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Practical Implementation of Price Regulation in Energy Sector

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Declaration:

Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted for any academic degree.

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ENERGEETIKA. ELEKTROTEHNIKA. MÄENDUS D75

Hinnaregulatsiooni praktiline rakendamine energeetika sektoris

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TTÜ KIRJASTUS

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ABBREVIATIONS AND SYMBOLS

BDM	benefit distribution method
CAIDI	customer average interruption duration index
CAPEX	capital expenses
CEER	Council of European Energy Regulators
CHP	combined heat and power
CPI	Consumer price index
DH	district heating
DSO	distribution system operator
EBITA	earnings before interest taxes amortisation
EBITDA	earnings before interest taxes depreciation amortisation
ECA	Estonian Competition Authority
ERRA	Energy Regulators Regional Association
EUR	European monetary unit euro
GWh	Gigawatt hour
HC	historical cost
IERN	International Energy Regulation Network
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LRAIC	long run average incremental cost
LRAIC BU	long run average incremental cost bottom up
MWh	Megawatt hour
NPV	net present value
OPEX	operational expenses
PV	present value
PV	present value
RAB	regulatory asset base
RC	replacement cost
ROE	return on equity
ROIC	return on invested capital
RoR	rate on return
RPI	retail price index
RPI-x	retail price index minus x
SAIDI	system average interruption duration index
SAIFI	system average interruption frequency index
TSO	transmission system operator
WACC	weighted average cost on capital

Unit prefixes
k kilo, 10^3
M Mega, 10^6
G Giga, 10^9
T Tera, 10^{12}
P Peta, 10^{15}

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1. Introduction

1.1. Motivation of the research

In the conditions of competitive market the unit price forms on the fundamental basis of both supply and demand. In the case of market dominance (monopoly) no competition occurs and the task to simulate competition is tasked to regulator. For example, in the condition of free electricity market the unit price of electricity is monitored but there is no argumentation which methodology should be preferred to calculate unit price. However, in the case of monopoly, it is essential to choose proper methodology of price regulation in order to gain the best result.

Economist have long recognized that the market outcome for natural monopolies leaves much to be desired. In particular price is higher and output is lower than the social optimum. Recognition of this problem, among other issues, has led to a long history of attempts to regulate natural monopolist and to vast literature to discussing the problems of attempts at regulation [1].There are two main type of monopolies: natural monopolies like networks, where the competition is not achievable and ordinary monopolies, where the monopoly position may disappear, in case of removing administrative restrictions or other market developments. In energy sector the electricity and gas networks are typical natural monopolies, where electricity and gas production or supply are the ordinary type of monopolies. That means, by selecting proper price regulation methodology, it is possible to reach the result which is close to the social optimum, in the case of which the service provided by utility has the highest quality for minimum price. The same principle is one of the main targets in energy strategies of different countries to reach the highest quality of service for minimum price.

Since the fair price can be formed on competitive market only, it is important to analyse whether the open competitive market can be introduced instead of monopoly.

As mentioned before the types of monopolies may categorize as natural or ordinary monopolies. In the case of natural monopoly the competition would result to wasteful duplication of resources and higher costs. Any natural monopoly involves operation of substantial infrastructure component with respective economies of scale and decreasing average costs, making it less costly for a society to have such market served by a single firm instead of many [2], [3]. In some of the cases like air traffic control centre or power dispatch control centre, the duplication of services is impossible due to the technical safety reasons. Typical natural monopolies are any type of networks like power or gas networks. The distribution of drinking water and collection of wastewater is generally understood to be a natural monopoly because its output can be produced at least cost by a single firm [4]. The power network and distribution of drinking water and collection of wastewater are natural monopolies in the term of service supplied and the modern life standard or doing of business are impossible without the services described. Vice versa, a large number of modern households or business facilities are functioning without gas supply, where for example heat can be supplied e.g. by district heating.

Concerning the technological level of power systems, it is reasonable that a customer uses the service provided by the network instead installing individual power generation facility. Modern technologies, such as the solar panel, gas or liquid fuel engine, battery, power inverter, etc. are available, enabling the customer to rely on individual power supply. However, disconnection from power networks can be effective only in case if installation of individual power generation facility guarantees lower price for the customers. This type of technical solution can be effective in the case of power supply of a single house located away from existing power network. By calculation of all costs related to the power network: connection fee, network tariff, electricity price and all kind of subsidies and state taxes, installation of individual power generation facility can be economically more effective than connection to the existing power grid.

A good example of technology developments in telecom sector can be introduced. Some 15 to 10 years ago the telecom service providers had been natural monopolies and strong type of price regulation was introduced. Due to the rapid technological development, the monopoly status of the telecom utilities is disappearing. On the open market conditions, customers are free to make choice among different service providers, both fixe line and mobile companies. On the open market condition there is no need to regulate the prices. Depending on the concrete market, there can be transit service providers possessing market dominating power, but regarding the Estonian telecom market as an example, competition among transit providers exists as well. The conclusion is that on Estonian condition there is no direct need for economic regulation of the telecom sector any more. The possible misuse of market dominating position on this market could be solved according to the general competition law. The bottom line is that rapid technological changes have caused dramatic changes in the economic regulation as well. Thus, it is important to know that technological developments may change the monopolies and it is important to consider this fact in forming the condition for economic regulation.

Historically, the water supply is one of the oldest or so called classical monopolies. For example, the history of water supply system of the city of Tallinn dates back to 1345 [5]. Theoretically, it is possible to install a single well and water treatment system for each of the buildings or for separate building groups. But in practice, the idea cannot be realized due to the environmental restrictions. The single way to provide the water service is the centralised water and wastewater system, which means that the water utility is in market dominating position. Also, it is only theoretical option to establish parallel water systems in rural areas with high population density or to establish some kind of competition among different water treatment plants.

As mentioned before, all kind of networks are in the position of natural monopoly, even in the case where the customer can replace a specific good or service provided by specific infrastructure. The natural gas supply can be highlighted as an example. The gas network is natural monopoly, especially for the gas supplier, because this is the single option to provide gas to the customer. From customer´s point of view, it depends on the situation. If the customer is using gas for heating but other options, such as like district heating, electrical heating, heat pump, LPG etc., are available to get the service for similar price, the customer is free to select alternative supply sources, and gas as commodity is not in monopoly situation.

The nature of ordinary monopoly is the fact that market can be liberalised and the monopoly situation is not granted. A good example is the liberalisation of electricity and gas markets in the EU, where the prices of networks are regulated, but in generation and supply there exists free competition. There are been dramatic changes in market design, where 20 years ago both generation and supply have been in the position of administrative monopoly [6]. The main characteristic of the administrative monopoly is that competition is prohibited by law. For example, according to the Estonian Electricity Market Act [7] the customer was obligated to buy the electricity from the supplying network operator. This clause was annulled by the full market liberalisation on 1 January 2013.

The administrative monopoly can be characterised by the fact that the market dominating position is granted by the law and the competition in specific sector is not allowed. In Estonia, the district heating is an example of the administrative monopoly in the energy sector, where the local authority has the right to establish district heating zones on its territory and the use of alternative heating sources is not allowed there [8].

The ordinary monopoly may exist without any grant issued by the law. In this case, there is no administrative monopoly. This can be due to the small size of the market, geographical location, or historical reasons, which make the entrance to the market impossible for new competitors. Also the entrance to the market may be too difficult, even if the circumstances for such market entry are provided. A good example of a non-administrative market in the Baltic States and Finland is the natural gas market. In Estonia, it was stated by the first ever Energy Act, valid since 1998, that all commercial gas customers are eligible, which means the permission to consume natural gas from each of competing gas supplier [9]. Since 2001, the market was even more liberalised and some specific clauses, restricting the gas import, were removed from the legislation. The Natural Gas Act was amended again on 1 July 2007, when the natural gas market was fully liberalised, also including all household customers. Those are explicit signals that the goal of the energy policy was to liberalise the market. But in fact the market was not open until 2015, due to the geographical reasons (the single gas supply source was from Russia). The big changes on gas market happened in 2015 where the LNG terminal was opened in Klaipeda, Lithuania, offering alternative gas supply from Russia.

Another example of non-administrative monopoly in Estonia are the cash handling services, where the company G4S is in the market dominating position [10]. This is very similar to the history of the gas market: no political or legislative approach has been applied to establish the monopoly on this specific sector. The market dominance exists because of objective reasons, like size of the market, high financial barriers to market entering, and the very specific character of the service, causing high quality requirements.

As mentioned before, the district heating is subject of administrative monopoly in Estonian condition, where the customer cannot choose among alternative heat sources like gas heating, electrical heating or heat pumps. Additional issue is the status of the district heating network, whether the network is a monopoly even in the case where there is no district heating zoning and the customers are free to select among alternative heating sources. Since the district heating network is very similar to other infrastructure like electricity, gas or water network, it can be considered as natural monopoly where competition would result to wasteful duplication of resources and higher costs. Similar to other natural monopolies, the district heating network involves an operation of a substantial infrastructure component with respective economies of scale and decreasing average costs, making it less costly for a society to have such market served by a single firm instead of many [2]. It is perspicuous that the construction of parallel district heating network in a modern city with high population density is not realistic. Even if the district heating is not an administrative monopoly and alternative heating sources are available, the network remains on monopoly position for an independent heat supplier (CHP plant for example). Without third party access to the network, the independent heat supplier is isolated from potential customers. The third party access to the natural monopoly is regulated according to the general competition law.

In addition, the importance of the local status of the district heating network, where the size of the market is restricted, has to be considered. Definition of market is extra broad in the electricity or gas market; in opposite, the district heating market is defined by concrete municipality. Defining of present electricity market in Estonia, it should be considered as a part of larger Scandinavian-Baltic electricity market. In future, the similarities with the gas market will occur as well, as gas connections between Estonia and Finland and also Poland and Lithuania will be completed. Considering the district heating market, if there is surplus in generation in Tallinn (the capital city) but deficit in Tartu (the second largest city), it is impossible to sell this surplus, due to the fact that there is no connection of separate networks. The simple economic test indicates, that in this case is more reasonable to build additional generation capacity instead of building a pipeline. It is important to consider facts like these while designing different energy markets, as the electricity and gas markets have steeply different character compared to the heating market.

Summing up, it is clear that economic regulation of monopolies is necessary. As mentioned before, there is a clear option to replace the ordinary monopoly, especially an administrative one, but natural monopoly also still exists, where introduction of free competition is unrealistic or even impossible. The necessity for economic regulation is mostly associated with the market failure of non-competitive markets where effective competition is by definition the scarcest. Theory holds that such an environment leads to socially sub-optimal prices, production volumes and income redistribution [2]. If the natural monopoly is not regulated, it may cause too high costs included to the price of the service, too high prices to customers and restrictions of third-party access to the network [11].

There are two main theories of regulation: "public interest theories of regulation" and "private interest theories of regulation" [12].

The "public interest theory of regulation" assumes that regulators have sufficient information and enforcement powers to effectively promote the public interest. This tradition also assumes that regulators are benevolent and aim to pursue the public interest. Fundamental to "public interest theories" are market failures and efficient government intervention. According to these theories, regulation increases social welfare.

The "private interest theories of regulation" proceeds from different assumptions. Regulators do not have sufficient information with respect to cost, demand, quality and other dimensions of firm behavior. They can therefore only imperfectly, if at all, promote the public interest when controlling firms or societal activities. Within this tradition, these information, monitoring and enforcement cost also apply to other economic agents, such as legislators, voters or consumers. And, more importantly, it is generally assumed that all economic agents pursue their own interest, which may or may not include elements of the public interest. Under these assumptions there is no reason to conclude that regulation will promote the public interest. "Private interest theories" explain regulation from interest group behavior. Transfers of wealth to the more effective interest groups often also decrease social welfare. Interest groups can be firms, consumers or consumer groups, regulators or their staff, legislators, unions and more. The "private interest theories of regulation" therefore overlap with a number of theories in the field of public choice and thus turn effectively into theories of political actions. Depending on the efficiency of the political process, social welfare either increases or decreases [12].

The conclusion is that the “public interest theory of regulation” assumes that economic regulation is necessary and guarantees customers´ welfare. However, the “private interest theories of regulation” set a number of conditions to be fulfilled in order to achieve any positive effect of economic regulation. The main condition to achieve the positive result of economic regulation depends on the quality of the regulatory institution, like independence of regulatory institution, adequate financial resources available etc. Those problems are widely solved in the EU context where the internal directive of electricity and gas markets [13], [14] sets very clear requirements on financing and independence of the regulatory institutions. Therefore the problems arisen by the private interest theory of regulation are in large scale eliminated by the EU legislation.

Therefore, there is no dispute that the necessity for economic regulation exists. Even if an EU member state decides to finish the price regulation in some sectors like district heating or water supply, the price regulation of electricity and gas networks is mandatory according to the EU directives. Therefore, the topic of price regulation remains essential and ascertain the optimal price regulation methodology is ultimately important.

The motivation of the research is to analyse the practical experience and the results of price regulation in Estonia in the last 15-years period, since 2000. To analyse and compare the pros and cons of different regulatory methods, to analyse the risks associated to the implementation of different methods. To carry out conclusions on the investigated materials, and to propose the most suitable optimum which is balancing the interest of both customers and companies. So the thesis can be regarded as helpful practical material to assist regulators in applying the most efficient way of economic regulation.

1.2. The aim and research tasks

The first objective of the price regulation should be sustainability — the regulated company must be able to finance its operations and make any required investment, so that the company can continue operating in the future [15]. From customers´ perspective, high quality of the service provided and minimum price are the expectations. It is clear that the level of the service must be the optimal one. Theoretically, it is possible to reach a theoretical maximum of the quality by building double or triple transmission lines, exceeding the n-1 criteria. It is also possible to build double distribution lines or a backup generator to each of the power customer. But one must agree that this type of technical solutions are theoretical only.

The quality norms are usually set by the legislation and not by the regulator. In Estonian case, the power quality norms are set in the Grid Code, approved by the governmental decree [16]. Depending on the legislation of the specific jurisdiction, the task of the regulator is to select or to assist in selection of the regulatory methodology which corresponds to the main objective of the price regulation. From shareholders´ point of view the reasonable rate of return on capital invested shall be guaranteed. The summary of different regulatory objectives indicates, that the main criteria of selecting of regulatory methodology is to reach the maximum efficiency where the customers´ and the companies´ interests are in balance.

The different price regulation methods are intervened and the so-called pure or classical Rate of Return (RoR) or RPI-x does not exist in practical price regulation. The elements of both methodologies are used in practice, adding the principles of LRAIC bottom up methodology[1]. The RPI-x methodology is often called as incentive type of regulatory method. In a simplified approach, the classic type of RPI-x seems to be the most desirable, due the fact that it is oriented to efficiency gains. But in reality there is a critical level of efficiency for each company.

Another issue is the cost of economic regulation. In the case of a small number of large size utilities it is efficient to apply an advanced and costly regulatory system. It pays off due to the fact that the efficiency for the society is higher than the resources spent on regulation. Another issue is the large number of small utilities, like the situation of regulated sectors in Estonia.

The effect of economic regulation on the level of whole society is analysed by Hertog [12], [17]. It is important to find the optimal level. From a certain level or a so called optimal point, the additional resources spent on regulation will give no additional effect, but in contrast to desired result will be an additional burden for the society. The core of this basic framework is captured in the following diagram on Figure 1.1.

Imagine an unregulated natural monopoly firm supplying public utility services. The firm makes supernormal profits, charges different prices to different consumer groups and does not supply services to high-cost consumers in rural areas. Economic theory predicts an inefficient allocation of resources. Without regulatory intervention these costs are at its highest at the point where the EL-curve intersects with the vertical axe (intersection not visible). Intervening in the market results in a decline of these welfare cost. The stronger the level of intervention, the lower the welfare losses in the private sector will be. The naïve "public interest theory of regulation" for example, would explain 'fair rate of return' regulation from the presence of the natural monopoly firm. Prices must

[1] The different price regulatory methods are described in details in chapter 2.

decline and production increased until societal resources are allocated efficiently. The more complex "public interest theories of regulation" take the costs of regulatory intervention into account. The more a regulator intervenes in the private operation of the firm, the higher the intervention costs will be (curve IC). The regulator must have information on cost and demand facing the firm before efficient prices can be determined. There will be compliance cost for the firm in terms of time, effort and resources. It will have to comply with procedures, adapt its administration and incur productivity losses.

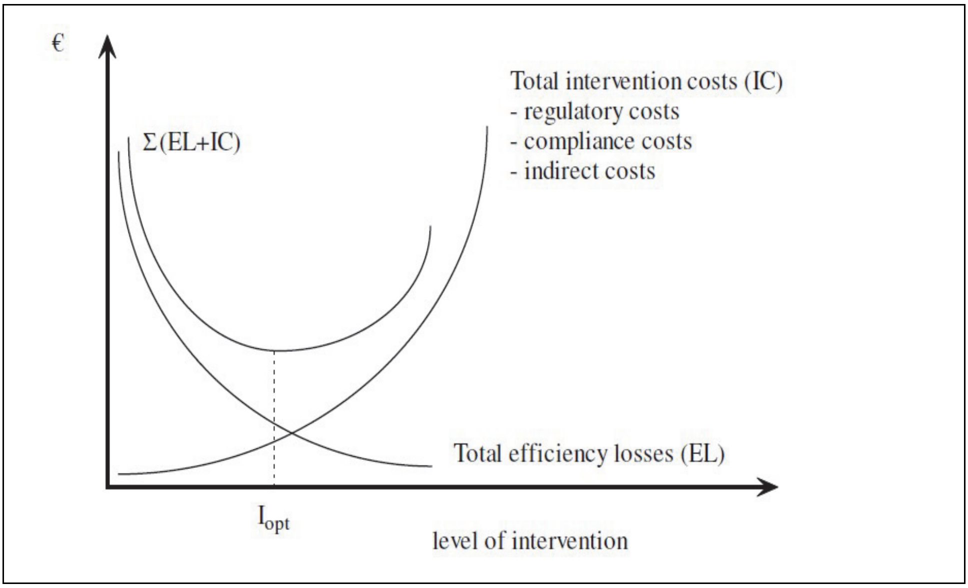

Figure 1.1. Optimal level of welfare loss control

Once put into practice, the cost of monitoring firm behaviour and enforcement of the regulations arises. It is to be expected that the firm will behave strategically and conceal or disguise any relevant information for the regulator. Furthermore, indirect costs are to be expected. The less profit the firm makes, the lower the effort in decreasing production cost or in developing new products and production technologies. Also less tangible effects are predicted. Regulatory intervention makes private investments less secure: risk premiums rise, investments decline and economic growth will slow down, etc. The regulator is aware of these costs and has several options to choose from: it could for example regulate prices or profits or a combination of both. Whichever it chooses, there will be different intervention costs and different consequences for static and dynamic efficiency. The optimal level of intervention (I_{opt}) implies trading off resources allocated to increasing levels of regulatory intervention and decreasing levels of inefficient firm behaviour. Complicating the policy options further, for politicians there are alternatives to the regulation of prices, profits, service levels, etc. The legislator could also decide to franchise an exclusive right to operate the market or erect a public enterprise to maximize welfare. Again, these institutions require different cost of intervention and have different effects in terms of static and dynamic efficiency or other policy goals. Amongst others, they differ with respect to the informational requirements, the administrative costs and the burden for the private sector including the cost of errors, distributional effects, governance, accountability, risks of capture and corruption, and more. The public interest theories of regulation thus basically assume a comparative analysis of institutions to have taken place to efficiently allocate scarce resources in the economy. Equivalent reasoning applies to the field of social regulation. Imagine that lifting weight, for example a patient in a hospital or cement in the construction sector, creates back trouble or even work disability. Employees are often not very well aware of the risks they run, and even if they do they will find it difficult to deal with small risks such as 0,0001. The costs involved however, may be considerable: medical costs, lost earnings and risk of injury and pain, and consequences for relatives and friends. The inefficiency in the allocation of resources in the absence of regulation is again depicted by the curve EL. A regulator may decide on, for example, regulating maximum weights. She needs to identify the potential risk involved, how this risk varies with exposure to lower weights and different circumstances. Then the maximum allowable weight lifting must be determined. The regulator knows that increasing levels of intervention or standard setting will increase costs (curve IC). The more detailed and precise, the higher the regulatory costs. The higher the weight standard, the higher also compliance costs will be: more nurses in the hospital and increasing use of capital equipment in the construction sector. Indirect costs will also increase with the level of intervention: there will be a lower ratio of input to output and substitution between now comparatively higher priced labour and capital equipment. Not only will employment decline but also the speed of technical change. The setting of the standard lowers the incentive to seek for technologies to further prevent lifting costs below the standard. Again, the regulator is aware of these costs and has several options to choose from. It could set an output or performance standard limiting the number of incidents. It could prescribe an input standard by specifying the use of certain care technologies or machinery. Alternatively, it could set a target standard that imposes criminal liability for certain harmful consequences or it could impose process standards obligating procedures to have the firm identify the risks and deal with them. All these forms of intervention have different intervention costs and compliance costs and different effects in terms of static and dynamic efficiency or other policy goals. The optimal standard or level of intervention depicted in the diagram is I_{opt}. And again, complicating matters further, for political decision makers there are alternative institutions to regulation, such as providing the firm and the employees with information and have private law and tort liability to deal with any costs involved or, in cases of severe dangers to life and health, a prohibition to use of certain techniques, equipment or materials. [12], [17].

As mentioned before, in the case of large number of small utilities, the cost of regulation shall be especially considered by selecting of regulatory methodology. For example, in Estonian case the number of regulated utilities is 260 and the number is increasing due to the fact that the DH and water sector are regulated by the Competition Authority since 2011 and not all utilities regulated by local authorities before, are not submitted the tariff application [18], [19], [20], [21], [22], [23], [24]. The annual turnover of the smallest companies may not exceed 50 000 €. It can be assumed that by applying of economic regulation, it is possible to save 5% for the society. In this case, it is reasonable to apply the regulation, if the costs for that are not exceeding 2,500 € per annum. However, it is clear that within this budget is impossible to introduce the advanced type of RPI-x regulation. From utilities point of view, the administrative burden of selecting of regulatory methodology shall be considered. If a large utility is on equal level with regulator to present data or to have discussions, a small utility suffers lack of resources for that. Beside direct administrative costs, also indirect costs related to the regulation exist, like the cost of capital. The level of regulatory risk is included to the cost of capital [25]. This shall be considered by selecting of regulatory methodology.

Concerning regulation of a large number of small utilities, there is a good example from the Estonian district heating sector. The district heating is not natural but administrative monopoly in Estonia. The number of regulated utilities is 142, including 113 network operators and 29 heat generators [23], [24]. The price of each of utility shall be fixed by the energy regulator (Estonian Competition Authority). According to the market analyses prepared by the Competition Authority [20], the market share of larger utilities (with annual sales more than 10,000 MWh) is 93%. This corresponds to 27% of utilities. It means that the market share of small utilities is 7% only, which corresponds to 73% of utilities. Another trend is correlation of efficiency to the size of the utility, presented on. There is a clear trend, that larger utilities are more efficient than the small ones.

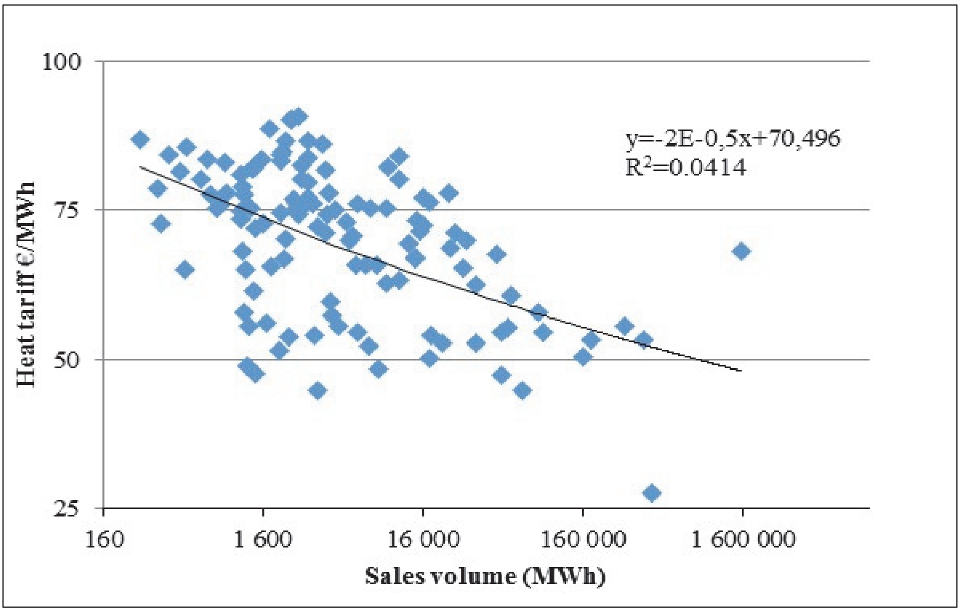

Figure 1.2. Correlation of heat price to the size of the utility.

The result of the study indicates that the selection of suitable regulatory methodology is important in the case of a large number of small utilities.

The aim of the doctoral thesis is to analyse the use of different regulatory methodologies and to find the suitable option to apply in condition of a large size of small scale utilities, taking into account the Estonian 15-years' experience in implementation of price regulation. The results of the study can be used in practical implementation of price regulation in Estonian Competition Authority and by the other energy regulators as well. The study is looking for answers for the following questions:

1. What are the results using classical type of regulatory methods.
2. What are the risks associated to using different regulatory methods in practice.
3. What type of regulatory method is suitable for a large number of small size utilities which possess restricted administrative resources.

To achieve the aim of the study, the following research tasks are set up:

1. To explain the concept of classical type of regulatory methods Rate of Return (RoR), RPI-x; Long Run Incremental Costs Bottom Up (LRAIC BU) and to provide an overview of the theoretical implementation of those methods;

2. To explain the concept of regulatory methods implemented in practice by analysing the experiences implemented by different regulators.
3. To explain the concept of calculation of Regulatory Asset Base (RAB) by analysing the experiences implemented by different regulators (the concept of calculation of RAB in practice).
4. To introduce the Estonian experience in implementation of price regulation by a large number of small size utilities.
5. To estimate the risk associated by implementation of different regulatory methods.

1.3. Methodology

Theoretical part of the research consists of public and private interest theories of regulation. The "public interest theory of regulation" assumes that regulators have sufficient information and enforcement powers to effectively promote the public interest. The "private interest theories of regulation" assumes that regulators do not have sufficient information on company's costs and other input data for tariff calculations and can therefore only imperfectly, if at all, promote the public interest when controlling firms or societal activities. The discrepancy between those theories is that according to the "public interest theories of regulation" the implementation of price regulation has a positive impact on society. According to the "private interest theories of regulation" the financing of economic regulators is just wasting of society's financial resources. Regardless of the theoretical approach the implementation of price regulation in electricity and gas sectors is the commitment of each EU member state.

The different price regulation methods are introduced, including ex-post and ex-ante methods. From ex-ante methods of price regulation the following are analysed in details: 1) the so-called pure or classical rate of return (RoR); 2) the classical RPI-x (incentive type of regulatory method) and 3) the LRAIC "bottom up" method. In addition to the theoretical implementation of RoR and RPI-x the implementation of those methods in practice is analysed. Strengths and weaknesses of all methods are clarified by analysing the results of each type price regulation method, as described in international and domestic literature. The impact and results of different regulatory models is calculated by using of economic models. The different methods for determination of the value of regulated asset base (RAB) are analysed in details: 1) the Historic Cost method; 2) the Replacement Cost method; 3) the LRAIC "bottom up method" and the Market Value Method. The impact and results of different RAB valuation methods is calculated by using of economic models. In the last case, the *ex-post-facto* method is combined with these mentioned methods. The results of price regulation in Estonia are followed in 15-years period.

Quantitative methods of econometric analysis is applied by including source critical data on regulated utilities in Estonia. The correlation method used for heat pricing is an example. To realise the research, the next set of theoretical framework has been composed, first-hand applying the methods of qualitative research. Under the conditions of pragmatically oriented final result to be found, mixed questions are used to analyse the different aspects related in practical use of different price regulation methods, analysing both so-called classical RoR and RPI-x and those methods implemented in practice, including practical results of 15-years used incentive type of RoR methodology in Estonia. Comparison of the results of econometric and indirect methods of assessment of effects are used to clarify the credibility of existing indirect estimates. The data have been obtained from various sources. Important sources are annual reports of different utilities and different studies conducted by the Estonian Competition Authority. In addition to these, the data obtained from Statistics Estonia are used.

2. Different price regulation methods

2.1. Introduction to different methods

The regulatory methods can be divided to two main categories: *ex-ante* and *ex-post* [26]. By using of ex-ante regulation, the prices are fixed by the regulator. By using of ex-post regulation, the prices or fees are applied by the company without any coordination by the regulator and the regulator may control later whether these prices or fees meet the criteria set by the legislation. At present, the Natural Gas Act [27] in Estonia has applied such a regulation, whereby the market dominant gas company must base its prices on the costs and earn justified return of the investment made. A similar regulation is applied in the district heating sector in Finland and Sweden, where the companies apply prices designed by themselves and the regulator has the right to control their justification [28]**.** The same type of ex-post price control is implemented by the Competition Act [29]. According to the competition regulation, the abuse of the dominant position is prohibited, including establishing or applying unfair prices or other unfair trading conditions. In Estonia there are several practices by implementation of the Competition Act in cases of abuse of the market dominating position by unfair pricing [10], [30].

The ex-ante methods can be divided in three main categories:

1. Rate of return (RoR)
2. RPI-x
3. Long Run Incremental Costs Bottom UP (LRAIC)

According to different sources the above mentioned regulatory methods have different definitions. The RPI-x is defined as incentive type of regulation [15] [1] [4]. The definitions price cap, price cap with cost pass through and revenue cap have been used to characterise the RPI-x methodology [31]. The term RPI-x has been used in this research for this methodology.

The RoR and RPI-x are more or less based on existing network installations and to the historical costs associated to the operation of those existing assets. In contrast to RoR or RPI-x the LRAIC BU model is based on hypothetical system [25]. By using of LRAIC the only data corresponding to the existing situation are the demand and capacity and geographical location of the existing customers. That means that the basic approach of those methods is totally different.

Furthermore, a method can have different subdivisions, depending on which economical risks are left to be handled by the company. From companies´ point of view, the profit is the main result of the regulation. The profit is dependent on different inputs [31]:

$$\prod = PQ - C_x (Q) - C_n (Q) \quad (2.1.)$$

$\prod$ - company's profit

P - price

Q - sales volume

C_x - exogenic or uncontrollable costs

C_n - endogenic or controllable costs

The profit covered by alternative regulatory methods is described in Table 2.1 [31]. It is important to highlight that the methods described are of the so-called classical type. In practice, the regulatory methods are hybrids, containing elements from alternative methods.

Table 2.1. Profit elements covered by alternative regulatory regimes

Regulatory system	Covered by regulation	Ignored by regulation
Price cap	P	Q, C_x, C_n
Price cap with cost pass-through	P, C_x	Q, C_n
Revenue cap	P, Q	C_x, C_n
Rate of return	P, Q, C_x, C_n	-

2.1.1. Sales volume

The sales volume is an essential input in price regulation and its relevance depends on the share of fixed costs. By power distribution or transmission most of the costs except the power losses are fixed and independent from the sales volume. The same rule is valid in district heating networks where the heat losses are the single variable cost element[2]. By gas distribution or transmission, close to

[2] By performing of more detailed technical analyses it is possible to find out that a part of power or heat losses are fixed and not variable costs. The power losses in transformers are fixed and not related to the sales volume. There is a constant heat loss in DH Network, not dependent on sales volume.

100% of all costs are fixed which means that the costs are fully independent from sales volume. In energy sector the energy generation is the field where the variable costs may have significant share from the total cost base. This heavily depends on the fuel or energy source used by power or heat generation where the gas fired power plant has a large proportion of variable costs. In the case of hydro power plant, the variable costs are close to 0. The energy generation is not natural monopoly where the free competition principles can be introduced. In contrast to the energy generation, the network utilities are natural monopolies, which indicates that there is high impact of sales volumes to the financial results of those companies and this should be considered by implementing price regulation.

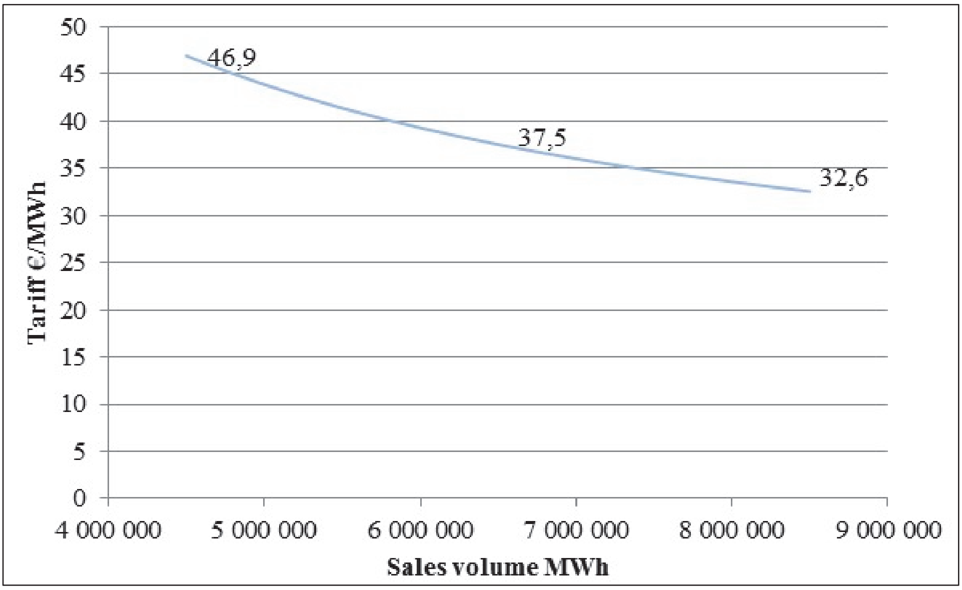

Figure 2.1. DSO tariff sensitivity to sales volume.

According to the price components of the largest Estonian power distribution operator Elektrilevi OÜ there is sharp dependence of distribution tariff from the sales volume (presented in Table 2.2. and on Figure 2.1.) [32]. The base scenario is by sales volume 6 500 GWh. By declining of sales volume by 2000 GWh (31%), the tariff should be increased by 25%. In opposite by increasing of sales volume by 2000 GWh, the cost based tariff should be reduced by 15%. This example demonstrates the influence of sales volume to the tariffs and results of the power network company.

Table 2.2. Tariff components of power DSO.

