the activity-level analysis into a single composite driver (i.e., MEAV, units distributed, spans cut, total faults, length of overhead lines and customer numbers).
RIIO-ED2 top-down CSV	A composite scale variable (CSV), based on MEAV (49%), network length (24%), customer numbers (10%), faults (9%), and peak demand (8%). We followed Ofgem's RIIO-ED2 approach, where they assigned a cost driver to each high-level cost area. Weights for each cost area were calculated based on the industry average proportion of total expenditure (totex) used in the totex regressions.
Density/topography	
Customers per network length (network density)	Costs are expected to relate to the distribution of consumers within a DNO's network. A denser network may drive costs up as it requires a more complex interventions (e.g., London), while a sparse network may also drive costs up (e.g., as engineers may need to travel further for repair/maintenance). We considered linear and quadratic customers per network length. Including a quadratic density variable aims to capture the U-shaped relationship between costs and density (i.e., sparse areas may drive costs up due to engineers needing to travel further, and dense areas may drive costs up due to traffic congestions and costs associated with more complex networks).
Inverse density	In RP6, the UR used network length over customers numbers as a density driver (inverse of network density)
%OHL	The share of OHL captures impacts from sparsity, rurality and network design.
Customers per network area (area density)	Density could alternatively be measured by the density of customers within the service area, rather than in relation to the length of the company network. We considered linear and quadratic customers per network area.
Gini index	The Gini index captures the variance of the area-based density measure within a company. This driver reflects the fact that companies with a high density variance will be comprised of areas of high density and of low density (sparsity) combining the challenges described above.

Note: drivers highlighted in blue were employed by the UR in the RP6 final determination.

4. MIDDLE-UP REGRESSION RESULTS

This section discusses our regression results for the RP6 rerun, our exploration of possible modelling improvements, and our preferred set of models for the RP7 price control. We also discuss the results of the sensitivity analyses on our chosen models, in order to assess the robustness of our conclusions, and to understand the materiality of alternative approaches taken by NIE Networks on pre-modelling adjustments.

4.1. RP6 MODEL RERUN

UR used the following models to assess NIE Networks' efficiency in the RP6 final determination:[12]

- Model 1.1: IMFT&I as dependent variable, and network length, density and %OHL as independent variables;
- Model 1.2: IMFT&I as dependent variable, and middle up CSV (i.e., a 50% weight to network length, a 25% weight to customer numbers, and a 25% weight to units distributed), %OHL, and time dummies as independent variables;
- Model 1.3: IMFT&I per customer as dependent variable (i.e., a unit cost model), and inverse density (i.e., network length over customers numbers), %OHL and time dummies as independent variables;
- Model 1.4: NOCs as dependent variable, and network length, density (i.e., customers per network length) and %OHL as independent variables;
- Model 1.5: BSC as dependent variable, and middle up CSV and %OHL as independent variables; and
- Model 1.6: CAI as dependent variable, and middle up CSV as independent variables.

Table 4.1 and Table 4.2 show the results of the IMFT&I, NOCs, CAI and BSC RP6 rerun, using the updated data for RP7.

The coefficients can be interpreted as elasticities, for instance a 1% increase in network length results in a 0.821% increase in IMFT&I costs. Results in yellow are statistically significant at the 10% level; and results in red are statistically insignificant at the 10% level. The efficiency score is the percentage difference between modelled and actual costs over the RP6 period (2018-2022). The score above 1 indicates inefficiency (i.e., less efficient than the industry average), and a score below 1 indicates efficiency.

We also show the upper quartile (UQ, 75th percentile) efficiency score of the industry, and the difference between NIE Networks' efficiency score and the UQ (i.e., the catch up challenge). A catch-up challenge above 0% indicates that NIE Networks' efficiency score is less efficient than the UQ, and below 0% (i.e., negative) indicates that it is more efficient than the UQ. Ofgem for RIIO-GD2 and RIIO-ED2 have pushed network companies to achieve efficiency consistent with a higher level of efficiency, setting the benchmark at 85th percentile. The appropriate efficiency benchmark depends on the quality of the data, and the confidence in your modelling results. We considered this to be similar as the RP6 price control, and therefore concluded that the UQ benchmark, using RP6, remains appropriate for RP7.

[12] The UR's detailed RP6 approach can be found in Appendix B.

Table 4.1: Regression results for IMFT & indirects RP6 rerun

	IMFT & Indirects (inc connection			IMFT & Indirects (exc connection		
	Model 1.1	Model 1.2	Model 1.3	Model 1.1	Model 1.2	Model 1.3
Log of network length	0.821***			0.839***		
Log of middle-up CSV		0.874***			0.909***	
Log of network density	0.739***			0.904***		
Length of overhead lines as a % of network length	0.703**	0.185	0.734**	1.030***	0.242	1.052***
Log of inverse density			0.257			0.099
2013 dummy		0.009	0.012		0.009	0.011
2014 dummy		0.075**	0.076**		0.087**	0.090**
2015 dummy		0.054*	0.052*		0.055	0.055
2016 dummy		0.061*	0.056*		0.054	0.051
2017 dummy		0.065*	0.057*		0.053	0.048
2018 dummy		0.066*	0.057*		0.068	0.062
2019 dummy		0.068	0.055		0.069	0.059
2020 dummy		0.072	0.051		0.078	0.061
2021 dummy		0.066	0.037		0.075	0.051
2022 dummy		-0.232***	-0.182**		-0.341***	-0.250**
Constant	-6.742***	-5.098***	-8.767***	-7.751***	-5.635***	-9.556***
Model robustness tests						
Adjusted R2	0.874	0.859	0.777	0.843	0.808	0.730
RESET test	0.001	0.000	0.017	0.000	0.000	0.110
Normality of model residuals	0.047	0.097	0.009	0.068	0.001	0.001
Heteroskedasticity	0.025	0.118	0.000	0.003	0.025	0.000
Chow test	0.985	N/A	N/A	0.842	N/A	N/A
NIE Networks efficiency score	0.865	0.833	0.891	0.814	0.761	0.843
UQ	0.970	0.966	0.957	0.974	0.956	0.957
Catch-up challenge	-10%	-13%	-7%	-16%	-19%	-11%

** p < 0.1, ** p < 0.05, *** p < 0.01*

Middle-up CSV = a 50% weight to network length, a 25% weight to customer numbers, and a 25% weight to units distributed (or energy throughput).

