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Financing investment in the European electricity transmission network: Consequences on long-term sustainability of the TSOs financial structure

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Abstract: This article focuses on the ability of European TSOs to meet the demand for substantial investments in the electricity transmission grid over the next two decades. We employ quantitative analysis to assess the impact of the required capital expenditures under a set of alternative financing strategies. We consider a best-case scenario of full cooperation between the European TSOs. It appears that under current trends in the evolution of transmission tariffs, only half the volumes of investment currently planned could be funded. A highly significant increase in transmission tariffs will be required to ensure the whole-scale investments can be delivered. Finally, alternative strategies can dampen the impact on tariffs but they can only partially substitute for this increase in charges paid by network users.

Keywords: *Investment, Electricity transmission grid, Transmission System Operator*

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1. Introduction

The development of the European electricity transmission grid plays a key-role in the strategy of the European Union to address challenges such as decarbonisation of the generation mix, security of supply, and market integration. However it is unclear today whether regulated Transmission System Operators (TSOs) will be able to cope with substantial amount of investments that are unprecedented since liberalisation.

Previous studies such as the one realised by Roland Berger (2011) have been considering the investment issue by focusing on volumes of investments over one or two decades. The main question they address is whether sufficient volumes of debts and equity will be available: they do not consider the resulting yearly constraints on the parameters observed by investors to assess the financial health of a company. Other works focus on the definition of an adequate regulatory framework and required incentives to ensure that investments are delivered by TSOs: a good review of the related issues can be found in Guthrie (2006).

Our approach differed as we focused on identifying an appropriate financing strategy for TSOs to meet the need for capital expenditure. By opposition to the works previously mentioned, we considered that an adequate regulatory framework would be in place and that the corresponding volumes of debt would be accessible on financial markets at a reasonable cost. We then compared a set of financing options by measuring the costs for network users to deliver a given volume of investment while conserving good financial ratings (corresponding to an investment-grade for rating agencies).

We took as given a set of investments identified in previous studies by the European Commission and the European TSOs, and we focused on the resulting annual financial constraints for TSOs in the ENTSO-E area over the period 2012-2030. We built our analysis on some of the insights delivered by Neuhoff, Boyd et al. (2012): grid investment will be mostly financed against revenues charged to users, and TSOs cannot finance the full scale of investments by simply raising debt. If TSOs are to find money on capital markets, they must obey to some constraints on a set of financial ratios. We assessed quantitatively these challenges, estimated the financing gap for a set of investment scenarios, and studied the potential of alternative financing strategies to fill this gap at lower costs for consumers.

We neglected local restrictions to focus on the challenges faced by a virtually integrated European electricity transmission industry. In order to simplify the results, and due to the increasingly tight relationship between the different European TSOs, we made the assumption of a single virtual TSO responsible for the whole transmission network in the ENTSO-E area. Our framework is therefore a best-case scenario in which some constraints specific to a given TSO are neglected.

Our results show that in their current financial situation, and under historical trends in transmission tariffs, TSOs will not be able to achieve more than half of the investment plans. Higher capital expenditures would result in financial degradation of TSOs and a rapid loss of their investment grade. Tariffs will have to increase significantly if the totality of the investment plans is to be met. Alternative financing strategies could lower costs for consumers, but only to a minor extent.

2. General framework of the study

2.1. Challenging wave of investments in the European electricity transmission grid

The European electricity transmission grid is facing significant needs for new transmission lines, mostly in order to incorporate renewables[2] and new conventional plants, but also to

[2] According to the ENTSO-E, 80% of the bottlenecks that are to appear in the European transmission grid by the end of the decade are related to RES-integration.

address security of supply, and ensure market integration. In addition, a major share of the existing network is to be renovated in the coming decades (IEA 2011). As a result, European TSOs will be exposed to uninterrupted and substantial capital expenditures over the two next decades.

The ten-year plan established in 2012 by the European Network of Transmission System Operators for electricity (ENTSO-E) identified investments of €104 billion to be spent in the next ten years on projects of pan-European significance alone. Even with plans by European TSOs to raise their investments by approximately 70% compared to the period 2005-2009, there would still be a significant investment gap to be met (Roland Berger 2011).

2.2. **Ability of the TSOs to finance investments**

Definition of financeability

The life of transmission assets is on average 40 years but can be much longer in some cases. As a consequence, high upfront costs must be covered at times of investment while pay-back is delivered though a low return over a long period. Even in case when profitability in the long-term is ensured, TSOs still need to raise the money initially.

Financeability hereby refers to the ability of TSOs to raise finance from capital markets in order to meet their investment program. We consider that in order to achieve their objectives, it is necessary that the TSOs conserve good financial ratios, corresponding to an investment grade status for rating agencies. In addition, financeability implies that the return on the regulatory asset base is sufficient to cover the costs of capital of investors.

Sources of financing

There are three basic ways in which TSOs can finance capital expenditures: investors can raise debt (loans from commercial banks or institutions, corporate bonds), fund investment internally by retaining earnings, or find external sources of equity.

Since liberalisation, debt emission has been the option most commonly employed by integrated utilities in general and European TSOs in particular(IHS CERA 2013). As a result, the volume of debt has kept rising (the leverage of European electricity TSOs is typically about 60-70% today), which limits the ability of these companies to acquire further debt without losing their credit rating.

Internal equity is a major source of financing for some small European TSOs, but it cannot be sufficient alone at times when investment needs increase significantly. Moreover, investors in TSOs traditionally expect a high dividend pay-out ratio, which limits the ability of TSOs to finance investments internally. An empirical study realised by National Grid (2012) revealed that utilities continue to pay a substantial dividend (at least 50% of profits) even when they need to raise equity.

