Incentives in Electricity Network Regulation to Enable the Clean Energy Transition

Osmo Siirto
Teemu Nurmi
Helen Electricity Network Ltd.
Helsinki, Finland
osmo.siirto@helen.fi, teemu.nurmi@helen.fi

Abstract— **Electricity networks have a crucial role in enabling the clean energy transition. The increase in renewable energy sources, like wind and solar power is vital in achieving the environmental targets and providing affordable and clean power for consumers. For DSOs, an additional capital is necessary to execute their significantly increased investments programs. In this paper, a review of regulatory incentives contributing to enable the clean energy transition is conducted. Since the funding of the increased investment needs is vital, we particularly focus on this study to the asset valuation and renumeration methods. From the review, the most promising incentives are taken into further evaluation. Case studies and cashflow calculations in a base case and in energy transition with different asset valuation approaches were developed and studied. Based on the outcomes, it is not completely equal weather to take account the inflation in the reasonable rate of return or in the regulatory asset base. Finally, we propose potential methods, like the increased WACC and the benefit-sharing, to promote the energy transition.**

Index Terms-- **Electricity distribution network, Energy transition, Incentives, Regulation, Regulatory Asset Base.**

I. INTRODUCTION

Electricity grids are set to become increasingly important as clean energy transition progresses. The electricity transmission will drastically increase. The generation of electricity alters in favour of renewable energy, like wind and solar. This electricity generation has high volatility. There are generation units from vast wind and solar parks down to household-sized small units. Simultaneously, the location of generation units is significantly demanding new connections for efficient electricity transmission. On the consumption side, there will be an enormous rise in realizing the clean energy transition. Electrification of district heating includes coal-burning CHP power plants being phased out in favour of electric boilers and industrial heat pumps. Also domestic heating solutions opt electricity. In addition, the electrification of transport means higher demands of electricity and distribution capacity and further also the development of the grids.

The rapid increase in investment needs in the past few years has created challenges to Distribution System Operators' (DSOs') financial stability and cash flow. In many European countries, distribution network regulation primarily focuses on ensuring keeping customers' network costs at an affordable level. For DSOs, additional capital is necessary to execute their significantly increased investments programs. However, the regulated remuneration of DSOs is insufficient in meeting this increased capital requirement, so DSOs need external financing. Investors typically require equity as a condition for granting loans which poses problems for many DSOs with limited equity. Even if external loans are granted, the backward-looking nature of the regulated remuneration means that the funds are only recovered by the time when the investments reach the end of their regulatory lifetime replacement interval. Increase in external funding will also impact negatively on the debt-to-equity ratio, potentially leading DSOs towards liquidation. This scenario discourages DSOs to increase the investments to the necessary level to connect all the needed new electricity production and consumption into the grids.

The electricity network regulation plays a crucial role in determining the profitability of network investments. It is essential for the economic regulation of DSOs to support grid development and enable sufficient grid investments to ensure a successful energy transition for both the society and network customers. It would be far more costly to the society if electricity networks become bottlenecks of this development.

In this paper, a comprehensive literature review is conducted on electricity network regulation. The paper studies and benchmarks various methods selected from the literature review. An evaluation of the methods and their steering effects is conducted. As a part of this evaluation, case studies and cashflow calculations with different scenarios were developed and calculated. Finally, we propose potential methods to incentivise the energy transition.

II. REVIEW ON REGULATION FRAMEWORKS AND INCENTIVES TO SUPPORT ENERGY TRANSITION

The IEA Report "Electricity Grids and Secure Energy Transitions" warns that grids are becoming a bottleneck for

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energy transitions. While investing in renewables has almost doubled in the last decade, investments in grids have remained stagnant. This delayed action means prolonging the reliance on fossil fuels, resulting in increased emissions and costs to the society [1]. Scenarios for high electrification in the Netherlands and Germany are based on doubling of electricity demand and electricity generation will grow even faster than demand [2]. The need for urgent investments is also recognised by the European Commission. The socio-economic welfare losses of delaying the network upgrades necessary to connect renewables and flexible demand will frequently outweigh the additional initial cost of anticipatory investments [3].