Source: CEPA analysis

Table 4.2: Regression results for NOCs, CAI and BSC RP6 rerun[13]

	Including connection costs				Excluding connection costs	
	Model 1.4	Model 1.5	Model 1.6		Model 1.5	Model 1.6
Cost aggregation	NOCs	CAI	BSC		CAI	BSC
Log of network length	1.031***					
Log of middle-up CSV		0.810***	0.575***		0.838***	0.592***
Log of network density	1.389***					
Length of overhead lines as a % of network length	1.648***	0.242			0.328*	
Constant	-12.759***	-5.153***	-3.098***		-5.709***	-3.422**
Model robustness tests						
Adjusted R2	0.817	0.755	0.548		0.683	0.454
RESET test	0.000	0.376	0.194		0.095	0.349
Normality of model residuals	0.220	0.003	0.028		0.000	0.137
Heteroskedasticity	0.720	0.341	0.081		0.041	0.056
Chow test	0.000	0.000	0.000		0.000	0.000
NIE Networks efficiency score	0.875	0.879	0.824		0.783	0.695
UQ	0.889	0.951	0.905		1.011	0.897
Catch-up challenge	-1%	-7%	-8%		-23%	-20%

** $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$*

Source: CEPA analysis

Overall, we consider that the modelling results are similar to RP6, and perform broadly as expected:

- Across all models, the **scale driver** is statistically significant at a 1% significance level. All coefficients are positive, suggesting operating a longer network results in higher costs for the companies.
- The coefficient on **% OHL** is statistically significant at a 1% significance level in models 1.1, 1.3 and 1.4, and at a 10% significance level in model 1.5 (excluding connection costs). The coefficient is statistically insignificant in model 1.2 and model 1.5 (including connection costs).
- The **density** variables in model 1.1 and model 1.4 are statistically significant at a 1% significance level. Density reflects the distribution of consumers within a DNO's area which should affect costs incurred. The coefficient on density is positive, suggesting that companies operating in more dense area incur higher costs. The inverse density variable (network length over customer numbers) is statistically insignificant in the unit cost model (model 1.3).

[13] NOCs does not include connections costs and therefore we do not show model 1.4 including and excluding connection costs.

- Overall, the **time dummies** used in models 1.2, 1.3 and 1.4 do not perform well, in terms of statistical significance. The 2022 dummy is statistically significant and negative, in contrast to the coefficients on other years. This is because this time dummy reflects NIE Networks' data only, and therefore also reflects company specific effects for NIE Networks. Additionally, we believe there is insufficient technical rationale for including time dummies. In general, you would include time dummies if there are any observed effects over time that should not be allowed to affect efficiency scores. We are not aware of such effects.
- The **RESET test** fails in model 1.1, 1.2, 1.3 (including connection costs only) and 1.4, suggesting a functional form misinterpretation. We have conducted additional testing to explore potential alternative specifications (see Section 4.2).
- The **adjusted R2** in model 1.3 is lower than the other models. However, this is expected as model 1.3 uses a unit cost dependent variable and therefore does not have a scale driver as explanatory variable. Normally, scale variables explain a large share of variation in costs.

4.2. Approach and conclusions to modelling improvements

Overall, we have concluded that the RP6 model rerun perform broadly similar as UR's modelling results in the RP6 final determination. However, the RESET test fails in various models, and not all variables were statistically significant. Therefore, we have sought to improve UR's RP6 models, focusing on alternative drivers, including squared terms and different levels of aggregation. See Section 3.4 for more details on the cost drivers we have explored. We performed a targeted model improvement process based upon our findings in the RP6 re-runs, and from our experience in applying econometric analysis to RIIO-ED2. We have developed five questions which we assessed in order to develop a suitable modelling suite for RP7. To assess these questions, we considered the statistical and robustness tests outlined in Figure 3.1. Specifically, we considered the following questions:

- **Are alternative cost aggregations appropriate in RP7?** We tested models using different aggregations of costs, including: totex; IMFT&I; NOCs; CAI; BSC; and Tree Cutting costs. We present which cost items are included in which cost aggregation in Appendix C.

  Conclusion: we recommend models for IMFT&I and NOCs cost aggregations only. We have tested models for CAI, BSC and Tree Cutting but concluded that the model performance was not sufficiently robust to use this for the efficiency evaluation. In particular, our results showed that the R squared of the disaggregated models were significantly lower compared to UR's RP6 models. Additionally, we also tested totex models, which we discussed further in Section 5..

- **Which scale drivers are most suitable?** At RP6, UR used network length and the middle-up CSV as its primary cost drivers. We consider the performance of alternative scale drivers as listed in Table 3.3.

  Conclusion: we did not find substantial improvements from the use of alternative scale drivers compared to network length and the MU CSV, as used in RP6. Therefore, we recommend that the scale drivers used in the RP6 final determination remain appropriate.

- **Which density variable is most suitable?** At RP6, UR used network density (customers per network length) as its density driver. Due to the failing of the RESET test in the RP6 re-run, which suggests model misspecification, we consider the use of a quadratic density term. We also tested an alternative density driver, area density (customers per area), which was suggested by NIE Networks and its advisors.

  Conclusion: we use a network density term as this directly reflects the density on the network. The quadratic form generally improves model fit, but we had concerns regarding the shape of the quadratic relationship and therefore have not used this in our final models.

- **Is the use of the % OHL driver appropriate in RP7?** In the RP6 re-runs, the % OHL driver has a mixed statistical performance. We test models including and excluding this driver to assess whether it continues to be appropriate for use in RP7.

Conclusion: the removal of OHL% improved the statistical robustness, as the model now passes the RESET test. However, the %OHL driver is statistically significant and has a clear rationale to be included, as this driver directly reflects topological differences (i.e., urban vs rural areas), including variations in wayleaves costs. To acknowledge the benefits of including this driver, and the problems with the statistical robustness (i.e., the failure of the reset test), we have decided to recommend models including and excluding this variable.

- **Is the use of the time dummies appropriate in RP7?** In the extended dataset, the use of time dummies for years 2013-2022 may risk overfitting. In addition, they perform poorly in our RP6 re-runs. We test models including and excluding the time dummies, and consider a linear time trend variable, to assess the appropriateness of controlling for time in RP7.

  Conclusion: the linear time trend is not statistically significant in any of the regressions. Therefore, we consider there is not sufficient proof to include a time trend in the models. Additionally, we recommend not using any time dummies in the RP7 models. We believe there is insufficient technical rationale for including time dummies. In general, you would include time dummies if there are any observed effects over time that should not affect efficiency scores (e.g., COVID effects). We are not aware of such effects.