Raising external equity is an attractive option when the debt level has to be kept under a given threshold. Yet it is also a more expensive option. By opposition to bond-holders, the returns of equity investors vary with the profits and losses of the company: they therefore require a higher return to compensate for this equity risk. In addition to higher costs, there are two main obstacles to financing investments, due to the fact that most European TSOs are still publicly owned[3] (Roland Berger 2011). On the one hand, cash-strapped European States are not able to inject liquidities: as pointed out by Helm (2009), States facing budgetary

[3] Even in situations of private ownership (as in Belgium, Italy and Spain), public entities still hold a large minority share.

constraints prefer to protect operational expenditures (OPEX) and reduce capital expenditures (CAPEX). On the other hand, States might be reluctant to dilute their ownership share of crucial assets with major public goods properties.

Financing strategies

Each of the three possible sources of financing is therefore associated with specific limitations, costs, and constraints. In this article we study the potential of a set of financing strategies to fill the investment gap while conserving good financial ratios. The definition of these strategies is based on Neuhoff, Boyd et al. (2012).

Under the "business-as-usual strategy" scenario, capital expenditures are financed using debt and a minor share of the earnings that has not been distributed as dividends.

In the "Issue additional equity" scenario, the high dividend pay-out ratio is maintained but the TSOs issue additional equity (instead of debt) to finance capital expenditures.

In the "Shift to growth model" scenario, the dividend pay-out ratio is lowered and TSOs retain earnings in order to finance capital expenditures internally. Shareholders do not receive their return as cash but from holding the share for a while and selling it at a higher value.

3. Assumptions behind calculations

We calculated the impact on the balance-sheet of a virtual unified European TSO, using as inputs the initial situation in 2012 and a set of assumptions regarding annual expenditures until 2030. We were then able to extract the evolution of the financial ratios of the TSO and the impact on tariffs for the consumer.

3.1. **Defining a virtual single aggregated European TSO**

In order to simplify the results, we made the assumption that the different European (i.e. members of ENTSO-E) TSOs could be virtually aggregated into a single European TSO, in charge of the whole volume of investments.

One might argue that the TSOs aggregated into our stand-alone company widely differ in terms of size, investment plans, ownership, and financial situation. However we consider our assumption to be valid, as a first approximation. The rationale behind our hypothesis is two-fold.

On the one hand, similar key sources of financing will be accessible to most European TSOs. Public funds are often designed on a supra-national basis, as in the case of the European Investment Bank, the European Bank for Reconstruction and Development, the European Energy Programme for Recovery and the Energy Infrastructure Package. Banks and potential investors also rarely restrain the geographical scope of their investments to a single country[4]. Moreover, TSOs remain relatively low-risk business in all the countries that are part of the ENTSO-E. As long as these TSOs remain in the "investment grade" range, which was still the case for all of them in 2011 (Roland Berger 2011) investors are likely not to treat them very differently one from the other. It is also likely that as a result of European integration, the differences remaining today will tend to disappear by 2030 (See Ruester, Marcantonini et al. (2012) for a discussion of these issues).

On the other hand, cross-border industry consolidation and mergers between TSOs is not unrealistic, as proven by the investments of TenneT and Elia in Germany. Smaller TSOs facing significant investment needs could cooperate with larger TSOs having an easier access to financing.

[4] A recent example of cross-border investments is the buy-out of 40% of Portugal's national power grid *Redes Energéticas Nacioanais* by China's State Grid Corporation and Oman Oil.

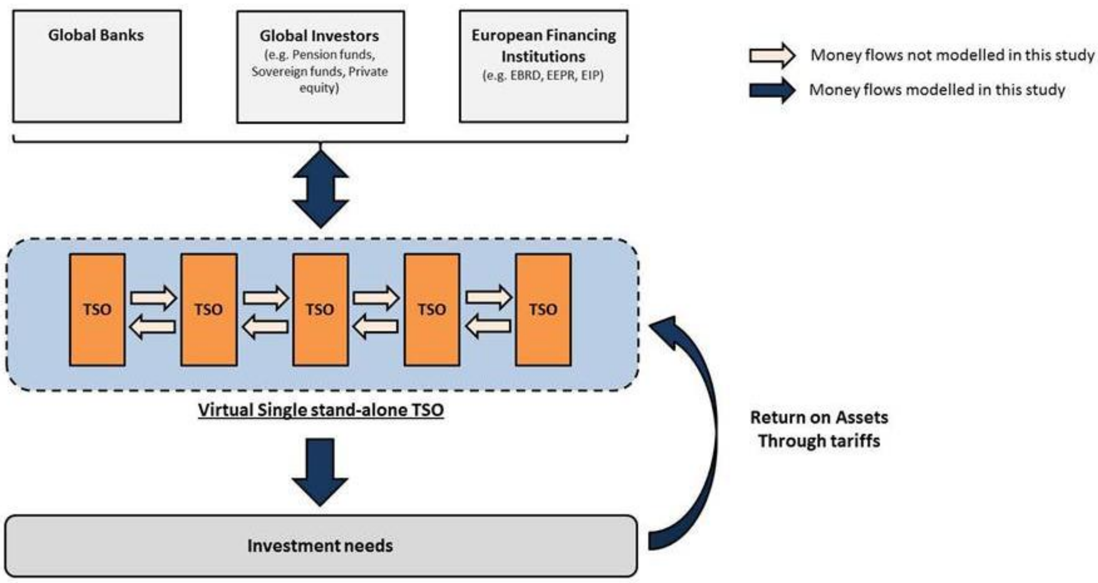

Figure 1: Illustration of the assumption of a single stand-alone European TSO

As a result, we considered that the required funds could flow from one pool of financing sources, and then be distributed between a set of communicating vessels to fulfil a common set of investment needs (See Figure 1).

Note that smaller TSOs facing significant investment needs and ownership-restrictions might be exposed to more challenging local constraints that would not appear in this study. Our primary focus was to identify constraints at the scale of the European transmission grid industry: our study can be considered as a best-case scenario for which full integration (or at least full cooperation) of the European TSOs would be achieved.