Given the critical importance of funding the increased investment needs in energy transition, this study places particular emphasis on the asset valuation and remuneration methods. An effective asset valuation method for calculating the initial regulated asset base and the depreciation of the assets are essential in establishing a balanced financial framework in the economic regulation and calculating the allowed income of utilities benefiting consumers, the society, and DSOs alike. In European electricity network regulation, there are three basic methods in assessing the initial regulatory asset base (RAB):

- Historical costs
    - Applying actual cost incurred in the network construction or acquirement. Typically, inflation is not considered, thus also an indexed historical cost method can be used.
- Re-evaluation of assets
    - Determining the true fair market value of fixed assets. The re-evaluation can be done once or on a frequent basis (e.g. annually)
- Mix of historical costs and re-evaluation of assets
    - Combining historical costs and a re-evaluation of assets using for example indexed replacement values for equity financed parts and historical for debt financed assets.

The most common RAB valuation method in the electricity DSO regulation CEER countries is using the historical costs or the re-evaluation of historical costs [4].

In order the RAB to enable a fair remuneration for both old and new investments, it must take into account the residual value of the network assets. Thus, the RAB calculation must be linked to the depreciation of the assets. The two common methods for the depreciation in the European electricity network regulation are the straight-line depreciation and an accelerated depreciation. The straight-line depreciation distributes the asset's cost equally over its regulatory life span. An accelerated depreciation like double declining balance enables a larger deduction in the initial years after the asset acquirement. The RAB can consist of multiple elements, like fixed network assets, working capital, leased assets or assets under construction depending on the regulation framework. It is important to note that asset valuation methods, incentives and their effects on the allowed income and investment profitability in the utility regulation should be studied in the context of the country-specific regulation framework, including all the incentive mechanisms and individual parameters affecting the allowed income [4]. The cost of capital of a regulated company represents the expected return that investors could anticipate from alternative investments with a comparable risk. Investors are unlikely to provide capital unless the investment is expected to meet or exceed its opportunity cost of capital [5]. Weighted Average Cost of Capital (WACC) method is generally used in estimating the value of cost of the capital, and it is consistent with the methodology used by many regulators.

Next is presented the findings of the regulatory methods and incentives and that were found promising in order to support the energy transition.

A. Replacement Cost Value Approach

The replacement cost value (RCV) approach is used by some European countries like in Ireland, Finland, Sweden and partly (the equity-financed share of assets) in Germany [6]. The replacement value of an electricity network is the same as the cost of building a similar new network at current cost levels [7] The straight-line depreciation is calculated from the adjusted replacement value. Since the adjusted straight-line depreciation is calculated from the network operator's adjusted replacement value, it ensures a sufficient cash flow to finance the needed replacement investments. Both in Finland and Sweden, pre-estimated unit costs are used in the determination of the regulatory replacement value of the component. This is a benefit-sanction incentive, which encourages network operators to make investments cost-effectively [4].

B. Increased WACC

The regulation method for German transmission system operators has a novel and a functional approach: a greater rate of return for new assets. This model contributes to financing the substantial need for grid investments in the energy transition. The reasons and benefits for providing a higher WACC of 5.07% for new investments instead for a WACC of 3.51 % are [8]:

- higher business risks involved in new investments need to be compensated by a higher rate of return to ensure that investors receive an adequate return for the risk taken.
- a higher WACC for new investments creates incentives for investors to invest in new network projects
- the determination of the return rate for new investments is based on a market-oriented approach which ensures that the return is competitive

A higher WACC for new investments contributes to the long-term stability and viability by ensuring that sufficient funds are available for necessary infrastructure investments. In the regulation methods for electricity system operators of Slovakia, there is a concept called WACC+ [4]. In the WACC+ method, a system operator is able to receive an increased WACC of 2 % compared to the approved WACC value for investments enabling

- renewable energy

- electricity storage facilities
- connection facilities for charging electric vehicles
- connection of the ancillary and flexibility service facilities
- development and restoration of the facilities for system automation and digitalization,
- system and flexibility services
- improving the quality of services for system users and electricity end-consumers.