As a result of the conclusions from these five questions, we have made some changes to the RP6 final determination models which are summarised in Figure 4.1.

Figure 4.1: RP6 final determination models (left), and CEPA's RP7 recommended models (right)

Model 1.1	Model 1.2	Model 1.3	Model 1.4	Model 1.5	Model 1.6
Cost					
IMFT&I	IMFT&I	IMFT&I per customer	NOCs	CAI	BSC
Cost drivers					
Network length	MU CSV	OHL%	Network length	MU CSV	MU CSV
Network density	OHL%	Inverse network density	Network density	OHL%	
OHL%	Time dummies		OHL%		

Model 2.1	Model 2.2	Model 2.3	Model 2.4	Model 2.5	Model 2.6
Cost					
IMFT&I	IMFT&I	IMFT&I	NOCs	NOCs	NOCs
Cost drivers					
Network length	MU CSV	Network length	Network length	MU CSV	Network length
Network density	Network density	Network density	Network density	Network density	Network density
OHL%	OHL%		OHL%	OHL%	

We have made the following changes to the RP6 final determination models:

- Model 2.2 is created by adding network density to model 1.2, as we consider this an important driver of costs. Additionally, we removed the time dummies for model 1.2, as the coefficients on the year dummies were mostly statistically insignificant and there is no clear rationale to include the time dummies.
- We remove Model 1.3 as this model performed less well in terms of statistical robustness (e.g., the inverse density driver was statistically insignificant). We replace this model with Model 2.3, a version of Model 1.1 without OHL%, as this model now passes the RESET test.
- We drop the models for CAI and BSC as they perform much worse in RP7 in comparison to RP6, in particular the R squared is significantly lower compared to the RP6 final determination and the RP7 middle up models.
- We run the same models for NOCs as for IMFT&I, as we found similar conclusions for NOCs as in the IMFT&I models.

Table 4.3 shows the detailed results of our recommended models for the RP7 price control review. All drivers included in the models are statistically significant at the 5% significance level. The R squared is similar as UR's RP6 final determination models. Models 2.1, 2.2, 2.4 and 2.5 fail the RESET test, indicating a potential misspecification such as missing non-linear explanatory variables in the model. Therefore, we have tested quadratic drivers in the models (i.e., trans log), which did not seem to resolve the problem. We consider that, in the context of other statistical measures of model performance, the failure of the RESET test is not a reason in its own right to dismiss a model which performs well on other criteria (see Section 3.1).

Table 4.3: CEPA RP7 recommended models

	IMFT & Indirects (inc connection costs)			IMFT & Indirects (exc connection costs)			NOCs		
	Model 2.1	Model 2.2	Model 2.3	Model 2.1	Model 2.2	Model 2.3	Model 2.4	Model 2.5	Model 2.6
Log of network length	0.821***		0.810***	0.839***		0.823***	1.031***		1.006***
	{0.000}		{0.000}	{0.000}		{0.000}	{0.000}		{0.000}
Log of middle-up CSV		0.834***			0.851***			1.041***	
		{0.000}			{0.000}			{0.000}	
Log of customers per network length	0.739***	0.339**	0.437***	0.904***	0.495**	0.460***	1.389***	0.888***	0.679***
	{0.000}	{0.035}	{0.000}	{0.001}	{0.026}	{0.002}	{0.000}	{0.000}	{0.001}
Length of overhead lines as a % of network length	0.703**	0.768***		1.030***	1.096***		1.648***	1.728***	
	{0.013}	{0.010}		{0.006}	{0.005}		{0.003}	{0.003}	
Constant	-6.742***	-5.996***	-5.300***	-7.751***	-6.983***	-5.639***	-12.759***	-11.756***	-9.380***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Model robustness tests									
Adjusted R2	0.874	0.873	0.845	0.843	0.842	0.788	0.817	0.811	0.741
RESET test	0.001	0.000	0.287	0.000	0.000	0.256	0.000	0.000	0.110
Normality of model residuals	0.047	0.004	0.821	0.068	0.125	0.422	0.220	0.256	0.052
Heteroskedasticity	0.025	0.111	0.120	0.003	0.013	0.006	0.720	0.635	0.909
Chow test	0.995	0.493	0.976	0.872	0.362	0.962	0.549	0.801	0.572
NIE Networks efficiency score	0.865	0.881	0.820	0.814	0.830	0.754	0.875	0.896	0.773
UQ	0.970	0.998	0.942	0.974	0.992	0.949	0.889	0.906	0.889
Catch-up challenge	**-10%**	**-12%**	**-12%**	**-16%**	**-16%**	**-19%**	**-1%**	**-1%**	**-12%**

** p < 0.1, ** p < 0.05, *** p < 0.01*

Middle-up CSV = a 50% weight to network length, a 25% weight to customer numbers, and a 25% weight to units distributed (or energy throughput).

Source: CEPA analysis

4.3. Sensitivity analysis

We perform a range of sensitivity analyses on our chosen models, in order to assess the robustness of our conclusions, and to understand the materiality of alternative approaches taken by NIE Networks. We consider the impact of these sensitivities on the significance of regression estimates, the statistical and robustness tests outlined in Section 3.1.1, and the impact on NIE Networks' efficiency score and implied catch-up challenge. We present the detailed econometric results of all sensitivities in Appendix D.

In addition to the inclusion and exclusion of connection costs, which acts as a sensitivity that was included in our preferred set of core models, we perform the following sensitivities:

- **Regional labour sensitivity:** In our core models, we apply a regional labour adjustment to 100% of labour costs for all companies, assuming that companies incur all their labour costs locally.

  NIE Networks and its advisers argue that an assumption that all labour must be sourced locally for all networks would bias the efficiency assessment in favour of companies operating in high-cost areas at the expense of those operating in low-cost areas, such as Northern Ireland. Therefore, it applies the RWA only to labour costs that are assumed to be incurred locally, using Ofgem's locally incurred labour ratios. However, we consider it inappropriate to assume NIE Networks incurs any labour outside its operating area, as it is operating in the lowest wage area in the UK. Therefore, as a sensitivity, we test the use of ED2 locally incurred labour ratios to GB DNOs, whilst maintaining the application of regional labour adjustments to 100% of NIE Networks' labour costs. This differs from NIE Networks' approach, which also applies these ratios to NIE Networks' labour costs. We summarise the discussion on the approach to regional labour adjustments in Section 2.2.8.

- **Wayleaves sensitivity:** In our core models, we include wayleaves costs for all companies. Wayleave payments are associated with the cost of rent payments to landowners to cover the financial impact of having equipment on their land, or having to access this.