Sales	GWh	6 574
Power losses	%	6,3%
Power losses	GWh	442
Electricity price	€/MWh	42,9
Cost for electricity	m€	18,9
Non-controllable costs	€/MWh	13,5
Non-controllable costs	m€	88,8
Operational costs	m€	49,4
Depreciation	m€	42,9
Return	m€	45,1
Total revenue	**m€**	**156,3**
Price	**€/MWh**	**37,3**

Another calculation is made for the DH systems where the heat tariff relationship to sales volumes is represented. The differences in cost composition arise because of fuels used for heat generation. By using biomass there is much higher proportion of fixed costs than by using gas. This is due to the fact that burning of wood is much more capital intensive and requires higher operational costs as well. By using biomass the proportion of fixed costs is close to 50% whereas in the case of usage of gas the costs remain below 20%. Due to this fact, in the case of using wood the heat tariff is much more sensitive to sales volume than by using gas. The results are presented in Table 2.3. and on Figure 2.2.

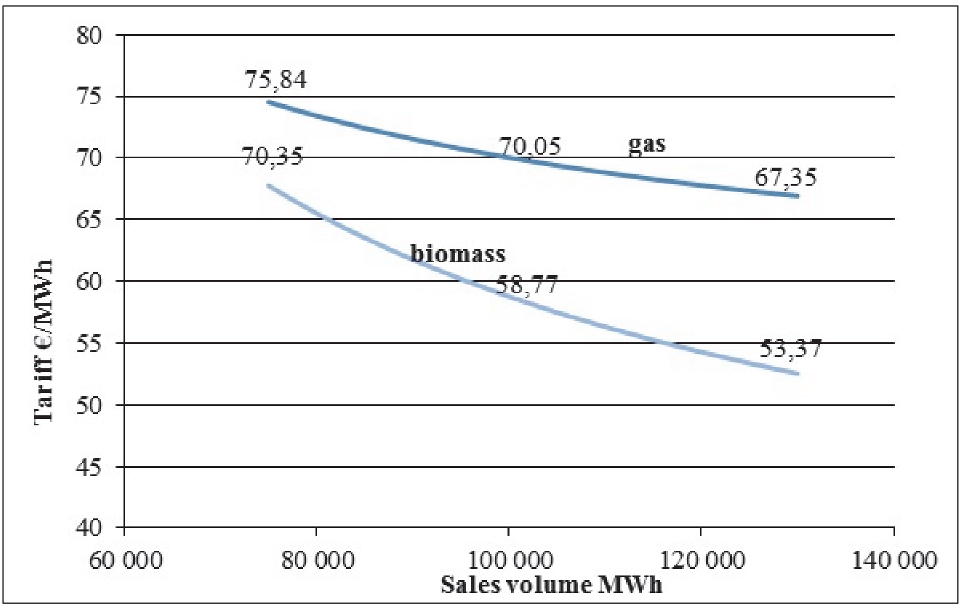

Figure 2.2. Heat tariff sensitivity to sales volume.

The conclusion on sales volume. The sales volume is an important input in calculation of service tariff and forming the price regulation, especially in regulation of natural monopolies where the proportion of fixed costs is high.

Table 2.3. Tariff components for heat generation

		Gas		Biomass	
Heat sales	MWh	100 000		100 000	
Heat generation	MWh	118 404		118 330	
Heat losses	MWh	18 404		18 330	
Heat losses	%	15,5%		15,5%	
Amount of fuel	MWh	131 560		139 211	
Heat generation efficiency		90%		85%	
Price of fuel	€/MWh	38		16	
Environmental cost	€/MWh	3,0		4,5	
Operational running costs	€/MWh	3,5		5,0	
Costs					
Fuel costs	€	5 005 000	71,4%	2 227 381	37,9%
Environmental cost	€	300 000	4,3%	450 000	7,7%
Operational running costs	€	350 000	5,0%	500 000	8,5%
Operational fixed costs	€	700 000	10,0%	1 400 000	23,8%
Depreciation	€	250 000	3,6%	500 000	8,5%
Return	€	400 000	5,7%	800 000	13,6%
Revenue	**€**	**7 005 000**	100,0%	**5 877 381**	100,0%
Heat price	**€/MWh**	**70,05**		**58,77**	

2.1.2. Uncontrollable costs

There are endless discussions among the regulators and utilities, which type of costs shall be defined as uncontrollable in the case of which the full pass-through principle should be used [15]. A regulated company may face significant costs that are both uncertain and largely outside its control. An example could be purchases of gas by a district heating company that are indexed to oil prices, and therefore effectively tied to the world oil markets. The cost of this gas could easily change by 10% or more from one year to the next, judging from past experience. If the utility were forced to charge heat tariffs indexed only to a general price index, it would be exposed to a significant risk, raising its cost of capital, and hence the expected price paid by its consumers.

The regulated costs are outside of companies´ control, even if the proportion of these costs is of marginal size. For example, the costs for electricity distribution or the water tariffs are of marginal importance for a district heating company. But due to the fact, that the costs are fixed by the regulator and totally outside of the companies´ control, these costs are accepted as uncontrollable by the regulator

[33]. Another issue is usage of construction price index and the retail price index by regulating the operational costs like maintenance or labour costs. It is clear that by indexing of all those costs, there will be no incentive for the company to improve the efficiency. Therefore those costs are generally not considered as uncontrollable and the pass-through scheme is not used for these cost elements. There are examples of regulation of the power generation where the electricity companies are not entitled to automatic pass-through of fuel costs, presumably to give them an incentive to generate electricity as cheaply as possible and to respond to changes in relative fuel prices by altering the fuel mix [31].

The importance of uncontrollable costs depends on the type of regulated utility. Due to the fact that the proportion on variable costs is limited by classical natural monopolies like power, gas or district heating networks, the proportion of uncontrollable costs is higher on ordinary or administrative monopolies where free competition could be introduced. The uncontrollable costs are generally missing in gas networks. The single regulative risk is purchase of transmission or distribution service from gas transmission system operator or from another gas distribution network. But this cost element is a regulated one. There is a similar situation on regulation of power or district heating networks, the main difference compared to the gas networks is that the power or heat losses are a part of the tariff. Depending on the market structure, the price of electricity used for compensation of power losses is market based or regulated. For price regulation in Estonia, the regulated electricity price was used until the market opening in 2013. On the liberalised electricity market, the market price is used.

Another topic is the price of energy included to end customer's tariffs in the conditions of a regulated energy market. The uncontrollable costs have extra high regulatory risk in this case, due to the fact that the majority of costs are related to the purchase of electricity or gas. In Estonian electricity market this is not a topic anymore because the market is liberalised and forming of prices is based on free competition. The household gas tariffs are still regulated, but rather liberal price regulation has been introduced in Estonian case. The regulator is fixing the sales margin added to the purchasing price of natural gas. The end user prices are formed by gas company, based on purchasing price and sales margin, fixed by the regulator [27]. This method is a combined ex-ante and ex-post price regulation where the risk of uncontrollable costs is eliminated for the company, but the regulator may impose ex-post control and check whether the end user tariffs are formed in accordance to the gas purchase price and the sales margin.

Similar to electricity or gas supply the cost of energy is an important uncontrollable cost element by forming of district heating tariffs, due to the fact that the costs for fuel make an important part of any district heating tariff. In Estonian case, the tariff formula principle is used, where the tariffs are formed according to the formula fixed by the regulator. A fuel costs pass-through principle is used by fixing of end users tariffs according to the formula [8]. The disadvantage of this regulatory system is the lack of incentive from utilities side to invest to alternative, more efficient generation facilities.

The conclusion on uncontrollable costs. On some source of uncontrollable costs the company has no possibility to save on those costs and 100% pass-through regulatory scheme should be implemented. Those costs are the regulated costs mainly: network or water tariffs. Another this type of cost element is the purchase of fuel or electricity in the conditions of non-liberalised energy market. If the company has choice to select supplier for some type of costs, like electricity losses in open market condition, some sort of incentive mechanism should be implemented and 100% pass-through scheme is not appropriate anymore.

2.2. Rate of return methodology (RoR)

Regulation of prices, as historically practised in the US and a number of other countries, has often involved Rate of Return (RoR) regulation [31], [1], [15]. By using the classical type of RoR, the different regulatory risks, such as sales volume, controllable and uncontrollable costs, are covered. The regulated company is allowed to charge prices that would cover its operating costs and give it a fair rate of return on the fair value of its capital. When the prices moved out of line with the company's costs, it could apply for a new set of prices [31], [15]. These results, in accordance with existing comparisons of regulatory regimes, seem to imply that companies under RPI – x regulation are exposed too much higher levels of systematic risk in comparison with those under RoR regulation, and that the cost of capital for these firms is therefore likely to be higher [31].

The result is that by applying of RoR methodology the risks are lower on the company level. It is clear that the RoR is not totally risk free for the company. It depends on the specific jurisdiction, on which way the methodology is implemented and as mentioned before, the methods implemented in practice are rather hybrids and not of classical type of methodologies. One of the risks associated to RoR is the regulatory lag. There are two types of regulatory lags: objective and subjective. The objective regulatory lag means that each tariff approval needs some efforts and time from company and regulator. This kind of efforts are e.g. preparing of tariff application, presenting of data, checking the data accuracy, preparing of administrative decision, having public hearings, etc. There is clear willingness from the side of the regulator to fix the prices. In opposite, the subjective regulatory lag means that the regulator may delay the decisions due to bureaucracy or to avoid unpopular decisions.

The regulatory lags are presented as company risk mainly, but in fact there exists the risk on the customers´ side as well. It depends on specific jurisdiction and existing legislation but it may occur if the tariffs should be reduced but the company is making all kind of efforts to avoid the tariff reduction. This type of risk – in this case it is better to call it company lag instead of regulatory one – is a clear case in Estonian jurisdiction where the companies have a number of legal but tricky moments to postpone the tariff reduction.

Another risk associated to the RoR is the risk of overinvestment, due to the fact that using the classic type of RoR, all investments are included to the tariff [31], [25]. The US regulators are reacting to this problem, not allowing to include to the tariffs unjust investments [31]. Averch and Johnson are criticising the RoR regulation methodology from the over-investment point of view. The model the regulated firm as maximizing profits subject to a constraint on the earned rate of return, and show that if the regulated rate of return is higher than the cost of capital, then the regulated firm will overinvest in capital [1]. That means, the Averch-Johnson effect occurs in the case where the WACC, set by the regulator, is too high, exceeding the actual WACC of the specific company. This gives a wrong incentive for investments.

RoR regulation and RPI-x can be interpreted as the poles of a spectrum of possible regulatory systems. Therefore, more incentive-oriented regulatory systems, such as price caps, have been established [25]. A number of other sources describes the lack of incentive orientation as the main shortage of RoR. Since all companies´ costs are covered and the required return on capital guaranteed, the RoR is oriented to fulfil the companies´ objectives and does not seem to be customer friendly.

There is a question why to use the ex-ante type of regulation which is more expensive than the ex-post type of methodology. If the objective of price regulation is to guarantee the return on capital, much cheaper ex-post regulation could be introduced. By using of ex-post type of methodology, the company is calculating the tariffs which guarantees that all costs are covered and reasonable return is included to the tariffs. The role of the regulator is to control, whether the calculations are correct and the return on capital is on reasonable level. To avoid misunderstanding, the regulator can issue guidelines on specific regulatory issues like accounting of regulatory asset base and calculation of return. By using of ex-post type of regulation, there is no risk on regulatory lag, due to the fact the company is free to apply new tariff in the case of changes of the input data. Since the forecast of input data may differ from actual results, the under-over recovery system can be introduced. In that case, the incorrect prognosis is compensated to the company or to customers and in longer perspective the actual return corresponds exactly to the regulated. This type of regulatory system corresponds to the classical type of RoR and can be defined as classical type of RoR without regulatory lag. By implementation of this type of ex-post RoR, the role of the regulator is very limited, the regulator operates as calculator by checking the accuracy of calculations made by the company.

Comparing to RPI-x or LRAIC, the main advantage of RoR is lower cost for regulation (administration costs) and simple way of implementation. As mentioned before, the regulation with the lowest cost is the ex-post type of RoR. By using this methodology the regulator may select specific companies to control. This can be based on risk assessment. For example, the regulator may concentrate to control the results of large scale utilities mainly, based on the fact that those have the hardest impact to the national economy. Compared to the ex-post type, the ex-ante type of RoR has higher administrative cost, which is still much lower than the cost by implementation of RPI-x or LRAIC. The implementation of RPI-x sets regulatory periods and specific data's for fixing of tariffs. In the case of RoR, there are no specific time periods for fixing of the tariffs by the regulator and the company is free to select by applying new tariff. The company may apply the existing tariff for years and not turn to the regulator. This saves a lot of regulators´ resources and makes the regulation less costly.

The practical implementation of RoR differs from the simplified approach, where the return is continuously guaranteed for the company. As mentioned before, the US regulators have regulated the investment programmes, which differ a lot from the classical RoR. There is 15 years' experience of implementation RoR in Estonia [2]. The method implemented is a hybrid, including a number on elements from RPI-x regulation. The Estonian experience indicates, that the RoR method implemented is not oriented to the companies´ interest only, but a balanced one. The return on capital invested was in an expected range or even below the level allowed by the regulator, the tariffs are flat in real terms, the quality of the service has been approved and the companies have met the energy conservation targets [18]. As a result of the analysis and based on Estonian experience, the RoR method was assessed to be the best method for long term objectives. The impact of RoR method was also controlled against the overall results of the activities of Elektrilevi OÜ, the largest power distribution company of Estonia, where one can observe improvements in the quality of the network services while the price of the network service remained stable and its profit of the utilities was in an expected range [26].

2.2.1. Practical implementation of RoR based on Estonian experience

The RoR implemented in Estonia includes a number of elements from RPI-x where various risks shall be covered by companies. There is a 15-years' experience by using this methodology in economic regulation of energy, water and railway utilities [2]. One of the main principles in using this methodology is the company's right to present the application to fix the new tariff on any time. The railway regulation is set up otherwise: the regulator shall fix the tariff on certain time fixed in the law [2]. In regulation of energy and water utilities the companies are obliged to monitor the cost base. In that case the tariff is not covering all costs, the company can apply for a tariff increase. This moment occurs for example in the case where the sales volume has declined, uncontrollable costs like fuel or electricity have increased or the cost of capital has changed. For implementation of new tariffs the regulator´s approval is needed. This can be a time-consuming process with administrative burden, but the company has provided this right fixed by the law.

In Estonia, the situation is rather different in case of declining input costs providing bases for tariff decrease. This is the case where the sales volume has increased, fuel or electricity prices are declining or the actual cost of capital is lower than set by the regulator. In the case described above, the company has no obligation to drop the tariffs automatically. There is a clause fixed in District Heating [8] and Public Water Supply and Sewerage Acts [34], imposing the company's to present a new tariff application to the regulator in case where the price decrease exceeds 5%. But according to Estonian administrative practice the companies have several reasons to postpone this obligation. On this reason, the regulation is not implemented in practice. The same is valid for electricity and gas sector which contain no clause to force the companies to decline the tariffs in case of decline in cost base. There is no direct obligation to compensate the extra profit to customer in this case. In companies´ perspective, this type of administrative regime is certainly reducing the risks and corresponds to RoR regulation method.

By using classic type of RoR, the risk of sales volume is covered by the regulation (Table 2.1.) [31]. Applying this method in practice, the regulatory lag has an impact. By prognosing the sales volume, the weighted average of last three years is used as a rule. If there are significant changes in customer structure, the detailed analyses are prepared [35]. By using the weighted average consistently, it is possible to eliminate the risk. The special situation is in case of constantly declining sales volumes, like district heating in Estonia, where the sales is declining due to the demographic situation and energy conservation measures implemented by the customers. In this case, the sales volume is clear risk for companies. In cases like this, the under-over recovery system similar to revenue cap could be used [36]. This type of system was used in energy regulation until 2012. In order to decrease the administrative burden, the under-over recovery is not used anymore.

By using of classic type of RoR the risk of uncontrollable costs is covered by the regulation as well (Table 2.1.) [31]. Despite the companies´ right to turn to the regulator by applying for a new tariff, this type of regulatory lag risk exists. As described above, according to the Estonian regulatory regime the regulatory lag is customers´ risk as well in case of declining cost where the company has an opportunity to earn additional return. The cost pass-through principle combined with cost under-over recovery could be used in this case. If the company is earning more or less than expected return due to the changes in uncontrollable costs, this will be over- or under-recovered by fixing the tariffs [36]. For example, if the fuel cost of a district heating company is more than expected, it will be compensated to the company during the next regulatory period. Or vice versa, if the fuel price is cheaper than expected, this amount will be paid back to the customers during the next regulatory period. This type of scheme was used in Estonian price regulation but is abolished now in order to simplify the price regulation.

To sum it up, the main principle of RoR regulation where the company has the right to apply a new tariff to compensate the uncontrollable has been a rule of 15-year price regulation. According to the District Heating Act [8], the heat price is calculated based on the formula, where the uncontrollable input data like fuel and electricity price are fixed separately. In case of change in those input data the heat price will be adjusted automatically. By regulation of power or gas networks the uncontrollable costs like network service or electricity are defined separately. In the case of changes in these costs, a company may apply the regulator to fix new tariffs.

Using RoR, the risk of exogenic or controllable costs is covered by the regulation (Table 2.1.) [31]. That is the case where the company carefully monitors costs and the tariffs are actually fixed by the regulator in accordance to the basis of the historical costs of the company. This is the case of classic RoR method. The method used in Estonia differs a lot from the classical type of RoR where the costs included to the tariffs may differ from the company´s historical cost base and the regulator is actively demanding implementation of cost saving measures. By using of this incentive type of RoR, the controllable costs are not covered by the regulation. There are different measures to analyse the costs saving potential used in practical price regulation [35].

- Observation of the dynamic of expenses in time and its comparison with the dynamics of the consumer price index (CPI).
- Analysis of justification of various cost components and technical indicators.
- Benchmarking of utilities.

There is a multitude of costs not to be included to the tariffs.

- Expenses related to monetary claims unlikely to be collected.
- The capital expenditure of fixed assets acquired using connection charges paid by consumers.
- The capital expenditure of fixed assets acquired using non-refundable aid (e.g. the EU external aid programmes).

- Costs related to ancillary non-regulated activities.
- Costs arising from changes in the value of assets (write-downs of the balance of inventories, write-downs of current assets, impairment of value of fixed assets, losses from the sale and liquidation of property, plant and equipment and intangible assets, etc).
- Penalties and fines for delays imposed on the undertaking pursuant to law (fines for administrative violations, penalty payments, compensation for damages, etc.).
- Costs not related to business activities (sponsorship, gifts, donations etc.).

From the different costs listed above, e. g. the non-payments and sponsorships are company´s costs in real life. If the company is unable to avoid such cost elements, the costs are to be covered from return.

To reach the energy conservation target, the obligation to reduce the district heating losses has been set to the companies [37], [38]. The reason of obligation was the extremely high district heating losses up to 25-30% by starting the price regulation in 2000s. The similar approach is applied by reducing the power losses where the regulator can establish an obligation to reduce the losses in certain amount for in defined period [7], [35]. The fulfilment of the obligation is company´s risk similar to the efficiency target x used by RPI-x regulation. The company can maximise the return by saving more than established by the regulator. In an opposite case, the difference shall be paid from the company´s return.

This is a typical incentive type of regulation where the company's target is to reduce the cost for maximisation of return. The difference to the RPI-x regulation is the lack of the regulatory period. It is the company´s choice whether to operate within the cost base defined by the regulator where all saving can be kept within the company or to present an application for fixing new tariffs. It is a significant difference from the classic type of RoR because the tariffs are not fixed on company's historical costs but the cost base set by the regulator includes the cost saving obligation.

The regulator is assessing company´s investment program and may not approve it in the case where the program is inefficient and for example the same target could be reached by a reduced investment program. For evaluation of investment programs for larger utilities, external consultants have been employed by the regulator [39]. But the regulation of investment is much weaker than by using RPI-x. By using RPI-x, the precise investment program is set for the entire regulatory period. By implementing RoR, the tariffs are fixed on a basis of annual cost of the company the investment program being a part of that and established for a specific year. The company may present the long term perspective investment plan to the regulator but this more just an indication and not so obligatory for the company. In the case if the company does not apply in many years to fix the tariffs, the regulator is in the situation where these investment are made in reality. It is now very complicated situation for the regulator to refuse to include those investment to the tariffs. This is a clear risk of Averch-Johnson effect by implementation of RoR, where the company is making overinvestment in the case the WACC exceeds the company´s cost of capital.

Beside of the last mentioned, one of the objectives of RoR is to reduce administrative burden. Implementing this methodology in Estonia the regulator is not requiring regular data collection. The historical data and prognosis are presented in the case of application of new tariff. In the period between fixing of tariffs the regulator has no control on the investment and, as mentioned above, the regulator is in complicated situation not to accept these investment in the tariff. The main regulatory tool to avoid the overinvestment is to tend towards lower level by WACC calculations. From the other side, there is lower risk on underinvestment by implementing of RoR. First, there is no intensive regulation of investment, due to the fact that in the period of tariff fixing the company is pretty free to make business decisions. Secondly, there is not such a pressure on costs savings like by using of RPI-x because the company has the right to apply to the regulator for fixing of new tariffs in the case the old tariffs are not sufficient to cover the costs anymore.

By regulating the utilities the ownership issue should be still considered, despite to the fact that according to the law all enterprises, not depending on the ownership form, should be treated in equal way. In Estonia a number of the largest utilities are state owned. The majority shareholder of gas and power transmission system operator (AS Elering) is the state owned company. The largest distribution system operator (Elektrilevi OÜ) and the owner of railway infrastructure (AS Eesti Raudtee) are state owned enterprises as well. In water sector, the Tallinn water company is in private ownership, the rest of water utilities are owned by local communities. The risk of Averch-Johnson effect is higher for state or municipal owned companies in the case if the owner is not setting concrete numbers for return on capital or is setting the cost of capital on too low level, which may result in overinvestment. High risk of overinvestment occurs in water sector where a large number of investment are financed from grants. The return on those investment is 0, which may lead to inefficient investment policy. The return on equity is set for all state owned companies, published by the Ministry of Finance [40]. The more detailed analyses of the company's cost of capital and regulatory WACC can be found in chapter 4.1.2. In Table 2.4 the regulatory WACC and the cost of capital set by the owner are presented.

Table 2.4. Regulatory WACC and company´s cost of capital of AS Elering and Elektrilevi OÜ.

	2010	2011	2012	2013	2014	Average
Company's cost of capital Elering	7,28%	7,72%	7,82%	7,06%	6,11%	7,20%
WACC set by the regulator Elering	7,56%	7,78%	7,81%	6,74%	5,58%	7,09%
Company's cost of capital Elektrilevi	7,18%	7,09%	6,92%	6,82%	7,45%	7,09%
WACC set by the regulator Elektrilevi	7,76%	7,83%	7,83%	6,76%	5,61%	7,16%

In order to avoid overinvestment in state or municipal owned companies, the concrete ROE (return on equity) targets should be set by the shareholder. The regular dividend payments are important as well. The numbers in Table 2.4. are indicating that the average company´s cost of capital and regulatory WACC have been on equal levels. In the first three years of the period considered, the WACC was above the company´s cost of capital which is a high risk of overinvestment. During the years 2012—2014, the situation has changed and the WACC has been below company´s cost of capital, which should reduce the risk of overinvestment.

The service quality requirements are not a part of the price regulation system similarly to a number of other jurisdictions. The regulator can impose any sanctions on the company by not fulfilling the quality requirements, neither to include a premium to the tariffs in case the company is over performing. The quality requirements can be considered as informative. There is a general requirement to ensure the supply of gas and district heating. More advanced quality requirement system occurs in electricity supply [41]. The companies are obligated to record the quality indicators like CAIDI, SAIFI and CI but those are indicative and not a part of the price regulation system. Those indicators can be used by analysing the results of price regulation and network development. There are quality requirements for network set in the legal act describing the maximum allowed service interruption time and certain customer service criteria. If the company is not fulfilling the quality norms on service interruption time, the compensation by reducing the network fees shall be paid to the customer.

The result by analysing the RoR introduced in Estonia indicates that the method used is incentive type of RoR. The company has the right to apply at any time to the regulator for fixing new tariffs. But that tariffs based on historical costs are not guaranteed and there exists company risk on cost efficiency. If the company is unable to fulfil the cost saving obligation set by the regulator, the inefficiency shall be covered from the company´s profit. If the utility manages to reduce its costs, it earns additional profits. The system is similar to RPI-x where the company has incentive to save the costs.

The regulatory model introduced in Estonia can be characterised as having set up the goal to save on administrative costs. There is no requirement for systematic data collection, the historical data and prognosis are prepared only by applying of new tariff. This system can be defined as some kind of regulatory deterrence where the company knows that applying of tariffs will arise notably heavy administrative burden. This is some kind of motivation system to rely on existing tariffs and not to turn to the regulator for fixing new tariffs.

The weakness of incentive type of RoR remains the weak regulation of investment and the risk of overinvestment. The risk of overinvestment can be reduced by setting the WACC to equal or below the company´s cost of capital.

The conclusion on RoR regulatory methodology in Estonia. The regulatory model introduced in Estonia is different from the classical type of RoR. Despite the fact that the company can apply on any time for fixing of new tariffs, the return on capital is not guaranteed. The main difference from classical RoR is the intensive regulation of operational costs, where the tariffs are not set on the basis of company's historical costs. Therefore the regulatory model can be named as incentive type of RoR. The main difference from RPI-x is the absence of fixed regulatory period and weaker regulation on investments. Therefore the incentive type of RoR is a hybrid method between classical type of RoR and RPI-x regulation.

2.2.2. The results of price regulation in Estonia

The main results of the 15-years price regulation are the efficiency gains in energy savings and the fact that the companies' actual return is mostly equal or below the WACC set by the regulator. The prices in real terms have been almost stable or even declining [18] [26]. The outcome clearly indicates that the RoR implemented in Estonia does not guarantee the required return which is one of the main characteristics of the classic type of RoR. On Figure 3.3. the average return on invested capital during the last 10-years period of the largest Estonian utilities is presented. The district heating company AS Eraküte has slightly exceeded the WACC set by the regulator. The power networks which present the natural monopolies have not reached the WACC: Figure 2.3. and Figure 2.4. [18]. The market share of the three largest power distribution operators is 93% [42] which makes explicit the impact of price regulation. The results of the Tallinn water company exceed the WACC by more than 2 times; the fact can be explained as the result of a non-regulated natural monopoly[3].

[3] Before amendment of Estonian Public Water Supply Act in 2010 the prices of water utilities were set by the local authorities. The water tariffs set in Tallinn are on too high

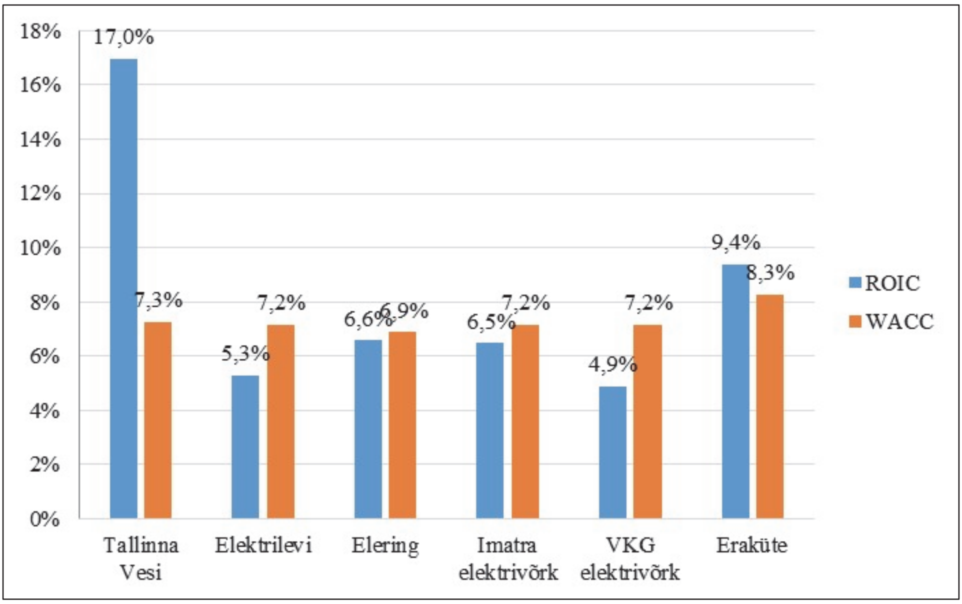

Figure 2.3. Average 10 years (2005—2014) return on invested capital of the regulated utilities.

Analysing the results, the price developments in real terms shall be considered. The main target of RPI-x is the decline of tariffs in real terms, this is included to the price formula as a negative value of the x-factor. By using of RoR, the price development in line with inflation could be expected. The analyses of power networks indicates that the tariffs have been declining in real terms (Figure 2.5.) [18]. The tariffs of Elektrilevi (88% market share) and Imatra Elekter have been declining in real terms. The tariffs of Elering (power transmission operator) have been increased by 11%. The main reason of tariff increase is the intensive investment program carried out by building international links where the asset base of the company has increased by 1.55 times. Without of building of those international links, the tariffs would have been decreased from 100% to 83% in real terms (Figure 2.6.) [18].

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level, which enables the company to earn to high return. In 2011 Tallinn water company applied to the Estonian Competition Authority to fix even higher tariffs than set by the City of Tallinn. The regulator rejected the application and issued the prescription to lower the tariffs to the level enabling the tariffs to the level which ensures the company the justified return. The both regulators decisions are appealed at the court. The court issued an initial legal protection to the water company, which mean that the tariffs are frozen. Due to this situation the company is continuously earning the unjustified high return.

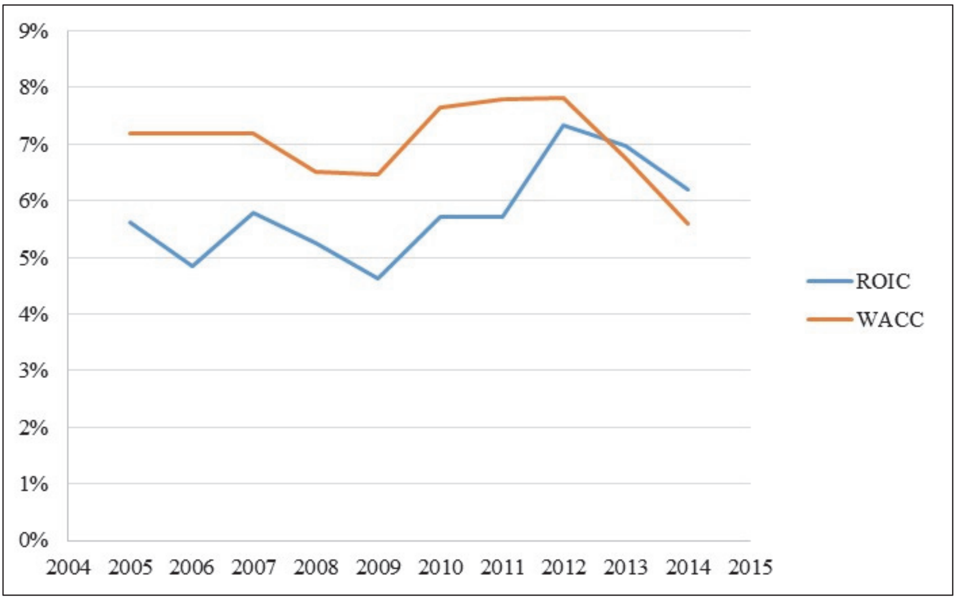

Figure 2.4. Return on invested capital of power networks incl. Elering, Elektrilevi, Imatra, and VKG.

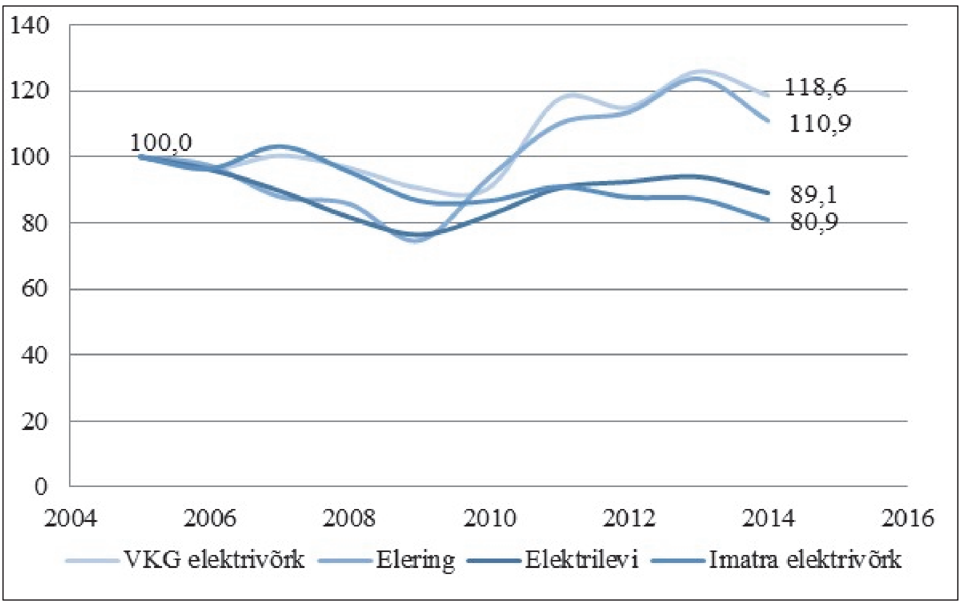

Figure 2.5. Percentual change of tariffs of the largest power networks in real terms.

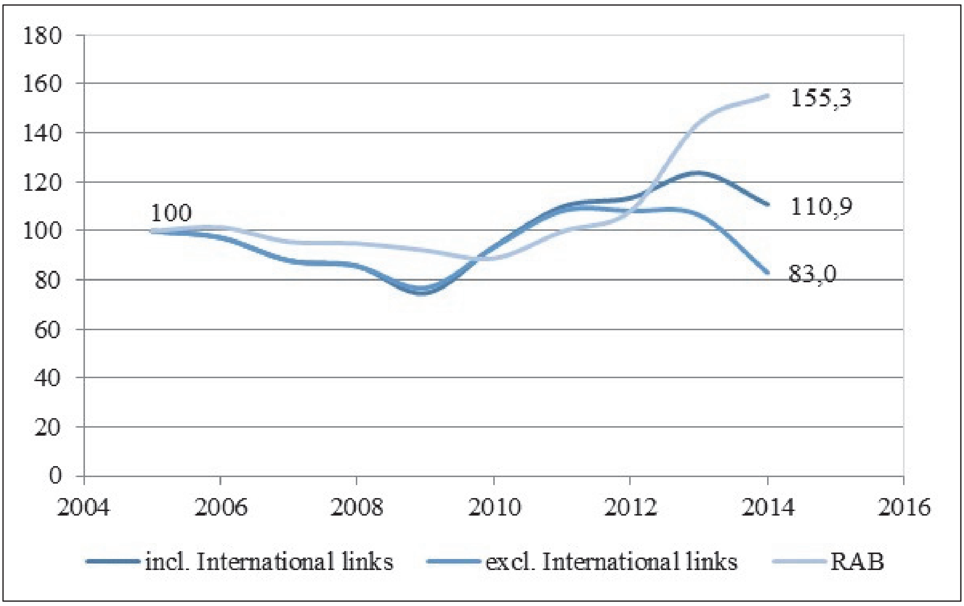

Figure 2.6. Percentual change of tariffs and RAB of Elering in real terms

The reduction of electricity losses in power distribution networks is a success story of Estonian price regulation. 15 years ago, by start of economic regulation, the power losses of 20% had been common case. Today the losses are close to the technical minimum where the further reduction is not possible. The reduction of electricity losses is presented on Figure 2.7. and Figure 2.8. [18]. On Figure 2.7. the electricity losses of the three largest DSO's[4] in percentages are presented. On Figure 2.8. the summarised electricity losses of those companies are presented. As demonstrated on the charts, the electricity losses of the largest distribution operator Electrilevi have been decreased in three times during this period. The similar trend is characterising all other DSO-s as well. The total amount of annual energy savings is 500 GWh which is 7,5% from Estonian end consumption today. This amount of saved energy has direct impact to the distribution tariffs as well.