C. *Flexibility Incentive*

A flexibility incentive is a complementary solution to new network investments to promote network operators in developing solutions of demand-side and flexibility. In Finland, the flexibility incentive is as maximum 1 % of the operator's total turnover from network operations in the unbundled profit and loss. Costs and the impact of the incentive is deducted in the realised adjusted profit calculation. The flexibility incentive intends to encourage development and utilisation of flexible network solutions to achieve wider use of demand response [4].

D. *Benefit-Sharing*

The European Commission urges innovative approaches such as a benefit sharing to contribute the energy system resilience at affordable prices [9]. An alliance benefit-sanction compensation method has been used especially in infrastructure projects. The service providers' earnings are related to the target cost, which refers to the pre-estimated total cost of the project. For example, if the final project cost is below or over the target cost, the benefit or sanction is shared with the participants of the alliance by predetermined ratios [10].

Benefit sharing has been studied by Pototschnig and Rossetto [11] as a regulatory tool to encourage innovative and cost-efficient solutions as an alternative to traditional investments. The regulator defines the level of the sharing factor, which could range from 0 to 100%. The higher the sharing factor, the greater is the incentive for the network operator and correspondingly the benefit for customers is then smaller. The savings to grid users are determined by:

$$Savings\ to\ grid\ users = (1-\alpha) \times (C* - C) \tag{1}$$

where C* is the net present value of the allowed revenues required to cover the costs of the traditional efficient solution, C is the net present value of the allowed revenues required to cover the costs of the more efficient, innovative solution and α is the sharing factor.

Benefit sharing is a promising approach to encourage and intensive network operators to develop new innovative solutions for more efficient grid usage and to manage power congestions.

E. *Regulatory Sandbox*

The use of flexibility mechanisms may still face obstacles by national regulation. Regulatory sandboxes may be used to overcome this gap by enabling and supporting the development of local flexibility mechanisms [12]. Regulatory authorities may introduce legislations incorporating the concept of a sandbox to create a regulatory framework and an experimental environment that encourages flexibility and processes for facilitating and accelerating the energy transition. With the help of sandbox applications, the designated test or pilot implementations provide protected spaces for projects to allow regulatory trials and the development of both local flexibility and required regulation [13].

III. EVALUATION OF SELECTED METHODS

A. *Benefit-Sharing*

First for the evaluation, we selected the benefit sharing because itis novel and innovative in the electricity network regulation. The next example is from the transmission system operator (TSO), however the method is applicable also in the DSO regulation. In [11], it is presented an illustrative example of the benefit-sharing: a need to increase the transmission cross-border capacity by 600 MW. The traditional solution is a new 400 kV overhead line, 300 km. A more efficient, innovative solution identified by the TSO is the deployment of a dynamic line rating system over the three already existing lines. The net present value of the revenue requirements $C*$ to cover the costs of the traditional solution is around 323 million EUR and the net present value of the revenue requirements C to cover the costs of the more efficient, innovative solution is about 133 million EUR. Thus, the savings to the customers is 190 million EUR and with a sharing factor of 20 % the incentive to the TSO is 38 million EUR. When this approach was consulted with the regulators, most respondents argued in favour of a rapid (1-3 years) disbursement of the incentive payments, since this would provide stronger incentives for the network operator. On the other hand, this approach might need more time and grid expertise for the regulators to evaluate the proposed schemes. However, to enable the large-scale electrification and integration of renewable energy regulators should consider the adoption or piloting of this scheme.