NIE Networks and its advisers argue that wayleaves costs are not comparable between GB and NIE Networks, due to the higher share of overhead lines compared to other DNOs. As a sensitivity, we test the exclusion of wayleaves costs. We summarise the discussion on wayleaves costs in Section 2.2.6.

- **Company exclusion sensitivity:** In our core models, we include all GB DNOs and NIE Networks in the sample in order to estimate the relationship between costs and cost drivers. However, NIE Networks and LPN are data outliers when considering density/sparsity, and so it is plausible that their inclusion in the data sample may disproportionately influence regression results. To test the robustness of our preferred models, we test the stability of the regression results and coefficient estimates when excluding outlier companies.

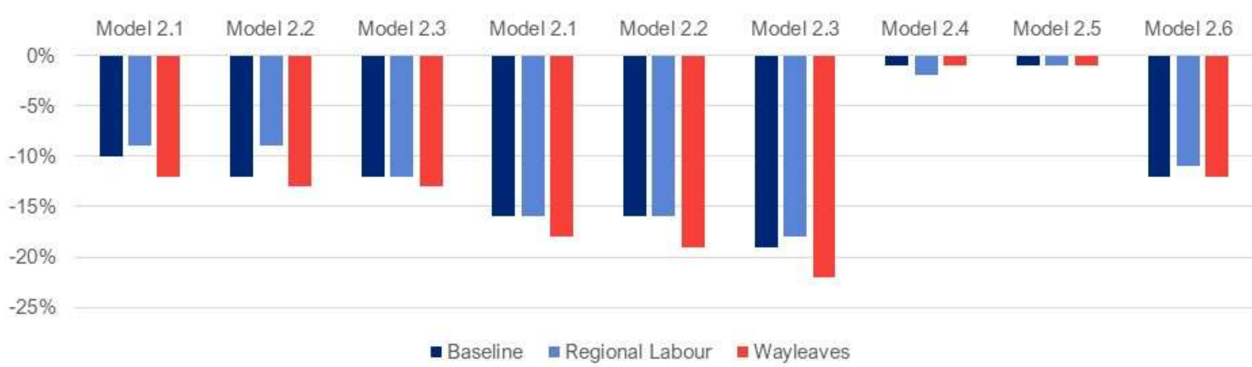
  We test the exclusion from the data sample of NIE Networks and LPN separately when running our econometric models.[14]

The aim of the regional labour and wayleaves sensitivities is to check the impact on NIE Networks' efficiency score, as these decisions were the main disagreements between CEPA's models and NIE Networks' and its advisor's submission. Figure 4.2 summarises NIE Networks' catch up challenge for each of the sensitivities compared to the baseline model.

- **Regional wage:** This sensitivity only has a minor impact on NIE Networks' efficiency score, resulting in an average catch up efficiency challenge of -13% for IMFT&I, and -5% for NOCs (instead of -14% and -5%, for IMFT&I and NOCs respectively).
- **Wayleaves:** This sensitivity has a slightly larger impact on NIE Networks' efficiency score compared to the regional labour sensitivity, resulting in an average catch up officially challenge of -16% for IMFT&I, and -5% for NOCs.

Overall, we consider that the modelling results show consistent efficiency outcomes, and assumptions on pre-modelling adjustments do not affect the conclusion on the direction of the catch-up challenge for NIEN compared to the UQ.

Figure 4.2: NIE Networks catch up efficiency challenge



Source: CEPA analysis

Additionally, we have also checked the robustness of the models by excluding outlier companies (i.e., NIE Networks and LPN) (see Appendix D). In assessing the robustness, we have considered changes to driver significance, point estimates of the coefficients and statistical tests. Overall, we consider that the parameter estimates stay statistically significant (with the exception of %OHL in model 2.5), and the coefficients are of a similar magnitude. The R square and other model diagnostics did not materially change, with the exception of the RESET test in model 1.3 when excluding NIE Networks from the sample - as this model now fails the RESET test. NIE Networks becomes

[14] Note that, for company exclusions, we are still able to estimate efficiency scores, as a function of the estimated relationships and company data.

materially more efficient when NIE Networks is excluded from the sample. This is as expected, as the data used to produce the econometric model excludes the first ranked company in the industry.

5. TOTEX RESULTS

In this section, we briefly discuss our considerations to the use of totex modelling for the RP7 price control, and show the regression results of the totex models that are closely aligned with Ofgem's bottom-up and top-down totex models used in RIIO-ED1 and RIIO-ED2.

As discussed in Section 3.3, we consider there are advantages and disadvantages in using totex models for RP7 efficiency modelling. We have explored Ofgem's RIIO-ED1/ED2 top-down and bottom-up totex model for RP7, with some minor adjustments:

- **Top-down:** for the top-down totex model we have used Ofgem's top-down CSV driver, that reflects high level drivers of DNOs' expenditure. The top-down driver includes MEAV (49%), network length (24%), customer numbers (10%), faults (9%) and peak demand (8%).
- **Bottom-up:** for the bottom-up totex model we have used a similar bottom-up CSV driver as Ofgem used in RIIO-ED1/ED2, which aggregates cost drivers used in Ofgem's activity-level analysis into a single composite driver. We have made some minor adjustments to account for the cost structure of NIE Networks. We also did not use capacity released, which Ofgem used in RIIO-ED2 in the bottom-up totex model to account for the step up in expenditure, as we did not include forecast data in the model.

Like the middle up and this aggregated models, we have run the totex models using historical data only from 2012 to 2022. We also use the same pre-modelling adjustments, as explained in Section 3.4. We show all results including and excluding connection costs.

Table 5.1 shows the regression results for the top-down and bottom-up totex models.

Table 5.1: Totex regression results

	Totex (inc connection costs)		Totex (exc connection costs)	
	Model 3.1	Model 3.2	Model 3.1	Model 3.2
Log of top-down CSV	0.768***		0.833***	
	{0.000}		{0.000}	
Log of bottom-up CSV		0.727***		0.795***
		{0.000}		{0.000}
Constant	-1.821*	1.541**	-2.579**	1.033*
	{0.059}	{0.027}	{0.021}	{0.062}
Model robustness tests				
Adjusted R2	0.717	0.689	0.689	0.690
RESET test	0.322	**0.000**	**0.028**	**0.009**
Normality of model residuals	**0.000**	0.797	**0.000**	0.186
Heteroskedasticity	**0.000**	**0.028**	**0.000**	0.332
Chow test	**0.003**	**0.017**	**0.041**	0.128
NIE Networks efficiency score	1.084	1.166	0.914	1.006
UQ	0.905	0.925	0.878	0.910
Catch-up challenge	**18%**	**24%**	**4%**	**10%**

** p < 0.1, ** p < 0.05, *** p < 0.01*
Source: CEPA analysis

Overall, we consider that the totex model results show mixed performance in terms of statistical robustness:

- Model 3.1 (excluding connection costs) and model 3.2 fail the RESET test, suggesting a functional form misspecification.