Figure 2.9. [26] presents the changes of the electricity supply security indicator SAIDI[5] in Elektrilevi OÜ from 2003 to 2014. The calculations of SAIDI do not take into account the impact of occasional weather impacts. The conclusion is that the quality indicators have been improved during this period.

[4] Elektrilevi, Imatra Elekter and VKG Elekter. The summarized market share of those companies is 93%.

[5] System Average Interruption Duration Index - the average outage duration for each customer served

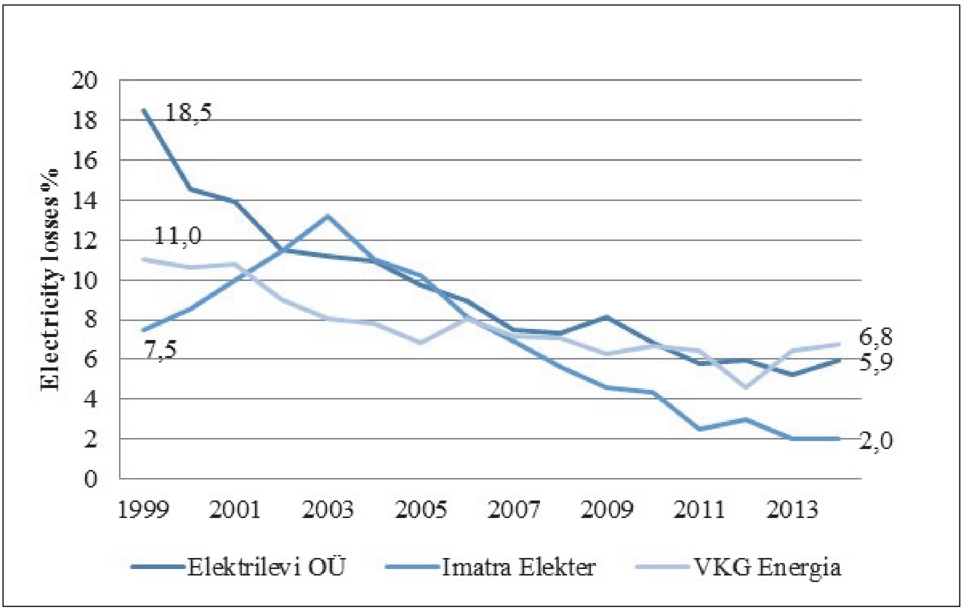

Figure 2.7. Electricity losses of distribution operators in percentages

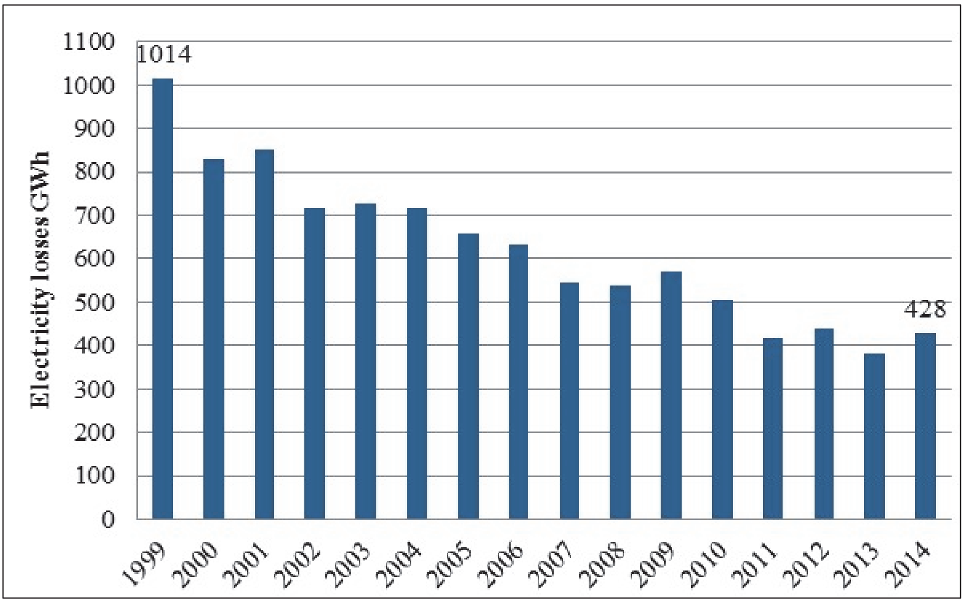

Figure 2.8 Summarized electricity losses of Elektrilevi, Imatra Elekter and VKG Elekter

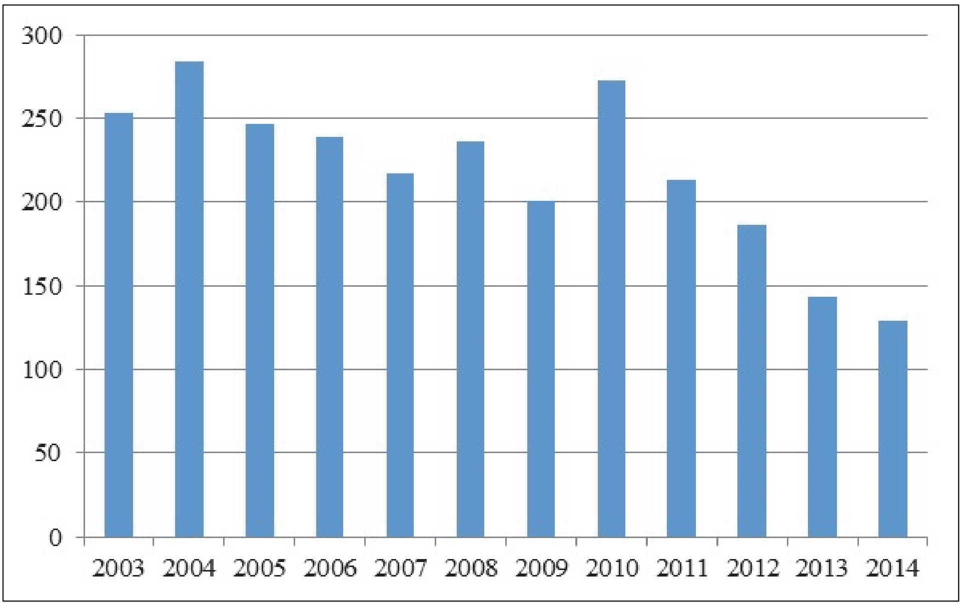

Figure 2.9. Changes in network quality indicator SAIDI in Elektrilevi OÜ

Evaluation of the price developments in district heating is much more complicated because the high share of fuel costs in the tariff. The analysis of an effective district heating system indicates the share of variable costs in a system in range from 41 to 50% [43]. Those modelled capital intensive district heating systems are expected to operate with maximum efficiency. Depending on the fuel used, the share of variable costs in the district heating system can reach up to 80% [20]. The fuel prices have been very volatile. The price of wood has been changed from 10.3 up to 23.7 €/MWh, or, 2.3 times. The same phenomenon can be seen in the price of natural gas: from 22.0 up to 44.5 €/MWh [20]. Just analysing the heat tariffs in real terms would not give an adequate picture.

The tariffs developments of larger DH utilities have been analysed and presented on Figure 2.10 [18]. The heat tariffs have been increased 16% in real terms. Since the fuel price is an important element of heat tariffs, the development of oil prices is analysed with heat tariffs on Figure 2.11. The oil price has increased in nominal terms by 67% in the 10-year period, where the nominal increase of heat tariffs is 71%. This is an indication that the heat price development has been in a range.

The same trend by saving on energy losses has been in regulation of district heating as well. The energy losses have been declining since the economic regulation was applied. On Figure 2.12. [18] the heat losses in percentage of larger DH utilities are presented. On Figure 2.13. [18] the summarised heat loss of those utilities is presented. The heat losses have been declined from 20.1% to 16.6% and the summarised heat loss by 29%.

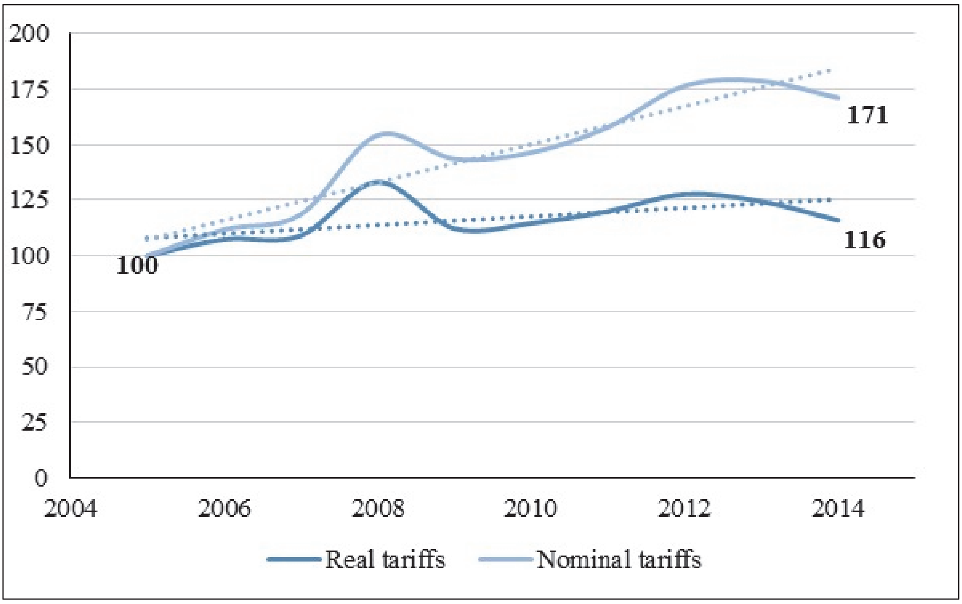

Figure 2.10. Percentual change of heat tariffs of larger DH utilities

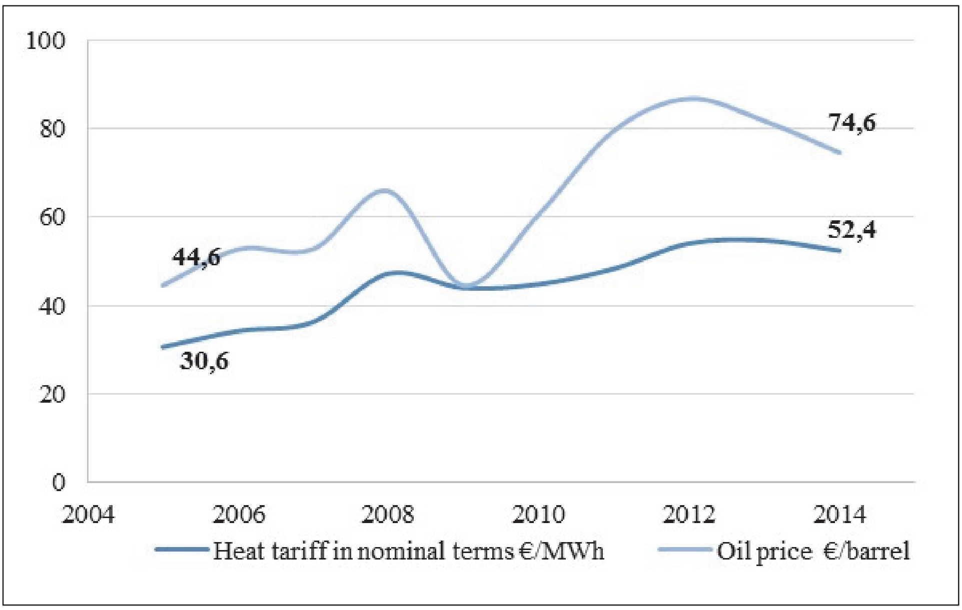

Figure 2.11. Heat tariffs in nominal terms compared to oil prices.

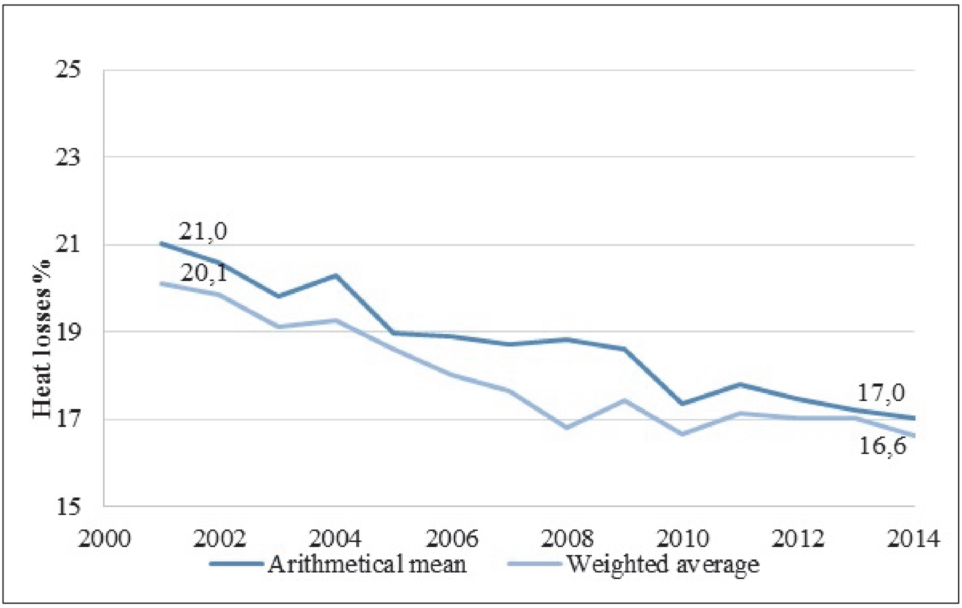

Figure 2.12. Heat losses in percentage larger DH utilities.

By analysing the implementation of the incentive type of RoR in Estonia, the result of the regulation is rather positive. The prices have been declining in real terms and the service quality has been improved.

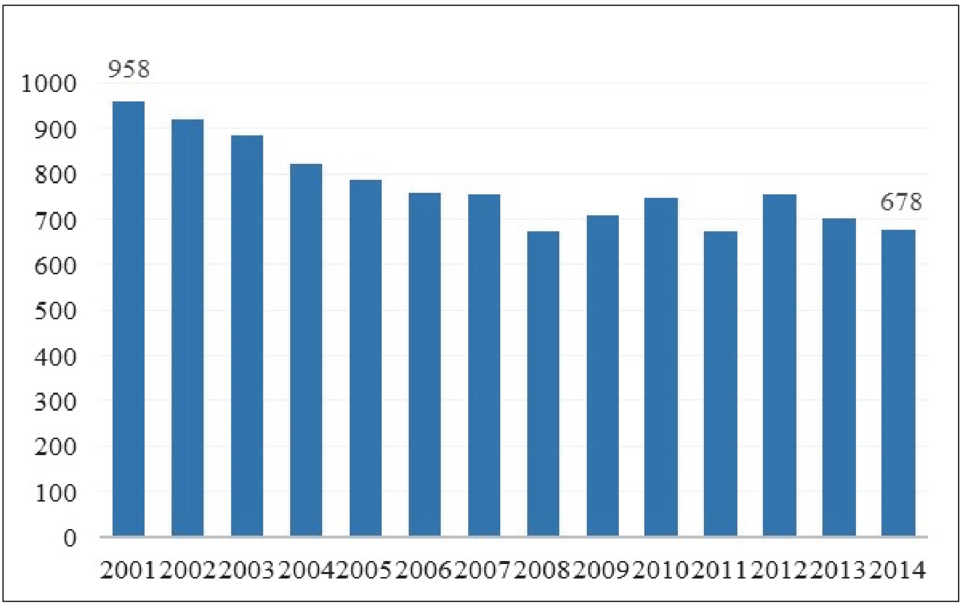

Figure 2.13. The summarized heat loss of larger DH utilities in GWh.

The conclusion on incentive type of RoR regulatory methodology in Estonia. The conclusion is that the incentive type of RoR has the biggest impact on company's operational costs. The clear indicator is the reduction of energy losses, where the regulator is pushing the company toward of efficiency in operating costs. The similar indicator is the fact that the actual return is mostly below the allowed return by the regulator. This is indicating that a part of the operational costs, not included to the tariff by the regulator is financed from company's return. This fact is also indicating, that the RoR implemented in Estonia is not a classical one, where the allowed return is guaranteed to the company. The fact that the tariffs are declining in real terms is indicating some relation to the RPI-x, which is indicating, that the incentive type of RoR implemented in Estonia has some elements of RPI-x.

2.2.3. Summary RoR

The implementation of classical RoR assumes that the risks are covered by regulation. The difference is in regulatory lag risk. If the tariffs are set by the regulator by using of ex-ante type of regulation, this risk exists. By using of ex-post type of regulation where the tariffs are set by the company, the risk of regulatory lag is missing.

Based on Estonian experience the incentive type of RoR can be used, where the tariffs are not set up based on company´s historical cost and the efficiency target is set by the regulator. Based on that, there exists a number of different versions of RoR.

1. **Classical RoR ex-post**. The tariffs are set by the company, the endogenic (controllable) costs are not regulated.

2. **Classical RoR ex-ante**. The tariffs are fixed by the regulator. The endogenic costs are based on company´s historical costs. To cover the risk on exogenic (controllable) costs and on sales volume, the new tariff should be applied.

3. **RoR revenue regulation**. The tariffs are fixed by the regulator. The endogenic costs are based on company´s historical costs. The risk on sales volume is covered and the tariffs are based on the factual sales volume. The under-over recovery system [36] can be used. To cover the risk on exogenic (controllable) costs, the new tariff should be applied.

4. **RoR with cost pass-through**. The tariffs are fixed by the regulator. The endogenic costs are based on company´s historical costs. The risk on exogenic

(non-controllable) costs is covered[6]. To cover the risk on sales volume, the new tariff should be applied.

5. **Revenue regulation with cost pass-through**. The tariffs are fixed by the regulator. The endogenic costs are based on company´s historical costs. The risk on exogenic (non-controllable) costs and sales volume is covered.

The incentive type of RoR methods 6, 7, 8 and 9 are identical to 2, 3, 4 and 5. The only difference is that the endogenic (controllable) costs are not covered by regulation and the cost efficiency target is set by the regulator. Is similar to RPI-x, if the company cannot reach the efficiency target, the difference shall be financed from company´s resources.

6. **RoR incentive**. The tariffs are fixed by the regulator. The efficiency target on endogenic costs is set by the regulator. To cover the risk on exogenic (controllable) costs and on sales volume, the new tariff should be applied.

7. **RoR incentive revenue regulation**. The tariffs are fixed by the regulator. The efficiency target on endogenic costs is set by the regulator. The risk on sales volume is covered and the tariffs are based on the factual sales volume. To cover the risk on exogenic (controllable) costs, the new tariff should be applied.

8. **RoR incentive with cost pass-through.** The tariffs are fixed by the regulator. The efficiency target on endogenic costs is set by the regulator. The risk on exogenic (non-controllable) costs is covered. To cover the risk on sales volume, the new tariff should be applied.

9. **RoR incentive revenue regulation with cost pass-through.** The tariffs are fixed by the regulator. The efficiency target on endogenic costs is set by the regulator. The risk on exogenic (non-controllable) costs and sales volume is covered.

The summary of regulatory risks covered by different regulatory models is presented in Table 2.5. The risks on sales volume, endogenic and exogenic costs are covered by classic type of RoR [31]. By analysing the use of RoR in practice, the regulatory lag risk is not covered by this type of regulation. The regulatory lag may exist in subjectivity. In that case, the unpopular decision is simply postponed. The regulatory lag may exists in objective manner, due to the fact that certain time is needed for the regulatory approval. The ex-post type of RoR, where the

[6] There exist two methodes to cover risk on sales volume. According to the first method the tariff application is presented to the regulator. According to second option the under-over recovery is used.

company is free to fix the tariffs without regulator´s approval is free from this risk. On that reason, the regulatory risk is considered separately.

Table 2.5. Profit elements covered by alternative RoR regulatory regimes

	Regulatory system	Fully covered by regulation	Covered by regulation except risk of regulatory lag	Ignored by regulation
1	**Classical RoR ex-post**	Q, C_x, C_n		
2	**Classical RoR ex-ante**		Q, C_x, C_n	
3	**RoR revenue regulation**	Q	C_x, C_n	
4	**RoR with cost pass-trough**	C_x,	Q, C_n	
5	**Revenue regulation with cost pass-through**	C_x, Q	C_n	
6	**RoR incentive**		Q, C_x	C_n
7	**RoR incentive revenue regulation**	Q	C_x	C_n
8	**RoR incentive with cost pass-through**	C_x,	Q	C_n
9	**RoR incentive revenue regulation with cost pass-through**	C_x, Q		C_n

Q- sales volume; C_{x-} exogenic (uncontrollable costs). C_n endogenic (controllable costs)

Conclusions on RoR

1. From companies´ point of view, all of risks are covered by using of ex-post type of RoR. By using of classic type of RoR, all risks except the regulatory lag are covered.

2. The incentive type of RoR has a number of number of similarities with RPI-x. The regulatory model is directed to efficiency gains. The costs are not based on company´s historical costs.

3. The use of incentive type of RoR can be successful in achieving of cost savings and technical efficiency. The company is free to select the length of the regulatory period by deciding when to present the tariff application. Within the regulatory period, the company is free to increase the profit by saving of costs.

4. Risks of overinvestment may occur by using of RoR. RPI-x is more efficient by regulation of investment. There is less risk on underinvestment by using of RoR.

5. All type of RoR have rather modest administrative burden. The ex-post type of RoR has the lowest administrative burden.

2.3. Implementation of RPI-X methodology

As described above, the RPI-x can be considered as opposite methodology to RoR. Overall, empirical work suggest that incentive regulation as implemented has improved welfare relative to Rate of Return regulation [1]. The main principle of another opportunity, RPI-x, is that if a company is able to implement the efficiency targets during the regulatory period, the company will earn additional profit. If the efficiency targets set by the regulator are not fulfilled, than the return will be below the level set by the regulator.

There are a number of risks associated with the RPI-x, as described in formula 2.1. A number of RPI-x versions can be applied for mitigation of those risks [25] [31]:

- **Price cap with cost pass-through:** sales volume is not covered, uncontrollable costs are covered by regulation
- **Revenue cap**: sales volume is covered, uncontrollable costs are not covered
- **Revenue cap with cost pass-through**: both, sales volume and uncontrollable costs are covered by the regulation

The main principle of RPI-x regulation is fixing of tariffs according to a formula for a certain regulatory period. The determination of the length of the regulatory period is of essential importance. It has to be reasonable. If the period is too short, the company has no time for implementation of efficiency targets. If the period is too long, the preparation of prognosis and calculations is going to be too complicated. The reasonable length of the regulatory period is proposed to be from 4 to 5 years [15] [1] [44]. The tariffs are adjusted according to inflation and the x-factor is added to the formula which presents the efficiency target. The main principle is that the tariffs should increase less than inflation that means that the x-factor is of negative value. In some special cases, the x-factor can have positive value, in particular if the company is investing more than depreciation. The method is described with the formula:

$$tariff_1 = tariff_0 \times (1+RPI \pm x) \quad (2.2.)$$

The Energy Regulators Regional Association (ERRA) has prepared a study to analyse different regulatory methods by concentrating to the RPI-x. The study is characterising the RPI-x methodology as something between RoR and LRAIC where the regulative costs are not directly linked to the companies´ historical costs but are still representing technical system existing in reality, where the LRAIC model represents a fully hypothetical system, which does not exist in reality [45].

The main difference between RPI-x regulation and traditional Rate of Return regulation is that under the former system, prices are no longer directly based on the company's actual costs. At the one extreme, under a pure Rate of Return scheme, prices would be set on the basis of the company's actual costs. This provides no incentives for higher productivity. The other extreme is to completely unlink prices from actual costs; this provides very strong incentives for productivity improvement. Price-cap (RPI-x) systems are located somewhere between these two extremes. That is, prices and costs are detached from each other, but not to a full extent; there still remains some interdependency [45].

The results of RPI-x are illustrated on Figure 2.14. The regulatory period starts with tariff p_0; the efficient tariff is p_e. By using of classic RoR, the tariff remains on the level of p_0, due to the fact that the tariffs are set based on historical costs and there is no efficiency target set by the regulator. By using of RPI-x consumers enjoy gains (represented by area A) due to a reduction in the initial price p_0. The utility retains extra profits due to cost savings in excess of the X factor (area B). For society as a whole, efficiency savings are given by the area A+B [45].

By the ending of the first regulatory period the company is applying tariff p_t. Presenting the actual results to the regulator, it is easy to identify that the efficient tariff is p_e. Now it is the choice of the regulator whether to start the second regulatory period with p_t and another period for efficiency gains or to start immediately with p_e and to require further efficiency gains. Most like the regulator is going to start by p_e because the using of p_t would give automatically extra profit B to the company. It's clear that the effective tariff cannot be 0 and if the real effective tariff is on the level of p_e, than the tariff should be flat on this period. The risk of RPI-x is, that setting the tariff below p_e, the long-term sustainability of the utility will be affected. Another issue to be found on is the timing to achieve the efficiency gains. It is clear that all changes on the company level need proper time period and from this point of view the regulatory period should be within a reasonable timeframe.

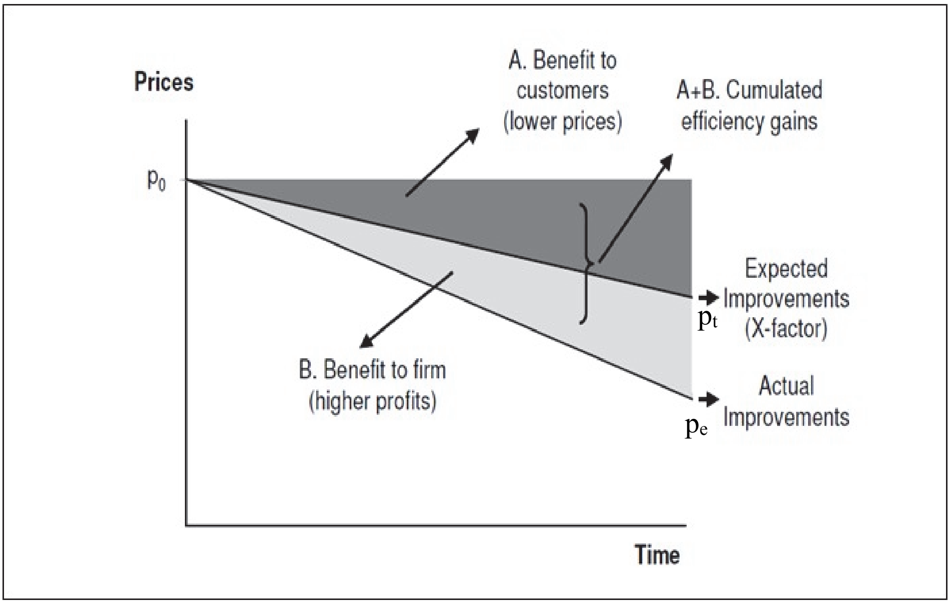

Figure 2.14. The results of RPI-x

The first impression from RPI-x is very positive, like this method would solve all problems and allow to gain the efficient level of tariffs with great benefit for the society. There are a number of issues to be considered by practical implementation. Problems arise in terms of the proper calculation of the price index, the impact of quality, the impact of finite time period for price cap (RPI-x) regulation, and issues renegotiation of the terms of regulation [1], [4]. As mentioned before, if the x is calculated in manner, where the tariff set by the regulator is below the real efficient price p_e, there is a risk to the long-term sustainability of the company.

Another issue is the regulation of investment. By using of RPI-x, the regulator is fixing the investment program for the regulatory period. Therefore the correct prognosis are of essential importance. By presenting of incorrect investment prognosis, it is easy from company´s point of view to achieve better result than presented in the prognosis. The need for evaluation of the investment programs demands special skills from the regulator, including engineering knowledge’s as well.

Therefore the RPI-x can be characterised as more costly than the RoR where the prognosis shall be prepared for each of the regulatory period and the regulator is obligated to assess the adequacy of that prognosis. By practical implementation of RPI-x, the systematic submission of data within the regulatory period is required as well. In opposite, by using of RoR there is no time constraint by fixing of tariffs and this is based upon the application of the company. This makes the using of regulators resources much more flexible, including the fact that there is no direct need to submit the data during the regulatory period.

By implementing of classical RPI-x, the tariffs are fixed for the whole regulatory period, based on the prognosis. In the case the sales volume or uncontrollable costs are not in accordance to the prognosis, the company´s profit is not in accordance to the prognosis set by the regulator and the company is earning additional profit or loss. If the company can save on costs, its profit will be higher. If the costs are higher than set in prognosis, the profit will be lover in this case. The same can be said about the investments. If the company can save on investments, it is possible to increase the profit. In the opposite case, the difference should be financed from company´s resources.

For example, the amount of investment programme fixed for the regulatory period is 100 m€, but the company was able to save 20 m€ on investment. Since the customer has paid depreciation and return on this 20 m€, it seems to be fair to return this amount which was not spent in reality. By implementing of classical RPI-x, this would be company´s savings. To be very liberal, the RAB for the next regulatory period would include the predicted investment of 100 m€. This would be a premium for the company for good results and efficient investment.

The main risk concerning the regulation of investment is the fact that the regulators do not have sufficient information with respect to cost, demand, quality and other dimensions of firm behavior. This is one of the main thesis of the private interest theories of regulation [17], [12]. It is very difficult to disagree with this assumption. One of the main basis for RPI-x regulation is the quality of the investment plans prepared by the company. It is clear that the companies have remarkable advantages in this respect, holding the exact information about the need of investments in order to achieve the targets. Therefore the setting of strong quality requirements is an essential element for using of RPI-x regulation. The quality norms shall include sanctions imposed, if those requirements are not fulfilled by the company. The size of the sanctions should be big enough to eliminate the company’s ambitions to save on investment. If the company can fulfil the quality norms by implementing efficient investment and the long-term sustainability is guaranteed, than the objective of the regulation is fulfilled. In principle it’s not the regulator´s business to analyse and regulate the companies´ investments if those two requirements are fulfilled. Those type of quality requirements and sanctions are an important part by practical implementation of RPI-x model which differs a lot from the pure type of classical model. A good example is the quality regulation of different utilities in the UK and Ireland which includes quality norms combined with sanctioned system [1], [4], [44]. For electricity supply, the quality norms are related to the interruptions by the customers. Those quality indicators like CAIDI, SAIFI, AIDI and different customer service norms are widely used by European energy regulators [46], [47].

2.3.1. Implementation of classical RPI-x

Since the including the investments to the RAB is an essential part of the RPI-x regulation, this subject is analysed, assuming that the classic type on regulation is used. By using of this model the calculation on x factor is of high importance. The x-factor includes the changes in demand, operating cost efficiency, including the technical efficiency like savings on heat or power losses, and the investment efficiency. The calculations of x-factor is based on the formula where the net present value of the company's revenues and the allowed costs during the regulatory equals [45]:

$$\sum_t \left[\frac{1}{(1+r)^t}\cdot(1\text{-}x)^t\cdot p_0\cdot Q_t\right]=\sum_t \left[\frac{1}{(1+r)^t}\cdot(C_t+WACC\cdot RAB_t+D_t)\right] \quad (2.3.)$$

t- the length of the regulatory period

r- discount rate

p_0- tariff set in the beginning of the regulatory period

Q_t- sales volume in year t

C_t- operating costst in year t

WACC- the rate of return (WACC) set by the regulator

RAB_t- the value of regulatory asset base in year t

D_t- depreciation in year t

The value of regulatory asset base (RAB) is calculated according to the formula:

$$RAB_{t+1} = RAB_t + I_t - D_t \; (2.4.)$$

RAB_t – the value of RAB in year t

I_t – investment made in year t

D_t – depreciation in year t

In Table 2.6, there is a sample calculation for a 5-year regulatory period for a power distribution network. The formula 3 is used for calculation of the x-factor [45].

$$\sum_{t=0}^{n}\left[\frac{R(t)}{(1+WACC)^t}\right]-\sum_{t=0}^{n}\left[\frac{p_{0}\cdot(1-x)^{t}\cdot Q(t)}{(1+WACC)^t}\right]=0\;(2.5.)$$

R(t)- required revenue by company in year t

As described by the formulas above, the required revenue equals to the revenue calculated by the regulator, which is based on the tariffs set by the regulator. The calculations are presented in Table 2.6. [45]. The increase of sales volume by 1.5% per annum is expected in the model. As the classic type of RPI-x model is applied, the sales volume is the risk of the company and not covered by the regulation. If the sales volume is exceeded, the company will earn excess profit. If the sales is below expected volume, the company will earn less profit than expected. The natural monopoly has very limited possibilities to increase the demand and by making better forecasting on this matter. That's mean that company and regulator are on rather equal position on those prognosis.

According to the model there is the obligation to save 0.1% per annum on electricity losses during the 5-years regulatory period. This obligation is calculated to the x-formula. By making of prognosis, the company is on a better position. By knowing the technical situation of the network, the company has the correct information on energy saving potential. Of course, the opposite effect may occur if the regulator sets unrealistic efficiency targets to the company.

Table 2.6. Allowed revenue calculated by the regulator

year		0	1	2	3	4
sales volume	GWh	10 000	10 150	10 302	10 457	10 614
power losses	%	6,0%	5,9%	5,8%	5,7%	5,6%
power losses	GWh	638	636	634	632	630
electricity price	€/MWh	40,0	40,8	41,6	42,4	43,3
RAB initial value	m€	1 000	1 030	1 060	1 090	1 120
starting RAB	m€	1 000	1 000	999	997	995
depreciation	m€	30,0	30,9	31,8	32,7	33,6
investments	m€	30	30	30	30	30
closing RAB	m€	1 000	999	997	995	991
average RAB	m€	1 000,0	999,6	998,2	996,0	992,8
WACC		8,0%	8,0%	8,0%	8,0%	8,0%
expenses						
electricity		25,5	26,0	26,4	26,8	27,3
OPEX reduction per annum	0,0%					
OPEX	m€	40,0	40,0	40,0	40,0	40,0
depreciation	m€	30,0	30,9	31,8	32,7	33,6
return	**m€**	**80,0**	**80,0**	**79,9**	**79,7**	**79,4**
return discounted	**m€**	**80,0**	**74,0**	**68,5**	**63,2**	**58,4**
required revenue	m€	175,5	176,8	178,1	179,2	180,3
required revenue discounted	m€	175,5	163,7	152,7	142,3	132,5
tariff	€/MWh	17,55				
tariff (x factor applied)		17,55	17,41	17,28	17,14	17,00
allowed revenue		175,5	176,8	178,0	179,2	180,5
allowed revenue discounted		175,5	163,7	152,6	142,3	132,6
discount factor		1,00	0,93	0,86	0,79	0,74
PV required revenue	766,7					
PV allowed revenue	766,7					
x	0,8%					
NPV	0,0					
total return	**398,9**					
total return PV	**344,1**					

The price of electricity is set according to the existing market price. It is predicted that the price will be changed according to the general inflation (retail price index). By making prognosis of the market price, both the company and the regulator are on rather similar position. The company has the possibility to hedge the price risk by using financial instruments.