3.2. Investments program

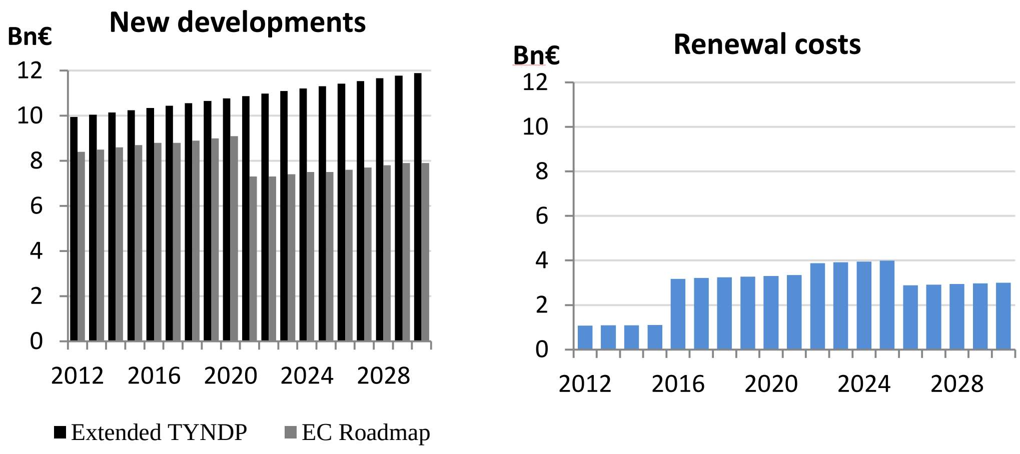

Figure 2: Annual investment costs in the ENTSO-E area over the period 2012-2030 (€2012 Billion)

In this study, the volume of investment is exogenously determined and is independent from the financing strategy. We identified two main categories of transmission investments: grid expansion required to accommodate both demand growth and the deployment of renewables on the one hand, refurbishment and replacement of existing assets on the other hand. The resulting investment profiles are represented in Figure 2.

New developments

We employed two possible scenarios for investments in new projects.

The first scenario for transmission investments (hereby referred to as "Extended TYNDP") was based on the TYNDP 2012, involving 52,300 km of new circuits for a total cost of €104 billion over the period 2012-2021. As the period we considered extended up to 2030, we made the assumption that development would remain similar until 2030. The total investment needs identified over the period 2012-2030 were therefore estimated to be close to € 207 billion.

To obtain a yearly investment profile for our stand-alone TSO, we considered the investments to be constant (in terms of length of circuits built) within each period. The annual investments were then adjusted for the sector-specific inflation[5].

The second scenario (hereby referred to as "EC Roadmap") was based on the Impact Assessment of the Energy Roadmap 2050 published by the European Commission in 2011 (European Commission 2011). Under the Current Policy Initiative scenario, we deducted that TSOs in the ENTSO-E area would face investment needs equal to € 79 billion over the time period 2012-2020, and investment needs equal to € 76 billion over the time-period 2021-2030. As in the previous scenario, the annual investment was considered to be constant in terms of km of circuits within each period. We also considered that the costs per km of new circuits were similar to the ones of the TYNDP.

Renewal of ageing networks

We added to these two scenarios for new projects a single complementary scenario for renewal costs of the existing network. In order to establish the needs for infrastructure renewals, we used the analysis developed in the IEA World Energy Outlook 2011.

The IEA considered that assets are to be replaced when reaching 40 years of age on average. For OECD Europe, the IEA estimated the share of existing networks to be replaced by 2015 to 8%, the share to be replaced between 2016 and 2025 to 21%, and the share to be replaced between 2026 and 2035 to 15%. According to the IEA, this would result in a total cost of

[5] Our calculations were realised using real values. However the inflation specific to investments realised by the TSOs might differ from the more general Consumer Price Index. Based on historical data from France, we obtained an average annual additional inflation of 1.13%. This result was obtained by comparing the TP12 index for construction works in "Electricity networks" (*Réseaux d'électrification*) to the harmonised consumer price index over the period 1996-2012.

$2010 82 billion for the European Union over the period 2011-2035. This figure scales up to a total cost of €2012 76 billion for the ENTSO-E area[6]. Once again, we considered investments to be constant (in terms of length of circuits built) within each of these three periods.

Finally, according to the TYNDP 2012 edited by ENTSO-E, 8,300 km of refurbishment could be avoided between 2012 and 2021 thanks to the investments in new assets. We considered the renewals investments would therefore be reduced by a corresponding constant annual amount all along this period.

Note that while the volumes of investment required for infrastructure renewal are not as important as the ones related to new investments (See Figure 2), they are still too important to be neglected.

3.3. **Calculating tariffs and the TSO revenues**

The revenues of European TSOs are determined by the regulatory framework. In this analysis, it is considered that the regulatory scheme in place is a simple "cost-plus" mechanism: costs are directly passed to consumers, and there are no incentives in place to reduce these costs. While the majority of regulatory schemes in Europe feature different performance incentives, any scheme should at least aim to cover costs and provide a satisfactory return on capital. In the absence of significant efficiency gains, our assumption of a fixed return seems reasonable.

As a result, tariffs are designed in our model to cover depreciation costs, network losses (proportional to consumption) as well as network-related OPEX (proportional to network

[6] The resulting cost per km of these refurbishment investments is relatively smaller than the one for new investments. However this can be explained as a significant part of the costs can be avoided in case of refurbishment.

length), and to provide a return on the regulated asset base. Costs related to the provision of system services are excluded from our analysis. Further details can be found in the appendix.

3.4. Establishing Financeability standards

In order to assess the quality of the financial ratios of the single TSO, we used the methodology employed by the rating agency Moody's to establish the rating of companies developing regulated electric and gas networks (Moody's 2009).

For more clarity, we focused on the two main quantitative credit metrics taken into consideration by Moody's. Each of them account for 15% of the overall rating, and about 40% of the quantitative part of the rating. The adjusted Interest-Cover Ratio is calculated as Earnings before Interest and Taxes (EBIT) divided by interest payments: it reflects the flexibility of the regulated TSOs to pay interests on their debts. The Gearing level is calculated as the volume of debt divided by the total value of the Regulated Asset Base: it represents the loan to value ratio. More details can be found in the methodology published by Moody's (2009).