- Model 3.1 and model 3.2 (excluding connection costs) fail the Chow test, suggesting a structural break at the beginning of the RP6 price control. This suggests that the cost-driver relationship before the start of RP6 is significantly different from that of the more recent years.
- The R squared is lower compared to the RP6 middle up models. However, the drivers in these totex models still explain a reasonable variation of costs.
- The spread of efficiency scores for the bottom-up models is very wide.

Overall, due to the lack of robust models, we consider that it would not be appropriate to set a catch up efficiency challenge to NIE Network's totex based on these modelling results. However, this model can be used as a sense check against UR's bottom-up analysis for totex.

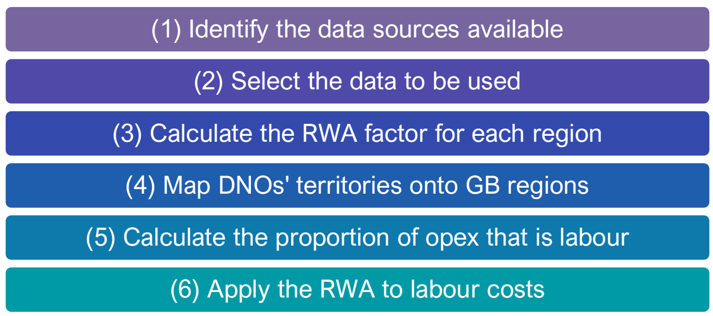
Appendix A REGIONAL LABOUR ADJUSTMENT CALCULATION

Regional wage adjustment calculation

Adjustments for regional wage differentials are used by regulators (e.g., Ofgem in RIIO-ED2) to increase the comparability of data. The rationale for this adjustment is that wages vary across regions, and thus the cost of labour for companies that employ workers locally will also vary. We have made a regional wage adjustment (RWA) to account for these regional differences in the cost of labour available to DNOs operating in different regions.

At a high level, the approach to developing a RWA has followed the process illustrated in the figure below.

Figure A.1: Calculating and applying the regional wage adjustment



Source: CEPA analysis

Data on average wages is available from the ONS ASHE survey for the UK. In developing a RWA, the main decisions are around the following areas:

- **Job categories:** Estimates of wages are available for different job types, which are grouped into categories using Standard Occupational Classification (SOC). Ideally the RWA should reflect the types of work undertaken by electricity network companies. The ASHE data is broken down into several SOC-code levels, with 1,2 3 or 4 digit codes. 1-digit SOC codes reflect broader job categories (e.g., managers, professional occupations) and 4 digit reflecting the most specific categories (electrical engineers, production managers and directors in manufacturing).
- **Measure of wages:** Estimates are available for both hourly and weekly average wages. There is regulatory precedent for using both, and each have their own benefits/ drawbacks. ASHE also publishes wage data with and without overtime.
- **All employees versus full-time employees only**: ASHE publishes data for all employees and full-time employees only. Full-time employee data could be more appropriate when weekly wages are used rather than hourly wages. Since part-time workers are likely to work fewer hours per week, their weekly wage is also likely to be lower, which could skew results.
- **Mean or median wage rates:** the AHSE data report both mean and median wages. Using median wages can be beneficial if there is evidence that the data is skewed by a particular job type. However, as there is no such evidence, we consider that the mean will be more representative for electricity companies.
- **Number of regions in GB, and mapping of DNOs:** The RWA aims to control for differences in wages across regions. Including Northern Ireland, ASHE data distinguishes regional labour into 12 different regions, which reflects the most granular regional approach. In RIIO-2, Ofgem argued that it may be the case that labour is relatively mobile across regions and so there would be no structural differences in the wage rate available to companies. The number of regions in UK used in the calculation should reflect the regions which have structural differences in wages.

- **Company share of labour:** The RWA should be applied only to the labour component of costs. This could be done based on the company's reported labour share, or based on a notional labour share (applied across all companies).

We briefly discuss each of these below, and propose sensitivities to deal with potential uncertainties/ trade-offs between alternative approaches. We then briefly set out the calculation and application of the RWA.

Job categories

ONS ASHE wage data are disaggregated at an industry level, reproduced in Table A.. We have followed Ofgem's RIIO-ED2 approach to SOC code weight, using a mix of job categories that are representative of an average DNO as shown in Table A.. For each SOC code, Ofgem calculated the DNO's FTEs relative to its total FTEs to obtain the industry average occupational weight.[15] The decision for the level of granularity depends on the trade-off between increased detail of the job category versus data accuracy. In more granular SOC-levels, the data is less reliable and higher occurrence of missing data. We consider that using the 2-digit SOC codes that were used for RP6 remains appropriate.

Table A.1: SOC categories

Job category	SOC Code
Corporate managers and directors	11
Other managers and proprietors	12
Science, research, engineering and technology professionals	21
Teaching and educational professionals	23
Business, media and public service professionals	24
Science, engineering and technology associate professionals	31
Culture, media and sports occupations	34
Business and public service associate professionals	35
Administrative occupations	41
Secretarial and related occupations	42
Skilled agricultural and related trades	51
Skilled metal, electrical and electronic trades	52
Skilled construction and building trades	53
Customer service occupations	72
Process, plant and machine operatives	81
Transport and mobile machine drivers and operatives	82
Elementary trades and related occupations	91
Elementary administration and service occupations	92

Measure of wages

The ONS databases report two different measures of mean wages: one based on hourly wages, and one based on weekly wages.

An issue with weekly wages is that the average number of hours worked per week may vary across the regions. In terms of regulatory precedent, Ofgem used hourly wages in its RWA calculations during RIIO-ED2.

We recommend consistency with Ofgem's latest approach using hourly wages, since weekly wages may capture other elements of company policies and potential differences in the number of hours worked across different regions.