The company is making investment 30 m€ per annum during the regulatory period, according to the prognosis. By estimating the real need for investment, the companies´ position is much stronger than that of the regulator. Preparation of investment program demand expert knowledge’s on technical issues and it is obvious that the company knows very well the technical situation of the system and the real investment needed. The same is valid on estimation of efficiency potential where the company has much better view on the costs savings potential.

The depreciation is calculated on a simplified method where the single depreciation norm 1/30 is used and the depreciation is constantly calculated on the starting RAB value. The return (profit) is calculated on RAB value as well. By using of classical type of RPI-x the calculations are made for the whole regulatory period and no amendments are made during the period. Thus, WACC is calculated, based the information on the starting point of the period and constantly 8%. The calculation of WACC has always been a subject of dispute. On this matter the company and regulator are on equal position. The calculation of WACC demands special financial skills and a large company has resources enough to employ high level financial experts. But in this subject, the regulator has good chances to have equal based disputes with the company. Another issue is the fixing of WACC for 5-year period by the beginning of the regulatory period. The value of WACC is not a constant but permanently changes according to the financial conditions on the global markets [48]. The prognosis of risk free rate or the value of Euribor for next year is almost impossible task. Of course, the company has an option to fix the interest rates by using financial instruments. But the conclusion is that by forecasting the value of WACC for the next 5-years period, both company and regulator are on similar position.

The operational costs are expected 40 m€ per annum. The regulator has put an obligation to save 2% on operational costs per year on real terms. Since the inflation is expected to be the same, the operational costs are flat in nominal terms during the 5-year regulatory period. According to the calculations the present value of the company’s revenue is 766.7 m€ and the tariff p_0 is 17.6 €/MWh (the tariff in the first year of the regulatory period). Using the formulas 2 and 3 the value of x is 0.8. The regulators´ decision is to apply the following indexation formula for the regulatory period:

$$p_t = p_{t-1} \times (1 + RPI_{t-1} - x) \quad (2.6.)$$

Where x equals to 0.8 (x=0.8).

Table 2.7. Positive scenario

year		0	1	2	3	4
sales volume	GWh	10 000	10 200	10 404	10 612	10 824
power losses	%	5,90%	5,80%	5,70%	5,60%	5,50%
power losses	GWh	627	628	629	630	630
electricity price	€/MWh	40,0	39,6	39,2	38,8	38,4
RAB initial value	m€	1 000	1 025	1 055	1 080	1 100
starting RAB	m€	1 000	995	994	988	975
depreciation	m€	30,0	30,8	31,7	32,4	33,0
investments	m€	25	30	25	20	20
closing RAB	m€	995	994	988	975	962
average RAB	m€	997,5	994,6	990,9	981,4	968,7
WACC		8,0%	8,0%	8,0%	8,0%	8,0%
tariff (x factor applied)	€/MWh	17,55	17,41	17,28	17,14	17,00
revenue		175,5	177,6	179,7	181,9	184,0
electricity	m€	25,1	24,9	24,7	24,4	24,2
OPEX reduction per annum	5,0%					
OPEX	m€	40,0	38,0	36,1	34,3	32,6
depreciation	m€	30,0	30,8	31,7	32,4	33,0
return	**m€**	**80,5**	**84,0**	**87,3**	**90,7**	**94,3**
return discounted	**m€**	**80,5**	**77,8**	**74,9**	**72,0**	**69,3**
ROIC		8,1%	8,4%	8,8%	9,2%	9,7%
discount factor		1,00	0,93	0,86	0,79	0,74
total return	**m€**	**436,8**				
total return PV	**m€**	**374,4**				

Table 2.8. Negative scenario

year		0	1	2	3	4
sales volume	GWh	10 000	10 100	10 201	10 303	10 406
power losses	%	6,10%	6,00%	5,90%	5,80%	5,70%
power losses	GWh	650	645	640	634	629
electricity price	€/MWh	40,0	42,0	44,1	46,3	48,6
RAB initial value	m€	1 000	1 030	1 060	1 090	1 120
starting RAB	m€	1 000	1 000	999	997	995
depreciation	m€	30,0	30,9	31,8	32,7	33,6
investments	m€	30	30	30	30	30
closing RAB	m€	1 000	999	997	995	991
average RAB	m€	1 000,0	999,6	998,2	996,0	992,8
WACC		8,0%	8,0%	8,0%	8,0%	8,0%
tariff (x factor applied)	€/MWh	17,55	17,41	17,28	17,14	17,00
revenue		175,5	175,9	176,2	176,6	176,9
electricity	m€	26,0	27,1	28,2	29,4	30,6
OPEX reduction per annum	-5,0%					
OPEX	m€	40,0	42,0	44,1	46,3	48,6
depreciation	m€	30,0	30,9	31,8	32,7	33,6
return	m€	**79,5**	**75,9**	**72,1**	**68,2**	**64,1**
return discounted	**m€**	**79,5**	**70,3**	**61,8**	**54,1**	**47,1**
ROIC		8,0%	7,6%	7,2%	6,8%	6,5%
discount factor		1,00	0,93	0,86	0,79	0,74
total return	**m€**	**359,9**				
total return PV	**m€**	**312,9**				

Table 2.7 there is presented the "positive scenario" in company's perspective. The growth in sales volume is 2% instead of 1.5% set in prognosis. The savings on electricity losses is 0.2% instead of 0.1%. The electricity price was cheaper – 1% increase instead of 2% per annum. The savings on operational cost have been 5% in nominal terms instead of steady level during the regulatory period. There was a significant saving on investment: instead of expected 150 m€; the total investment cost was 120 m€ during the regulatory period. The results are positive

for the company. The present value of return is 344.1 m€ instead of 374.4 m€ set by the regulator. The return on invested capital (ROIC) was in the range of 8.1 and 9.7%, exceeding the allowed 8% return calculated by the regulator.

In Table 2.8. there is presented the ´negative scenario´ in a company´s perspective. The growth in sales volume is 1% instead of 1.5% set in prognosis. The electricity losses have been by 0.1% higher than expected, the electricity price was more expensive the expected – instead of 2% the increase of 5% per annum. The expected savings program on operational costs was not fulfilled and the costs increased by 5% per annum in nominal terms. Despite the fact that the expected prognosis was not fulfilled, the company´s investment program was in the range of the prognosis. As described before the company is always on much better position in prognosis of investments. By using the model where all savings on capital expenditures are in favour of the company, it is very unlikely, that the company presents underestimated prognosis of investments. It is clear that there are enough reserves in a capital extensive utility like power distribution. Even if the investment need is underestimated, it will not affect the technical capability of the company in a relatively short period of 5 years. In the first simplified approach it seems that from the company´s point of view, the results are not so good. The present value of return is 312.9 m€ instead of 374.4 m€ set by the regulator. The return on invested capital (ROIC) was in the range of 6.5 and 8, i.e. below the allowed 8% return calculated by the regulator.

By measuring the value of companies, the amount of free cash flow is the most important indicator [49]. The expenses by calculation of free cash flow is based on investments, interest expense and loan repayments. In the case the actual interest expenses are lower than expected, the company will earn additional cash flow. The same is concerning investments. If the actual investment are lower than expected in the regulatory calculations, the company is going to earn additional cash flow as well. This means that by using of classic type of RPI-x model is in company´s interest to save on the investment. It may happen that the company shall invest more than projected, but this option is less likely. As mentioned before, the company has good overview on the technical situation of the system and it is very unlikely to prepare an investment plan which predicts underinvestment by this type of regulatory scheme. The expected free cash flow is calculated and presented in Table 2.9. For both scenario's and presented in Table 2.10 and Table 2.11. It is estimated that the company is keeping the financial leverage on a steady level and the dept to equity ratio is 50% in all different scenarios.

Table 2.9. Expected free cash flow by regulator

average RAB		1 000,0	999,6	998,2	996,0	992,8
dept to equity ratio		50,0%	50,0%	50,0%	50,0%	50,0%
dept		500,0	499,8	499,1	498,0	496,4
equity		500,0	499,8	499,1	498,0	496,4
interest rate		3,0%	3,0%	3,0%	3,0%	3,0%
EBITDA		110,0	110,9	111,7	112,4	113,0
interest paid	m€	15,0	15,0	15,0	14,9	14,9
investments	m€	30,0	30,0	30,0	30,0	30,0
free cash flow	**m€**	**65,0**	**65,9**	**66,7**	**67,4**	**68,1**
free cash flow discounted	**m€**	**65,0**	**61,0**	**57,2**	**53,5**	**50,1**
total free cash flow	**m€**	**333,1**				
total free cash flow PV	**m€**	**286,8**				

Table 2.10. Free cash flow by positive scenario

average RAB		998	995	991	981	969
dept to equity ratio		50%	50%	50%	50%	50%
dept		498,8	497,3	495,5	490,7	484,4
equity		498,8	497,3	495,5	490,7	484,4
interest rate		3,0%	3,0%	3,0%	3,0%	3,0%
EBITDA		**110,5**	**114,8**	**119,0**	**123,1**	**127,3**
interest paid	m€	15,0	14,9	14,9	14,7	14,5
investment	m€	25	30	25	20	20
free cash flow	**m€**	**70,5**	**69,8**	**79,1**	**88,4**	**92,7**
free cash flow discounted	**m€**	**70,5**	**64,7**	**67,8**	**70,2**	**68,2**
total free cash flow	**m€**	**400,6**				
total free cash flow PV	**m€**	**341,3**				

Table 2.11. Free cash flow by negative scenario

average RAB		1 000,0	999,6	998,2	996,0	992,8
dept to equity ratio		50%	50%	50%	50%	50%
dept		500,0	499,8	499,1	498,0	496,4
equity		500,0	499,8	499,1	498,0	496,4
interest rate		3,0%	3,0%	3,0%	3,0%	3,0%
EBITDA		**109,5**	**106,8**	**103,9**	**100,9**	**97,7**
interest paid	m€	15,0	15,0	15,0	14,9	14,9
investment	m€	30	30	30	30	30
free cash flow	**m€**	**64,5**	**61,8**	**59,0**	**56,0**	**52,8**
free cash flow discounted	**m€**	**64,5**	**57,2**	**50,5**	**44,4**	**38,8**
total free cash flow	**m€**	**294,1**				
total free cash flow PV	**m€**	**255,6**				

According to the regulators calculations the free cash flow in total amount of 286.8 m€ was expected. Free cash flow by positive scenario is 341.3 m€ and by the negative scenario 255.6 m€. The results of different scenarios are presented in Table 2.12.

Table 2.12. Company's free cash flow by different scenarios.

	Regulators prognosis	Positive scenario	Negative scenario
total return PV	344,1	374,4	312,9
free cash flow PV	286,8	341,3	255,6

From the private capital point of view the main target of the company is to generate free cash flow for its shareholders [49]. As mentioned, a capital extensive company is rather flexible by planning of investment and based on that to manage the free cash flow as well. Let's assume that the actual interest rate is 4% instead of 3% and the company shall operate in accordance to the negative scenario, where the cost savings target was not met. There is a strong requirement from shareholders to earn the free cash flow as calculated for the regulatory period. The only possibility to fulfil this target is to save on investment. As described in Table 2.13, the total amount of investment is 90 m€ instead of 150 m€ calculated for the regulatory period.

Table 2.13. Negative scenario, maximum savings on investment

average RAB		995,0	984,7	973,8	962,3	945,0
dept to equity ratio		50%	50%	50%	50%	50%
dept		497,5	492,4	486,9	481,2	472,5
equity		497,5	492,4	486,9	481,2	472,5
interest rate		4,0%	4,0%	4,0%	4,0%	4,0%
EBITDA		**109,5**	**106,8**	**103,9**	**100,9**	**97,7**
interest paid	m€	19,9	19,7	19,5	19,2	18,9
investment	m€	20	20	20	20	10
free cash flow	**m€**	**69,6**	**67,1**	**64,4**	**61,7**	**69,1**
free cash flow discounted	**m€**	**69,6**	**62,1**	**55,3**	**48,9**	**50,8**
total free cash flow	**m€**	**332,0**				
total free cash flow PV	**m€**	**286,8**				

By analysing of different risks associated to the implementation of classic type of RPI-x, the customers´ risks seems to be higher, especially by implementing without strict quality norms. In case there are strict quality norms and the investment have been overestimated due to the lack of regulator´s knowledge, the level of service quality is not a risk and just the customers are going to pay higher tariffs. In the case where the company cannot fulfil the efficiency targets, set by the regulator, or is suffering due to the overestimated demand prognosis, it's possible save on investments. In long term perspective this can be a problem for the sustainability of the service. Therefore, the main risk of classic RPI-x is the savings on investments [26].

Another risk related to the implementation of classical RPI-x is the forecast of WACC, which is directly linked to the cost of money. Since the infrastructure utilities are capital intensive, by higher cost of money, the company should earn higher return and vice versa. This is important for the dept service as well. On Figure 2.15 the cost of money indicated by the yield of 10-years German bond is demonstrated [50], [51]. The 6-month of Euribor or some other indicators could be used as well for demonstration the changes of cost of money. Therefore the forecast of correct WACC for longer period is impossible.

By setting the 5-years RPI-x for period from 2000 to 2005, would have given for company additional return, due to the fact that the tariffs were set in the time of high interest rates. Again by setting the tariffs for the period from 2005 to 2010, there would be a significant loss in profit. By setting the tariffs for the period from 2010 to 2015, the company would earn enormous extra profit due to the declining interest rates. Like a number of other inputs, the cost of capital is uncontrollable cost element. The company can save by using of more efficient capital structure or by having of better interest rate on loan capital, but the company has no influence on cost of money on the general terms.

The infrastructure utilities are extremely capital incentive and the value of WACC has significant impact on tariffs. For Estonian power transmission operator AS Elering the difference in WACC by 1% means tariff increase or decrease by 7.8% [32]. According the example given, the setting of WACC in 2000 on level 5.26% would result in tariff difference of 15% in 2005. The same is with regulatory period from 2010 to 2015, where the tariff difference would result in 17.6% in year 2015. Those are rather high deviations from the prognosis prepared for the regulatory period.

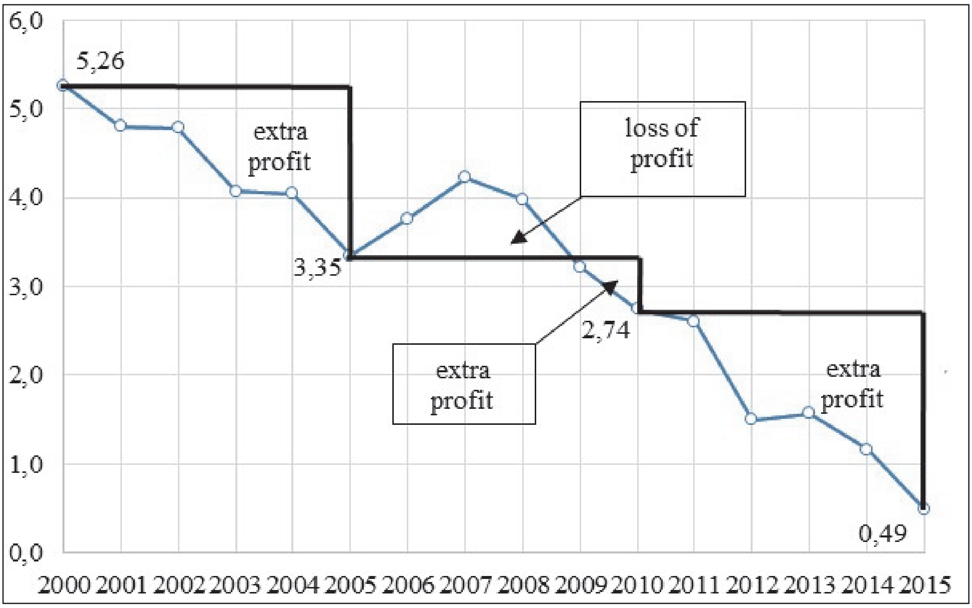

Figure 2.15. Yield of 10-year German bond.

This is the reason why the classic type of RPI-x is rarely implemented in practice. The RPI-x in practice includes strict regulation on investment, including periodical monitoring by the regulator. If a company is not fulfilling the investment program in accordance with the requirements set for the regulatory period, the excess cash flow will be compensated to customers by lowering the tariffs [44] [52], [53], [54]. The basis of calculation of RAB for the next regulatory period are the investment made in practice and not the prognosis made in theory [1], [4]. In order to keep the incentive for efficient investment, the Capital Expenditure Incentive Scheme was introduced by the water regulator in the UK. In this case, the company can earn additional profit by implementing more efficient investment policy, e. g., some more efficient technical solutions or savings on efficient procurement [1], [4].

2.3.2. Implementation of RPI-x in practice

As described in the analysis of RoR, the main shortcoming is the Averch-Johnson effect where the company has the trend of making overinvestment. After detailed analyses of the Estonian experience the conclusion is that the regulation of investment is the main shortcoming of the incentive type of RoR as well. Since there is no regularity for fixing of tariffs, the investment are not under control of the regulator. Therefore, the investment efficiency is one of the main targets of the RPI-x regulation [1]. The Capital Expenditure Incentive Scheme introduced by the water regulator in UK is a good example of that [4].

By implementing of revenue cap with cost pass-through, the controllable operational costs remain as a risk element for the company. By fixing the tariffs according to the RPI-x formula, the rising of tariffs according to the inflation is automatically included to this type of regulation. That is different from the RoR, where the tariffs are not automatically adjusted according to the inflation. For the company, the challenge is additional profit by efficient management, but the risk is that by achieving of the efficient level the regulator will demand more efficiency gains. Thus, the main objective of RPI-x regulation is the calculation of real x, which leads to the efficient tariff p_e and includes all different aspects like sales volume, operational costs, investment and technical efficiency. There is a theoretical example of calculation of x-factor which includes all those elements. The additional costs for increasing capacity are calculated on the basis of marginal costs [55]. The marginal costs are calculated according to the formula:

$$C_t = \beta_t \left(1 - \frac{(1-d)\times(1-\gamma)}{1+r}\right) \quad (2.7.)$$

C_t marginal cost of obtaining a unit of capacity for use in period t

β_t- the cost of installing a unit of capacity in period t

d- depreciation rate of capacity in each period

γ- technical progress rate

r- interest rate

By using the same technical progress rate for the operational cost, its possible to calculate the efficient level of operating costs.

$$c_t = c\frac{1-\gamma}{1+r} \quad (2.8.)$$

c_t efficient operating costs

c- expected operating costs

By using formula 2.7 and 2.8 the optimum price p_t can be calculated. In that case, the price includes the cost for adding new capacity.

$$p_t = C_t + c_t \quad (2.9.)$$

By calculating of x-factor for the regulatory period the investment and operational cost efficiency presented by γ should be taken into account. The efficient use of existing and new capacity also should be calculated.

Based on the theoretical approach presented above, the optimum price of the district heating system could be calculated in the case where new customers are connected to the grid. Let us assume that the capacity of the network is 10 MW. In order to preserve the capacity the investments are made in accordance to the depreciation rate 10% per annum. This corresponds to the capacity of 1 MW. The investment cost is 1 m€ per MW. The technical progress rate γ and the interest rate are 10%. Using the formula 2.5, the marginal cost for adding of 1 MW capacity is 0.26 m€.

$$C_t = 1 \times \left(1 - \frac{(1-0,1)\times(1-0,1)}{1+0,1}\right) = 0,26 \text{ m€} \quad (2.10.)$$

According to this example, the cost for adding an extra MW capacity is 0.26 m€ instead of 1 m€/MW (using the discount rate 10% 0.91 €/MW). Taking into account the technical progress rate for operational costs, it is possible to calculate the optimum price p_t, which equals to the regulative efficient price p_e.

By implementation of price regulation in practice, the increasing sales volumes and capacities should be taken into account by calculation of tariffs. If there is spare capacity available, then the marginal price should be used by increasing sales. Due to the fact that all customers should be equally treated by the monopoly, the marginal cost effect should be equally divided among all customers and the result is equal decreasing of tariff for every customer.

By implementation of RPI-x in practice, it is much easier to estimate the technical efficiency than to calculate the cost savings potential for operational costs like labour, maintenance, overheads, etc. By estimating the technical efficiency potential in a district heating system, it is possible to estimate the replacement cost of old networks and the savings on fuel. The same type of calculations can be made for other technical systems as well. For calculation of savings on operational costs different technics like benchmarking can be used.

Nevertheless, the evaluation of cost savings potential is rather subjective. This also makes rather subjective to calculate the x-factor as well.

Another important subject is the length of the regulatory period. If price controls are set too frequently, the utilities will have little incentive to increase their efficiency, since any profit from such efficiency gains will soon be regulated away under a lower price cap. Conversely, although increasing the duration of a price control will provide stronger incentive properties, between the price control reviews, the greater risk of adverse consequences from the price control being set at the wrong level. If the price control turns out, with hindsight, to have been too lax, there is a danger that companies will be allowed to retain excessive monopoly profits for extended periods. Alternatively, if the price control is set too tightly, there is a danger that a company will be unable to finance its regulated business, even if it is fully efficient [1]. That means, if the period is too short, there is no sufficient time for the company to realise the cost savings potential; if the period is too long, there is a risk concerning the wrong prognosis provided by the company. By using information asymmetry, the company can utilize the information for getting higher tariffs. The risk is that this type of errors will be fixed for too long time. The risks can be eliminated by termination of the regulatory period, or by setting the regulatory period with the stipulation that the changes are allowed during the period. There are such experiences by implementation of price regulation for power distribution and water supply in the UK [4]. The termination of the regulatory period or subjective changes made by the regulator are not good practice due to the fact that the fixing of tariffs according to the formula is the main basis of RPI-x regulation. Violating the rule described by the regulator turns the entire RPI-x system out of sense. It seems more rational to implement the profit-sharing scheme where so called "stop loss" is set for possible mistake. For example, if the profit is exceeding the number set by the regulator, the excess will be shared with customers.

The results of the research the RPI-x methodology are as follows:

1. The implementation of classical RPI-x is problematic and not feasible in practice, especially due to high risk of regulating of investment.

2. The setting of strict quality requirements is essential in implementation of RPI-x, otherwise the company is going to save on service quality.

3. It's reasonable to implement Capital Expenditure Incentive Scheme similar to the UK experience in energy and water regulation. The aim of the system is to reach the quality targets by efficient use of capital. This is the main advantage in comparison to RoR, which enables higher efficiency by the capital employed.

4. Especially by regulation of natural monopolies, the use of revenue cap with cost pass-through is adjusted, due to the reason that the natural monopolies have very little power to influence the sales volumes and uncontrollable costs.

5. The selection of proper length for the regulatory period is essential. The 5-years period widely used by regulatory practice is with reasonable maximum length. Longer than 5-year period gets the risk level too high, due to the prognosis adequacy and information asymmetry.

6. The correct prognosis of the cost of capital for longer period is impossible, therefore the interim adjustment of WACC is necessary, where the cost of capital can considered as uncontrollable cost element.

7. The continuation of the regulatory period is the basic element of RPI-x.

8. The implementation of RPI-x from administrative point of view costs more than RoR. By efficient use of RPI-x, the preparation of advanced economic and technical prognosis in real terms of money is an essential element. The supervision during the regulatory period, including regular data collection by the regulator, is of similar importance. The implementation of classical RPI-x is possible without any strict supervision and data collection during the regulatory period, but as described, the implementation of classic RPI-x is not feasible in practice.

2.4. LRAIC bottom up

By using of LRAIC Bottom Up (LRAIC BU), a hypothetical network or technical system is modelled by using of optimal technical solution which should guarantee all existing customers with high quality service [26]. Since the RoR and RPI-x are based on the existing technical system, the LRAIC BU relies on the hypothesis that the existing system is not the perfect one and the system which is designed using of LRAIC BU would afford to the customer the service with at least the same quality but with lower price. The method is solving the problem of "stranded assets" where there are components in company´s asset base, which are not necessary to provide the service or, the system is over dimensioned (over capacity) and is not in correspondence to the actual demand. In similar manner, the using of LRAIC BU is solving the issue of new technology or technical efficiency in the case where the use of more advanced technology would give more efficient result for the customer.

As described in paragraph 2.2, the classic RoR methodology is based on real historical costs of the company. RoR and LRAIC BU can be interpreted as the poles of a spectrum of regulatory systems where LRAIC BU is absolutely not based on historical costs. The sole fact is that by using of LRAIC BU, the system is modelled according to actual demand and geographical location of customers. For example, in modelling of power distribution system the actual demand and geographical location of existing customers is used. The geographical location of input points (for example substations owned by the transmission system operator) will be in accordance to the existing situation. This is in the case where the modelling concerns the distribution operator only. The location of distribution lines or substations is modelled using the best technology available, according to the optimal geographical location. By modelling of district heating system, by targeting the best available option for the customer, the location and capacity of heat generators will not correspond to the actual situation. The location and capacity of generators will be modelled, in order to get the optimal result for the customers. This type of modelling is mentioned as "greenfield scenario" [56]. The operational costs, including technical efficiency are in accordance to the modelled system. For example, the heat losses in a district heating system or heat generation efficiency are not historical parameters but indicating the efficiency by hypothetical using of optimal technology. By modelling of heat or power generation, the fuels neutrality approach may be used. In this case the hypothetical system is not using the fuel actual consumed but the optimal one, which gives the best result for the customer.

The LRAIC BU is widely used for regulation of postal [57] and telecom services [58]. In the energy sector there are some examples for using this methodology as well. This regulation is used in Finland by setting the value of regulatory asset base for power networks [59]. The Lithuanian Energy Regulator has analysed the method for determination of the value for power networks as well [60]. It's not a "greenfield scenario", because the geographical location of power lines and substations was not changed but the network has been adjusted in accordance to new technology and customers´ actual demand.

In energy sector, the LRAIC BU is effectively used for cost allocation in combined heat and power (CHP) generation. The main challenges in cost allocation is the fact that both, heat and power are generated by the same appliances. There is rather few equipment which is solely used for heat or power generation. For example the generator can be fully allocated for electricity generation, or the heat exchanger for heat generation. But most of equipment's like boiler, fuel preparation, turbine, etc. are used for both products.

The different methods for price regulation and cost allocation in CHP are studied in the report published by Energy Regulators Regional Association (ERRA) [28].

- Physical (or energy) method: variable costs are allocated to electricity and heat in relation to the produced energy products, or power-to-heat ratio. This method is easy to apply, but it tends to discriminate against heat.
- Method of alternative heat production: the costs of cogenerated heat are fixed at the level of alternative heat production costs (at heat-only boilers); the remaining costs are allocated to electricity.
- Method of alternative electricity production: same principle as in the previous method, but using electricity costs (or market based price) as the basis.
- Benefit distribution method (BDM): fuels used in cogeneration are allocated to electricity and heat in proportion to the amount of fuel consumption that would be necessary for alternative forms of heat and electricity supply (heat-only boilers and condensing power plants) to produce the same output as the cogeneration plant.

Physical and Benefit distribution method (BDM) represents the using of classical price regulation, e. g. RoR where the company´s historical costs are used. Based on that, the cost base for the entire CHP plant is determined and then divided for heat and power, using special formulas described below. By using BDM method, it is assumed that heat is generated with boiler efficiency. Based on that, the amount of fuel used for heat generation is calculated and divided from the total fuel amount. Based on this ratio, the costs among heat and power are divided. The same methodology is used as physical method for cost allocation by Estonian Competition Authority [61]. The methodology is described by the formulas:

$$B_{heat} = \frac{Q_{heat}}{\eta_{heat}} \quad (2.11.)$$

$$p_s = \frac{B_{heat}}{B_{el+heat}} \quad (2.12.)$$

$$t_{heat} = \frac{p_{heat} \times T_{el+heat}}{Q_{heat}} \quad (2.13.)$$

B_{heat}- fuel used for heat generation MWh

B_{el}- fuel used for electricity generation MWh

$B_{el+heat}$ – fuel used for the entire CHP plant MWh: $B_{el+heat}=B_{el}+B_{heat}$

η_{heat}- heat generation efficiency[7]

Q_{heat}- heat production MWh

p_{heat}- proportion of the costs allocated to heat generation

$T_{el+heat}$ - the cost base for the entire CHP plant both for heat and electricity

t_{heat} -heat price €/MWh

The price of electricity is calculated according to the same principles:

$$p_{el} = 1 - p_{heat} \quad (2.14.)$$

$$\mathbf{t_{el}} = \frac{\mathbf{p_{el} \times T_{el+heat}}}{\mathbf{Q_{el}}} \quad (2.15.)$$

p_{el}- proportion of the costs allocated to electricity generation

Q_{el}- electricity production MWh

t_{el} - electricity price €/MWh

An opposite BDM method can used as well, where electricity is the primary product. In this case the fuel used for electricity generation is calculated based on the efficiency in condensing mode. The principles for calculation of heat and electricity price remain the same.

The physical method is even simpler with the cost allocated proportionally in accordance to the generated heat and electricity amounts.

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[7] For calculation of heat generation efficiency two different approach are used. According the methodology used by the Estonian Competition Authority the boiler efficiency is calculated based on the steam boiler used at the CHP plant. In this case the heat generation efficiency is calculated according to the following formula:

$$\eta_{heat} = \eta_{steamboiler} \times \eta_{steampipes} \times \eta_{heatexchanger}$$

$\eta_{steam\ boiler}$- efficiency of steam boiler

$\eta_{steam\ pipes}$- efficiency of steam pipes;

$\eta_{heat\ exchanger}$- efficiency of steam-water heat exchanger

According to ERRA study [28] the heat generation efficiency is the efficiency of heat only boiler

$$p_{heat} = \frac{Q_{heat}}{Q_{heat} + Q_{el}} \; ; \; p_{el} = 1 - p_{heat} \quad (2.16.)$$

$$t_{heat} = \frac{p_{heat} \times T_{el+heat}}{Q_{heat}} \quad (2.17.)$$

$$t_{el} = \frac{p_{el} \times T_{el+heat}}{Q_{el}} \quad (2.18.)$$

The using of LRAIC BU model is adjusted in the case where the price of one product is regulated but another is sold on free market conditions. In the case of Estonia, the heat price is regulated and the heat is supplied by the monopoly. Electricity is generated in free market conditions and there is no price regulation for electricity generation. The aim of co-generation is the use of heat, which is the co-product in power generation process. In wider terms the heat customer will get no extra benefit from cogeneration, due to the fact that the heat can be produced with high efficiency from boiler house as well. Therefore it is important that in this type of market conditions the heat customers would not suffer. The method of alternative heat production is used in Estonian case, where the heat price is calculated based on alternative (hypothetical) boiler house with heat-only boilers. This is a typical implementation of LRAIC BU, where the production unit is designed in accordance to the actual demand of customers, using optimal technological design and the operational costs related to that.

The method of alternative electricity production, which is similar to alternative heat production can be used, especially in case where the electricity prices are regulated. In this case, an alternative condensation power generation plant will be designed, using the similar approach.

The use of LRAIC BU for the regulation of heat or electricity production is feasible and widely used in practice. The generation units are compact and the modelling is a rather easy task. The only input data's are: installed capacity, amount of energy produced, technical efficiency, investment and operational costs.

In opposite, the use of LRAIC BU for design of networks is rather expensive and complicated model. The Estonian Competition Authority has used the LRAIC BU model for calculating the heat price for an optimal district heating system [43]. The heat price is calculated for reference networks with annual consumption of 5 000, 50 000 and 300 000 MWh. That is simplification because the heat price is calculated based on average investment cost and efficiency parameters. The main efficiency parameter characterising the efficiency of the DH system is the consumption density MWh per meter of pipelines installed. The consumption density of 2.9 MWh/m was used for calculations. Using of this type of calculations, it is possible to get the result for an average system, which is not presenting the real situation. Each of the DH systems has its own characteristics: location of customers with different demand; high difference of generators and customers, which is important by calculating the hydraulics of the system; location of streets in the city; suitable location of heat generators in densely populated urban area; etc. The same approach is valid in designing other networks like these of water, electricity, gas, etc. That means applying of LRAIC BU model for a real infrastructure is complex and expensive exercise, similar to designing a network which is going to be built in reality. Nevertheless, the notable administrative advantage is absence of regulator´s subjectivity. If a special program is designed for calculation of networks, the regulator´s task is to insert the input data only. All calculations are made by the program. In this case, the regulator cannot influence the result by subjective reasons.

Another issue is the situation where the result of LRAIC BU demonstrates high inefficiencies of the system. In the case of cost allocation of CHP, those inefficiencies would be allocated to electricity, which should compete on open market conditions. In another case the inefficiencies of networks. It is explicit that time is needed in order to reach the efficiency goal, like the efficiency target put to one or more 5-years regulatory periods by using of RPI-x regulation. Concerning the value of regulated asset base, there is another risk described in details in chapter 0: the asset base of network industry contains large constructional facilities like power line corridors, railway beds or canalisation tunnels. Designing of those assets by using of LRAIC BU could result in a much higher assets price, due to the reason that those assets have been already paid off by the customers. Therefore this method could be used as an additional tool for calculation of efficiency indicators for implementation of RPI-x or incentive type of RoR methodology.

The results of the research the LRAIC BU methodology are as follows:

1. By implementing of LRAIC BU, the problems for using of stranded assets, ageing technology and/or technological and operational inefficiency are solved, since the system is designed by using optimal technological solution. It is a perfect instrument for the regulator in calculation of the efficient tariff p_e.

2. LRAIC BU is an effective method by implementation of price regulation in sectors of rapid technological changes where the classical monopoly is replaced by open market. Examples can be telecom sector.

3. LRAIC BU is an effective method for cost allocation in CHP generation, especially in the case where one of the product is regulated but another should compete under market conditions.

4. There is a risk in using the method for natural monopolies (for classical networks like water, electricity networks, railway, etc.). Designing of classical infrastructure could give much higher tariff to customer than the existing one.

5. Expensive to implement, especially in designing of concrete networks.

6. From administrative point of view, the big advantage is the absence of regulator´s subjectivity.

3. Regulatory asset base (RAB)

3.1. The aim and research task

The value of Regulatory Asset Base (RAB), asset used for providing of service has significant influence for establishing the regulated tariffs, due to the reason that the companies are capital intensive. For example, the share of capital expenditures (CAPEX) of Estonian power transmission operator AS Elering is 69%. The share of CAPEX in the largest Estonian power distribution operator Elektrilevi OÜ is 37% but taking into account the CAPEX of transmission operator, the share of capital expenditures in customers´ tariff is 60% [18]. The share of CAPEX components (profit and depreciation) of Elering and Elektrilevi is presented on Figure 3.2 and Figure 3.2 [32].