From a sample of TSOs' financial ratings, we defined two standards in line with typical TSO profiles. In order to reach the **higher standard**, a TSO must achieve a rating of Aa for adjusted Interest Cover Ratio, and a rating of A for gearing (this was the case of REE and Terna in 2009). In order to reach the **lower standard**, a TSO must achieve in our study a rating of A for adjusted Interest Cover Ratio, and a rating of Baa for gearing (this was the case of REN and Statnett in 2009). The corresponding values can be found in

Table 1. Note that both standards correspond to an investment-grade status.

	Adjusted Interest cover Ratio		Gearing	
	Rating	Value	Rating	Value
Higher standard	Aa	≥ 4	A	≤ 60%
Lower Standard	A	≥ 2	Baa	≤ 75%

Table 1: Threshold value for financial ratings by Moody's

In both cases, in order to achieve a given rating, the three-year average value of an indicator must remain on top of the corresponding threshold value. It is therefore possible to be below the threshold for a given year, which is also the methodology employed by Moody's.

4. Results

4.1. Results in the Business-as-usual scenario

Definition of the Business-as-usual scenario

The financing strategy applied in our business-as-usual (BAU) scenario was established after discussions with members of the industry and was designed to reflect actual trends.

In this scenario, there is no injection of external equity into the TSO, and the pay-out ratio is equal to 70%.

Financing gap under current trend in tariffs

Under this scenario, the annual rise in tariffs is limited to the trend observed for consumption-weighted average rise in electricity transmission tariffs observed in the ENTSO-E area between 2009 and 2011. Using the transmission tariffs reports published by ENTSO-E, this maximum rise in tariffs was estimated to be equal to 1.04% in real terms.

Tariffs in the first-year (i.e. 2012) were estimated using the transmission tariffs report of ENTSO-E. They correspond to a nominal pre-tax rate-of-return on assets equal to 7.5%

With a financing strategy based on debt emission, and with a limited rise in tariffs, both investment scenarios led to a severe degradation of the TSO financial status. The constraints related to new investments are such that the TSO financial ratios would correspond to a speculative grade in 2019 for the Extended TYNDP scenario and in 2021 for the EC Roadmap scenario. The financial situation of the TSO would then keep worsening until the end of the decade.

If an investment-grade were to be maintained, it would only be possible for the TSO to develop 47% of the new investments planned in the TYNDP scenario, and 61% of the EC Roadmap scenario.

Note that in any case, it would be impossible with such a financing strategy to achieve the higher standard defined in section 3.4. This is due to the fact that the initial gearing level is already close to the limit of this higher standard. Without further equity, either internal or external, it is then impossible to keep the debt level above the higher threshold.

	Scenario	
	Extended TYNDP	**EC Roadmap**
Share of investments achievable	47%	61%
Average nominal pre-tax ROA	6.1%	6.0%
Average nominal post-tax ROE	7.2%	7.1%
Amount of new debt required by 2030 (Billion Euro)	41	37

Table 2: Share of investment programs achievable under current trends in tariffs

Evolution of tariffs required to achieve the whole investment program

In our BAU scenario, there is no injection of external equity. In order to keep the debt level below a 75% threshold (the limit of our lower standard), the amount of earnings retained by the TSO must be high enough to cover equity needs. As the dividend pay-out ratio is also kept constant in this BAU case, a raise in transmission tariffs would then be mechanically required to increase retained earnings.

We estimated the increase in tariffs[7] required to ensure the financeability of 100% of our first investment scenario (extended TYNDP) to be equal to an annual rate of CPI+3.4%, roughly three times the trend observed in the past years. As the dividend pay-out ratio is kept constant, such an increase in tariffs would result in a significantly higher return on equity (ROE) equal to 12.0% (nominal post-tax). Similarly, ensuring financeability of our second investment scenario (EC Roadmap) would require an annual increase in tariffs equal to CPI+2.1% and it would result in a ROE equal to 8.2% (nominal post-tax).

A detailed decomposition of the rise in tariffs between 2012 and 2030 is provided in Figure 3. Note that the two most important sources of increase are depreciation and interests payments, with rise of dividends only accounting for a minor share of the total increase.

[7] Note that as explained in section 3.3, costs related to the provision of system services are not taken into consideration in this study.

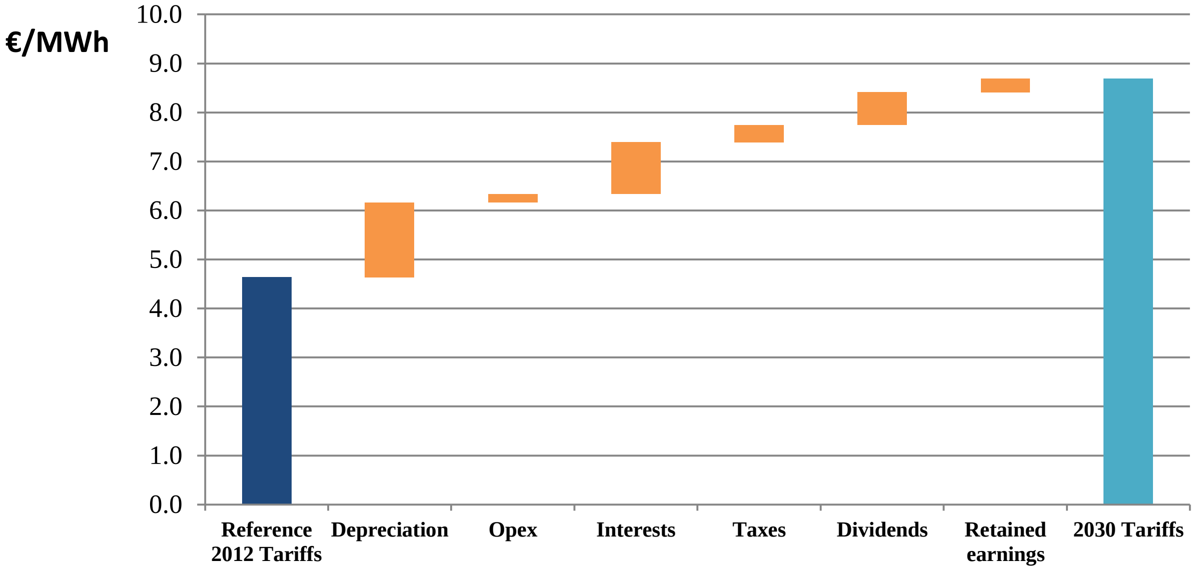

Figure 3: Components of the increase in tariffs required between 2012 and 2030 in order to achieve 100% of the Extended TYNDP investment program

4.2. Results for alternative financing strategies: issue additional equity

In the BAU financing strategy, a significant increase in tariffs will be required in order to cover substantial capital expenditures while keeping debt at a relatively low level. By injecting external equity, it could be possible to conserve the lower standard we defined, at a lower cost for consumers. However, as equity is more costly than debt, a trade-off has to be found between releasing the constraints on financial ratios by injecting equity, and funding investments with cheap debt rather than equity.