B. *Asset Valuation Methods and Replacement Cost Approach*

The asset valuation was selected for a more detailed evaluation because it is essential in the remuneration of investments. Since the most common asset base valuation method in the electricity DSO regulation CEER countries is using historical costs or a re-evaluation of historical costs, the non-indexed historical costs approach or the book value (BV) approach was selected for case studies. Also the replacement cost value approach was seen promising, because its ability to provide a remuneration to necessary replacement investments. Two different RCV approaches from Finland and Sweden were chosen. In Finland, the RCV approach has changed in the new regulation methods, so this also contributed to perform further studies to study the effects of the change. Also a unit cost-based benefit-sanction incentive is in use in Finland and Sweden. Thus, the case studies and calculations of the allowed capital cash flow were performed for the book value approach and for Finnish and Swedish RCV approaches.

First, we present a brief description of the replacement cost asset valuation in the Swedish regulation methods. The regulatory asset base is primarily valued based on the present purchase values (PPV), which are the replacement cost values for the existing assets, pre-set by the Swedish Energy Markets Inspectorate (Ei). The RAB is the sum of the present purchase values of all components that exists in the network. When calculating the Regulatory value (RV) the RAB is age-adjusted, and a reasonable rate of return based on a WACC method is applied on the age-adjusted RAB. In this study, we consider only the cash flow related to the capital, which is the Capital cashflow. The $Capital\ cashflow$ is calculated in Sweden as below, if the age of the component ≤ the regulatory lifetime (LT) of the component [14]

$$Capital\ cashflow = Depreciation + Return \quad (2)$$

$$= \frac{1}{LT} * PPV + \left(1 - \frac{age_{t\_n}}{LT}\right) * PPV * WACC \quad (3)$$

A real WACC is applied since the unit costs account for inflation.

In Finland, the calculation of the regulatory asset base is slightly more complex. The net present value or the regulatory asset base, regulatory asset value RAV for calculation of the return in year n is as follows [15]

$$RAV_n = RAV_{<2024,n} + \sum_{2024}^{n} RAV_{t\_n} \quad (4)$$

The RCV of network assets installed before year 2024 is based on the frozen unit prices set by Finnish Energy Authority.

$$RAV_{<2024,n} = \left(1 - \frac{age_{t\_n}}{LT}\right) * RCV_{<2024\_n} \quad (5)$$

Similarly, for investments made since 2024, the frozen replacement value is determined based on the unit prices set for each year of the investment, and then frozen. The RCV of components from year 2024 forward are valued by yearly unit prices and then the RCV of the component will be frozen.

$$RAV_{t\_n} = \left(1 - \frac{age_{t\_n}}{LT}\right) * RCV_{t\_n} \quad (6)$$

The depreciation is also calculated from frozen replacement costs

$$Depreciation = \sum_{i}^{n} \frac{RCV_i}{LT_i} \quad (7)$$

where RCV_i = the sum of frozen replacement values of the network component i for different years of the investment. Thus, the $Capital\ cashflow$ in Finland is as follows

$$Capital\ cashflow = Depreciation + RAV_n * WACC \quad (8)$$

When using historical costs or book values (BV) in the regulatory asset valuation, the $Capital\ cashflow$ is also calculated as in (2), a sum of the depreciation and the return. Almost all CEER countries use the straight-line depreciation, in which the asset is depreciated at a constant rate over its economic lifetime. When the purchase value PV and the age the component ≤ the economic lifetime (LT), the depreciation and the regulatory asset value are

$$Depreciation = \sum_{i}^{n} \frac{PV_i}{LT_i} \quad (9)$$

$$RAV_{t\_n} = \left(1 - \frac{age_{t\_n}}{LT}\right) * PV_{t\_n} \quad (10)$$

The nominal WACC is used in this BV approach and similarly in the Finnish RCV approach, since book values are not indexed and in Finland the RCV of the components are frozen.

In the case studies, two different simplified scenarios and models with these three selected asset valuation and regulation methods were evaluated. The calculations are exemplified with a real WACC of 4.53 % used in Sweden [16]. The inflation is estimated to be 2 % and for the calculations to be comparable, a nominal WACC on 6.53 % is used in BV and Finnish RCV approaches. The discount factor used in the studies is the nominal WACC. The test network and the scenarios and calculations were made using self-developed Python programs and MS Excel.