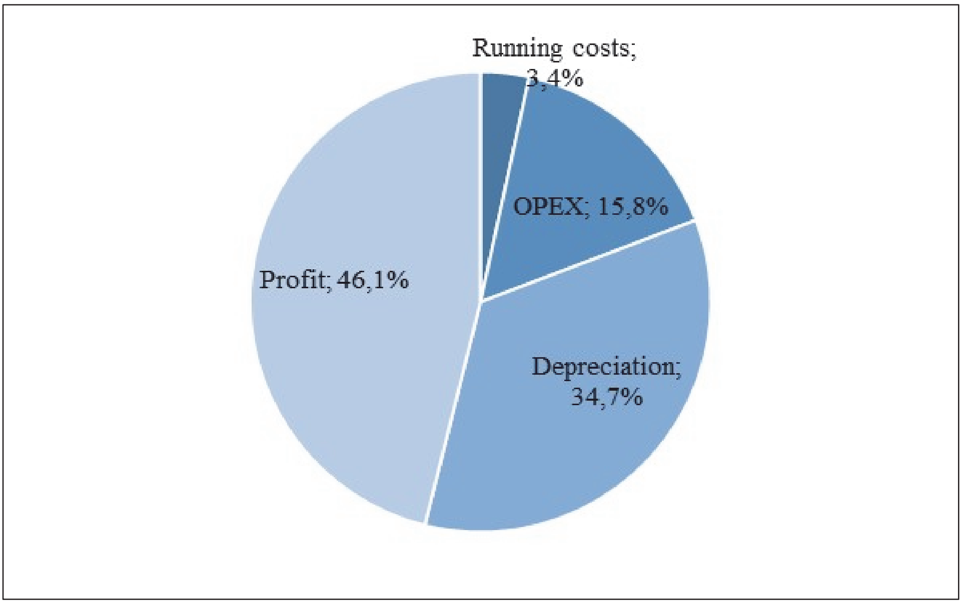

Figure 3.1 Costs structure of Estonian power TSO Elering.

The main problem is that typically the infrastructure is built decades before the starting of the price regulation. There is no continuity in accounting of the assets, from the acquisition until today. Another problem is extra-long technical life period of the assets, exceeding the lifetime set in the accountancy. For example, a canalisation tunnel or railway bed can last for centuries but the depreciation period used in accountancy is much shorter. The customer has paid off those assets but in reality the assets are still in use. In Estonian case, all classical infrastructure like water, railway or power networks is built during different political regimes starting with the Empire of Russia, proceeding the First Republic of Estonia, continuing with the period of the Soviet occupation, and ending with the restored Republic of Estonia. As the period of usage has had various currencies, hyperinflation and different principles of accountancy, it is clear that there is no continuity in accounting these assets. Another issue related to RAB is the efficiency of investment, in order to achieve the optimal investment level which affords for the customer high quality service with lowest tariff level.

The main principle of different price regulation methods is the principle to calculate the justified profit based on RAB by multiplying with weighted average cost of capital (WACC) [15]. The same method is suggested to measure the company value for enterprise acting on free market conditions [49].

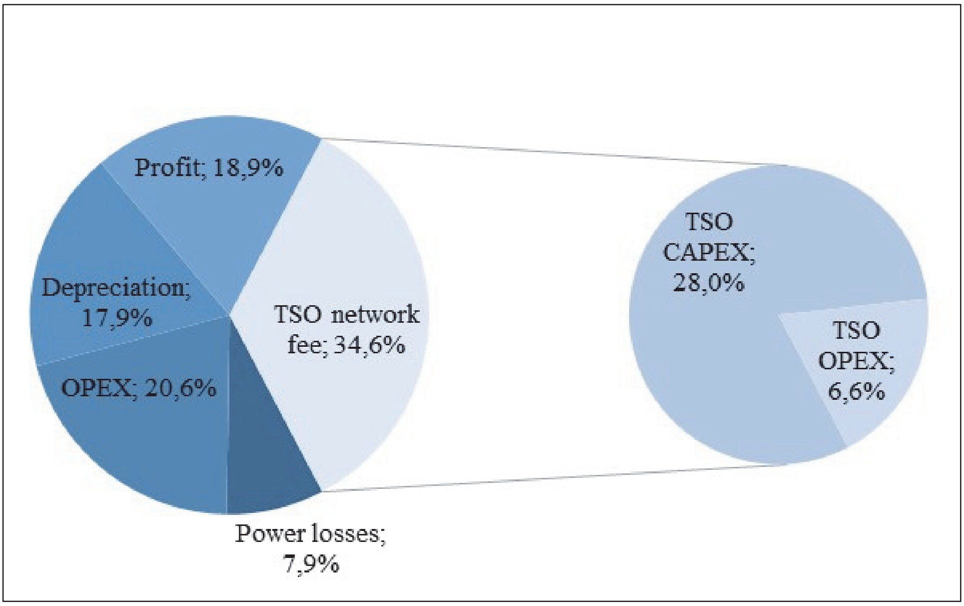

Figure 3.2 Costs structure of Estonian power DSO Elektrilevi.

Different evaluation principles of assets are described in a number of researches. Green and Pardina are analyzing regulatory models and different evaluation principles of RAB [15], Pedell is describing different methods from regulatory risk's point of view [25]. The Irish Commission for Energy Regulation has prepared a study on different regulatory option for water sector [44]. The studies on RAB has been prepared by International Energy Regulation Network (IERN) [62], Energy Regulators Regional Association (ERRA) [63], etc. The most common principles for asset evaluation are:

1. Historical cost (HC), in the case of which the value of assets is the net book value as published in annual accounts.

2. Replacement cost (RC) where the value of assets is calculated as the cost of replacing it with another asset today that will provide the same services and

capacity. The RC less stranded assets can be used. This method removes any inefficiency that exists in the RAB's current asset configuration, such as duplication, excess capacity and redundant assets.

3. Market value where the value of the asset is the potential sales price of the enterprise. In the case the company is traded on stock exchange, the market value is calculated on the basis of the stock price[8].

4. Privatisation value, where the value of the asset is the price paid for the company during its privatisation.

5. LRAIC BU where the value of assets is determined by designing of hypothetical network or technical appliance, using of optimal technical solution, in detail's described in chapter 2.4.

The complex of determination the value of assets of a regulated company is the fact that the company is not free to decide on tariffs. The free cash flow generated is depending on regulators decision. If the company acts on free market conditions, the amount of free cash flow depends on economic positions and managerial decisions made by the company. By determination of the value, the ability of the company to generate free cash flow is calculated. The same principle is used for both, regulated and not-regulated companies, where the main indicator is the profit (free cash flow), which depends on tariff, sales amount and companies costs: $\prod = PQ - Cx\ (Q) - Cn\ (Q)$ (2.1)[9].

By using the free cash flow principle for calculation of the value of regulated company, the result is the circularity [25]. The higher cash flow is generating the higher asset value. By calculation of company´s value by this method the mathematical result is infinite.

3.1.1. Theoretical accounting principle of RAB

The perfect accounting principle can be used in the case where the regulated company is established as "greenfield scenario" and the price regulation starts with operation. The value of RAB is the exact number of investment and the assets are depreciated in accordance to the expected technical lifetime. The depreciation and the justified return are included to the tariffs. The calculations are made in nominal terms. The calculations are simple and transparent in accordance to the formulas [35].

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[8] Not suitable to implement in practice due to the problem that this methodology Leads to a circularity problem (rate will determine the value of RAB which determines the return on RAB) [62], [25]

[9] Equation $\prod = PQ - C_x\ (Q) - C_n\ (Q)$ (2.1)

$RAB_1 = RAB_0 + I_1 - D_1$; $RAB_{n+1} = RAB_n + I_{n+1} - D_{n+1}$ (3.1.)

RAB_n – the value of RAB at the end of the certain year of regulation

RV_0- the value of RAB in the starting point of the regulation

I_n – investment maid in certain year of regulation

A_n-depreciation of certain year of regulation

The justified return is calculated on the basis of the formula:

$$\prod = WACC \times RAB \quad (3.2.)$$

$$RAB_1 = \frac{RAB_0 + RAB_1}{2}; RAB_{n+1} = \frac{RAB_n + RAB_{n+1}}{2} \quad (3.3.)$$

It is assumed that a regulated utility was constructed as "greenfield scenario" with investment cost of 100 m€ (example 1, Table 3.1.) The depreciation period is 20 years and the current annual investments are in accordance to the depreciation. The depreciation of those current investments is calculated in the same manner, based on their acquisition cost. The total depreciation included to the tariffs is the sum of depreciation on initial investment (RAB_0) and current investments. In this type of accounting, the continuity principle has importance. The initial investment of 100 m€ is totally depreciated by the end of year 20. The investment made in year 1 5.3 m€ shall be excluded by the end of year 21, etc. The WACC rate is 7% through the full period and all calculations are made in nominal terms.

Example 2 (Table 3.1) is similar but the difference is that the investment made are not in accordance to the depreciation but much less. This example corresponds to a gas or district heating network, as "greenfield scenario". The technical lifetime of this type of network is more than 20 years, and the need of investments for this type of networks is very limited, the replacement of measuring equipment's mainly. According to this sample, the current annual investment are 1% from the initial cost and inflated with the norm of 2% per annum.

Example 3 (Table 3.1) is similar. The difference is that the technical lifetime of the appliance is in accordance to the accounting principles. There is a need to replace the entire system by year 21. The initial cost of investment is the same in real terms, but since the calculations are made in nominal terms, the investment cost is inflated by the same norm of 2% per annum. This example corresponds to a boiler house. The technical lifetime of the boiler is 20 years. By the end of its life cycle, the optimal solution is the replacement of whole boiler house, not the boiler only.

By using the continuity principle, the result is perfect for both company and customer. All investment and reasonable return are included to the tariffs. There might be an issue by example 3, if the regulator takes the position that only assets in real operation can be included to RAB. In this case, the current investment made in the period from year 1 to the year 20 in amount of 24.3 m€, could be considered as stranded assets. But by using the continuity model, this would be unfair from the company´s point of view, since the investment have been really made and are important for customer as well. The use of this type of accounting in practice is possible for “greenfield scenario” utilities only. The problem is that most of regulated utilities are not “greenfield scenario” projects.

3.1. Historical cost.

The main advantages of HC method are the simple use and low administrative costs, due to the reason that the value of RAB is determined from the company´s books and there is no need to make additional analyses. The accounting principle is easy to implement as well. By using of regulative accounting it is simple to add investments and deduct depreciation. Even more easy is just directly to use the company’s bookkeeping.

The Irish Energy Regulator CER has prepared a detailed study to analyse the practical use of different RAB valuation methods [44]. The CER points out the positive and negative aspects by using the HC method. This is generally considered the simplest approach to valuing the RAB. It requires no adjustment to the calculation of the RAB, other than for new capital expenditure and depreciation of the assets. Administratively inexpensive for the regulator as it does not require detailed review of asset values – the HC will be known from the outset. Historic Cost does not reflect the current economic value of assets, as inflation has eroded their original purchase value. This would lead to an under-valued RAB and is therefore likely to reduce the regulated company’s incentive to invest. In addition, HC may not provide sufficient cash flow to the regulated business because of the under-valuation to fund efficient network investment.

In order to reduce the risk of underinvestment, CER recommends to use the indexed historic cost method, assets are valued at their original purchase price with an indexation factor (usually inflation) applied (e.g. an asset purchased in 1980 is inflated up to 2013 prices by applying the indexation factor of every year from 1980 up to 2013). Applying an indexation factor counters the erosion of the value of the asset over a period of time CER is recommending to use the indexed HC method. Considering that the CER proposes to inflate the RAB to account for inflation, the WACC also needs to be calculated in real terms [44].

Table 3.1. Accounting of RAB

Example 1

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
inflation	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%
RAB_0 opening value	100,0	100,0	100,0	100,0	99,9	100,0	100,0	99,9	99,9	99,9	99,8	99,8	99,8	99,8	99,7	99,8	99,7	99,7	99,6	99,6	99,6	99,6	99,6	99,6	99,6
Initial investment	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	0,0	0,0	0,0	0,0	0,0
depreciation norm	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%
depreciation of initial investment	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	0,0	0,0	0,0	0,0	0,0
current investments	5,3	5,5	5,8	6,1	6,5	6,8	7,1	7,5	7,9	8,3	8,8	9,2	9,7	10,2	10,8	11,3	11,9	12,5	13,2	13,9	9,1	9,3	9,5	9,7	9,8
cumulative value of current investment	5,3	10,8	16,6	22,7	29,2	36,0	43,1	50,6	58,5	66,8	75,6	84,8	94,5	104,7	115,5	126,8	138,7	151,2	164,4	178,3	182,1	185,9	189,6	193,2	196,5
depreciation of current investment	0,3	0,5	0,8	1,1	1,5	1,8	2,2	2,5	2,9	3,3	3,8	4,2	4,7	5,2	5,8	6,3	6,9	7,6	8,2	8,9	9,1	9,3	9,5	9,7	9,8
total depreciation	5,3	5,5	5,8	6,1	6,5	6,8	7,2	7,5	7,9	8,3	8,8	9,2	9,7	10,2	10,8	11,3	11,9	12,6	13,2	13,9	9,1	9,3	9,5	9,7	9,8
RAB closing value	100,0	100,0	100,0	99,9	100,0	100,0	99,9	99,9	99,9	99,8	99,8	99,8	99,8	99,7	99,8	99,7	99,7	99,6	99,6	99,6	99,6	99,6	99,6	99,6	99,6
RAB value (capital invested)	100,0	100,0	100,0	99,9	100,0	100,0	99,9	99,9	99,9	99,8	99,8	99,8	99,8	99,8	99,8	99,7	99,7	99,7	99,6	99,6	99,6	99,6	99,6	99,6	99,6
WACC	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%
operating profit	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0
freee cash flow	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0

Example 2

year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
inflation	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%
RAB0 opening value	100,0	96,0	91,9	87,8	83,6	79,4	75,2	71,0	66,7	62,4	58,0	53,6	49,2	44,7	40,2	35,7	31,1	26,5	21,8	17,1	12,3	12,6	12,8	13,1	13,4
Initial investment	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,0	0,0	0,0	0,0	0,0
depreciation norm	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%
depreciation of initial investment	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	0,0	0,0	0,0	0,0	0,0
current investment	1,0	1,0	1,0	1,1	1,1	1,1	1,1	1,1	1,2	1,2	1,2	1,2	1,3	1,3	1,3	1,3	1,4	1,4	1,4	1,5	1,5	1,5	1,5	1,6	1,6
cumulative value of current investment	1,0	2,0	3,1	4,1	5,2	6,3	7,4	8,6	9,8	10,9	12,2	13,4	14,7	16,0	17,3	18,6	20,0	21,4	22,8	24,3	24,8	25,3	25,8	26,3	26,8

depreciation of current investment	0,1	0,1	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,5	0,6	0,7	0,7	0,8	0,9	0,9	1,0	1,1	1,1	1,2	1,2	1,3	1,3	1,3	1,3
total depreciation	5,1	5,1	5,2	5,2	5,3	5,3	5,4	5,4	5,5	5,5	5,6	5,7	5,7	5,8	5,9	5,9	6,0	6,1	6,1	6,2	1,2	1,3	1,3	1,3	1,3
RAB closing value	96,0	91,9	87,8	83,6	79,4	75,2	71,0	66,7	62,4	58,0	53,6	49,2	44,7	40,2	35,7	31,1	26,5	21,8	17,1	12,3	12,6	12,8	13,1	13,4	13,6
RAB value (capital invested)	98,0	93,9	89,8	85,7	81,5	77,3	73,1	68,8	64,5	60,2	55,8	51,4	47,0	42,5	38,0	33,4	28,8	24,1	19,5	14,7	12,5	12,7	13,0	13,2	13,5
WACC	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%
operating profit	6,9	6,6	6,3	6,0	5,7	5,4	5,1	4,8	4,5	4,2	3,9	3,6	3,3	3,0	2,7	2,3	2,0	1,7	1,4	1,0	0,9	0,9	0,9	0,9	0,9
free cash flow	10,9	10,7	10,4	10,1	9,9	9,6	9,4	9,1	8,8	8,6	8,3	8,0	7,8	7,5	7,2	6,9	6,6	6,4	6,1	5,8	0,6	0,6	0,7	0,7	0,7

Example 3

year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
inflation	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%
RAB_0 opening value	100	96,0	91,9	87,8	83,6	79,4	75,2	71,0	66,7	62,4	58,0	53,6	49,2	44,7	40,2	35,7	31,1	26,5	21,8	17,1	12,3	152	145	138	131
initial investment	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,0	0,0	0,0	0,0	0,0
depreciation norm	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%
depreciation of initial investment	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	0,0	0,0	0,0	0,0	0,0
current investments	1,0	1,0	1,0	1,1	1,1	1,1	1,1	1,1	1,2	1,2	1,2	1,2	1,3	1,3	1,3	1,3	1,4	1,4	1,4	1,5	148, 6	1,5	1,5	1,6	1,6
cumulative value of current investment	1,0	2,0	3,1	4,1	5,2	6,3	7,4	8,6	9,8	10,9	12,2	13,4	14,7	16,0	17,3	18,6	20,0	21,4	22,8	24,3	171	172	172	173	173
depreciation of current investment	0,1	0,1	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,5	0,6	0,7	0,7	0,8	0,9	0,9	1,0	1,1	1,1	1,2	8,6	8,6	8,6	8,7	8,7
total depreciation	5,1	5,1	5,2	5,2	5,3	5,3	5,4	5,4	5,5	5,5	5,6	5,7	5,7	5,8	5,9	5,9	6,0	6,1	6,1	6,2	8,6	8,6	8,6	8,7	8,7
RAB closing value	96,0	91,9	87,8	83,6	79,4	75,2	71,0	66,7	62,4	58,0	53,6	49,2	44,7	40,2	35,7	31,1	26,5	21,8	17,1	12,3	152	145	138	131	124
RAB value (capital invested)	98,0	93,9	89,8	85,7	81,5	77,3	73,1	68,8	64,5	60,2	55,8	51,4	47,0	42,5	38,0	33,4	28,8	24,1	19,5	14,7	82,3	148	141	134	127
WACC	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%
operating profit	6,9	6,6	6,3	6,0	5,7	5,4	5,1	4,8	4,5	4,2	3,9	3,6	3,3	3,0	2,7	2,3	2,0	1,7	1,4	1,0	5,8	10,4	9,9	9,4	8,9
free cash flow	10,9	10,7	10,4	10,1	9,9	9,6	9,4	9,1	8,8	8,6	8,3	8,0	7,8	7,5	7,2	6,9	6,6	6,4	6,1	5,8	-134	17,5	17,0	16,5	16,0

The study prepared by Energy Regulators Regional Association (ERRA) [63] refers to the following disadvantages by using the HC method.

- HC may understate asset prices in times of high inflation.
- HC may overstate asset prices in times of technological change.
- HC may lead to unstable prices (e.g. prices may rise when new, more expensive assets replace existing assets).
- Data may be inadequate (especially for assets that have been acquired a long time ago) and returns may also be inadequate to support the funding of new investments.

The HC is mainly used by the regulators in the USA and by a number of European regulators for determination of the initial value of RAB. Like CER, ERRA underlines that this method is administratively inexpensive.

The study prepared by the International Energy Regulation Network (IERN) underlines the advantages by using of HC method:

- Objective and simple to implement because the values are tied to the financial records of the company
- No subjective assessment of the values of assets
- Transparent, predictable and widely used method. Avoids the disputes between the regulated operator and the regulator Provides a continual matching between the money the shareholders provide for investment and the cash flow that is provided back to investors [62].

The aspects are similar to the others studies analysed but the absence of subjectivity is underline as an advantage. The disadvantages mentioned in the IERN study are similar:

- Difficulty of implementation where accounting and property records are poor.
- Understating the economic value of assets during times of inflation and technological advances.
- Providing misleading economic signals to markets as to the real economic costs of the service [62].

The main problem by determination the value of RAB is the fact that the infrastructure has been established decades before starting the price regulation. For example the using of indexed HC is impossible in countries where the infrastructure was built in times of different political regimes. A good example is the railway infrastructure in Estonia. The railway beds are constructed during the Russian empire, adding the infrastructure built in first Republic of Estonia, in the period of the Soviet occupation and nowadays. The situation is similar in electricity networks, although this infrastructure was mainly built during the

Soviet times. There is no information available on acquisition costs of those assets. The currency system has been stable for last 20 years in Estonia. That means that the indexed HC could be used for the assets purchased since the middle of the 1990s.

As demonstrated in chapter 3.1.1, the result of HC method is perfect and fair from both company´s and customer´s point of view if the continuous accounting principle is used since the beginning of the operation of the utility. For the most infrastructure utilities this is not the case. This means that the book value of the assets can be very subjective. The book value of long-life assets might have been revaluated many times during history. For example, the technical lifetime a long life asset (gas or DH network) is 50 years but it is depreciated in company´s accountancy in 20 years. Then again, it is revaluated in company´s accountancy due the fact that it is still effectively in use. In this case the customer is paying unfairly twice for the investment.

As mentioned in different researches the HC may over- or underestimate the value of RAB. In case the value is overestimated, the customer is paying too high tariffs for the services provided. In case of underestimated value new investments should be partly financed from company's profit e.g. free cash flow. In long term perspective the company is earning back those investments, but the lack of free cash flow should be financed from company's accounts in this case.

Another issue related to the HC is the technical efficiency and stranded assets. Since the value of RAB is equal to the book value, the regulator is not analysing at all whether there are stranded assets like overcapacity, infrastructure not in use, etc. in the account. The same is valid for technological level where the regulator is not taking into account whether the assets in RAB corresponds to the optimal technical solution.

In using HC method, there are two different options. The first relies totally on company´s accounts. The value of RAB is calculated in accordance to the company´s accountancy and there is no regulatory accounting. Some regulatory adjustments can be implemented, like excluding the state aid funding or connection fees paid by customers from the accounts. But in principle, this type of regulation corresponds to the ex-post type of RoR regulation where the tariff calculations are made by the company and the regulator is imposing the ex-post type of control only.

The second option is to use HC for determination of opening value of RAB. In this case the value of RAB_0 is equal to company´s book value but further accounting is made or controlled by the regulator. In this case the regulatory accounting principle is similar to the formula 3.1.

$$RAB_1 = RAB_0 + I_1 - D_1 \; ; \; RAB_{n+1} = RAB_n + I_{n+1} - D_{n+1} \quad (3.4.),$$

where the opening value of RAB_0 equals the value determine by using of HC method. RAB_0 = HC.

From administrative point of view, the least costly method is to use company´s book keeping, but in this case the regulator is not controlling at all the investments. In practice, this method can be used for ex-post regulation only. The use of the regulatory accounting is not too complex and this type of method is effectively used in Estonian price regulation.

3.1.1. Estonian experience by using of HC method.

Both option of HC method are used in the case of Estonia. The second option by using of regulatory accounting is described in details. The opening value of RAB_0 is determined in accordance to the book value but the regulatory accounting is used for the record-keeping. As mentioned above, in Estonian case the history of the utilities goes back to many decades, the assets have been acquired during different political and fiscal regimes and there is no continuity in accounting of the assets.

The opening value of RAB_0 is set based on the HC (book value) at the certain time. The RAB is divided into two categories: old assets and new investment. Two different depreciation norm are used for both groups of the assets [36]. In order to make the calculations more transparent, only two depreciation norms are used: for old assets and for new investment. Both figures present the composition of assets and are calculated according to the following formula:

$$\sum n_{av} = \sum n_n \times p_n \quad (3.5.)$$

n_{av}- depreciation norm used for regulatory accounting

n_n- depreciation norm of corresponding component

p_n percentage of corresponding component in asset base

The depreciation norm for old assets RAB_0 is fixed for the entire period, due to the reason that its value is closed and no changes will be made. For calculation of depreciation norm for RAB_0 the study of Tallinn Technical University was used and the norm was calculated based on composition and residual lifetime of the existing asset base. For example, the depreciation norm of 16 years was calculated for power TSO and 15 years for the power DSO-s.

The depreciation norm for new investment depends on the composition of investment. It is different among the utilities. An example by calculation of depreciation norm for new investment is presented in Table 3.2.

Table 3.2. Calculation of depreciation norm for new investment.

	investment cost m€	proportion	lifetime years	average lifetime years
Overhead lines	500	46,7%	40	18,69
Cable lines	300	28,0%	50	14,02
Substations	200	18,7%	25	4,67
Meters	50	4,7%	15	0,70
IT	20	1,9%	10	0,19
Total	**1070**			**38,3**

The depreciation included to the tariffs is the sum of depreciation on old assets and new investment.

$$D_{tariff} = D_{old} + D_{new} \quad (3.6)$$

D_{tariff} – depreciation included to the tariffs

D_{old} - depreciation of old assets

D_{new} – depreciation of new investment

By using for calculation the scheme described above, the depreciation of old assets is a constant number during the depreciation period. The depreciation of new assets is calculated based on actual investment made. The example of using the depreciation method is presented in Table 3.3. The value of old assets is 100 m€ and it is depreciated during the 10 years period. The depreciation norm 4% is applied for new investment. According to the example, the old assets are fully depreciated by the end of year 10. Using this principle, all old assets purchased by different fiscal regimes are depreciated to this time point and the continuity principle described can be implemented.

The main advantage of this model is the full depreciation of old assets which value is disputable and there is no information available of their purchase value. There will be no more disputes on the issue of the value of those assets. The recording of new investment is made in a transparent manner. The disadvantage of this method is the rapid drop in the value of depreciation (in year 11), due to the fact that old assets are fully depreciated. According to the example, the sum of depreciation and return (profit) is declining in year 11 by 34% which is represented in tariffs as well. This rapid decline can be mitigated by introducing of longer depreciation period of old assets (15-16 years used for power networks in Estonian case). Another disadvantage is the pressure on tariffs from year 11, where the old assets are fully depreciated, but the depreciation of new assets is increasing until year 25.

Those disadvantages are described on Figure 3.3. where the tariff scenarios of Elering (Estonian Power TSO) are described [32]. In year 2019, there is a significant decrease of tariff, due to the fact that the old assets are fully depreciated. From year 2019 onwards until 2043 there is permanent increase in tariffs, because the accounting of new investments starts by 2003 and with average depreciation norm of 2,5% will last until 2043. According to the study prepared by ECA, the average customer tariff is flat from next 10-years period, starting by 2015, due to the significant tariff drop in 2019 [32].

Table 3.3. RAB calculation by using of two different depreciation norms

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Opening value of old assets	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100	100	0,0	0,0	0,0	0,0	0,0
Value of old assets in RAB	100,0	90,0	80,0	70,0	60,0	50,0	40,0	30,0	20,0	10,0	0,0	0,0	0,0	0,0	0,0
Opening value of new investment	0,0	15,0	30,0	46,0	62,0	78,0	94,0	111,0	128	146	165	184	204	225	246
Value of new investments in RAB	0,0	14,7	28,8	43,3	57,1	70,3	82,9	95,8	108	120	133	145	158	169	181
RAB opening value	100,0	104,7	108,8	113,3	117,1	120,3	122,9	125,8	128	130	133	145	158	169	181
Depreciation norm of old assets	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Depreciation of old assets	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	0,0	0,0	0,0	0,0	0,0
Depreciation norm of new investment	4,0%	4,0%	4,0%	4,0%	4,0%	4,0%	4,0%	4,0%	4,0%	4,0%	4,0%	4,0%	4,0%	4,0%	4,0%
Depreciation of new investments	0,3	0,9	1,5	2,2	2,8	3,4	4,1	4,8	5,5	6,2	7,0	7,8	8,6	9,4	10,3
Total sum of depreciation	10,3	10,9	11,5	12,2	12,8	13,4	14,1	14,8	15,5	16,2	7,0	7,8	8,6	9,4	10,3
New investments	15,0	15,0	16,0	16,0	16,0	16,0	17,0	17,0	18,0	19,0	19,5	20,0	20,5	21,0	22,0
RAB closing value	104,7	108,8	113,3	117,1	120,3	122,9	125,8	128,0	130	133	145	158	169	181	193
RAB value (capital invested)	102,4	106,8	111,0	115,2	118,7	121,6	124,3	126,9	129	131	139	151	164	175	187
WACC	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%
Operating profit	7,2	7,5	7,8	8,1	8,3	8,5	8,7	8,9	9,0	9,2	9,8	10,6	11,5	12,3	13,1
Depreciation + operating profit	17,5	18,4	19,3	20,2	21,1	22,0	22,8	23,7	24,5	25,5	16,8	18,4	20,1	21,7	23,4

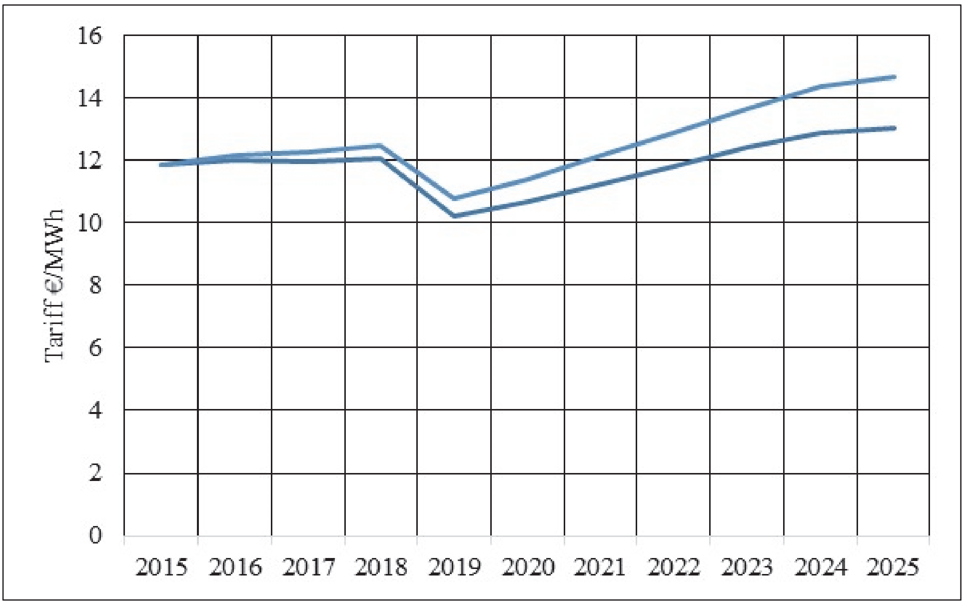

Figure 3.3 Tariff of TSO in real terms by different investment scenarios

The conclusion on Historical Cost method. The HC method uses the net book value of the company and is the simplest and least administrative costs method for evaluation of RAB. The HC method is perfect if the assets are acquired after the start of price regulation. For assets existing before the start of price regulation, the HC method may indicated too high or too low asset value. By overestimated value the customer is paying too high tariffs, by underestimated value the investments should be temporary financed from company's free cash flow, where the company is earning the investments back in long perspective. The Estonian experience by using of HC value is depreciating the assets acquired before the start of price regulation in accelerated manner. This method concentrates to accounting of newly acquired assets in consistent manner. The disadvantage of this model is rapid decrease in tariffs after the full depreciation of old assets and strong pressure on tariffs after that.

3.2. Replacement cost method

The replacement cost (RC) method is where the value of an asset is calculated as the cost of replacing it with another asset today that will provide the same services and capacity. The CER analysis underlines the main advantages of RC method [44]:

1. Assets of the RAB are valued at today's price which could provide an incentive to the regulated company to invest efficiently.

2. It facilitates technological change/improvement by allowing the regulator to reduce the value of existing assets if new, alternative and cheaper assets become available.
3. By using the replacement cost less stranded assets method, any assets that are considered stranded, where there is an unambiguous case that they are not required, not used and therefore inefficiently incurred – should, in principle, be removed from the RAB as they do not form part of the operational base of the infrastructure.
4. The using of optimised replacement cost method, provides an incentive to the regulated business to undertake optimum investment decisions

As the main disadvantage the CER report is underlining that valuing of the assets will be administratively and operationally burdensome for the regulator and regulated business. Both parties will use engineers, accountants etc. to value the assets of the RAB. The final views of both parties could differ. There is a risk of deterring new investment if some existing assets are set to zero by the regulator, or even below a level which the regulated business considers appropriate [44].

The report prepared by ERRA underlines that the RC method has a number of advantages. Assets are valued in current prices which may provide an incentive for efficient investment decisions as it allows the regulator to reduce the value of the assets once it becomes aware that a more efficient low-cost alternative asset is available. In this way, the regulatory asset base reflects the cost of replacing existing assets' service potential. It approximates the asset value above that the regulated companies will be subject to bypass risks. This reduces the risk of economically inefficient duplication of infrastructure. The disadvantages of replacement cost valuations are that they entail a degree of estimation and judgment. Secondly, the information is more expensive to collect than historical cost data because it may require expert advice (e.g. from engineers and accountants) on a number of network assets [63].

The report prepared by IERN describes the Depreciated Optimized Replacement Cost method, where the optimisation of the network is carried out in the same time with the revaluation of the assets. This method removes any inefficiency that exists in the RAB's current asset configuration, such as duplication, excess capacity and redundant assets. Suggests that investors in competitive markets do not get returns on assets that are redundant, overdesigned or technologically obsolete. The disadvantage is relatively complex to implement, and requires considerable input in terms of manpower and financial costs. It also requires a degree of subjective judgement about the optimum configuration of assets in the RAB, and about the processes of optimisation that are embodied in the derivation of the valuations [62].

In conclusion three main variations of the RC method can be used.

1. Simple RC where the valuation of the assets is realised based on existing infrastructure. The configuration, technological design or capacity of existing network are not analysed. Using this method, the technological inefficiency, overcapacity or inefficient configuration are not eliminated. The stranded assets are eliminated in very clear cases only. For example, if some parts of the network are still in asset base but in reality not used, due to the reason that no customers are connected anymore.

2. Optimised RC where the configuration of the network is not changed but all those stranded assets which are not necessary for providing service are removed from the asset base. The capacity of the network or equipment are modified in accordance to the actual demand. The most optimal technical solution is selected, but for example the type of fuel is not changed in heat or electricity generation.

3. LRAIC BU method where the network is designed based on geographical location and demand of existing customers. That means that geographical configuration differs from the existing network and the most optimal solution is selected. By energy generation, the single input data is the capacity and demand. The production unit is designed based on the most optimal technical solution and energy source[10].

The reports are referring to the high administrative costs and subjectivity factor by implementing of the RC method. Another issue in price regulation is the subject of operating costs and efficiency parameters. By using the simple RC method, historical cost and efficiency parameters can be mainly used for calculating of tariffs, hence the regulator is trying to push these factors to be more effective. But there is still the case that technology used for RC method is more efficient that the existing one. For example the existing district heating network is built from the old type of insulated pipes and the technical situation is very poor, with heat losses of 25%. Even using the same type of old technology for RC method, the heat losses of properly built system is not reaching the level of new technology, but are not as poor as the real situation and much lower heat losses are reachable by using of old technology. In this case is not fair from customer's point of view to use the historical data.