Financing gap under current trend in tariffs

		Equity injection as a share of total financing needs			
		0%	**15%**	**30%**	**50%**
Extended TYNDP	Share of investments achievable	47%	50%	54%	61%
	Equity injected by 2030 (Billion €)	0	7	16	32
	Average nominal post-tax ROE	7.2%	6.6%	5.9%	5.0%
EC Roadmap	Share of investments achievable	61%	66%	71%	81%
	Equity injected by 2030 (Billion €)	0	7	15	31
	Average nominal post-tax ROE	7.1%	6.3%	5.7%	4.7%

Table 3: Share of investments achievable in the 'Issue additional equity' scenario

By injecting equity, it will be possible to finance a larger share of investments program while conserving an investment-grade. Yet, as the costs of interests on debt are fixed and lower than the costs of equity, injecting further equity while maintaining tariffs at the same level will result mechanically in reducing the ROE (See Table 4). This would downgrade the attractiveness of investing into the company. The extent to which external sources of equity could be found to finance large-scale investments without increasing tariffs is therefore limited.

Evolution of tariffs required to achieve the whole investment program

By injecting a small share of external equity, it is possible to achieve the whole scale of the investment program while dampening the impact on tariffs. However, higher amounts of equity lead to further expenses in order to provide a satisfactory return to investors.

The optimum is found for relatively small level of equity injections, as illustrated in Figure 4. In order to achieve a 8% post-tax nominal ROE, the minimum annual increase in tariffs is obtained for equity injections equal to 8% of financing needs, which amount to € 10 billion over the time period 2012-2030. In order to achieve a 10% post-tax nominal ROE, the minimum annual increase in tariffs is obtained for equity injections equal to 4% of financing needs, which amount to € 5 billion over the time period 2012-2030.

Note that in any case, a significant rise in tariffs would still be required to achieve the whole scale of the investment programs.

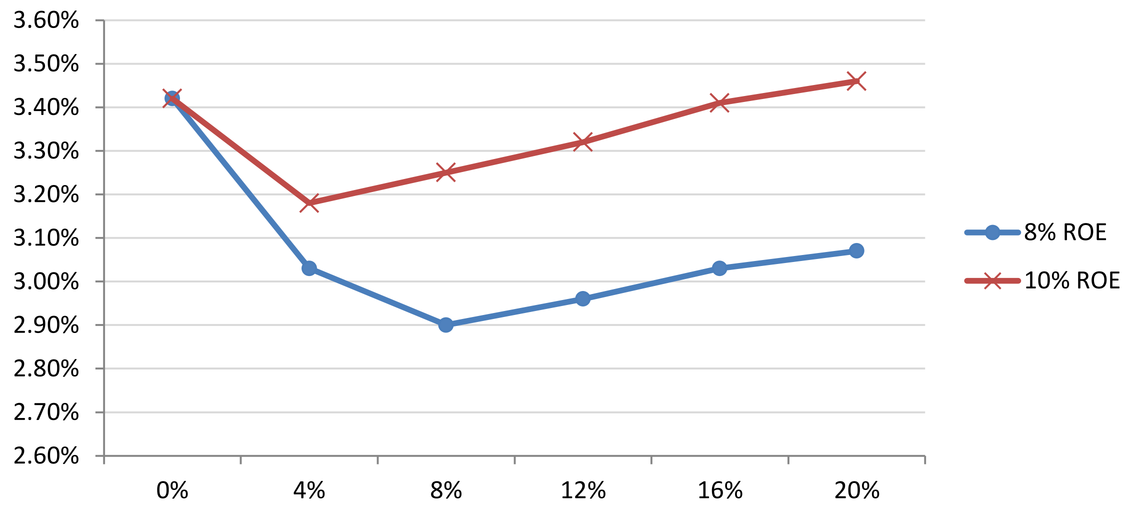

Figure 4: Average annual increase in tariffs required to achieve a given average ROE while conserving investment grade for different levels of equity injection in the 'Extended TYNDP' scenario

4.3. **Results for alternative financing strategies: shift to growth model**

Rather than finding sources of external equity, the TSO can fund investments internally by lowering the dividend pay-out ratio. Note that this would require a change in perception of investors, as TSOs are typically considered as a low-risk investment with a high pay-out ratio.

Financing gap under current trend in tariffs

By retaining earnings, it is possible to achieve a slightly higher share of the investment program for the same level of tariffs (See Table 4). However, for the same level of tariffs, as in the 'Issue additional equity' scenario, retaining earnings mechanically leads to a reduced ROE. In addition, there is also a shift in the nature of the return, as a more significant part of this return is received from holding the share and selling it back instead of receiving a cash dividend. As mentioned in section 2.2, this evolution might not be accepted easily by investors, who could then require a higher ROE. However in this study we neglected such an effect: our results once again constitute a best-case scenario regarding the evolution of transmission tariffs.