First, we evaluated a base case, the case C_0. In this case C_0, there is no growth in electricity demand, only constant and steady replacement investments. In the case C_0, the DSO has until year 2023 invested every year the same amount to network components than, what is the replacement cost value of dissolutions from the network. In year 2023, the replacement cost value of yearly installed components is 2 million EUR. Every network component has a regulatory lifetime LT of 50 years and every component is replaced at the end of their lifetime. For simplification and to illustrate an average situation, we assume that in Finnish and Swedish approaches, the network components are installed at the same costs as their regulatory unit values. In a real environment, there are variations in the DSO investment efficiencies compared to the unit costs.

In case C_0, the discounted cash flow for next 50 years is almost the same in Finnish and Swedish RCV approaches, 49 million EUR in Finland and 48 million EUR in Sweden. In the BV approach, this is considerably lower, 36 million EUR. However, we notice in Fig. 1 that the cashflow FIN is approaching the cashflow BV and equals it in the end of the period. This is a consequence of the freezing of the replacement value of investments to the year of their commissioning. When we calculate the discounted cash flow of last 25 years, the cashflow S of the Swedish approach outperforms both two other approaches, the cashflow S is 43 million EUR compared to cashflow FIN of 34 million EUR and cashflow BV of 33 million EUR.

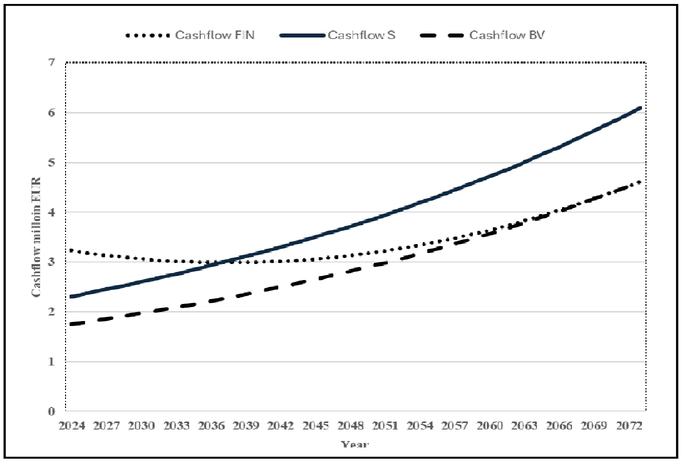

Figure 1. Capital cashflows in case C_0 for the Finnish and Swedish RCV approaches and book value approach

The Swedish RCV approach provides more capital cashflow than the widely used book value method during the entire period of the study, and more than the Finnish approach after 15 years. This demonstrates that it is not equal whether to take into account the inflation in WACC or in the asset base, contrary to what has been stated in [17]. The explanation for this phenomenon can be seen in (3). When the inflation is taken into account in the asset base, it has a positive impact both in the revenue and the depreciation. However, when the inflation is taken into account in WACC, the indexing contributes only the revenue.

Secondly, we evaluated an energy transition case, case$_{ET}$. The historical network of the case$_{ET}$ is similar to the case C_0 and all the replacement investments are done similarly as in case C_0. The difference in the case$_{ET}$ is, that there is a fast and widespread electrification and integration of renewable power ongoing, enabled with network investments. In this energy transition scenario, the estimated need for annual new investment is double compared to the amount of the replacement investment need.

In case C_{ET}, the book value approach provides the lowest capital cashflow during the whole period of the study. The Finnish RCV approach has the largest discounted cash flow for next 50 years, 45 million EUR, compared to 40 million EUR in the Swedish RCV approach and 32 million EUR in the BV approach. Fig. 2 presents that in this energy transition scenario it takes longer, 23 years, for the Swedish RCV method to provide more cashflow than the Finnish RCV method. This is because the considerable number of new investments and the nominal WACC is used in Finland. The new network assets contribute more to the revenue than to the depreciation, which effect is explained in (3).