There is also a choice between measures of wages that include or exclude overtime payments. While for some job categories, overtime may be an important part of the market price for labour, workers who are on salaries, rather

[15] https://www.ofgem.gov.uk/sites/default/files/2022-06/RIIO-ED2%20Draft%20Determinations%20Core%20Methodology.pdf p.329

than paid hourly, may not receive any compensation for overtime work. For an electricity company, there will be a mix of salaries (e.g., CEO) and hourly contracts (e.g., external contractors), so it is difficult to know exactly how important overtime is for a typical company. But the question is not how much overtime companies rely on but why the mix of overtime would differ across companies. There could be reasons for that, which are within company control (e.g., company policies on overtime pay will vary) but those drivers are not exogenous. It would be appropriate to take into account different overtime treatments between DNOs only if there is sufficient evidence that the company has no control over such drivers. We are not aware of any such drivers in GB or Northern Ireland and therefore use a wage measure that excludes overtime.

All employees versus full-time employees only

As we recommend using hourly wages, the wage will be independent of the number of hours worked per week. Further, since we would expect that DNOs employ part-time employees to some extent, it appears more appropriate to include this data in the analysis. In addition, excluding it could fail to consider potential difference in wages between full time and part time workers, which could influence our estimates and reduce the sample size. As a result, we propose to use all employee data.

Number of regions in GB

The ONS ASHE data is split into regions – 10 regions that encompass England & Wales, one region for Scotland and one for Northern Ireland. The choice regarding the number of regions in GB for the regional labour adjustment does not affect the adjustment factor for NIE Networks, since we propose to split Northern Ireland out as a separate region (since NIE Networks operates across all of Northern Ireland). However, it will impact the adjustment for GB DNOs and by consequence NIE Networks' relative efficiency.

Ofgem's approach in RIIO-ED2 was to use three regions, and assume that otherwise labour was sufficiently mobile to eliminate material differences in regional wages. However, for the purposes of this study we decided to follow regulatory precedent in Northern Ireland, using CEPA's RP6 approach; a twelve-region approach (eleven for GB, one for Northern Ireland). We combine this with a mapping of GB DNOs across those different regions based on an estimate of the services they provide in each region.

Company share of labour

The RWA should be applied to company labour costs, and we have identified two potential approaches to calculating this:

- using actual company labour costs; or
- using a notional labour weighting (i.e., applying the same fixed share across the DNOs based on an average of actual labour costs reported by the DNOs).

For RIIO- ED2, Ofgem applied industry notional labour shares to all DNOs for each cost activity. The notional approach abstracts from potential errors or biases in the information submitted by each individual company and helps guard against rewarding companies in the benchmarking analysis for simply having a different mix of labour/ capital. Using notional weights ensures potentially inefficient company are not rewarded. We use a notional labour weighting.

Calculation and application of the RWA

We have used 2011-2022 wage data from the ONS in calculating the RWA, since this corresponds to the period over which we have historic data from NIE Networks and GB DNOs. We calculate the RWA using the following five steps:

- **Step 1:** Select the appropriate job category (SOC codes) and wage measure (discussed above).
- **Step 2:** For each region, in each year, calculate an index of relative wages by dividing that region's wage estimate by the UK wage estimate.

- **Step 3:** Map DNOs to respective regions, and allocate the relevant regional wage indices to DNOs.
- **Step 4:** Average the annual RWA for each DNO across 2018-2022.

The baseline estimated RWA for each company is shown in the table below. The values indicate NIE Networks has the lowest regional labour rate among its comparators. Within GB it also shows that LPN and SPN have the highest labour rates (consistent with Ofgem's findings at RIIO-ED2).

Table A.2: RWA indices for each DNO

Company	Wage index
ENWL	0.96
NPGN	0.93
NPGY	0.94
WMID	0.95
EMID	0.95
SWales	0.94
SWest	0.94
LPN	1.19
SPN	1.06
EPN	1.03
SPD	1.00
SPMW	0.95
SSEH	1.00
SSES	1.03
NIEN	0.89

Source: CEPA analysis

Appendix B THE UR'S RP6 BENCHMARKING APPROACH

At RP6, UR used six models to assess NIE Networks' efficiency (see Figure B.1 below). UR used three models for assessing total IMFT & indirects, with a further three that assessed Network Operating Costs (NOCs), Business support costs, and CAI costs.

Figure B.1: The six regression models employed by the UR to assess NIE Networks' efficiency

Model 1.1	Model 1.2	Model 1.3	Model 1.4	Model 1.5	Model 1.6
Cost					
IMFT&I	IMFT&I	IMFT&I per customer	NOCs	CAI	BSC
Cost drivers					
Network length	MU CSV	OHL%	Network length	MU CSV	MU CSV
Network density	OHL%	Inverse network density	Network density	OHL%	
OHL%	Time dummies	Time dummies	OHL%		

The composite scale variable (CSV) employed in three of the models acted as a proxy for company size. The CSV placed a 50% weight placed on network length, 25% placed on customer numbers and 25% units distributed. The density variable was calculated by dividing the number of customers by network length. Model 1.2 and 1.3 also included time dummies, which allows for a different intercept in each year included in the sample.

CEPA also tested a number of capex models during the early stages of RP6. These models returned results consistent with poor model fit, and were not used in the UR's determinations as a result. Instead, UR reviewed capex allowances on a bottom-up basis.

UR applied Regional Labour Adjustments (RLA) to all costs to account for wage differentials across the UK.

NIE Networks proposed a number of special factor adjustments that acknowledged company-specific expenditure that it deemed un-comparable. These factors included:

- wayleaves costs;
- connection numbers;
- guaranteed standards of performance;
- ESQCR requirements; and
- local labour adjustments.

UR did not allow any of these special factor requirements in RP6, arguing that factors that contributed to upwards cost pressures on NIE Networks' costs would be offset by factors that had a favourable impact on NIE Networks' costs. However, UR did introduce the %OHL driver into its models to better account for NIE Networks' relative network sparsity in relation to its comparators.

UR did not conduct benchmarking analysis for NIE Networks' transmission business, and instead opted to apply the catch-up efficiency factor estimated in distribution network to transmission, with the rationale that NIE Networks operates as one business. This approach was also taken by the CC in its RP5 determination.

While the result of the benchmarking analysis suggested a catch-up efficiency challenge of 2%, UR concluded that it was appropriate to set a final allowances without a catch-up efficiency challenge, to provide headroom for NIE Networks to resolve challenges as they arise.