		Dividend Pay-out ratio		
		70%	**50%**	**30%**
Extended TYNDP	Share of investments achievable	47%	51%	54%
	Average nominal post-tax ROE	7.2%	6.4%	5.8%
	ROE received as dividends	5.0%	3.2%	1.7%
EC Roadmap	Share of investments achievable	61%	66%	71%
	Average nominal post-tax ROE	7.1%	6.3%	5.6%
	ROE received as dividends	5.0%	3.1%	1.7%

Table 4: Share of investments achievable in the 'shift to growth model' scenario

Evolution of tariffs required to achieve the whole program of investments

By retaining part of the earnings, it is possible to achieve the full scale of investments while limiting the increase in transmission tariffs. As in the previous financing strategy, an optimum has to be found between releasing constraints on financial ratios and paying a higher return on a higher share of equity.

In order to achieve a ROE equal to 8%, the optimum is found for a dividend pay-out ratio equal to 55%. In order to achieve a ROE equal to 10%, the optimum is found for a dividend pay-out ratio equal to 65%. Lower pay-outs lead to an expensive and unnecessarily high use of internal equity financing, while higher pay-outs make higher tariffs necessary to bypass constraints on financial ratios. In any case, the required increase in tariffs will remain relatively high.

Note that while both optimal pay-out ratios are still relatively high, lower dividend pay-out ratio will also result in a lower share of this return being provided under the form of cash dividends, which might not be without consequences on attractiveness to investors.

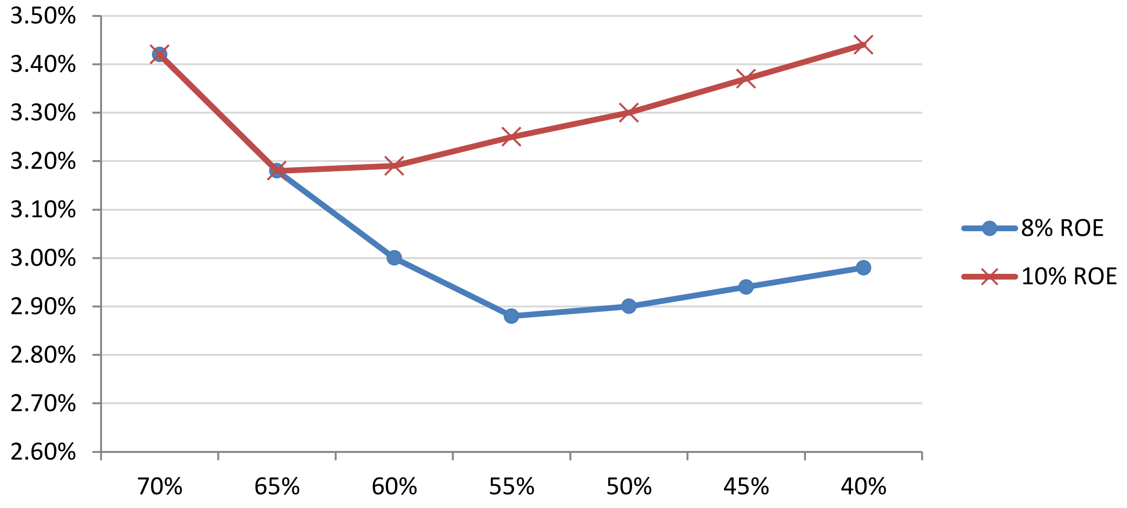

Figure 5: Average annual increase in tariffs required to achieve a given average ROE while conserving investment grade for different levels of dividend pay-out ratio in the 'Extended TYNDP' scenario

4.4. Policy implications of these results

As explained in the introduction, in this article we looked at the issue of financeability of investments in the transmission network with a different angle from existing works. More traditional issues include identifying and allocating costs and benefits, delivering adequate incentives to TSOs, or getting access to debt at reasonable costs[8]. Our analysis revealed that in addition, even if all these challenges were solved, there could still be limits on TSOs' ability to meet the need for investments.

Pure debt financing will lead to a threat that the volume of the debt might become too important for TSOs to face repayments. This situation is reflected in the degradation of key financial metrics. It means that TSOs' ability to meet their obligations would then be vulnerable to small perturbations of the allowed rate-of-return. Financing institutions will only accept such a situation if the regulatory frame is very stable and if returns are guaranteed in the long-term. Rules put into place should in particular minimise the eventuality of a regulatory hold-up.

Besides, according to our results, the business-as-usual financing strategy of TSO will not be the most adequate strategy to finance a significant wave of investments. Consequential savings could be achieved by resorting to alternative financing strategies. The implementation of these strategies will require an evolution of the perception of TSOs owners (mainly public entities), for instance opening TSOs to external sources of equity, and to new kind of investors attracted by growth entities.

In any case, an increase in investment will lead to a significant increase of costs, mostly to cover depreciation and interest payments. Transmission tariffs only constitute a small share of the total costs of electricity for consumers, but a three-fold increase of their annual growth

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[8] A recent discussion on the issues related to Cost-Benefit analysis of transmission projects can be found in Meeus, L., N.-H. Von Der Fehr, et al. (2013). "Cost benefit analysis in the context of the energy infrastructure package."

The topic of incentives for TSOs is for instance dealt with in Glachant, J.-M., H. Khalfallah, et al. (2012). "Implementing Incentive Regulation and Regulatory Alignment with Resource Bounded Regulators."

might nevertheless generate protests. It is important not to sacrifice significant benefits in the long-term to limit spending in the short-term. Similarly, it is key to make sure that the need for important sources of financing is perceived as being associated to real needs and not a result of bad management and costs getting out-of control.

5. Conclusion

In this study, we focused on assessing the ability of European TSOs to finance the substantial capital expenditures forecasted by 2030. As a first approximation, we only considered a first level of constraints at the scale of a virtually unified European transmission network operator. However, even in this 'best-case' scenario, we were still able to identify limits to the volume of investment achievable.

Under current trends in the evolution of transmission tariffs, the investment programs established in the EC roadmap and the TYNDP published by ENTSO-E will be unsustainable in the long-term. To avoid severe degradation of the TSOs financial profile, a significant increase in tariffs will be required.

Alternative financing strategies, such as issuing additional equity, or restraining dividends, could help achieving the whole-scale investment volumes at lower costs for consumers.