In application of optimized RC or LRAIC BU the using of historical data is even more problematic due to the fact that the optimized system is much different than the existing one. In this case the costs and efficiency parameters should be

[10] The LRAIC BU method is described in details in chapter 3.4.

selected in accordance to the optimized system and the price regulation should be similar to that using the LRAIC BU regulatory model.

Similar example, the existing district heating network is built partly from old type of insulated pipes and partly from new type of pre-insulated pipes. The actual heat losses from this type of system are 20% because the new type of pipes are 30% only from the total network. To apply optimised RC method, the DH network is designed 100% from pre-insulated pipes. In this case it is impossible to use the historical heat losses in tariff calculations. Instead of, the heat loss corresponding to the pre-insulated system shall be used. The same type of case is the installation of frequency control system to a DH circulation pump which is a rather simple way for cost reduction. In this case, if the pump with frequency control system is used by RC method, those saving should be calculated in tariffs as well. For example if the existing inefficient heat generator is replaced by modern technology by using of optimized RC method, not only the energy efficiency but savings on operational and maintenance costs also should be considered in calculation of heat tariffs.

Using of optimized RC or LRAIC BU is more expensive and subjective in comparison to the simple RC. If to use the simple RC, it is enough if the engineer has the list of equipment. In using of optimized RC, there is the risk of subjectivity by selecting of technology and optimal solution. By selecting the optimal solution, the economic calculation shall be made, in order to calculate which design is optimal from the customer's point of view. For example, in designing of DH network, calculations whether the replacement of existing network with pre-insulated pipes is efficient shall be made. The same case is the use of flue gas scrubber by the existing biomass boiler house. If this type of technical solution is missing but there is an intention to use it in the optimized RC, the economic benefit of the technology shall be estimated. It means that the Optimized RC is not simple revaluation of the existing assets but includes the economic calculation and the optimisation exercise as well.

By using regulatory models based on historical costs (classic type or ex-post RoR), the simple RC should be used by revaluation of the assets. This method eliminates the definite stranded assets only and is making no significant technological changes. Thus, it can rely on historical costs.

The subjectivity factor remains a risk element by using of different RC methods. Especially the risk occurs in determining residual technical lifetime of different assets. Another subjectivity risk is the evaluation of the technical design by using optimized RC method. By using of LRAIC BU, this type of subjectivity can be eliminated by applying standardized models. In that case, the subjectivity risk is low due to the fact that the design of network or other equipment is carried out by computer.

From the customer´s perspective, the usage of RC contains a significant risk. Applying classical infrastructure technology like water, gas, electricity or DH networks, evoke high risk that the customer shall pay for infrastructure costs which are historically paid off by the customer already. For example, there exists large infrastructure facility like water or waste water pipes in highly populated areas or railway bed or power lines corridors. All of those assets are with extremely long technical lifetime. By using RC method, there is high risk that the value of those assets is many times higher than their book value. This will have significant impact to the customers´ tariffs.

The RC method can be implemented in two main options. The value of RC can be the starting point by determination of the opening value of RAB but after that the regulatory accounting is similar to that used in the HC method for example. Formula $RAB_1= RAB_0+I_1-D_1$; $RAB_{n+1}=RAB_n +I_{n+1}-D_{n+1}$(3.1.) is used for calculation if the opening value of RAB equals replacement costs: RAB_0=RC.

The other option is calculation of the value of RAB by starting of each regulatory period and using the real WACC rate as demonstrated in Table 3.4. This option is much more expensive because the revaluation shall be done by the beginning of each regulatory period, as demonstrated. This option is much more expensive because the revaluation shall be done in the beginning of each regulatory period.

3.2.1. Consistent treatment of regulatory asset base using Historical Cost and Replacement Cost methods

By consistent implementation both, Historical Cost and Replacement Cost methods, the result of calculation of RAB, return on capital invested and depreciation are identical [25]. By using of HC value method, the RAB shall be multiplied by nominal WACC. By using of RC value method, the RAB shall be multiplied by real WACC. For calculation of real WACC, the following formula is used:

$$WACC_r = \frac{WACC_n - i}{1+i} \quad (3.7)$$

$WACC_r$ -real WACC

$WACC_n$ –nominal WACC

i- inflation rate

The example by using of HC and RC methods is presented in Table 3.4. [25]. The initial investment cost is 100 m€, the depreciation rate is 6 years, nominal

WACC rate is 10%, and inflation rate is 5%. The calculation of real $WACC_r$ 4.76 % is based on formula $WACC_r = \frac{WACC_n - i}{1+i}$ (3.7). By using of both methods in consistent manner, the result is the same and the discounted inpayment amounts 100 m€ in both cases.

Table 3.4. Calculation of RAB by using of HC and RC methods.

inflation	5,00%							
$WACC_{nominal}$	10,00%							
$WACC_{real}$	4,76%							
depreciation period	6							
Rates on the basis of replacement costs with replacement cost depreciation and specific real interest								
year		1	2	3	4	5	6	
replacement cost	100,00	105,00	110,25	115,76	121,55	127,63	134,01	
used replacement cost		87,50	73,50	57,88	40,52	21,27	0,00	
capital committed		105,00	91,88	77,18	60,78	42,54	22,33	
interest		5,00	4,38	3,68	2,89	2,03	1,06	
depreciation		17,50	18,38	19,29	20,26	21,27	22,33	
revenue from regulated rates		22,50	22,75	22,97	23,15	23,30	23,40	
inpayment		22,50	22,75	22,97	23,15	23,30	23,40	
discount factor		1,10	1,21	1,33	1,46	1,61	1,77	
discounted inpayment		20,45	18,80	17,26	15,81	14,47	13,21	**100,00**
Rates on the basis of acquisition costs and nominal interest								
year		1	2	3	4	5	6	
book value	100,00	83,33	66,67	50,00	33,33	16,67	0,00	
interest		10,00	8,33	6,67	5,00	3,33	1,67	
depreciation		16,67	16,67	16,67	16,67	16,67	16,67	
revenue from regulated rates		26,67	25,00	23,33	21,67	20,00	18,33	
inpayment		26,67	25,00	23,33	21,67	20,00	18,33	
discount factor		1,10	1,21	1,33	1,46	1,61	1,77	
discounted inpayment		24,24	20,66	17,53	14,80	12,42	10,35	**100,00**

By using of this type of calculations, it is important to use the depreciation norms in consistent manner. As described above, the real technical lifetime may exceed the depreciation used in accounting in many times. If the technical lifetime is 12 years, but the depreciation norm used in accounting is twice shorter, i.e. 6

years. By using the accounting in consistent manner, the depreciation and the return included to the customer tariffs shall be 0 in year 7. It is easy to violate the consistency rule by calculating the RC value in year 7 according to the revised technical lifetime 12 years. The RC of the assets in this case is 70.36 m€ according to the following formula:

$$70.36 = 134.01 \times 1.05 \times \frac{6}{12}$$

It is unfair from customer´s point of view because they are obliged to pay again for the investment which is already paid off by customers. This type of schemes should be avoided in consistent implementation of accounting methods.

The example is the case presented in chapter 3.1.1 by building the gas infrastructure as a "greenfield project". The investment cost is 100 m€, the depreciation period is 20 years and annual investment is below depreciation, due the fact that no big replacements are needed for this type of assets. By end of depreciation period in year 21, the value of RAB is 12.3 m€ and free cash flow is 0.6 m€. There is no need for larger scale investment and the residual technical lifetime of the gas infrastructure is at least 20 years or even more. The value of assets is calculated now in accordance to RC method, assuming that the residual life time is 20 years. The market value of building the gas infrastructure in market prices is 148.6 m€[11] in year 21. The RC value of the assets is 74.3 m€ and it is the basis for calculation of depreciation and return. That means that the amount of 62 m€ is calculated and not invested to the company. As the result of this type of revaluation, the free cash flow in year 21 is 6.8 m€ instead of 0.6 m€ and the sum of depreciation and return in the same year is 8.3 m€ instead of 2.1 m€. It is clear that this type of accounting principle is not consistent and fair, due to the fact that the customer is paying extra for the RAB value of 62 m€ which was not invested to the infrastructure (Table 3.6.).

The calculations presented in Table 3.4 are based on theoretical model which assumes that the change of investment cost is in accordance to inflation. In real economy the investment cost may change different from the inflation factor. Let us assume that the market value of investment cost is changing not in accordance to the inflation. The tariffs are set for 3 years regulatory period and RC method and real WACC are used for calculation. In the beginning of the second regulatory period, the market value of investment cost 150 m€ is used for calculation. In this case, the discounted inpayment is 110.18 instead of 100 m€. The result indicates that the utility is earning extra 10.18 m€ due to the fact that the market value of investment has changed (Table 3.5.). But in reality, the company has made no additional investment and is earning just because of the change of accounting

[11] It is assumed that the investment cost is inflated in accordance to the annual inflation $100 * (1+0.02)^{20} = 148.6$

principles. It is clear that this type of calculation is unfair from the customers´ point of view.

Table 3.5. Calculation of RAB using of RC and HC methods. The value of investment inflates not in accordance to the general inflation.

inflation	0,05							
$WACC_{nominal}$	0,1							
$WACC_{real}$	0,0476							
depreciation period	6							
Rates on the basis of replacement costs with replacement cost depreciation and specific real interest								
year		1	2	3	4	5	6	
replacement cost	100,00	105,00	110,25	115,76	150,00	157,50	165,38	
used replacement cost		87,50	73,50	57,88	50,00	26,25	0,00	
capital committed		105,00	91,88	77,18	75,00	52,50	27,56	
interest		5,00	4,38	3,68	3,57	2,50	1,31	
depreciation		17,50	18,38	19,29	25,00	26,25	27,56	
revenue from regulated rates		22,50	22,75	22,97	28,57	28,75	28,88	
inpayment		22,50	22,75	22,97	28,57	28,75	28,88	
discount factor		1,10	1,21	1,33	1,46	1,61	1,77	
discounted inpayment		20,45	18,80	17,26	19,51	17,85	16,30	**110,18**
Rates on the basis of acquisition costs and nominal interest								
year		1	2	3	4	5	6	
book value	100,00	83,33	66,67	50,00	33,33	16,67	0,00	
interest		10,00	8,33	6,67	5,00	3,33	1,67	
depreciation		16,67	16,67	16,67	16,67	16,67	16,67	
revenue from regulated rates		26,67	25,00	23,33	21,67	20,00	18,33	
inpayment		26,67	25,00	23,33	21,67	20,00	18,33	
discount factor		1,10	1,21	1,33	1,46	1,61	1,77	
discounted inpayment		24,24	20,66	17,53	14,80	12,42	10,35	**100,00**

.

Table 3.6. RAB calculation. Inconsistent use of accounting principles.

year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
inflation	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%
RAB0 opening value	100,0	96,0	91,9	87,8	83,6	79,4	75,2	71,0	66,7	62,4	58,0	53,6	49,2	44,7	40,2	35,7	31,1	26,5	21,8	17,1	12,3	83,1	79,7	76,2	72,7
Initial investment	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	0,0	0,0	0,0	0,0	0,0
depreciation norm	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*
depreciation of initial investment	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	0,0	0,0	0,0	0,0	0,0
depreciation of current investment	1,0	1,0	1,0	1,1	1,1	1,1	1,1	1,1	1,2	1,2	1,2	1,2	1,3	1,3	1,3	1,3	1,4	1,4	1,4	1,5	75,8	1,5	1,5	1,5	1,6
cumulative value of current investment	1,0	2,0	3,1	4,1	5,2	6,3	7,4	8,6	9,8	10,9	12,2	13,4	14,7	16,0	17,3	18,6	20,0	21,4	22,8	24,3	99,1	99,5	100,0	100,5	101,0
depreciation of current investment	0,1	0,1	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,5	0,6	0,7	0,7	0,8	0,9	0,9	1,0	1,1	1,1	1,2	5,0	5,0	5,0	5,0	5,0
total depreciation	5,1	5,1	5,2	5,2	5,3	5,3	5,4	5,4	5,5	5,5	5,6	5,7	5,7	5,8	5,9	5,9	6,0	6,1	6,1	6,2	5,0	5,0	5,0	5,0	5,0
RAB closing value	96,0	91,9	87,8	83,6	79,4	75,2	71,0	66,7	62,4	58,0	53,6	49,2	44,7	40,2	35,7	31,1	26,5	21,8	17,1	12,3	83,1	79,7	76,2	72,7	69,2
RAB value (capital invested)	98,0	93,9	89,8	85,7	81,5	77,3	73,1	68,8	64,5	60,2	55,8	51,4	47,0	42,5	38,0	33,4	28,8	24,1	19,5	14,7	47,7	81,4	77,9	74,4	71,0
WACC	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%
operating profit	6,9	6,6	6,3	6,0	5,7	5,4	5,1	4,8	4,5	4,2	3,9	3,6	3,3	3,0	2,7	2,3	2,0	1,7	1,4	1,0	3,3	5,7	5,5	5,2	5,0
depreciation + operating profit	11,9	11,7	11,4	11,2	11,0	10,7	10,5	10,2	10,0	9,8	9,5	9,3	9,0	8,8	8,5	8,3	8,0	7,8	7,5	7,2	8,3	10,7	10,5	10,2	10,0
cash flow	10,9	10,7	10,4	10,1	9,9	9,6	9,4	9,1	8,8	8,6	8,3	8,0	7,8	7,5	7,2	6,9	6,6	6,4	6,1	5,8	6,8	9,2	8,9	8,7	8,4

Another similar example can be calculated in the case where the market value of investment is less than the amount adjusted according to the inflation and the replacement cost value in year 4 is 100 m€ instead of 121.55 (Table 3.4). In this case, the company is earning less than expected and the discounted value for inpayment is smaller than 100 m€. This is unfair from the company´s point of view.

The result is that for consistent calculation of RAB in the case where the investment cost is properly recorded, the most appropriate way is to use HC method with nominal WACC.

The conclusion on Replacement Cost method. In case the assets are acquired after the start of price regulation, in theory there is no difference whether to use historic acquisition cost and nominal WACC or replacement cost and real WACC. By using of consistent accounting principles the results are the same. In practice the change of prices of investment may differ from the inflation, in this case the using of historic acquisition cost and replacement cost will give different result. The main risk by using of RC method from customers point of view is the inconsistent use of the method, where the already depreciated assets will be revaluated again. The risk is notably high by revaluation of long life assets built decades before the start of price regulation. Especially by using of optimized RC, which is eliminating inefficiency's the historical operational costs or efficiency indicators cannot be used, because the investment cost corresponds to more efficient operational standards. The same issue should be considered by using of simple RC method as well

3.3. LRAIC BU valuation method

As described in Chapter 2.4 there exists a separate regulation methodology LRAIC BU, where the optimized network or equipment is designed. The aim of this method is to design the system using modern technology with optimal network design. The method is free from the stranded assets.

In reality there exist stranded assets in most of the regulated utilities. There are certainly some parts of power or district heating network where the customers have disconnected from the network. Some of substations or lines are over dimensioned and with much higher capacity than actually needed. The heat or power generation unit may be over dimensioned. It is clear that no network corresponds 100% to the actual demand of its customers. In real life it is over- or under dimensioned.

The same issue arises in using new technology. In the free market conditions, the company selects the optimal solution by employing capital for new investment on the optimal manner, in order to maximise the profit. For the regulated utility, the market size is guaranteed and there is no direct need to invest in the optimal way. It should be considered that in most of utilities the classical technological solutions are used and the changes are not so rapid. A good example is that of the pre-insulated pipes used for district heating. In Estonia, a big part of the DH networks build with old-fashioned insulated pipes are still in use. Most of the new pipes installed are pre-insulated but before replacing of all pipes in a DH company, the economic calculations shall be made. The total replacement of all existing technology pipes is not in all cases the optimal solution, causing increase in customers´ tariffs.

The similar methods to LRAIC BU are described in CER study as methods of Replacement Cost Less Stranded Assets and Optimised Replacement Costs [44]. The IERN study is describing this method as Depreciated Optimized Replacement Cost method [62].

In both studies, high administrative costs of the methods have been underlined as the main disadvantage. The subjectivity issue has also been mentioned as a disadvantage. But the subjectivity problem in using of this methodology is not the same as using the RC method where the engineer decides subjectively which asset is stranded or in which cases another technological solution should be selected. By using the LRAIC BU on consistent manner where special software is produced for different type of utilities, the risk of the subjectivity factor can be eliminated. By using of standard solution the role of the regulator is just to enter the input data for a power or district heating network. Those data is the geographical location of customers and generators or substations. The software is designing the optimal configuration of the network. The exercise for designing of electricity or heat generation unit is less complex, where the input data are just capacity and demand.

The conclusion on LRAIC BU valuation method. As result, the main advantage of LRAIC BU model is the designing of optimal infrastructure from customers´ point of view. This optimal infrastructure is using effective technology and does not includes any stranded assets. The main risk by implementing this model is the fact that the result may differ a lot from the real situation. By designing of classical infrastructure elements like railway beds, wastewater channels and power line corridors with this method, the result might bring much higher tariffs for the customers. That means that this method should be implemented as a supportive regulatory instrument mainly. Another advantage of the model is the mitigation of subjectivity issue in price regulation, where the system is going to be designed by the computer model.

3.4. Stranded assets

The risk of stranded assets from the companies´ perspective is that some part of the assets are excluded from the RAB. The depreciation and return on those assets are not included to the tariffs. From the customers´ point of view the risk is to pay for the assets which are not necessary to provide the service. In free market conditions the return on the assets is not guaranteed and this risk is compensated by higher return.

The Irish energy regulator underlines two issues related to the subject of stranded assets. Excluding stranded assets from the RAB may deter investment, i.e. the network owner may not invest in some cases if there is a risk that the asset may become stranded. Identification of stranded assets by the regulator is somewhat judgmental. The regulator would need to demonstrate that a specific asset should not have been built based on reasonable assumptions, which would certainly be open to argument by the regulated company. In essence, the regulator would have to step into the shoes of the investment decision-maker [44].

The issue of stranded asset exists in using of methods of historical cost and replacement cost synchronically. In that case, the regulator may impose the changes to the RAB by excluding of stranded assets from RAB. Only the LRAIC BU is free of this problem because the infrastructure is designed by using optimal solution, free from stranded assets.

Another example is the case where the assets have been acquired before the price regulation has started and the third party describes the situation where the company has made wrong decisions of investment.

A good source for making this statement explicitly is example 3 from Chapter 3.1.1. (Table 3.1.). The initial investment of 100 m€ for heat generation was made in year 1. By the end of year 20, the boiler house is technically depreciated. In order to continue heat generation it is mandatory to purchase a new one with investment cost of 148.6 m€. The old boiler house including additional investment in the sum of 24.3 m€ made during the period of 20 years will be utilised. From those additional investments, 12 m€ are depreciated and included to the tariffs. The problem is the rest of 12.3 m€ which are stranded assets and should be excluded from the RAB. From the regulator´s point of view these assets do not exist in reality and should be removed from the RAB. In the calculations presented in Table 3.7, the 12.3 m€ under question are removed from the RAB. This is unfair from company´s perspective because the investment have been done in reality and have been necessary for heat generation. By using of consistent accounting of RAB these investments should be included to the RAB and not treated as stranded assets.

Table 3.7. Regulatory accounting, stranded assets are removed from RAB.

year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
inflation	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%
RAB_0 opening value	100,0	96,0	91,9	87,8	83,6	79,4	75,2	71,0	66,7	62,4	58,0	53,6	49,2	44,7	40,2	35,7	31,1	26,5	21,8	17,1	148,6	141,2	135,2	129,3	123,4
Initial investment	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	148,6	148,6	148,6	148,6	148,6
depreciation norm	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*
depreciation of initial investment	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	7,4	7,4	7,4	7,4	7,4
current investmens	1,0	1,0	1,0	1,1	1,1	1,1	1,1	1,1	1,2	1,2	1,2	1,2	1,3	1,3	1,3	1,3	1,4	1,4	1,4	1,5	0,0	1,5	1,5	1,6	1,6
cumulative value of current investment	1,0	2,0	3,1	4,1	5,2	6,3	7,4	8,6	9,8	10,9	12,2	13,4	14,7	16,0	17,3	18,6	20,0	21,4	22,8	24,3	0,0	0,5	1,0	1,5	2,0
depreciation of current investments	0,1	0,1	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,5	0,6	0,7	0,7	0,8	0,9	0,9	1,0	1,1	1,1	1,2	0,0	0,0	0,1	0,1	0,1
total depreciation	5,1	5,1	5,2	5,2	5,3	5,3	5,4	5,4	5,5	5,5	5,6	5,7	5,7	5,8	5,9	5,9	6,0	6,1	6,1	6,2	7,4	7,5	7,5	7,5	7,5
RAB closing value	96,0	91,9	87,8	83,6	79,4	75,2	71,0	66,7	62,4	58,0	53,6	49,2	44,7	40,2	35,7	31,1	26,5	21,8	17,1	12,3	141,2	135,2	129,3	123,4	117,4
RAB value (capital invested)	98,0	93,9	89,8	85,7	81,5	77,3	73,1	68,8	64,5	60,2	55,8	51,4	47,0	42,5	38,0	33,4	28,8	24,1	19,5	14,7	144,9	138,2	132,3	126,3	120,4
WACC	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%
operating profit	6,9	6,6	6,3	6,0	5,7	5,4	5,1	4,8	4,5	4,2	3,9	3,6	3,3	3,0	2,7	2,3	2,0	1,7	1,4	1,0	10,1	9,7	9,3	8,8	8,4
cash flow	11,9	11,7	11,4	11,2	11,0	10,7	10,5	10,2	10,0	9,8	9,5	9,3	9,0	8,8	8,5	8,3	8,0	7,8	7,5	7,2	17,6	17,1	16,7	16,3	16,0

Table 3.8. Regulatory accounting, inefficient investment included to the RAB.

year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
inflation	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%
RAB0 opening value	100,0	96,0	91,9	87,8	83,6	79,4	75,2	71,0	66,7	62,4	58,0	53,6	49,2	44,7	40,2	35,7	31,1	26,5	21,8	17,1	148,6	141,2	135,2	129,3	123,4
Initial investment	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	148,6	148,6	148,6	148,6	148,6
depreciation norm	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*	*5,0%*
depreciation of initial investment	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	7,4	7,4	7,4	7,4	7,4
current investment	1,0	1,0	1,0	1,1	1,1	1,1	1,1	1,1	1,2	1,2	1,2	1,2	1,3	1,3	1,3	1,3	1,4	1,4	1,4	1,5	0,0	1,5	1,5	1,6	1,6
cumulative value of current investment	1,0	2,0	3,1	4,1	5,2	6,3	7,4	8,6	9,8	10,9	12,2	13,4	14,7	16,0	17,3	18,6	20,0	21,4	22,8	24,3	0,0	0,5	1,0	1,5	2,0
depreciation of current investments	0,1	0,1	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,5	0,6	0,7	0,7	0,8	0,9	0,9	1,0	1,1	1,1	1,2	0,0	0,0	0,1	0,1	0,1
total depreciation	5,1	5,1	5,2	5,2	5,3	5,3	5,4	5,4	5,5	5,5	5,6	5,7	5,7	5,8	5,9	5,9	6,0	6,1	6,1	6,2	7,4	7,5	7,5	7,5	7,5
RAB closing value	96,0	91,9	87,8	83,6	79,4	75,2	71,0	66,7	62,4	58,0	53,6	49,2	44,7	40,2	35,7	31,1	26,5	21,8	17,1	12,3	141,2	135,2	129,3	123,4	117,4
RAB value (capital invested)	98,0	93,9	89,8	85,7	81,5	77,3	73,1	68,8	64,5	60,2	55,8	51,4	47,0	42,5	38,0	33,4	28,8	24,1	19,5	14,7	144,9	138,2	132,3	126,3	120,4
WACC	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%
operating profit	6,9	6,6	6,3	6,0	5,7	5,4	5,1	4,8	4,5	4,2	3,9	3,6	3,3	3,0	2,7	2,3	2,0	1,7	1,4	1,0	10,1	9,7	9,3	8,8	8,4
cash flow	11,9	11,7	11,4	11,2	11,0	10,7	10,5	10,2	10,0	9,8	9,5	9,3	9,0	8,8	8,5	8,3	8,0	7,8	7,5	7,2	17,6	17,1	16,7	16,3	16,0

From company´s perspective the key factor is the return on invested capital (ROIC) [49]. According to the example, the company is earning 1.9 m€ less in year 22, due to the fact that 24.3 m€ was removed from the RAB as stranded assets. In year 22 ROIC is 5.7% instead of projected 7%. That means that the company is earning less than the return calculated by the regulator:

$$\text{ROIC} = \frac{10.4 - 1.9}{148.8} = 5.7\%$$

Another example could be the case where the company is making an inefficient investment decision. Let us take the same example presented in Table 3.4 and assume that these 12.3 m€ assets could be used for the new boiler house as well. Instead of using these assets for construction of the new boiler house, they are utilised. It's not an efficient way of investment planning because these 12.3 m€ are simply wasted. It is clear that this is not customers´ responsibility to pay for the investment wasted by the company (Table 3.8).

The conclusion on stranded assets. The result is that even using consistent accounting principle for assets acquired after the start of the price regulation, there is a risk of stranded assets. If the investment has been made in an efficient way, there is no reason to punish the company by excluding those assets from the RAB. If the company has made inefficient investment decisions, it is clear that the customer shall not pay for these mistakes and the return lower than expected is a company´s risk in this case. For assets acquired before the start of the price regulation the using of stranded assets method is appropriate.

3.5. Market value

By using the market value as the basis for determination of RAB, it's assumed that the RAB equals to the value by selling the company on market conditions. If the company is listed on stock exchange, the market value is the value of the shares traded. The practical implementation of market value is not possible due to the circularity effect [25], [62] where the higher market value is causing higher tariffs through the higher value of the RAB.

Another possibility to use the market value is to set the privatisation value of the company as initial value of RAB [15]. But this method can be used only once – at the moment of privatisation. Otherwise, the method is the same as using of market value which will generate the circularity effect. By using of privatisation value, the accounting principles are similar to HC method: instead of book value, the starting value of RAB is determined by the privatisation value and the value of RAB is calculated according to the formula $RAB_1 = RAB_0 + I_1 - D_1$; $RAB_{n+1} = RAB_n + I_{n+1} - D_{n+1}$ (3.1)

The risk in using privatisation value as the initial value of RAB, is to get too high bids from the potential investors, which may lead to the tariffs higher than expected. The high risk is in case if the bidders know, that the privatisation value will be used for the determination of the initial value of RAB. This may lead to overbidding which will result in unjustified high tariffs. Another type of circularity and some type of conflict of interest may occur if the government would like to get higher price from the utility but in the same time would protect the customers as well.

The conclusion is that the use of market value is impossible due to the circularity effect. The privatisation value could be used only once by determination the initial value of RAB. By using this, there is a high risk for outbidding which may cause too high tariffs for the customers.

3.6. Conclusion of different methods for determination of RAB

The regulatory risks of different RAB valuation methods are analysed in the following Table 3.9.

1. The main issue by determination of the value of RAB is the long technical lifetime of the assets. A large number of assets have been acquired prior the start of price regulation. There is no information available on acquisition cost of those assets. The solution is the determination of the value of these assets and consistent regulatory accounting based on that value. The simplest measure is to use the HC method.

2. The mathematical result by using of HC and RC is the same by implementing of consistent accounting principles where the investment are depreciated on equal manner and the investment cost is inflated according to the inflation rate.

3. If the market price is used for the investment cost, the result of the RC method may differ from the HC method due to the reason that the change of investment cost is not in accordance to the inflation. Due to the technical developments, the increase of investment cost may be lower than inflation. It also may occur that the change in investment cost exceeds the inflation. Therefore the using of RC may not be in accordance to the regulation principle where the acquisition costs are included to the tariffs. According to the principle of the price regulation where the company is allowed to earn back all investment, the HC method and regulative accounting principle in nominal terms should be implemented.

4. In case the assets have been acquired before the start of the price regulation for determination of the opening value of RAB the HC or RC method can be used. In case of “greenfield project” the actual acquisition cost should be used for opening value. The accounting consistency is of high importance.

5. The use of market value is impossible due to the circularity effect. The privatisation value can be used only once, in determination of the opening value of RAB. The risk of using the privatisation value is the risk of overbidding which results higher tariffs.

6. By using of RC or LRAIC BU, there is a high risk of overvaluation of asset value. Especially for classical long life assets which have acquired decades before the start of price regulation. Implementing principles like these. The risk of higher customer tariffs should be considered.

7. By using of optimised RC or LRAIC BU methods the use of historical operational costs or efficiency indicators is not appropriate.

Table 3.9. Regulatory risks by using different RAB valuation methods

Regulatory risk	**Historical cost**	**Replacement cost**	**Regulative accounting based on replacement cost**	**Regulative accounting based on privatisation value**	**LRAIC BU**
Administrative burden, cost of regulation	Low. Simple and transparent accounting system.	High. There is systematic need to revaluate the value of the assets by fixing the tariffs. Complex mathematical calculations in real terms. Rather difficult to understand from customers´ point of view.	Moderate. Lower than by using of replacement cost method. There is a need to determine the asset value only once, prior to the start of price regulation.	Low. No need for extra costs, the price is determined during the privatisation process.	High. There is systematic need to design the system.
Subjectivity	Low. Based on book value from companies accounts.	High. The revaluation of the assets is subjective. Different expertise may result with different results.	High. However less risky than by using of RC method, because the valuation is once, prior the start of price regulation. The revaluation of the initial value of assets is subjective. Different expertise may result with different results	Low. Price is determined by the market.	Moderate. Depends on the methodology applied. If software model is used consistently and the methodology is public, than the subjectivity risk is rather low.

Under-investment	Low. Depends on the regulation method. Lower risk by RoR.	High. The basis of tariff calculations is not the investment made but the result of valuation based on RC. There is intention to save on investment.	Low. Depends on the regulation method. Lower risk by RoR.	Low. Depends on the regulation method. Lower risk by RoR.	High. The basis of tariff calculations is not the investment made but the result of valuation based on RC. There is intention to save on investment.
Over-investment	High. Depends on the regulation method. Lower risk by RPI-x with intensive regulation of investments.	Low The basis of tariff calculations is not the investment made but the result of valuation based on RC. There is intention to save on investment.	High. Depends on the regulation method. Lower risk by RPI-x with intensive regulation of investments.	High. Depends on the regulation method. Lower risk by RPI-x with intensive regulation of investments.	Low The basis of tariff calculations is not the investment made, but the result by designing the system using of LRAIC BU.
Consistent regulatory accounting	Moderate. Depends on the regulatory quality.	Low. The value of RAB is renewed by fixing tariffs.	Moderate. Depends on the regulatory quality.	Moderate. Depends on the regulatory quality.	Low. The value of RAB is renewed by fixing of tariffs by modelling the system.
Stranded assets	High. The RAB is calculated on the basis of company´s accounts, which may include the elements of stranded assets.	Moderate. Depends which method was used for revaluation of asset. Similar high risk to HC if the simple RC was used. Low risk if the replacement cost less	Moderate. The opening value of RAB depends which method was used for revaluation of asset. High risk if the simple RC was used. Low risk if the replacement cost less	High. The bases of the value of RAB is the privatisation value. The composition of RAB is not checked.	Low. The system is modelled in accordance to the optimal technical solution.

		stranded assets method is used.	stranded assets method was used.		
Old technology	High. The RAB is calculated based on company's accounts. The risk depends on price regulation methodology. Lower risk by RPI-x with intensive regulation of investment.	Moderate. Depends on which method was used for revaluation of asset. Similarly high risk if the simple RC was used. Lower risk if the optimised replacement costs method was used.	High. Depends which method was used for revaluation of asset. High risk if the simple RC was used. Lower risk if the optimised replacement costs method was used. The risk on new investment depends on price regulation methodology applied. Lower risk by RPI-x with intensive regulation of investments.	High. The basis of the value of RAB is the privatisation value. The composition of RAB is not checked. The risk on new investment depends on price regulation methodology applied. Lower risk by RPI-x with intensive regulation of investments.	Low. The system is modelled in accordance to the optimal technical solution.
Using of historical operational costs and efficiency indicators	Low. Technical design of the system is not changed and the system corresponds to the historical costs and efficiency indicators.	Moderate. Depends on which method was used for revaluation of asset. Lover risk if the simple RC was used. High risk if the optimised replacement costs method was used.	Moderate. Depends on which method was used for revaluation of asset. Lover risk if the simple RC was used. High risk if the optimised replacement costs method was used.	Low. Technical design of the system is not changed and the system corresponds to historical indicators.	High. Technical design of the system is completely changed and the historical costs and efficiency indicators cannot be used.

Company underperforms	Low. The risk depends on price regulation methodology.	Moderate. The risk is higher by using of optimised replacement costs or replacement cost less stranded assets methods. The risk depends on price regulation methodology.	Low. The risk depends on price regulation methodology.	Low. The risk depends on price regulation methodology.	High. Based on modelling of the infrastructure, the asset value can be much lower than the book value, in case where the infrastructure is very inefficient.
Customer is paying unreasonable high tariffs	Low. The risk depends on price regulation methodology.	High. The use of RC method may result much higher value of asset, especially for classical long life assets, which have been acquired decades before the start of price regulation.	High. The use of RC method may result much higher value of asset, especially for classical long life assets which have been acquired decades before the start of price regulation.	High. The bidding process may result high privatisation price.	High. The use of LRAIC BU method may result much higher value of asset, especially for classical long life assets which have been acquired decades before the start of price regulation.

4. Risk related to different price regulation methodologies.

4.1. Risks related to price regulation

As described above, the company's objective is to maximise the profit whereas customer's objective is to get the high quality service with low price. There are three main objections of the price regulation:

- Profit maximisation – company´s target
- High quality – customers´ target
- Low tariff – customers´ target

The price regulation hypothetically guarantees that the regulated utility reach the profit and quality target set by the regulation. The price regulation is not risk-free activity and the result is not comparable to the result reached on free market condition. Despite this fact the price regulation methods can be developed be reaching the target to eliminate the risks as much as possible. The different risks of price regulation are described in a number of scientific works [25]. The different risk elements are analysed in the following chapter by using the practical experience by implementation the price regulation in Estonia.

4.1.1. Return on invested capital and WACC

The calculation of WACC is a critical element of price regulation due to the fact that the most regulated utilities are capital incentive and those costs are an important part of the tariffs. The company's target is to maximise their profit whereas the regulator's objective is to calculate the justified WACC corresponding to the risks related to the specific utility. The inappropriate WACC may lead to wrong investment decisions. In the case where the tariff set by the regulator is higher than the actual cost of capital, the Averch-Johsoni effect occurs, i.e., the company is over-investing. In the perfect situation, the company´s cost of capital should be permanently equal to the regulator´s WACC but in reality this situation is impossible.