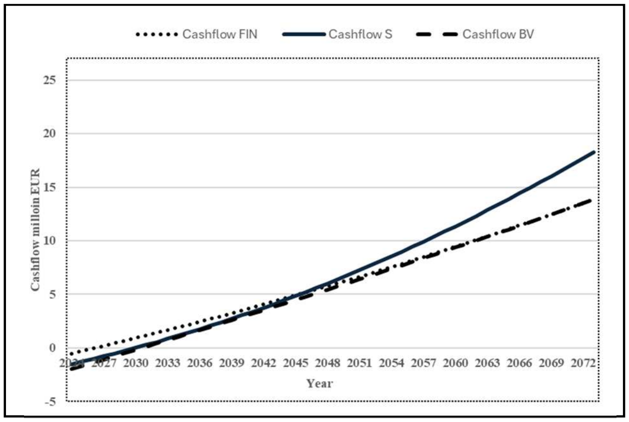

Figure 2. Capital cashflows in case C_{ET} for the Finnish and Swedish RCV and book value approaches

In the beginning of the caseET, all the capital cashflows are negative, so additional improvements to the capital cashflows are needed. Increased WACC for new investments is a feasible and a functional solution to improve the cashflows, since an increase in WACC affects the most to new assets. The method improves the capital cashflow and thus encourages DSOs to make the network investments to increase the network capacity and investors to finance this. The cashflow of all studied three methods supplemented with an increase 2 % in WACC for new network investments, is illustrated in Fig. 3.

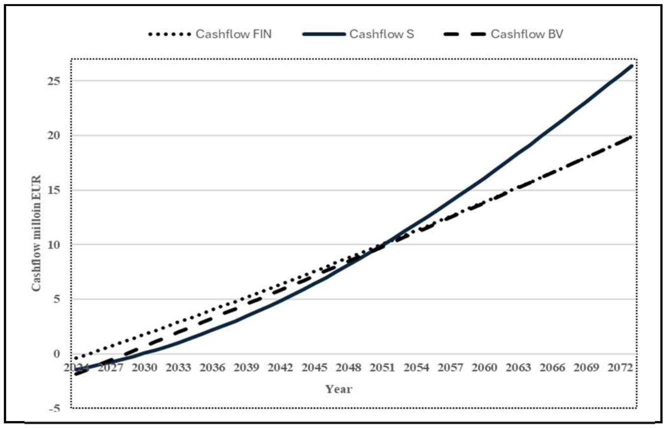

Figure 3. Capital cashflows in case C_{ET} for the Finnish and Swedish RCV and book value approaches supplemented with an increased WACC of 2 % for new investments

Fig. 3. with more positive cashflows shows that the increased WACC for new investments is a viable solution in the energy transition. This method can be introduced by national regulatory authorities, as done in Germany [8] and in Slovakia [4].

IV. CONCLUSIONS

The calculations revealed that it is not completely equal whether to take account the inflation in WACC or in the asset base. In the Swedish RCV, the inflation is adjusted in the asset base, and this has a positive effect both on the depreciation as well as on the revenue. In the book value and the Finnish RCV approach, the inflation is taken into account in WACC, contributing only to the revenue. The Swedish RCV approach provides a greater long-term cashflow than the BV approach in all studied scenarios. Although in the C_{ET}, the Finnish RCV approach has an advantage in the beginning, in the long run its cashflow aligns itself with the cashflow BV, caused by the freezing of the replacement cost values. Thus, of the three studied asset valuation methods, the Swedish RCV approach is the preferred option, when examining the capital cashflow.

In the energy transition scenarios, all studied three approaches resulted in a negative capital cashflow in the beginning, thus requiring additional measures. A preferred method to improve the remuneration in the energy transition is the increased WACC method for new investments, as done in Germany and in Slovakia. Benefit-sharing and flexibility incentive combined with regulatory sandbox would also be beneficial in promoting innovative solutions and flexibility to the network operators. A higher remuneration for new investments to enable the energy transition may cause grid costs to rise, but customers overall energy costs might decrease, since investments enabling electrification and renewable power provide more affordable electricity and energy for consumers. Also the grid tariffs may not necessarily increase, since new investments add more customers to divide the regulated grid revenue.

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