However these financing strategies cannot substitute fully to an increase in tariffs. A very radical shift would only allow a slightly higher share of the investment plans to be financed, at the expense of a decrease of the ROE. Injecting capital in the transmission business would not remain attractive under such conditions.

Note that in this analysis it has been considered that the cost of debt and capital were independent from the financing structure. Further constraints could appear when taking their interactions into account.

References

ENTSO-E (2012). Scenario Outlook and Adequacy Forecast 2012-2030.

European Commission (2011). "Energy Roadmap 2050." Impact Assessment. Part **2**(2): 114.

Glachant, J.-M., H. Khalfallah, et al. (2012). "Implementing Incentive Regulation and Regulatory Alignment with Resource Bounded Regulators."

Guthrie, G. (2006). "Regulating infrastructure: The impact on risk and investment." Journal of Economic Literature **44**(4): 925-972.

Helm, D. (2009). "Infrastructure investment, the cost of capital, and regulation: an assessment." Oxford Review of Economic Policy **25**(3): 307-326.

IEA (2011). World Energy Outlook.

IHS CERA (2013). The Energy Investment Imperative: Toward a competitive and consistent policy framework.

Meeus, L., N.-H. Von Der Fehr, et al. (2013). "Cost benefit analysis in the context of the energy infrastructure package."

Moody's (2009). Rating methodology: Regulated Electric and Gas Networks.

National Grid (2012). RIIO-T1 Business plan - Finance Annex.

Neuhoff, K., R. Boyd, et al. (2012). "European Electricity Infrastructure: Planning, Regulation, and Financing."

Roland Berger (2011). "The structuring and financing of energy infrastructure projects, financing gaps and recommendations regarding the new TEN-E financial instrument." Report prepared for the European Commission, DG Energy.

Ruester, S., C. Marcantonini, et al. (2012). "EU involvement in electricity and natural gas transmission grid tarification."

Appendixes

A.1 Details of the calculations

Variable	Description	Unit
$RAB(t)$	Regulated Asset Base at time t	M€
$Inv(t)$	Investments in new projects at time t	M€
$RenewInv(t)$	Renewal investments at time t	M€
$Dep(t)$	Depreciation at time t	M€
$AverageRAB(t)$	Average Regulated Asset Base at time t	M€
T	Accountable life expectancy of new assets	Years
T_0	Accountable life expectancy of existing assets	Years
$g(t)$	Network growth factor at time t	M€ / km
$Network\_Length(t)$	Network Length at time t	km
$Opex\_Network(t)$	Network-related OPEX at time t	M€
UC_OPEX	Network-related OPEX costs per km	M€/km
$Cons(t)$	Energy consumption at time t	TWh
$Cons\_Growth$	Energy consumption annual growth	%
$OPEX\_Losses(t)$	Costs related to losses at time t	M€
$Losses$	Energy losses as a share of energy consumption	%
$Energy\_Price$	Wholesale electricity price	€/MWh
$OPEX\_tot(t)$	OPEX at time t	M€
$Allowed\_ROA(t)$	Allowed maximum return on assets at time t	M€
r	Allowed rate-of-return on assets	%
$Revenues\_Lim(t)$	Maximum revenues due to the limited increase in tariffs at time t	M€

$limit$	Limited annual increase in tariffs	%
$Revenues(t)$	Revenues at time t	M€
$Tariffs(t)$	Transmission tariffs at time t	(€/MWh)
$Revenues\_after\_Debt(t)$	Revenues after debt servicing at time t	M€
$Interest\_Rate$	Interest rate on debt	%
$Debt(t)$	Volume of debt at time t	M€
Tax_Rate	Corporate Tax rate	%
$Taxes(t)$	Corporate taxes paid at time t	M€
$Div(t)$	Dividends emitted at time t	M€
$Payout$	Dividend pay-out ratio	%
$Retained\_Earnings(t)$	Retained earnings at time t	M€
$Fin\_Needs(t) =$	Financing needs at time t	M€
$Equity\_Injection$	Share of the financing needs injected as equity	%
$Equity(t)$	Volume of Equity at time t	M€
$Gearing(t)$	Gearing at time t	%
$Adjusted\_ICR(t)$	Adjusted Interest Cover Ratio at time t	
$Effective\_ROA(t)$	Effective rate of return on assets at time t	%
$Effective\_ROE(t)$	Effective rate of return on equity at time t	%
$Effective\_ROE\_Div(t)$	Effective rate of return on equity paid as dividends at time t	%

Regulated asset base and Depreciation costs

Depreciation $Dep(t)$ is linear in our analysis. We considered that new assets would have a depreciation period T equal to 40 years. This figure is in line with the data provided within the TSO annual reports and the analysis developed in the IEA WEO 2011.

Using TSOs annual reports, it was estimated that the average remaining lifetime of the existing ENTSO-E network was equal to 20 years T_0.

$$Dep(t) = \frac{RAB(0)}{T_0} + \sum_{i=Max(0,t-T)}^{t} \frac{Inv(i) + RenewInv(i)}{T} \tag{1}$$

The regulated asset base $RAB(t)$ increases with investments related to new projects $Inv(t)$, investments for network refurbishing $RenewInv(t)$ and is reduced by depreciation $Dep(t)$. The initial regulated asset base $AverageRAB(0)$ was estimated from TSO reports to be initially equal to € 65 billion.

$$RAB(t) = RAB(t-1) + Inv(t) + RenewInv(t) - Dep(t) \tag{2}$$

<u>Network-related OPEX</u>

In this study, network-related OPEX costs are considered to be proportional to the length of the existing network $Network\_Length(t)$. Based on data from RTE 2011 annual report, OPEX costs UC_OPEX were estimated to be equal to 0.014 M€2012/km. In this study, we assumed that no efficiency gain would be achieved by the TSOs.

$$OPEX\_Network(t) = Network\_Length(t) \times UC\_OPEX \tag{3}$$

The initial length of the electricity transmission network $Network\_Length(0)$ was estimated to 305,000 km by ENTSO-E within the TYNDP 2012.