As described in chapter 2.3.1. the risk by using of classical type of RPI-x methodology is the fixing of WACC for the entire regulatory period. Since the risk free rate is not a constant value, but changes over time, the fixed WACC is not representing the true cost of money. Similar risk is by using of RoR methodology, where by increasing of cost of money (risk free rate) the company will apply the new tariff, but in case of declining cost of money, the company is earning higher return.

The other issue from company´s perspective is that WACC is calculated differently by the regulator. These risks have exhaustively been analysed by Pedell [25]. The problems related to the WACC calculations in Estonia have been analysed by Sander [48]. The classical formula for WACC calculation is as follows [48], [25], [50].

$$WACC = \frac{E}{E+D} \times r_e + \frac{D}{E+D} \times r_d \times (1 - t) \quad (4.1.)$$

r_e – cost of equity,

r_d – cost of dept,

E – value of equity,

D – value of dept,

t – corporate tax rate.

The cost of dept is calculated as follows:

$$r_d = r_f + d_p \quad (4.2.)$$

r_f – risk free rate

d_p – dept risk premium

The cost of equity is calculated as follows:

$$r_e = r_f + ß \times r_m \quad (4.3.)$$

ß – beta factor

r_m – market risk premium

Dept to equity ratio. The regulatory dept to equity ratio (50/50 or 60/40) is used, which differs from actual ratio of the company [25]. Basically the cost of equity is more expensive than the cost of dept, company with low leverage level is getting lower WACC than in reality.

Risk free rate. The risk free rate is calculated based on government bond. In Estonian case the governmental bonds are missing and the risk free rate is calculated based on German bonds. The country risk premium is added to the German bond which makes the calculation more subjective.

Cost of dept. The regulated cost of dept differs from the actual company´s cost of dept [25]. In general the cost of dept is calculated on risk free rate by adding risk of depts. In reality the cost of dept equals tot the cost of capital available for the company on the market. The company´s cost of debt could be identified by issuing of company´s bonds which is limited to a very small number of companies in Estonian case.

Market risk premium. The question is whether to use the data of the domestic stock exchange, European average or the US data. In Estonian case which is similar for other Central and East European countries, the history of the stock exchange is too short to be used for calculations. The US history of more than 100 years is appropriate for calculation of market risk premium [49]. Sander [48] is referring to the analyses prepared by Credit Suisse [64] which indicates that the regulator has a variety of data to choice. The analyses are presented in Table 2.1. [48].

Table 4.1. Geometric mean of market risk premiums 1900–2012.

Country	Market risk premium
Belgium	2,30%
Denmark	1,80%
Finland	5,30%
France	3,00%
Germany	5,20%
Ireland	2,60%
Italy	3,40%
Netherlands	3,30%
Norway	2,20%
Spain	2,10%
Sweden	2,90%
Switzerland	2,00%
UK	3,70%
Europe	3,40%
World	3,20%
Eurozone	3,40%

Beta factor. The beta factor is presenting the data of companies listed on the stock exchange [25]. In real situation most of the regulated companies are not listed and in Estonian case even too small to be notified. That means that the beta factor used by the regulator is not corresponding to the certain regulated company. It is a situation where the regulator has no alternative because the actual data of the company could be available only in the case where the company would be listed on the stock exchange.

By calculation of the beta factor, the financial leverage should be considered. There exist different asset and equity beta. The financial leverage will increase the beta factor. If the leverage is 0, the asset beta equals equity beta. By calculation of asset beta, the following formula is used [25]:

$$\beta_A = \frac{\beta_E}{1+(1-t)\times\frac{D}{E}} \quad (4.4.)$$

β_A – asset beta

β_E – equity beta

t – corporate tax rate

D – dept value
E – equity value

For practical calculation the meaning is that if the beta value for a specific sector is found from the database, the first exercise is to convert the value of beta to asset beta.

Corporate tax. The problem is whether the costs related to the corporate tax should be included to the tariffs or not. Pedell [25] is on the position that for the purposes of cost-orientated rate regulation total tax payments have to be covered, which is achieved by using the average tax rate for the calculation of rates. In the same opinion is CER assessing different regulatory models for regulation of Irish water sector [44]. There are two approaches to incorporating tax requirements into the allowed WACC of the regulated company. The regulator can either allow a pre-tax WACC or a post-tax WACC. A pre-tax approach allows the regulated company to earn a return out of which to settle tax expenses. In a post-tax approach taxes are modelled separately from the return (WACC) as a cost item in the allowed revenues of the regulated company. A post-tax WACC allowance would require detailed analysis of the specific tax requirements of the utility, which may shift from year to year. Therefore, CER is proposing to use the pre-tax WACC approach because it is a transparent and stable approach – the Irish corporation tax rate of 12.5% is known from the outset of the regulatory framework [44].

The European energy regulators are using different approach by including the corporate tax to the customer's tariffs. The issue is whether to use pre-tax or post-tax WACC in calculation of return. The majority of regulators are using pre-tax WACC in the case of which the corporate tax is included to the tariffs [62].

By calculation of post-tax WACC, the formula similar to that pointed in Chapter 4.1. is used [65] [25]. The purpose of calculation post-tax WACC is the usage of tax-shield effect. The employing of dept capital enables to deduct the interest expenses from the profit. This reduces the corporate tax. The post-tax WACC is calculated based on the following formula:

$$\mathrm{WACC_{post-tax}} = \frac{E}{E+D} \times r_e + \frac{D}{E+D} \times r_d \times (1 - t) \quad (4.5.)$$

In order to calculate the pre-tax WACC which is higher, the corporate tax rate should be used. The pre-tax WACC is calculated based on the following formula [65], [25]:

$$\mathrm{WACC_{pre-tax}} = \frac{\mathrm{WACC_{post-tax}}}{1-t} \quad (4.6.)$$

That means the regulatory risk is whether the corporate tax is calculated to the tariffs or not.

4.1.2. Calculation of WACC in Estonian price regulation

The calculation principles are described in methodology issued by ECA [50]. The WACC calculated by ECA is regulative and sector based[12]. Therefore the regulative WACC differs from the actual WACC calculated for a specific company. Another specific issue in Estonia is the absence of corporate tax. The difference of regulative and specific company based WACC is analysed in this research.

Dept to equity ratio. In Estonia, the regulative 50/50 dept to equity ratio is used, which therefore differs from actual companies' ratios. The reason for using of regulative ratio is the common practice used by the regulators and achievement to ensure the equal treatment of all regulated utilities. The basis for calculation of customers´ tariffs is not depending on the company's actual capital structure and therefore is the same for all companies of the sector.

Risk free rate. There is no governmental bond in Estonia. Therefore the 10-year German Bonds plus country risk premium are the basis by calculating the risk free rate. The average 5-years yield of the 10-years German Bond is used for the calculations, in order to mitigate the market volatility. By calculation of country risk premium, the data of countries with similar credit risk is used[13]. The regulatory risk is in subjectivity factor where the Estonian country risk premium is not based on actual market data but calculated, based on the data of similar countries.

Cost of debt. By calculating the cost of dept the similar regulative approach is used. The cost of dept is calculated based on the risk free rate plus debt premium. The regulative cost of dept differs from actual company´s figures. The reason for using of regulative ratio is the common practice used by regulators and achievement to ensure the equal treatment of all regulated utilities. According to the figures calculated for 2015, the regulative cost of dept is higher than the average long-term interest rate paid by the Estonian companies. The regulated figures vary from 3.7 to 3.86 percent, but the actual interest rate in Estonia was 2.7% [50]. That means that an average company can earn extra on dept capital.

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[12] For example there is the same WACC for all district heating utilities operating in this sector, which differs from the WACC calculated for power or gas distribution companies.

[13] By calculation of WACC for 2015 the data of Chech Republik, Belgium and Slovakia are used.

Market risk premium. One of the options is to use the data of return on the national stock exchange. The problem of using the national data is the 20-years short history of the stock exchange. The 100-years period is suitable for calculation of historical returns [49], [48]. Therefore, the historical return on the US stock exchange is used by calculation of the market risk premium [50].

Beta factor. The single regulated company listed in stock exchange is AS Tallinna Vesi. In principle, the actual beta factor could be used for this company only. For the rest of the regulated companies, the international data is used [50] [66]. That is one of the subjectivity risks where the sector average indicators are used. For the case of AS Tallinna Vesi the regulative equity beta factor is 0.78. The company´s actual figure is 0.48 [50] which means the company is getting some higher return on this context.

Corporate tax. The classical corporate tax rate is 0 in Estonian case. There is an issue on treatment of the tax shield. Whether the post-tax or pre-tax WACC should be used. The difference of Estonian tax regime is the fact that the profit is not taxed based on annual results. The tax liability is in case of paying dividends. It is a company´s decision whether to pay the dividends or not. The company has the opportunity to postpone the payment of tax for longer period by deciding instead of paying of dividends to keep cash in company.

In the case the corporate tax is 0 (t=0), the WACC is calculated by using the formula 4.1 in the following manner. The pre-tax WACC equals to post-tax WACC in this manner.

$$\mathrm{WACC} = \frac{E}{E+D} \times r_e + \frac{D}{E+D} \times r_d \quad (4.7.)$$

$$\mathrm{WACC}_{pre\text{-}tax} = \mathrm{WACC}_{post\text{-}tax} \quad (4.8.)$$

According to the Estonian tax regime there is no effect of the tax shield and Formula 4.8. should be used by calculation of WACC [48]. The same principle has been implemented by calculation of WACC in Estonian price regulation. In theory, Formulas 4.5. and 4.6. could be used for WACC calculation in case where the total net profit is consistently paid for dividends. But this is just theory and not the case valid in practice.

According to the regulation theory, the return should be calculated on the basis on a company´s WACC. The regulatory risk is the fact that the company´s WACC differs from the regulative WACC calculated by the regulator. The difference in company and regulated WACC is analysed on the basis on the data of the two largest energy utilities in Estonia: AS Elering (power TSO) and Elektrilevi OÜ (the largest power DSO). The government as the shareholder has set and published very clear expectations on return for these companies. This clear target enables to prepare precise WACC calculation for the companies [40], [67], [68], [69]. In order to evaluate the regulative calculations, the WACC is calculated by using two different options. By option 1, the cost on equity is calculated on the basis of CAPM model, similar used for regulative calculation. By option 2, the target on return on equity, established by shareholder is used as input data. The cost on dept is the actual number from companies' annual reports. The results are presented in Table 4.2. The detailed calculations are presented in Table 4.3 and 4.4.

Table 4.2. WACC for Elering and Elektrilevi

Elering	2010	2011	2012	2013	2014	average
WACC cost of equity calculated	6,18%	7,01%	6,11%	6,20%	6,18%	6,34%
WACC cost of equity shareholder	7,28%	7,72%	7,82%	7,06%	6,11%	7,20%
WACC regulator	7,56%	7,78%	7,81%	6,74%	5,58%	7,09%
Elektrilevi						
WACC cost of equity calculated	6,48%	7,07%	5,83%	6,04%	5,43%	6,17%
WACC cost of equity shareholder	7,18%	7,09%	6,92%	6,82%	7,45%	7,09%
WACC regulator	7,76%	7,83%	7,83%	6,76%	5,61%	7,16%

The results indicate that the average regulative WACC calculated and the expectations of the shareholder are rather similar. The difference in calculation is that the regulator is setting higher figures on cost of dept whereas the shareholder is expecting higher return on equity. The differences described have very similar result as mentioned above. The peculiarity in calculations is that the cost on equity expected by the owner is somewhat higher than calculated by using of the CAPM model.

Table 4.3. Detailed WACC calculations for Elering

	2010			2011			2012			2013			2014		
	Cost of equity calculated	Cost of equity shareholder	Regulator	Cost of equity calculated	Cost of equity shareholder	Regulator	Cost of equity calculated	Cost of equity shareholder	Regulator	Cost of equity calculated	Cost of equity shareholder	Regulator	Cost of equity calculated	Cost of equity shareholder	Regulator
Nominal risk free rate (German 10-y bond) (r_f)			3,71			3,58			3,35			2,81			2,33
Country risk premium (r_c)			1,80			1,90			2,04			1,51			0,99
Dept risk premium (d_p)			0,70			0,90			1,03			1,03			0,92
Cost of dept (r_d)	**4,28**	**4,28**	**6,21**	**5,10**	**5,10**	**6,38**	**4,80**	**4,80**	**6,43**	**3,70**	**3,70**	**5,35**	**3,40**	**3,40**	**4,24**
Nominal risk free rate (German 10-y bond) (r_f)	2,74		3,71	2,61		3,58	1,50		3,35	1,57		2,81	1,16		2,33
Country risk premium (r_c)	1,90		1,80	2,04		1,90	1,51		2,04	0,99		1,51	0,64		0,99
Market risk premium (r_m)	5,00		5,00	5,00		5,00	5,00		5,00	5,00		5,00	5,00		5,00
Asset beta ($ß_a$)	0,35		0,34	0,42		0,37	0,44		0,38	0,61		0,38	0,71		0,36
Equity beta ($ß_e$) t=0%	0,75		0,68	0,92		0,74	0,88		0,76	1,30		0,76	1,49		0,72
Cost of equity t=0% (r_e)	**8,39**	**10,77**	**8,91**	**9,24**	**10,77**	**9,18**	**7,42**	**10,86**	**9,20**	**9,04**	**10,90**	**8,12**	**9,24**	**9,10**	**6,92**
Corporate tax rate (t=21%)	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
Value of dept (D)	0,54	0,54	0,50	0,54	0,54	0,50	0,50	0,50	0,50	0,53	0,53	0,50	0,52	0,52	0,50
Value of equity (E)	0,46	0,46	0,50	0,46	0,46	0,50	0,50	0,50	0,50	0,47	0,47	0,50	0,48	0,48	0,50
WACC (t=0)	**6,18%**	**7,28%**	**7,56%**	**7,01%**	**7,72%**	**7,78%**	**6,11%**	**7,82%**	**7,81%**	**6,20%**	**7,06%**	**6,74%**	**6,18%**	**6,11%**	**5,58%**

Table 4.4. Detailed WACC calculations for Elektrilevi.

	2010			2011			2012			2013			2014		
	Cost of equity calculated	Cost of equity shareholder	Regulator	Cost of equity calculated	Cost of equity shareholder	Regulator	Cost of equity calculated	Cost of equity shareholder	Regulator	Cost of equity calculated	Cost of equity shareholder	Regulator	Cost of equity calculated	Cost of equity shareholder	Regulator
Nominal risk free rate (German 10-y bond) (r_f)			3,71			3,58			3,35			2,81			2,33
Country risk premium (r_c)			1,80			1,90			2,04			1,51			0,99
Dept risk premium (d_p)			0,80			0,90			1,07			1,07			1,08
Cost of dept (r_d)	4,16	4,16	6,31	4,05	4,05	6,38	4,12	4,12	6,47	3,86	3,86	5,39	3,91	3,91	4,40
Nominal risk free rate (German 10-y bond) (r_f)	2,74		3,71	2,61		3,58	1,50		3,35	1,57		2,81	1,16		2,33
Country risk premium (r_c)	1,90		1,80	2,04		1,90	1,51		2,04	0,99		1,51	0,64		0,99
Market risk premium (r_m)	5,00		5,00	5,00		5,00	5,00		5,00	5,00		5,00	5,00		5,00
Asset beta (β_a)	0,39		0,37	0,52		0,38	0,49		0,38	0,61		0,38	0,57		0,35
Equity beta (β_e) t=0%	*0,52*		0,74	*0,70*		0,76	*0,74*		0,76	*0,93*		0,76	*0,90*		0,70
Cost of equity t=0% (r_e)	7,23	8,16	9,21	8,14	8,16	9,28	6,71	8,37	9,20	7,21	8,40	8,12	6,31	9,50	6,82
Corporate tax rate (t=21%)	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
Value of dept (D)	0,24	0,24	0,50	0,26	0,26	0,50	0,34	0,34	0,50	0,35	0,35	0,50	0,37	0,37	0,50
Value of equity (E)	0,76	0,76	0,50	0,74	0,74	0,50	0,66	0,66	0,50	0,65	0,65	0,50	0,63	0,63	0,50
WACC (t=0)	6,48%	7,18%	7,76%	7,07%	7,09%	7,83%	5,83%	6,92%	7,83%	6,04%	6,82%	6,76%	5,43%	7,45%	5,61%

4.1.3. Conclusions risks related on WACC calculations

As described in Chapter 4.1.1, the target is to build up the regulatory regime where the return on invested capital equals to company´s WACC. Since there are a lot of subjectivity factors, the regulatory risk should be considered by calculation of WACC [25]. The study prepared by the World Bank indicates, that from company´s perspective the RoR method has less risk than the RPI-x [31]. This is reflected in the lower beta values. By calculation of company´s WACC these lower beta values should be taken in account. This indicates that the applied regulation methodology has impact on the actual WACC of a specific company.

The WACC has direct impact on company´s profit and customers´ tariffs. But even more important is the impact on company´s investment policy. The risk of overinvestment by using of RoR was described more in details in Chapter 2.2. That is the case where the regulative WACC exceeds the company´s cost of capital. The risk of overinvestments is much lower by using of RPI-x. By using of classical RPI-x, there is a clear incentive to save on all type of costs. By using of RPI-x in practice, there is strong regulation of investment. By using of LRAIC BU, the overinvestment risk is close to zero, due to the reason that the return is not calculated on actual investment which enhances strong intention to save on investments.

The risk of under-investments is extremely high by using of LRAIC BU where the return is not calculated on actual investment. The risk is rather high by using of classic RPI-x where there is strong intention to save on all type of costs. By using of RoR, all investment are included to the tariffs which provides clear intention to invest. But if the WACC is on too low level, it may result in under-investment because the capital is simply flowing to the direction of the higher returns. Following, the risks related on WACC calculation by implementing of different regulatory regimes are described.

Using RPI-x in the case where the WACC exceeds the company´s capital cost, the customers suffer because of too high tariffs. Using the classic RPI-x, there is no direct impact on investment, due to the company´s incentive to save on all type of costs. By practical implementation of RPI-x, including intensive regulation of investment, the higher WACC leads the company to invest. There is an indirect impact on investment by using of classical RPI-x. In situation where the cash flow does not include the justified return, a company is trying to save even more on investment. Even by practical implementation of RPI-x, including the regulation of investment, there is a clear information asymmetry among the company and regulator. There is no intention from company´s side to invest with lower than actual capital cost. The result is in tend to underinvest. In long term perspective there is a clear risk on the quality of service.

By using of RoR in the case where the WACC exceeds company´s capital cost, the customers suffer on too high tariffs. As mentioned above, there is a clear risk of overinvestment. By using of incentive type of RoR, it is possible to reduce those risks somehow but full elimination of these risks is not possible. In the case where WACC is lower than company´s cost of capital, the owners are suffering on lower than justified returns. There is not such high risk on underinvestment as in the case of using of RPI-x, due to the fact that the company is not saving on investment. But if the WACC is systematically on too low level, it may result in underinvestment because the capital is simply flowing to the direction of the higher returns.

By using of LRAIC BU in the case where the WACC exceeds the company´s capital cost, the customers suffer on too high tariffs. There is no clear impact on investment, due to the fact that the tariff calculation is not based on investment actually made. In situation of reduced cash flow the company is trying to save on everything, including investment. In long-term perspective this may lead to lower quality of service.

Another risk is the fixing of WACC for longer period, without adjusting to the market cost of capital in reality. This is a clear risk by implementation of classic type of RPI-x, where the calculations are made for longer period and not adjusted according to the real market situation. The similar risk may occur by classic RoR in times of declining interest rates, where the company has no incentive to apply for new tariffs and the regulator has no legal tools to force the company to apply for adjusted tariffs. This risk can be fully covered by regulatory regimes, where the tariffs are adjusted annually in accordance to the real cost of money. Those methods can be RPI-x, LRAIC BU with annual adjustments or RoR with legal tools for the regulator, to adjust the tariffs by own initiative.

4.2. Risks related to the price regulation

Circularity effect. The risk in circularity effect is the fundamental difference by calculation the company value for regulated utilities [25]. If the company is acting on free market condition, it is valued based on the free cash flow or in other words, the company´s value is created on market conditions. The higher generated cash flow results in higher market value of the company. In the case of the regulated utility, the free cash flow is set by the regulator in process of price regulation. Due to the circularity effect the value of RAB cannot be based on company´s market value.

Non-controllable costs are risk for both company and customer. These risks can be reduced by implementing of all different types of regulatory models. The company´s risk is in the regulatory lag, where certain non-controllable costs are increased but not reflected in the tariffs. The customers´ risk may occur if these costs are reduced but not included to the tariffs. By using of cost pass-through system, the risk of non-controllable costs can be fully eliminated.

Sales volume is the same type of company´s and customers´ risk as the non-controllable cost. For the regulated monopoly there are very limited possibilities to impact the sales volume. By using of under-over recovery or revenue cap systems, the risk can be fully eliminated.

Regulatory lag. There exist both regulatory lag on subjective and objective circumstances. The subjective type of regulatory lag is a full company risk where the regulator is subjectively delaying the process of decision making. The reason can be regulator´s bureaucracy or unwillingness to make unpopular decisions by increasing the tariffs. Other reasons for subjective lag are underfinanced regulator with very limited resources to handle the tariff proposal in time or political pressure. The subjective regulatory lag is limited by using of RPI-x where the regulatory periods are fixed in the law and the regulator is supposed to make the decisions in time. This type of risks is much higher by using of RoR regulatory model where there are no fixed regulatory periods and the company may turn to the regulator applying for fixing of tariffs in any moment. It's certainly takes some time for the regulator to make the decision on tariff approval. This risk can be mitigated to fix concrete terms for the regulator for fixing of tariffs[14].

The objective type of regulatory lag [25] is the reality situation where each of tariff fixing requires some time and human resources like data collection exercise, regulatory decision, etc. It is company´s risk even in the case where the regulator is acting as quick as possible and has no subjective ambition to delay the decision. Similarly to the subjective type of regulatory lag, the risk can be mitigated by using RPI-x regulatory regime.

Regulatory lag, asymmetry in prognosis and actual costs. This risk can be considered as a type of objective regulatory lag. There is a clear time difference in prognosis to the actual costs. The length of this time difference depends on regulator´s actions.

There can be a clear time difference or regulatory lag between the prognosis and actual costs. As described in Chapter 2.3.1 the WACC, calculations prepared by the regulator are based on historical and not on actual data. All WACC components like risk free rate, beta factor or dept to equity ratio are based on history and not reflecting the actual situation at the moment. The same is valid to other tariff components as well. The operating costs, efficiency parameters, etc. are based on prognosis and not reflecting the actual data at the moment. Concerning these cost elements, the regulator certainly can intend to put costs

[14] There are concrete terms fixed in Estonian legislation.

savings obligation on the company. However the regulator is relying on prognosis which is not the real situation at the moment.

According to the example from Estonian regulatory regime, the company is applying for new tariffs and presenting the application on 1. October 2015. Its tariff application is based on actual historical costs of 2014 and the prognosis. The regulator will take half a year for analyses and will making the decision on 1. April 2016. The company is obligated to announce the tariff increase at least 3 months prior the tariff will be effective for the customer. In this case the tariffs are effective since 1. July 2016. According to this example, the tariffs applied in the second half of 2016 and in 2017 are based on the information of 2014. There is a three year lag on prognosis and actual cost and one must agree the period is rather long. The financial data for WACC calculations can e. g. be changed during this period. That means the company´s actual cost of capital can be even more different from the calculations made by the regulator.

Information asymmetry. The regulators knowledge on information is never reaching the company´s level. Despite the strength of the regulators, the company has always better information. That’s the risk where the company is presenting purposely incorrect data in order to fix a higher tariff. The risk of non-controllable costs or sales volume can easily be eliminated by using of under- over recovery or cost pass-through methods. But there exists a large asymmetry on technical efficiency, costs savings potential, investment need or on technical situation. In order to have complete information on those issues, the regulator should step in to company´s actual management which in fact is unrealistic.

The information asymmetry risk is higher in implementation of RPI-x where the costs are fixed for the entire regulatory period and the revival is possible by the end of the regulatory period. The tariffs are linked with inflation. Despite implying the efficiency factor x, in nominal terms the tariffs tend to increase in accordance to the inflation.

By using of classic type of RoR, the risk on information asymmetry is lower. Since the tariffs are based on the historical costs, there is no intention behalf the company to manipulate with these data. By using of incentive type of RoR, the risk is higher because the target of the regulation is to achieve costs savings. The company has the right to apply for a new tariff fixing at any moment. Therefore the main rule of this method is the fact that due to inflation there is always some increase of costs for the company. The vice versa situation may occur where the input data are decreasing. For classic infrastructure utilities like network operators this can be e. g. the cost of capital. For energy generators, this cost element can be the decreasing fuel prices. There is a clear customer´s risk in this situation, where the actual cost based tariffs are reduced but the company is not presenting the tariff application to the regulator.

Using LRAIC BU, the risk on information asymmetry is very low. The only data presented by the company are the sales volume, capacity demand and uncontrollable costs. The risk of sales volume and uncontrollable costs can easily be covered by introduction of under-over recovery or cost pass-through system. The information asymmetry on capacity is not so critical element, this input data can be controlled by the regulator.

The risk of too high tariffs. The main goal of price regulation is to set the tariff equal to efficient tariff p_e. The target of the RPI-x regulation is incentive cost savings. Thus, the deviation from the historical costs is the objective of this regulation. The incentive type of RoR has similar incentive on cost savings. The only difference is that the regulation of investments is not so intensive. The risk of too high tariffs is lower especially by implementing of RPI-x. The risk is higher by using of classic type of RoR, where the tariffs are based on historical costs and there is no clear incentive on cost savings. The highest risk is by using of LRAIC BU. Especially for classical infrastructure utilities like water supply, railway or power lines the hypothetical designing of infrastructure may cause rapid increase of customers´ tariffs.

The risk of too low tariffs. The risk is the setting of unrealistic p_e where the company is unable to reach the cost saving target set by the regulator. The high risk is by using of RPI-x where the unrealistic tariff will result the savings on investment programs and the shareholders will suffer on lower than justified return. By using of RoR, this risk is rather limited. By using of classical type of RoR, the tariff is based on actual historical costs. By using of incentive type of RoR, the regulator is pushing the company towards cost savings but in comparison to the RPI-x, the tariffs are not fixed for the regulatory period. In the case of insufficient financing, the company can always turn to the regulator and apply for new tariffs. There is a very high risk by implementing of LRAIC BU. If the utilities design is extra inefficient, the hypothetical design of infrastructure may result in situation where the company is unable to finance its activities.

Risk on stranded assets. The risk from company side is that the regulator excludes some elements from the RAB. From the customer's point of view, the risk is paying for assets which are not really needed. Even doing the business with highest performance, some part of the assets will be stranded anyway. That is the case on competitive market as well where some of the investment decisions are not efficient. On free market conditions the wrong investment decisions are reflected in company´s results. Concerning the regulated utility, there is the question of responsibility, whether the customer or the company should pay for the wrong investment decisions.

In the case of consistent accounting of the assets where all necessary investments have been made, but based on objective situation some part of the assets cannot be used anymore, there is justified expectation to include those investments to the tariffs[15]. In case the investment is made as result of wrong investment decisions or poor management, there is an issue, whether these costs should be included to the tariff.

The real situation is that most of the assets of regulated utilities have been acquired before the price regulation. The value of those assets have been identified by using historical cost or replacement cost methods. The value of these assets is hypothetical, it may include elements which are actually not needed. That is the case where the customer has justified expectation not to include those assets to the tariffs.

The risk of stranded assets is by implementation of both RPI-x and RoR. There is no risk of stranded assets by using of LRAIC BU, due to the fact that the hypothetical utility is designed as the optimal solution without any stranded assets.

Administrative risk. The administrative burden is an indirect risk. The inefficient or too expensive regulator is indirectly paid by the customers and utilities. It does not matter whether the regulator is financed by state budget or by regulatory fees. The administrative burden is reflected in tariff, because the cost related to regulation is indirectly included to the customers´ tariffs. There is higher regulatory burden by using of RPI-x or LRAIC BU. The regulatory burden is much lower by using of RoR type of regulation, especially by using of ex-post type where there is no active involvement of the regulator.

From the other side there is a risk of insufficient regulation where the regulator is badly managed or has no sufficient resources to carry out the tasks. In this case there is a high risk on customer side, where the tariffs might be on artificially low level.

Risk on overinvestment. The overinvestment risk means full freedom in a company´s investments policy where no cost savings is considered. In this case all investments made are included to the RAB. The highest risk on overinvestment is by using of classic type of RoR. By using of incentive type of RoR, the cost efficiency is regulator´s target, but reducing of the risk of overinvestment is rather complicated. Like by using of classical RoR, a company can rely on existing tariff for longer period and may avoid the regulator for years. In this case it is very difficult for the regulator to exclude some of the investments already done from the RAB. The best regulatory tool to avoid overinvestment is to keep the WACC at least equal or below the company´s cost of capital. Another risk by using the

[15] Example presented in chapter 3.7.

incentive type of RoR is the fact that the regulator is demanding cost efficiency with no regulation of investment. This may lead the company to direction where the investment target is to achieve the efficiency goal set by the regulator with no detailed analyses on investment, because all investments will be included to the tariffs anyway.

No risk of overinvestment occurs by using of LRAIC BU where the RAB is not calculated based on actual investment and the company´s target is to save on that as much as possible. The similar approach is by using of classical RPI-x where there is clear target of the company to save on all type of costs, inclusive investment. Low risk on overinvestment is by practical use of RPI-x where the regulator may force the company to do certain type of investment. Anyway the risk is not comparable to the risks related to RoR because the investment is under regulatory control.

Risk on overinvestment may occur in the case where the adequate return rates are not set for state owned enterprises. By regulation of operating efficiencies there is no difference on regulation of private or state owned enterprises. If the cost of capital for state owned enterprises is set on too low level, there is a clear risk on Averch-Johnson effect where the company is overinvesting due to the reason that its cost of capital is higher than WACC. To reduce this risk, the regulator should calculate the cost of capital towards lower level. But the problem is in equal treatment of private and state capital, where the WACC should be calculated on equal basis not depending on the ownership. That means that the setting of lower WACC for state enterprises to avoid overinvestment is not an appropriate measure.

The risk on underinvestment. The underinvestment risk occurs where a company´s policy is to provide the service by maximal utilisation of the existing system. This trend is positive by reaching the target with minimum cost. The fact is the inertia of the classical infrastructure, which can be effectively in operation for longer period in the circumstance of underinvestment. The problems may occur after decades of systematic underinvestment. This risk is the highest by using of LRAIC BU where the RAB is based on hypothetical utility and not on real investment. The risk is high by using of classic type of RPI-x as well where the company is intended to save on everything including the investment. The risk can be mitigated by practical using of RPI-x, where the regulator is actively regulating the investment. The risk is low by using of RoR. But if the WACC is systematically on too low level, it may result in underinvestment even by using of RoR, where the capital is simply flowing to the direction of higher returns.

Regulator´s subjectivity. Regulator´s subjectivity is related to the independence of the regulator. The regulators independence is stated in EU Electricity and Gas Directives [13], [14]. It is stated that the regulatory body shall be independent on all type of industry and political interest. The regulatory body shall have enough fiscal and human resources to carry out the tasks of price regulation. Despite the independence clauses have been set by the directives, the subjectivity risks remain for all type of regulators. The subjectivity risk depends on the level of the regulatory intervention. There is lower risk by using of RoR because the costs are based on company´s historical data. There is risk of regulatory lag and the calculation of WACC by the regulator by using of those models. The regulatory subjectivity is much higher in using of RPI-x where the regulator determines the cost saving obligation and is actively involved to the investment decisions.

The regulator´s subjectivity can be on high level by using of LRAIC BU where the utility is designed by the regulator and may differ a lot from the existing one. By using of LRAIC BU on an open manner where the utility is designed by the computer program, the subjectivity risk can be reduced significantly.

The risks related to the price regulation are summarised in Table 4.5.

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Table 4.5. Risks related to the price regulation

Risk	**RPI-x**	**RoR**	**LRAIC BU**
WACC is above company´s cost of capital	The tariff is too high for customers. By using of Classic RPI-x there is no impact on investment. By practical implementation there is some risk of overinvestment due to the information asymmetry.	The tariff is too high for customers. Risk of overinvestment.	The tariff is too high for customers. No impact on investment.
WACC is below company´s cost of capital	Risk of underinvestment. Less by practical using of RPI-x with intensive investment regulation. Risk on the service quality. Less than justified return for shareholders.	Risk of underinvestment. Risk on the service quality. Less than justified return for shareholders.	There is no direct impact on investment. Indirect risk of underinvestment, by reduced cash flow the company's intention is to save on every type of cost, including investment. Risk on the service quality. Less than justified return for shareholders.
WACC is different from the market cost of capital	High risk by using classic type of RPI-x, where the WACC is fixed for longer period and not adjusted according to the market cost of capital. No risk by practical implementation of RPI-x, where the WACC is calculated for each of the year of the regulatory period.	Risk in times of declining interest rates, where the regulator is not adjusting the tariffs on own initiative.	High risk in case the tariffs are set for longer periods. No risk if the tariffs are fixed at least once per annum.
Effect of circularity	Depends on RAB method. Similar by using RPI-x or RoR	Depends on RAB method. Similar by using RPI-x or RoR	No risk.
Sales volume	Exists by classic type of RPI-x. No risk by using of revenue cap.	Risk of Regulatory lag. No risk by using of revenue regulation or under-over recovery.	Risk exist. No risk by using of revenue regulation or under-over recovery.

Non-controllable cost	Exists by classic type of RPI-x. No risk by using of cost-pass through.	Risk of Regulatory lag. No risk by using of cost-pass through.	Risk exist. No risk by using of of cost-pass through
Cost efficiency	Low risk. The method is oriented to cost-efficiency.	High risk by using of classic type of RoR. Risk is reduced by using of intensive type of RoR.	No risk.
Regulatory lag subjective and objective	No risk.	Risk exists. Risk can be reduced by fixing of dates for tariff approval.	No risk if the tariffs are set for certain regulatory period similar to RPI-x. Risk exists, if the tariff fixing similar to RoR, based on company´s application.
Information asymmetry	High risk. By using of cost-efficiency oriented method, the company´s trend is to use the information asymmetry to mitigate the efficiency target. The cost base is fixed for the entire regulatory period.	Low risk by using of classic RoR. Higher by using of incentive RoR. Less risk because the cost base is not fixed for the entire regulatory period.	Low risk.
Price above efficient price p_e	Low risk. The method is oriented to cost-efficiency.	High risk by using of classic RoR. Moderate risk by using of incentive RoR.	High risk. The value of RAB can be much higher than actual, due to the fact that the existing network includes elements with extremely long technical lifetime, which have already paid off by the customers.
Price below efficient price p_e	Moderate risk. The regulator may set unrealistic efficiency target.	Low risk. Higher by using incentive RoR, but the company has always the right to present new tariff application.	High risk. In case where the technical design of the existing company is very inefficient.