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Appendix C COST AGGREGATION

Cost Area	Cost Activity	Totex	IMFT & Indirects	CAI	BSC	NOCs
Load related costs	Connections	Sensitivity	False	False	False	False
	New Transmission Capacity Charges	True	False	False	False	False
	Reinforcement	True	False	False	False	False
Non-load capex (excluding Non-op capex)	Legal & Safety	True	False	False	False	False
	Asset Replacement	True	False	False	False	False
	Refurbishment	True	False	False	False	False
	Civil Works	True	False	False	False	False
	Operational IT & Telecoms	True	False	False	False	False
	Environmental Reporting	True	False	False	False	False
	Flooding	True	False	False	False	False
	Diversions	False	False	False	False	False
	Blackstart	True	False	False	False	False
	BT21CN	False	False	False	False	False
	QoS & North of Scotland Resilience	False	False	False	False	False
	Physical Security	False	False	False	False	False
	Rising and Lateral Mains	False	False	False	False	False
	Overhead Line Clearances	True	False	False	False	False
	Worst Served Customers	False	False	False	False	False
Network Operating Costs	Inspections & Maintenance	True	True	False	False	True
	Tree Cutting	True	True	False	False	True
	ONIs	True	True	False	False	True
	Faults	True	True	False	False	True
	NOCs other	False	False	False	False	False
	Severe Weather 1 in 20	False	False	False	False	False
	Smart Metering Roll Out	False	False	False	False	False
NABC	NABC	False	False	False	False	False
Non-GB DNO Costs	Meter Reading	False	False	False	False	False
	Metering Services	False	False	False	False	False
	Market Opening	False	False	False	False	False
Closely Associated Indirects	Core CAI	True	True	True	False	False
	Wayleaves	True	True	True	False	False
Business Support Costs	Core BS	True	True	False	True	False
Non Op Capex	IT and Telecoms (Non-Op)	False	False	False	False	False
	Property (Non-Op)	True	True	False	True	False
	Vehicles and Transport (Non-Op)	True	True	True	False	False
	Small Tools and Equipment	False	False	False	False	False
HVP	High Value Projects	False	False	False	False	False
Shetland	Shetland	False	False	False	False	False

Appendix D SENSITIVITY RESULTS

D.1. Core results

	IMFT & Indirects (inc connection costs)			IMFT & Indirects (exc connection costs)			NOCs		
	Model 2.1	Model 2.2	Model 2.3	Model 2.1	Model 2.2	Model 2.3	Model 2.4	Model 2.5	Model 2.6
Log of network length	0.821***		0.810***	0.839***		0.823***	1.031***		1.006***
	{0.000}		{0.000}	{0.000}		{0.000}	{0.000}		{0.000}
Log of middle-up CSV		0.834***			0.851***			1.041***	
		{0.000}			{0.000}			{0.000}	
Log of network density	0.739***	0.339**	0.437***	0.904***	0.495**	0.460***	1.389***	0.888***	0.679***
	{0.000}	{0.035}	{0.000}	{0.001}	{0.026}	{0.002}	{0.000}	{0.000}	{0.001}
Length of overhead lines as a % of network length	0.703**	0.768***		1.030***	1.096***		1.648***	1.728***	
	{0.013}	{0.010}		{0.006}	{0.005}		{0.003}	{0.003}	
Constant	-6.742***	-5.996***	-5.300***	-7.751***	-6.983***	-5.639***	-12.759***	-11.756***	-9.380***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Model robustness tests									
Adjusted R2	0.874	0.873	0.845	0.843	0.842	0.788	0.817	0.811	0.741
RESET test	0.001	0.000	0.287	0.000	0.000	0.256	0.000	0.000	0.110
Normality of model residuals	0.047	0.004	0.821	0.068	0.125	0.422	0.220	0.256	0.052
Heteroskedasticity	0.025	0.111	0.120	0.003	0.013	0.006	0.720	0.635	0.909
Chow test	0.995	0.493	0.976	0.872	0.362	0.962	0.549	0.801	0.572
NIE Networks efficiency score	0.865	0.881	0.820	0.814	0.830	0.754	0.875	0.896	0.773
UQ	0.970	0.998	0.942	0.974	0.992	0.949	0.889	0.906	0.889
Catch-up challenge	-10%	-12%	-12%	-16%	-16%	-19%	-1%	-1%	-12%

** p < 0.1, ** p < 0.05, *** p < 0.01*

D.2. Regional labour sensitivity: 100% labour ratio used for NIEN, ED2 labour ratios used for GB DNOs

	IMFT & Indirects (inc connection costs)			IMFT & Indirects (exc connection costs)			NOCs		
	Model 2.1	Model 2.2	Model 2.3	Model 2.1	Model 2.2	Model 2.3	Model 2.4	Model 2.5	Model 2.6
Log of network length	0.814***		0.807***	0.833***		0.820***	1.030***		1.006***
	{0.000}		{0.000}	{0.000}		{0.000}	{0.000}		{0.000}
Log of middle-up CSV		0.829***			0.847***			1.041***	
		{0.000}			{0.000}			{0.000}	
Log of network density	0.679***	0.281*	0.460***	0.846***	0.439**	0.483***	1.372***	0.871***	0.685***
	{0.000}	{0.081}	{0.000}	{0.001}	{0.045}	{0.001}	{0.000}	{0.001}	{0.001}
Length of overhead lines as a % of network length	0.508*	0.573**		0.844**	0.910**		1.595***	1.675***	
	{0.070}	{0.045}		{0.015}	{0.011}		{0.003}	{0.003}	
Constant	-6.391***	-5.666***	-5.349***	-7.419***	-6.670***	-5.689***	-12.669***	-11.671***	-9.398***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Model robustness tests									
Adjusted R2	0.882	0.884	0.867	0.857	0.858	0.820	0.821	0.816	0.750
RESET test	0.003	0.000	0.345	0.000	0.000	0.352	0.000	0.000	0.138
Normality of model residuals	0.037	0.009	0.850	0.008	0.025	0.540	0.202	0.222	0.052
Heteroskedasticity	0.008	0.032	0.096	0.000	0.002	0.005	0.740	0.651	0.995
Chow test	0.997	0.536	0.984	0.696	0.147	0.929	0.540	0.804	0.564
NIE Networks efficiency score	0.871	0.888	0.839	0.820	0.836	0.770	0.876	0.897	0.778
UQ	0.961	0.974	0.957	0.982	1.000	0.945	0.892	0.909	0.889
Catch-up challenge	-9%	-9%	-12%	-16%	-16%	-18%	-2%	-1%	-11%