In order to calculate the growth of the network length, we employed a growth factor g equal to 1.90 M€2012/km for new investments, based on the figures provided within the TYNDP framework.

$$Network\_Length(t) = Network\_Length(t-1) + \frac{Inv(t)}{g(t)} \qquad (4)$$

Network losses

In our analysis, network losses are directly proportional to the total energy consumption $Cons(t)$. The ratio was taken from the ENTSO-E memo 2010, which indicated a ratio $Losses$ equal to 1.5% of energy consumption for network losses at the scale of ENTSO-E.

The initial consumption $Cons(0)$for the ENTSO-E area was extracted from the ENTSO-E

$$OPEX\_Losses(t) = Cons(t) \times Losses \times Energy\_Price \qquad (5)$$

System adequacy retrospect 2011 indicating a consumption of 3320 TWh in 2011. For annual consumption growth $Cons\_Growth$, we used a value provided within the *System Outlook and Adequacy Forecast* edited by ENTSO-E (2012), indicating an annual growth of 0.77% for electricity consumption over the next decade.

$$Cons(t) = Cons(t-1) \times (1 + Cons\_Growth) \qquad (6)$$

For wholesale electricity prices $Energy\_Price$, we used a constant real value of 55€/MWh, in line with current prices (See for instance the Quarterly report on European electricity markets edited by DG energy). Note that there are high uncertainties regarding the evolution of electricity prices but that their impact on TSOs' financial ratios is limited as costs are passed through to consumers.

Return on assets and tariffs

The maximum TSOs revenue $Allowed\_ROA(t)$ is the product of the allowed rate-of-return r and of the value of the regulated asset base $AverageRAB(t)$.

$$AverageRAB(t) = RAB(t-1) + RAB(t) \quad (7)$$

$$Allowed\_ROA(t) = AverageRAB(t) \times r \quad (8)$$

In the case when the increase in tariffs is not limited, tariffs are calculated so that they are equal to the sum of passed-through costs (Network-related OPEX $OPEX\_Network(t)$, network losses $OPEX\_Losses(t)$, and depreciation costs $Dep(t)$) and of the allowed-return. In the case when the increase in tariffs is limited to the current trends $limit$, the return provided to the TSO is reduced in consequence to $Revenues\_Lim(t)$.

$$Revenues\_Lim(t) = Revenues\_Lim(t-1) \times \frac{Cons(t)}{Cons(0)} \times (1 + limit)^{\ t} \quad (9)$$

$$OPEX\_tot(t) = OPEX\_Network(t) + OPEX\_Losses(t) \quad (10)$$

$$Revenues(t) = Min(Revenues\_Lim(t), Allowed\_ROA(t) + OPEX\_tot(t) + Dep(t)) \quad (11)$$

$$Tariffs\ (t) = \frac{Revenues\ (t)}{Cons(t)} \quad (12)$$

Interests on debts

We picked a standard interest rate $Interest\_Rate$ equal to 4.0%. The initial gearing (at the beginning of 2012) was calculated from TSOs annual reports and is equal, for an aggregated TSO of all the members of the ENTSO-E, to 58.9%. The corresponding initial volume of debt $Debt(0)$ is hence equal to € 38 billion.

$$Debt\_Servicing(t) = Debt(t-1) \times Interest\_Rate \quad (13)$$

$$Revenues\_after\_Debt\_Servicing(t) = Revenues(t) - Debt\_Servicing(t) \quad (14)$$

Corporate tax rate

The central assumption for corporate tax $Taxes(t)$is a weighted average of the different corporation tax rates existing in Europe[9] (data for 2012 were extracted from the KPMG website). As EBIT is strongly related to the regulated asset base in our model, the weights employed were the national network lengths.

The resulting weighted-average corporate tax Tax_Rate was 27%.

$$Taxes(t) = Max(0, Revenues\_after\_Debt\_Servicing \times Tax\_Rate) \quad (15)$$

$$Revenues\_after\_Taxes(t) = Revenues\_after\_Debt\_Servicing(t) - Taxes(t) \quad (16)$$

Dividends

Dividends are calculated as a fixed proportion $Payout$ of the revenues after interests and taxes $Revenues\_after\_Taxes(t)$.

$$Div(t) = Payout \times\ Revenues\_after\_Taxes(t) \quad (17)$$

Financing needs

The first source of financing is the share of revenues after taxes that is not used to pay dividends $Retained\_Earnings(t)$.

The remaining financing needs $Fin\_Needs(t)$ are covered through equity $Equity\_Issue(t)$, to the extent of a constant ratio $Equity\_Injection$ of the financing needs. The rest is covered through debt emission.

$$Retained\_Earnings(t) = Revenues\_after\_Taxes(t) - Div(t) \quad (18)$$

[9] Corporate taxes strongly vary (from 10% to 34%) among the countries concerned.

$$Fin\_Needs(t) = Inv(t) + RenewInv(t) - Retained\_Earnings(t) - Dep(t) \quad (19)$$

$$Equity\_Issue(t) = Fin\_Needs(t) \times Equity\_Injection \quad (20)$$

$$Debt(t) = Debt(t-1) + Fin\_Needs(t) - \ Equity\_Issue(t) \quad (21)$$

$$Equity(t) = Equity(t-1) + Retained\_Earnings(t) - \ Equity\_Injection(t) \quad (22)$$

<u>Financial ratios</u>

The two main indicators we employed are based on definitions provided in Moody's (2009).

$$Gearing(t) = \frac{Debt(t)}{Debt(t) + Equity(t)} \quad (23)$$

$$Adjusted\_ICR(t) = \frac{Revenues}{Debt\_Servicing(t)} \quad (24)$$

Different returns are also taken into account in our analysis.

$$Effective\_ROA(t) = \frac{Revenues(t)}{AverageRAB(t)} \quad (25)$$

$$Effective\_ROE(t) = \frac{Revenues\_after\_Taxes(t)}{\frac{Equity(t-1)+Equity(t)}{2}} \quad (26)$$

$$Effective\_ROE\_Div(t) = \frac{Div(t)}{\frac{Equity(t-1)+Equity(t)}{2}} \quad (27)$$