Stranded assets	Moderate. Depends on RAB method.	High risk by using of classical RoR based on historical cost and company´s books. Moderate by using of incentive RoR, depends on RAB method.	No risk.
Overinvestment	No risk by using of classic RPI-x. Low risk by practical RPI-x with intensive investment regulation. Risk is reduced if the WACC equals company´s capital cost.	High risk in case the WACC exceeds the company's capital cost (Averch-Johnsoni effect).	No risk.
Underinvestment	High risk by using of classic RPI-x. Low risk by practical RPI-x with intensive investment regulation. The risk is reduced if the WACC equals company´s capital cost.	No risk by applying classic RoR. Low risk by incentive type of RoR with investment regulation. The risk occurs in case the WACC is systematically below the company´s cost of capital.	High risk. The tariff is not based on actual investment made by the company.
Administrative burden	High risk. High regulatory burden by preparation complex calculation for the entire regulatory period. Regular data collection within the regulatory period.	Low risk. Low regulatory burden.	High risk. High regulatory burden by the modelling of networks. Lower regulatory burden by modelling generation units.
Regulator´s subjectivity	High risk. Active involvement by the regulator.	Low risk by using of classic RoR. Moderate risk by using incentive RoR.	Low risk in case the network or facility is designed by computer program.

5. Discussions, selection of methodology.

The difference of RoR and RPI-x has been mostly evaluated in a number of scientific research. The aspects of methods are analysed in Table 5.1. [55]

Table 5.1. RPI-x versus rate of return

	RPI-x (Price cap)	RoR
Firm's flexibility over relative prices	Yes	No
Regulatory lag	Long	Short
Sensitivity of prices to realized costs	Low	High
Regulatory discretion	Substantial	Limited
Incentives for cost reduction	Strong	Limited
Incentives for durable sunk investment	Limited	Strong

Amstrong and Sappington are comparing classic type of RPI-x (price cap) and RoR methodologies, which in reality do not exist. Most of the methods used in practice today are hybrids, including elements of both regulatory model. The classic RPI-x and RoR methodologies are described in Table 5.2. [55].

However, RoR regulation can promote observable infrastructure investment by limiting the risk that such investment will be expropriated. In contrast, price cap regulation can provide strong incentives for unobservable cost-reducing effort, especially when the regulatory commitment period (the length of time between regulatory reviews) is relatively long. Therefore, the choice between these two forms of regulation will depend in part on the relative importance of the two forms of investment. In settings where the priority is to induce the regulated firm to employ its existing infrastructure more efficiently, a price cap regime may be preferable. In settings where it is important to reverse a history of chronic under-investment in key infrastructure, a guaranteed rate of return on (prudently incurred) investment may be preferable [55].

Table 5.2. Comparison of classical RPI-x and RoR.

Classic RPI-x	**Classic RoR**
Only the firm's average price is controlled (which leaves the firm free to control the pattern of relative prices within the basket of regulated services).	The regulator sets prices, and affords the firm little discretion in altering these prices.
The rate at which prices can increase over time is fixed for several years, and is not adjusted to reflect realized costs and profits during the time period.	Prices are adjusted as necessary to ensure that the realized rate of return on investment does not deviate substantially from the target rate.
Current prices are not explicitly linked to current costs.	Prices are adjusted to reflect significant changes in costs.
The regulator has considerable discretion over future policy (once the current price control period has expired).	The regulator is required to ensure that the firm has the opportunity to earn the target rate of return on an ongoing basis.
Because prices are not directly linked to costs for relatively long periods of time, the firm can have strong incentives to reduce its operating costs.	Because the firm is ensured a reasonable opportunity to earn the authorised return on its investments over the long term, the firm has limited concern that its sunk investments will be expropriated by future regulatory policy Because it links prices directly to realized costs, rate-of return regulation is unlikely to induce substantial unobserved cost-reducing investment.

The goal of price regulation is the reaching the perfect situation where the company is providing the high quality service with efficient price p_e, enabling the company to earn justified return. The perfect situation is where:

1. The company has reached the maximum cost efficiency (efficient operational costs, high technical efficiency).
2. The investments are made in optimal manner to new technology by avoiding both under and overinvestment.
3. The service has high quality.
4. The company´s return is justified and in accordance to its effective cost of capital.

5. The administrative burden is on optimal level.

There is no methodology which ensures the fulfilment of all these objectives. By combination and detailed assessment of different methods it is possible to reach the situation close to the perfect one. The perfect result can be in free market situation without price regulation. Therefore, before setting on administrative monopoly it is reasonable to analyse whether to replace the monopoly with competitive market. A good example is the opening of electricity and gas markets in the EU during the last two decades. In conclusion, the 5 different regulation methods are evaluated based on the research (Table 5.3.).

Table 5.3. Criteria by using of different methodologies

Objective	**Classical RoR**	**Incentive type of RoR**	**Classical RPI-x**	**RPI-x**	**LRAIC BU**
Cost efficiency	Low	Moderate	High	High	High
Optimal investment	Over-investment risk	Over-investment risk	Under-investment risk	Under-investment risk	Under-investment risk
Service quality	High	Moderate	Low	Moderate	Low
Justified return	Ensured for company[16]	Not ensured	Not ensured	Not ensured	Not ensured
Administrative burden	Very low	Low	High	Very high	Very high

Cost efficiency. Technical efficiency is a component of cost efficiency related to technical indicators like boiler efficiency, network losses, etc. It is relatively easy to set and to monitor these indicators. Both the company and regulator are able to assess the cost savings potential by improving the technical efficiency. The technical efficiency targets can be efficiently used as a regulatory tool beside the quality indicators. This has been efficiently used in incentive type of RoR regulation in Estonia [18]. There are no efficiency targets by using of the classical RoR, where the costs are based on the historical data of the company. By using of RPI-x or LRAIC BU, the technical efficiency is one of the targets of the price regulation.

[16] From customers point of view there is a clear risk of unjustified high return in times of declining interest rates.

The other cost efficiency elements are savings on operational costs like labour force, maintenance, organisational structure, etc. The estimation of this type of cost savings is more complex. The lowest cost efficiency target is by using of the classic RoR where the costs are set based on company´s historical data. The using of incentive RoR ensures much stronger pressure on company´s cost, where the highest cost efficiency incentive is by using of RPI-x or LRAIC BU.

Optimal investment. As referred above, there is a limited risk of durable sunk investment by using of RPI-x. But in case of chronic underinvestment, the RoR should be preferred [55]. There is a risk of underinvestment by using of classic RPI-x or LRAIC BU where the company is free to save on investment in order to maximise the return. The contrary risk of overinvestment is by using of RoR, especially by calculating the WACC higher than company´s cost of capital.

Quality of service. The setting of administrative quality norms is not a complicated task. The solution is in adapting of certain norms set by government or regulator´s degree. Beside the norms it is possible to introduce the penalty system where company is paying direct penalties or reducing the tariffs in the case the quality norms are not fulfilled. But the issue is that the actual quality relies on the technical situation of the utility, not dependent which norms have been set on the papers. The highest quality level can be insured by classic RoR. If the quality norms are strict enough, the WACC is from company´s perspective on adequate level and all investment are included to the tariffs, the highest quality is ensured for the customer. Rather high quality can be reached by using of incentive RoR or by using of RPI-x with strong regulation on investment. The first one is rather liberal on company´s investment decisions and by the second one the regulator is checking carefully, whether the planned investment are done ore not [26], [52], [54]. In contrast to that, by using of classical RPI-x or LRAIC BU the company is free to save on investment and there is a real risk on quality of service.

Justified return._The justified return defined by WACC is guaranteed by using of classical RoR. The effect of regulatory lag may reduce slightly the return, but from others side the sliding cost (historically extremely low interest rates) may improve company's results or even to lead to the situation where the company is not applying for new tariffs, due to the reason that existing tariffs are fixed by higher WACC. Of course, the result of 15-years' experience by using the incentive type of RoR indicates that the companies returns are below WACC[17]. The using of RPI-x enables the company to earn additional return by implementing of cost savings. The classical RPI-x gives a bigger change for the company in this perspective. By using of LRAIC BU the results can be very different and depends on specific utility. By using of this model for a water utility with long history, the results might be in unexpected high profit. But using this model for a very

[17] Chapter 2.2.2. The results of price regulation in Estonia.

inefficient power distribution network, the result can be the tariff which is not covering the cost for this specific network. The result of the study made for Estonian district heating companies indicates, that the most of companies are inefficient according to the LRAIC BU model [20] [43]. By using this model for regulation of district heating, the return of most companies would be below WACC.

Administrative burden. Administrative burden is the lowest by using of RoR. The using of RPI-x is with much higher burden, including comprehensive data collection exercise and complex calculation for the regulatory period. The costs are rather moderate during the regulatory period. By practical use of RPI-x the administration costs are higher, because of monitoring and data collection during the regulatory period. The costs are high by using of LRAIC where the modelling of the utility is needed for each of the tariff fixing.

6. Conclusion

The price regulation has some similarities to the complex social systems [70], [71] where the complexity of input data, social predictions and economic forecasts form complex issue. In the process of implementation of price regulation, a number of input data is applied, presenting interdependent occasion, recurrence and impact. There is clear impact of prognosis adequacy to the output of price regulation. In the current research, the results of applying of different price regulation methodologies, risks associated to the different methodologies and hedging of those risks have been analysed. Similar to the economic forecast, the calculation of optimal tariff which corresponds to the price formed in conditions of perfect competitive market is not possible. The conclusion is that market liberalisation and removal of administrative monopolies is reasonable approach. The examples are the liberalisation of electricity and gas markets in EU or the district heating zoning at the moment in Estonia, where market liberalisation could give a more effective result than price regulation.

In the conditions of competitive market the unit price forms on the fundamental basis of both supply and demand. In the case of market dominance (monopoly), no competition occurs and the task to simulate competition is tasked to the regulator. Therefore, the price regulation for those specific sectors is necessary. Further study of price regulation enables to implement optimal methodology which is balancing both company's and customers' interests and thus is optimal for the society. The main target of price regulation is to calculate the efficient tariff p_e The goal is to calculate the efficient tariff as similar as possible to the optimal tariff which corresponds to the price formed in conditions of perfect competitive market The level of price control can vary from soft type of ex-post implemented according to the competition legislation to the incentive type of RPI-x. Beside of the fact described, the ex-ante type of price regulation of power and gas network are strictly required according to the EU directives [13], [14].

Fifteen years of Estonian experience in implementation of price regulation results in reasonable pricing together with acceptable quality, including strong improvements in energy efficiency. The regulatory deterrence is one of prior elements of price regulation principles implemented, where the regulator is not demanding regular data collection but the tariff fixing is a rather complex exercise for the utility. In those conditions a company's intention is to relay on existing tariff as long as possible and to avoid the regulatory authority. The conclusion is that the suitable price regulation method for a large number of utilities with limited administrative resources is the incentive type of RoR. A company's incentive is to save on costs by using of existing tariff and to avoid the regulatory authority.

The determination of the value of RAB is problematic in circumstances where the assets have been acquired prior the start of price regulation. This is the case in most European countries, where the price regulation started in 1980s. Especially in Central and Eastern Europe, the consistent accounting is impossible due to the change of both political and currency system. The use of replacement cost method is problematic in particular for assets with extremely long technical lifetime like railway beds, power lines corridors, waste water canals, etc. Usually those assets have been already paid off by customers and applying replacement cost method would result with unfair pricing for customers. The conclusion is concentration to consistent accounting of new investment and ensuring that depreciation and fair return on those investment is included to the tariff.

The main risks of classical RPI-x is the accuracy of prognosis. In times of declining or rising interest rates (cost of money). The difference between actual WACC and prognosis WACC might lead to significant difference in prognosis and cost based tariffs. Another issue is accuracy in sales volume prognosis. This risk can be mitigated by using revenue regulation. Another significant risk of classic RPI-x is company's tendency to save on investments, in order to maximise the profit. The main risk of classic RoR is lack of incentive on efficiency and overinvestments, especially when the WACC set by the regulators is above the company's actual WACC. Another risk of classical RoR is the lack of efficiency gains from company.

The conclusion is that the risks of classic RPI-x can be hedged by regulation on investments and current adjustment of non-controllable inputs (e. g. cost of money) to real economic situation. The efficiency gain can be approved by implementation of incentive type of RoR where the regulator is regulating the efficiency in active manner. The risk on overinvestments can be mitigated by implementation of the best practice by WACC calculations. However, despite of that the risk of overinvestments still remains higher than by using of RPI-x. Therefore the regulatory methods used in practice are not classic type of RoR or RPI-x but hybrids, consisting of the elements of both classical RoR, RPI-x and LRAIC BU methods. Total simulation of efficient infrastructure system can be reached by using of LRAIC BU, where the entire infrastructure system is based on hypothetical model. This type of regulatory model is able to eliminate all type of inefficiencies. The conclusion is that using of LRAIC BU can arise unpredictable result, especially in case of long-lasting infrastructure elements which are already paid off by customers. Thus, the LRAIC model is an additional instrument to the price regulation models. The model can efficiently be used for dividing of cost in a CHP plant.

The research can be used in practical implementation of price regulation. The most obvious target group are developing countries where the price regulation is still in preliminary phase. In countries like these, the results of the current research can be used for designing of price regulation system. The research has a practical value by implementation of price regulation in Estonian Competition Authority.

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ABSTRACT

The main research task of current doctoral thesis is the analyses of different price regulation methodologies, the risks associated to different methods, different options of hedging those risks and the implementation of those methods in practice. The results implementation of price regulation in Estonia was analysed, including the practical implementation of Estonian experience. The rate of return, RPI-x and LRAIC BU was analysed in the frame of the research.

In the conditions of competitive market the unit price forms on the fundamental basis of both supply and demand. In the case of market dominance (monopoly) no competition occurs and the task to simulate competition is tasked to the regulator. However, in the case of monopoly, it is essential to choose proper methodology of price regulation in order to gain the best result. The main target of price regulation is to calculate the efficient tariff p_e. The calculation of the efficient tariff p_e is complex, due to the fact that the number of different input data is large and the proper forecast of those data is complicated. Therefore the efficient tariff p_e can only be formed in the conditions of perfect market. There is a number of sectors where the administrative monopolies are set by the government, like power generation and supply or district heating, which is a case in Estonia. For those sectors where the administrative monopolies are established, the market liberalisation would give the better result. The price regulation has some similarities to the complex social systems where is a complexity of input data. The number of input data in price regulation is not comparable to the input data for economic forecast, but still there is a number of different input data and several risks related to different price regulation methodologies. Therefore the risks can be mitigated by analysing of different price regulation methodologies, but the efficient tariff p_e is not reachable.

The further study of price regulation methodologies is needed, because there is no competition among the natural monopolies and the price control should be implemented for this type of utilities. The level of price control can vary from soft type of ex-post implemented according to the competition legislation to incentive type of RPI-x. Beside of this fact the ex-ante type of price regulation of power and gas network is strictly required according to the EU directives which means, that there is no dispute whether to implement the price regulation in those sectors.

The suitable price regulation method for a large number of utilities with limited administrative resources is the incentive type of RoR. According to Estonian experience this model will result in reasonable pricing, with acceptable quality, including strong incentive in energy efficiency improvements. The regulatory deterrence can be implemented on an efficient way, where the regulator is not demanding regular data collection, but the tariff fixing is a rather complex exercise for the utility. In those conditions the company's intention is to relay on existing tariff as long as possible and to avoid the regulatory authority.

The regulated infrastructure utilities are capital intensive, where the proportion of costs associated to the capital cost may for up to 80% from the total cost base. Therefore the determination of RAB is with high importance. The different methods like historical cost, replacement cost, LRAIC and market value methods for determination of RAB has been analysed in the research. The determination of consistent value of RAB is problematic in circumstances where the assets have been acquired prior the start of price regulation. This is the case in most of European countries, where the price regulation started in 80-s. In Central and Eastern Europe the consistent accounting is impossible due to the change of political and currency system. The use of replacement cost method is problematic especially for assets with extremely long technical lifetime like railway beds, power lines corridors, waste water canals, etc. Usually those assets have been already paid off by the customers and the using of replacement cost method would result in unfair pricing for customers. The solution of this issue is the concentration to consistent accounting of new investment and ensuring that the depreciation and fair return on investment is included to the tariff.

The regulatory methods used in practice are not classic type of RoR or RPI-x, but hybrids, consisting from the elements of classical RoR, RPI-x or LRAIC BU methods. The main risks of classical RPI-x is the accuracy of prognosis. In times of declining or rising interest rates (cost of money) the difference in actual and prognoses WACC might lead to significant difference in prognoses and cost based tariffs. Another issue is the accuracy in sales volume prognosis, this risk can be mitigated by using of revenue regulation. Another significant risk of RPI-x is company's tendency to save on investments, in order to maximise the profit. Those risk can be mitigated by practical implementation of RPI-x where the investments are heavely regulated and the prognosis currently adjusted to the real economic situation.

The main risk of classic RoR is overinvestments, especially when the WACC set by the regulators is above the company's WACC. Another risk of classical RoR is the lack of efficiency gains from company. The efficiency gain can be approved by implementation of incentive type of RoR where the regulator is regulating the efficiency in active manner. The risk on overinvestments can be mitigated by implementation of the best practice by WACC calculations, but despite of that the overinvestments risk remains still higher than by using of RPI-x.

The design of hypothetical infrastructure is possible by using of LRAIC BU method. The hypothetical efficient network can be designed by using of this method. The using of LRAIC BU has high risk in case of long lifetime infrastructure, where the method my result in extremely high tariffs for customers. Therefore the method can be used as a supportive tool for this type of infrastructure utilities. The method has been effectively used for cost allocation of CHP plant in practice.

KOKKUVÕTE

Antud doktoritöö peamiseks eesmärgiks on analüüsida erinevaid hinnaregulatsiooni metoodikaid, nende rakendamisega seotud riske, võimalusi riskide maandamiseks ning erinevate metoodikate rakendamise võimalusi. Seejuures analüüsiti Eestis rakendatud hinnaregulatsiooni tulemusi ja selle praktilist rakendamist. Erinevatest regulatsioonimetoodikatest on analüüsitud tulumäära, THI-x ja hüpoteetilise seadme metoodikaid ning samuti nende erinevaid variatsioone.

Hinnaregulatsioonil on teatud määral sarnasus sotsiaalsete komplekssüsteemidega, kus on tegemist suure arvu sisenditega, mis on omavahel seotud. Hinnaregulatsiooni rakendamisel on samuti palju sisendeid ning nende täpne prognoosimine ei ole võimalik. Analoogselt sisenditega on hinnaregulatsiooni rakendamisel suur hulk riske, mida on käesolevas töös analüüsitud ja hinnatud, millise metoodika rakendamisega on konkreetseid riske võimalik maandada. Analoogselt majanduse etteennustamisega on võimatu arvutada efektiivset hinda, mis kujuneks vaba konkurentsi tingimustes. Seetõttu on mõttekas kaaluda administratiivsete monopolide puhul üleminemist vabale turumajandusele. Energeetikas on sellisteks näideteks elektri- ja gaasituru liberaliseerimine EL-s ning kaugkütte korraldus Eestis, kus on seadusega sätestatud kaugküttepiirkonnad, kus alternatiivsete kütteliikide kasutamine ei ole lubatud.

Hinnaregulatsiooni metoodikate uurimine ja arendamine on oluline. Loomulikel monopolidel puudub hinnakonkurents ning teatud tüüpi hinnaregulatsiooni rakendamine on vajalik. Rakendatava hinnaregulatsiooni tase võib seejuures olla alates konkurentsiseaduse alusel rakendatavast *ex-post* regulatsioonist kuni detailse THI-x regulatsioonini. EL elektri- ja gaasi siseturu direktiivide alusel on sätestatud kohustuslik *ex-ante* hinnaregulatsioon elektri- ja gaasivõrkudele, seetõttu ei ole EL-i liikmesriikides ka küsimust nimetatud hinnaregulatsiooni rakendamises.

Piiratud administratiivsete ressurssidega, suure arvu ettevõtete hinnaregulatsiooniks on sobilik nn. intensiivne tulukuse määra metoodika. 15-aastane metoodika rakendamise kogemus Eestis näitab, et teenuste hindade areng on olnud mõistlikul tasemel, kvaliteet on üldiselt paranenud ning oluline areng on saavutatud energia kokkuhoiul. Nimetatud metoodika on suunanud ettevõtte olulisel määral tegevuskulude kokkuhoiule, mille üheks komponendiks on energia sääst. Rakendatud hinnametoodika oluline element on nn. regulatiivne heidutus, kus regulaator ei nõua andmete esitamist hinnaregulatsiooni perioodide vahelisel ajal. Samas hinna kooskõlastamise protsessis toimub ettevõtte põhjalik analüüs, millega kaasneb märkimisväärne administratiivne koormus ettevõttele. Ettevõttel on motivatsioon hoida kulusid kokku, müüa teenust kooskõlastatud hinnaga ning mitte esitada uut hinnataotlust.

Infrastruktuuri ettevõtted on kapitalimahukad, kus kapitalige seotud kulude – põhivara kulumi ja põhjendatud tulukuse osakaal võib olla kuni 80%. Seetõttu on reguleeritava vara väärtuse leidmisel väga oluline mõju teenuste hindade kujunemisel. Uurimistöös on analüüsitud erinevaid reguleeritava vara väärtuse metoodikaid, nagu bilansiline, jääktaastamise, hüpoteetilise seadme ja turuväärtuse metoodikaid. Samuti nimetatud metoodikate rakendamisega seotud riske. Reguleeritava vara väärtuse määramine on problemaatiline olukorras, kus vara on soetatud enne hinnaregulatsiooni algust. Nimetatud probleem on valdav, sest Euroopas sai aktiivne hinnaregulatsioon alguse 80. aastatel, samas on infrastruktuur ehitatud aastaid enne seda. Kesk- ja Ida-Euroopa riikides ei ole vara väärtuse järjepidev arvestus võimalik, sest suur osa varast on soetatud erineva riigikorra ja rahandussüsteemi ajal. Jääktaastamise väärtuse kasutamine on problemaatiline väga pika elueaga varade osas, mille hulka kuuluvad raudteetammid, elektriliinide koridorid, kanalisatsiooni tunnelid jm. Reeglina on nimetatud varad tarbijate poolt juba kinni makstud ja jääktaastamise väärtuse rakendamine tooks tarbijatele kaasa põhjendamatu hinnatõusu. Lahendus on kontsentreeruda eelkõige uute investeeringute järjepidevale arvestusele ning tagada, et hindadesse oleks lülitatud nimetatud investeeringute kulum ja ettevõttele tagatud põhjendatud tulukus teostatud investeeringutelt.

Praktikas kasutatavad hinnaregulatsiooni metoodikad ei ole klassikalised tulukuse määra või THI-x metoodikad, vaid kombinatsioon erinevatest metoodikatest, mis sisaldavad ka hüpoteetilise seadme metoodika elemente. Klassikalise THI-x peamine risk on prognooside täpsus pikemaks ajaperioodiks. Kaalutud keskmise kapitali hinna arvutamise aluseks oleva raha hinna ehk riskivaba tulumäära prognoosimine on võimatu ning selle fikseerimine pikaajaliseks regulatsiooniperioodiks võib tuua kaasa olulise kõrvalekaldumise hinna kulupõhisuse printsiibist. Analoogselt on probleemiks ka müügikoguse prognoosimine, nimetatud riski maandamiseks saab kasutada erinevaid lahendusi nagu müügitulu regulatsioon või saamata jäänud või liigselt saadud tulu kompenseerimine. Klassikalise THI-x oluliseks riskiks on ka kokkuhoid investeeringutelt eesmärgiga teenida suuremat kasumit. Nimetatud riski on maandatud investeeringute intensiivse reguleerimisega, mis sisuliselt tähendab loobumist klassikalise THI-x kasutamisest.

Klassikalise tulumäära metoodika peamiseks riskiks on üleinvesteerimine, eriti olukorras, kus regulaatori kalkuleeritud kaalutud keskmine kapitali hind ületab ettevõtte tegelikku kapitali hinda. Teiseks riskiks on ettevõtte vähene motivatsioon kulude kokkuhoiuks. Kulude kokkuhoidu saab oluliselt parandada, rakendades intensiivset tulumäära meetodit, kus regulaator kontrollib aktiivselt ettevõtte tegevuskulude põhjendatust ja efektiivsust. Nimetatud metoodikal on põhinenud ka Eestis 15 aasta jooksul energeetikasektoris rakendatud regulatsioon. Üleinvesteeringute riski saab maandada võimalikult täpse kaalutud keskmise kapitali hinna arvutusega, kuid vaatamata sellele on ka intensiivse tulumäära metoodika rakendamisel nimetatud risk oluliselt kõrgem kui THI-x puhul.

Hüpoteetilise, efektiivse infrastruktuuri saab edukalt projekteerida, kasutades nn. hüpoteetilise võrgu mudelit. Nimetatud mudeliga on võimalik projekteerida hüpoteetiline efektiivne võrk. Selle puuduseks on asjaolu, et meetod võib anda prognoosimatu tulemuse. Eelkõige võib toimuda oluline hinnatõus pika tehnilise elueaga võrkude osas, mille puhul on vara juba tarbijate poolt kinni makstud. Seetõttu saab nimetatud metoodikat kasutada eelkõige tulemuste kontrolliks. Edukalt saab nimetatud metoodikat kasutada soojuse ja elektri koostootmise kulude jagamisel.

Elulookirjeldus

1. Isikuandmed

Nimi	Märt Ots
Sünniaeg ja-koht	23.08.1966 Tallinn
E-posti aadress	mart.ots@konkurentsiamet.ee

2. Haridus

Õppeasutus	Lõpetamise aeg	Haridus
Tallinna Tehnikaülikool	1991	Soojustehnika insener
Tallinna Tehnikaülikool	2002	Soojustehnika teadusmagister

3. Keelteoskus (alg-, kesk- või kõrgtase)

Keel	Tase
Eesti	emakeel
Inglise	kesktase
Saksa	kõrgtase
Vene	kesktase
Soome	algtase

4. Täiendusõpe

Õppimise aeg	Täiendusõppe korraldaja nimetus
2015	Tallinna Tehnikaülikool. Elektrotehnika alused
2014	Tallinna Tehnikaülikool. Soojustehnika alused
2000	EL Komisjon, Energeetika ja transpordi peadirektoraat
1992-1993	Göteborgi Chalmersi Tehnikaülikool, Rootsi
1992	Kieli Majandusakadeemia, Saksamaa

5. Teenistuskäik

Töötamise aeg	Tööandja nimetus	Ametikoht
2008-	Konkurentsiamet	peadirektor
2001-2008	Energiaturu Inspektsioon	peadirektor
2000	Majandusministeerium	energeetika osakonna juhataja asetäitja
1998-2000	AEA Technology plc	programmi direktor
1995-1998	Majandusministeerium	nõunik, investeeringute osakonna juhataja
1991-1995	Energiaamet	nõunik, peadirektori asetäitja

6. Teadustegevus, sh tunnustused ja juhendatud lõputööd
   - Konkurentsiamet. Elering AS investeeringute mõju võrgutasudele, 2015.
   - Konkurentsiamet. Efektiivse kaugküttesüsteemi modelleerimine ja efektiivse soojuse hinna arvutamine, 2015.
   - Välisministeerium. Moldova Vabariigi konkurentsi ja majandusregulatsiooni asutuste arendusprojekt. Avaliku halduse, e-riigi ja asutustevahelise koostöö arendamine, 2014.
   - EBRD. Majandusregulatsiooni arendamine Venemaa Kaug-Ida energia-süsteemis, 2013.
   - Konkurentsiamet. Riikliku regulatsiooni otstarbekus väikestes kaugküttesüsteemides, 2013.
   - Välisministeerium. Vaba konkurentsi ja majandusregulatsiooni süsteemide arendamine Moldova Vabariigis, 2013.
   - Konkurentsiamet. Põlevkivisektori konkurentsiolukorra analüüs, 2013.
   - Rootsi Konkurentsiamet. Gruusia Konkurentsiameti arenguprojekt. 2012.
   - EL TAIEX programm. Gruusia Konkurentsiameti arendamine ELi liitumise protsessis, 2010.
   - EL TAIEX programm. Hinnaregulatsioon ja energia kokkuhoid Türgi elektri jaotusvõrkudes, 2010.
   - Konkurentsiamet. Kulude jagamine elektrienergia tootmisel biomassist, 2010.
   - Konkurentsiamet. Taastuvate energiaallikate ja koostootmise toetuse skeemide analüüs 2010-2012.
   - Konkurentsiamet. Kulude jagamine soojuse ja elektri koostootmisel, 2009.
   - KPMG Estonia. Hinnaregulatsiooni metoodika elektrisektorile, 2002.
   - Energiaturu Inspektsioon. Ukraina energeetika regulaatori arenguprojekt, 2006.
   - Göteborgi Chalmersi Tehnikaülikool. Energeetika ja Majandus. Göteborg, ISSN 0283-8761, 1993.

Kaitstud tööd
- Magistritöö. Energiaettevõtete regulatsioon ja selle rakendamise võimalused Eestis. Juhendaja prof. Aadu Paist, 2002.
- Diplomitöö. Pneumotuhaärastuse rakendamine Narva Elektrijaamades. Juhendaja dots. Arvi Prikk, 1991.

Juhendatud tööd
- Marilin Tilksoni magistritöö. Taastuvenergia toetuste analüüs – tuuleelektrijaamade näitel, 2014.
- Triin Raudsepa magistritöö. Pakkumismenetluse rakendamise võimalused taastuvenergia toetuste jagamisel Eestis, 2014.
- Rauno Rahniku magistritöö. Põlevkivielektri konkurentsivõime avatud elektrituru tingimustes, 2015.

Curriculum Vitae

1. Personal data

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E-mail address mart.ots@konkurentsiamet.ee

2. Education

Educational institution	Graduation year	Education (field of study/degree)
Tallinn University of Technology	1991	Master of Science in Thermal Engineering
Tallinn University of Technology	2002	Master of Science in Thermal Engineering

3. Language competence/skills (fluent, average, basic skills)

Language	Level
Estonia	mother tongue
English	average
German	fluent
Russian	average
Finnish	basic skill

4. Special courses

Period	Educational or other organisation
2015	Basis of Electrical Engineering, Tallinn University of Technology
2014	Basis of Thermal Engineering, Tallinn University of Technology
2000	European Commission, DG TREN
1992-1993	Göteborg Chalmers Technical University, Sweden
1992	Academy of Economics in Kiel, Germany

5. Professional employment

Period	Organisation	Position
2008-present	Estonian Competition Authority	Director General
2001-2008	Estonian Energy Market Inspectorate	Director General
2000	Estonian Ministry of Economic Affairs	Deputy head of Energy Department
1998-2000	AEA Technology plc	Program Director
1995-1998	Estonian Ministry of Economic Affairs	Counsellor, head of Investment Department
1991-1995	Estonian Energy Department	Expert, Deputy Director General

6. Research activity, including honours and thesis supervised

Research activity

- Estonian Competition Authority. Study on impact of investments on tariffs of power TSO, 2015.
- Estonian Competition Authority. Study on LRAIC BU model for modelling of DH systems and calculation of efficient DH tariff, 2015.
- Estonian Ministry of Foreign Affairs. Improving good governance of competition and regulatory authorities in the Republic of Moldova: public administration, e-governance and inter-institutional cooperation, 2014.
- EBRD. Russia Far East Energy Sector Regulatory System Review 2013.
- Estonian Competition Authority. The rationality of price regulation in small scale district heating systems, 2013.
- Estonian Ministry of Foreign Affairs. Enhancing the protection of free market competition and economic regulatory systems in Moldova through education and good governance. Project financed by 2013.
- Estonian Competition Authority. Study on competition situation in Estonian oil shale sector, 2013.
- Swedish Competition Authority. Development project of Georgian Competition Authority, 2012.
- EU TAIEX program. Strengthening of Georgian Competition Authority in EU accession, 2010.
- EU TAIEX program. Price regulation and energy conservation in Turkish power distribution companies, 2010.
- Estonian Competition Authority. Economic analyses of renewable energy and go-generation support scheme in Estonia 2010-2012.
- Estonian Competition Authority. Study on cost allocation methods in biomass CHP plant, 2010.
- Estonian Competition Authority. Study on cost allocation in CHP plant, 2009.
- KPMG Estonia. Study on price regulation methodology for Estonian electricity sector, 2002.
- Estonian Energy Market Inspectorate Strengthening of Energy Regulatory Authority of Ukraine, 2006.
- Göteborg Chalmers University of Technology Economic Evaluation of Energy Conservation Measures ISSN 0283-8761, Göteborg 1993.

Defended thesis

- Master Thesis. Economic Regulation of Energy Utilities and possibilities of Implementation in Estonia (Energiaettevõtete regulatsioon ja selle rakendamise võimalused Eestis). Supervisor prof. Aadu Paist, 2002.
- Master Thesis. Pneumatic Ash Utilisation System in Narva Power Plants (Pneumotuhaärastuse rakendamine Narva Elektrijaamades). Supervisior PhD Arvi Prikk, 1991.

Thesis supervised

- Marilin Tilkson Master Thesis. Analysis of renewable energy subsidies – exemplified by wind parks (Taastuvenergia toetuste analüüs – tuuleelektrijaamade näitel), 2014.

- Triin Raudsepp Master Thesis. Renewable Energy Subsidies and the Implementation of Tendering Features in the Support Scheme in Estonia (Pakkumismenetluse rakendamise võimalused taastuvenergia toetuste jagamisel Eestis), 2014.
- Rauno Rahnik Master. Thesis Competitiveness of Oil Shale Electricity in Open Market Conditions (Põlevkivielektri kokkurentsivõime avatud elektrituru tingimustes), 2015.

DISSERTATIONS DEFENDED AT TALLINN UNIVERSITY OF TECHNOLOGY ON *POWER ENGINEERING, ELECTRICAL ENGINEERING, MINING ENGINEERING*

1. **Jaan Tehver**. Boiling on Porous Surface. 1992.
2. **Aleksandrs Cars**. Woodhips Combustion Technology. 1992.
3. **Endel Risthein**. Electricity Supply of Industrial Plants. 1993.
4. **Tõnu Trump**. Some New Aspects of Digital Filtering. 1993.
5. **Vello Sarv.** Synthesis and Design of Power Converters with Reduced Distortions Using Optimal Energy Exchange Control. 1994.
6. **Ivan Klevtsov**. Strained Condition Diagnosis and Fatigue Life Prediction for Metals under Cyclic Temperature Oscillations. 1994.
7. **Ants Meister**. Some Phase-Sensitive and Spectral Methods in Biomedical Engineering. 1994.
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11. **Kalju Meigas**. Coherent Photodetection with a Laser. 1997.
12. **Andres Udal**. Development of Numerical Semiconductor Device Models and Their Application in Device Theory and Design. 1998.
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14. **Jüri Joller**. Research and Development of Energy Saving Traction Drives for Trams. 2001.
15. **Ingo Valgma**. Geographical Information System for Oil Shale Mining – MGIS. 2002.
16. **Raik Jansikene**. Research, Design and Application of Magnetohydrodynamical (MHD) Devices for Automation of Casting Industry. 2003.
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