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

D.3. Wayleaves sensitivity: Excluding wayleaves

	IMFT & Indirects (inc connection costs)			IMFT & Indirects (exc connection costs)			NOCs		
	Model 2.1	Model 2.2	Model 2.3	Model 2.1	Model 2.2	Model 2.3	Model 2.4	Model 2.5	Model 2.6
Log of network length	0.819***		0.809***	0.838***		0.822***	1.031***		1.006***
	{0.000}		{0.000}	{0.000}		{0.000}	{0.000}		{0.000}
Log of middle-up CSV		0.832***			0.851***			1.041***	
		{0.000}			{0.000}			{0.000}	
Log of network density	0.767***	0.367**	0.468***	0.957***	0.548**	0.507***	1.389***	0.888***	0.679***
	{0.000}	{0.034}	{0.000}	{0.001}	{0.029}	{0.003}	{0.000}	{0.000}	{0.001}
Length of overhead lines as a % of network length	0.694**	0.759**		1.044***	1.111***		1.648***	1.727***	
	{0.018}	{0.014}		{0.009}	{0.008}		{0.003}	{0.003}	
Constant	-6.845***	-6.099***	-5.421***	-7.962***	-7.198***	-5.821***	-12.752***	-11.750***	-9.374***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Model robustness tests									
Adjusted R2	0.873	0.872	0.846	0.836	0.835	0.784	0.817	0.811	0.741
RESET test	0.000	0.000	0.233	0.000	0.000	0.151	0.000	0.000	0.109
Normality of model residuals	0.024	0.005	0.881	0.029	0.063	0.402	0.219	0.255	0.053
Heteroskedasticity	0.005	0.025	0.040	0.000	0.000	0.000	0.722	0.637	0.906
Chow test	0.992	0.426	0.985	0.866	0.366	0.947	0.544	0.799	0.567
NIE Networks efficiency score	0.856	0.872	0.813	0.791	0.806	0.731	0.875	0.896	0.773
UQ	0.972	1.001	0.942	0.974	0.991	0.955	0.889	0.907	0.889
Catch-up challenge	-12%	-13%	-13%	-18%	-19%	-22%	-1%	-1%	-12%

** p < 0.1, ** p < 0.05, *** p < 0.01*

D.4. Company exclusion sensitivity: Excluding LPN from the data sample

	IMFT & Indirects (inc connection costs)			IMFT & Indirects (exc connection costs)			NOCs		
	Model 2.1	Model 2.2	Model 2.3	Model 2.1	Model 2.2	Model 2.3	Model 2.4	Model 2.5	Model 2.6
Log of network length	0.813***		0.754***	0.783***		0.712***	0.863***		0.775***
	{0.000}		{0.000}	{0.000}		{0.000}	{0.000}		{0.000}
Log of middle-up CSV		0.808***			0.782***			0.861***	
		{0.000}			{0.000}			{0.000}	
Log of network density	0.733***	0.329**	0.488***	0.860***	0.470**	0.563***	1.259***	0.830***	0.895***
	{0.000}	{0.046}	{0.000}	{0.001}	{0.037}	{0.001}	{0.000}	{0.002}	{0.000}
Length of overhead lines as a % of network length	0.673**	0.660**		0.817**	0.808**		1.004*	0.993	
	{0.020}	{0.037}		{0.016}	{0.025}		{0.091}	{0.106}	
Constant	-6.624***	-5.622***	-4.860***	-6.906***	-5.980***	-4.767***	-10.201***	-9.176***	-7.572***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Model robustness tests									
Adjusted R2	0.874	0.876	0.855	0.846	0.851	0.821	0.841	0.844	0.820
RESET test	0.001	0.000	0.278	0.000	0.000	0.063	0.000	0.000	0.116
Normality of model residuals	0.050	0.017	0.351	0.113	0.218	0.170	0.013	0.001	0.000
Heteroskedasticity	0.025	0.111	0.120	0.003	0.013	0.006	0.720	0.635	0.909
Chow test	0.995	0.493	0.976	0.872	0.362	0.962	0.549	0.801	0.572
NIE Networks efficiency score	0.866	0.886	0.845	0.824	0.842	0.800	0.908	0.930	0.876
UQ	0.966	0.974	0.920	0.958	0.978	0.927	0.881	0.897	0.879
Catch-up challenge	-10%	-9%	-8%	-13%	-14%	-13%	3%	3%	0%

** p < 0.1, ** p < 0.05, *** p < 0.01*

D.5. Company exclusion sensitivity: Excluding NIE Networks from the data sample

	IMFT & Indirects (inc connection costs)			IMFT & Indirects (exc connection costs)			NOCs		
	Model 2.1	Model 2.2	Model 2.3	Model 2.1	Model 2.2	Model 2.3	Model 2.4	Model 2.5	Model 2.6
Log of network length	0.817***		0.808***	0.830***		0.818***	1.023***		1.000***
	{0.000}		{0.000}	{0.000}		{0.000}	{0.000}		{0.000}
Log of middle-up CSV		0.827***			0.839***			1.031***	
		{0.000}			{0.000}			{0.000}	
Log of network density	0.598***	0.216*	0.339***	0.660***	0.273**	0.299***	1.218***	0.742***	0.524**
	{0.000}	{0.076}	{0.000}	{0.000}	{0.033}	{0.006}	{0.000}	{0.001}	{0.014}
Length of overhead lines as a % of network length	0.546**	0.630**		0.763***	0.847***		1.470***	1.572***	
	{0.027}	{0.019}		{0.005}	{0.005}		{0.004}	{0.005}	
Constant	-6.129***	-5.428***	-4.919***	-6.679***	-5.944***	-4.990***	-11.993***	-11.056***	-8.740***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Model robustness tests									
Adjusted R2	0.862	0.857	0.842	0.838	0.829	0.800	0.775	0.765	0.702
RESET test	0.039	0.003	0.000	0.001	0.000	0.004	0.000	0.000	0.001
Normality of model residuals	0.096	0.001	0.044	0.075	0.010	0.001	0.120	0.154	0.010
Heteroskedasticity	0.025	0.111	0.120	0.003	0.013	0.006	0.720	0.635	0.909
Chow test	0.995	0.493	0.976	0.872	0.362	0.962	0.549	0.801	0.572
NIE Networks efficiency score	0.799	0.821	0.751	0.710	0.730	0.651	0.792	0.820	0.671
UQ	0.967	0.993	0.954	0.969	0.991	0.949	0.872	0.879	0.889
Catch-up challenge	-17%	-17%	-20%	-26%	-26%	-30%	-8%	-6%	-22%

** p < 0.1, ** p < 0.05, *** p < 0.01*

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