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Net zero energy housing as en economical potential for escaping the housing overburden

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field of study QUANTATIVE FINANCE

The thesis written under the supervision of

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Statement of the Supervisor on Submission of the Thesis

I hereby certify that the thesis submitted has been prepared under my supervision and I declare that it satisfies the requirements of submission in the proceedings for the award of a degree.

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Summary

The below paper is a revision paper for potential utilization of net zero energy building as a mechanic to decrease the housing burdening in European dwellings. The Research method used: revision of the most recent knowledge about nZEB, deriving the cross areas (building physics and economy) equations to understand the nZEB economy and finally devising the Monte Carlo simulation of derived equations with the market limitations.

Keawords

housing overburden, renewable energy, zero energy housing, household economy

Area of study (codes according to Erasmus Subject Area Codes List)

14.3 Ekonomia

Theme classification

not applicable

The title of the thesis in Polish

Budownictwo zeroenergetyczne jako potencjałredukcji przepalania przychodów gospodarstwa domowego przez koszty mieszkalnictwa

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Introduction

While studying economy, the most apparent to me became the notion that all we learn is a approximation of a reality. Very little of an economic drill can be applied to the ones life. The high macroeconomy or microeconomy have very little in common with the life of people. After leaving the university, never have I had more motivation to bring my work to life to have an actual impact on people's life. The interest in sustainability and the notion of world as a ticking bomb that no one can defuse became very close to me. The reality in which we live, so well described by economy has a very big flaw. The agent (homo economicus) maximizes its own utility often by the cost of other agents. Take an example of driving cars. While we all use transportation for our own and societal benefit, the invisible thread of CO_2 is behind each end every car and bus drive. The notion that majority of our actions have both positive and negative impact (where positive is towards us and negative towards everyone) has bugged me since I finished the studies in 2016. While having this in mind I have attended numerous contests and exhibitions to showcase potential business or non-business solutions to this problem.

One of the solutions for those social problems was an idea of a house that produces more energy than it uses. The idea of SOLACE house has been born. An all-year house of net zero energy requirement that can be transported in one transportation or container. By the time we started our work on the project, little did we know that Zero Energy Housing is a widely researched term and lot in the area has been already tested and validated. After 2 years of work on the project, the SOLACE house has been erected in Warsaw at Rektorska 4 street. We can now gladly test its full energy production potential with the building physics and used thermal solution like HVAC, recuperation, polyurethane thermo-insulator and also the triple glassed windows. All those solutions has been introduced in the non-formal manner to our concept. We have been meeting with engineers, specialist and business representatives to acquire knowledge how to build a repetitive building of Net Zero Energy characteristics.

All of the above has brought me to writing this thesis. I would like to bring to the society both the unraveling feeling of using economy to bring up some real solutions to live and how to build up theory behind a sustainable solution. Both theory and practicalities of knowledge for me and my company has been of my great interest.

The study below was build on a problem we wanted to solve and recent alerting accumulation of information about the term 'housing overburden". This term describes a man or a household, whose disposable income is spend in 40% on Housing and costs connected with it, like rent or electricity bills.

One of the proposed solutions in a article [Rognlie, 2014] was lowering the housing burden of a household via zero energy housing. This type of housing is characterized by production of power from renewable sources of energy sufficient to ensure the required amount of electricity by a household. Moreover, there are countries that applied the support policies to induce growth of prosumers in the market.

The below study has an important role to our business and me personally. While literature discuses both environmental and sector mechanics of introduction to the prosumer distributed economy, but there is a little research on the perspective of a lifetime economical value for the customer. The prosumer lifetime economical surplus is the key interest of the study, will dwellers of zero energy house can substantially benefit from the house energy production. The sub-thesis of the paper is that it could bring them both independence and freedom from the housing overburdening.

The hypothesis in this paper is that the Zero Energy Houses can substantially decrease social housing overburdening of dwellers with certain market parameters (chapter 1) and building characteristics (chapter 2). Method chosen for the study was to first derive the market and building parameters affecting the possibility of obtaining the zero energy house from both economical and technological stand point. In the second stage of research the parameters has been sorted to a probabilistic and deterministic values and tested via Monte Carlo simulation with most promising deterministic values for maximizing the family surplus (chapter3). As a final, the results has been discussed and dwell on in terms of potential future solution to bring the Net Zero Energy buildings to a larger group of people.

The remark has to be made at the end of the introduction that all the data in the model given are functions ex-ante. Not all the people use their houses in the same way and each of the dwellers has different habits and daily routines using different values of the electricity daily. One can have very long baths and another can never turn off the lights. There are also dwellers with special needs for the energy like disabled people with additional life supporting devices. There are also hobbies or interests that generate additional demand for electricity and thus changing the final D_e.

Knowing this, the study will describe dwellers of the average European use of energy and average demand for the energy produced. This will allow assessment of the potential of zero energy homes to generate surplus for the dwellers rather than solve the individual dweller situation.

Chapter 1

Housing overburdening

1.1. Proposed hypothesis

While there are numerous methods to put the finances of the family on the higher level, the proposed study will reflect on the potential of bringing the family monetary surplus via the Zero Energy Housing implementation. The zero energy house can substantially influence the Housing cost H via substantial lowering of the H_e - energy compound of the final housing costs via reducing the demand on the import of the energy from the grid. The accessibility to the solutions generating renewable energy on site has grown in last decade. As the fig 1.1 shows, the number of the PV installations in the world is rising. The acceptance of this technology has boomed in the last decade and hopefully will not decline. The biggest controversy of the PV technology focuses on the disproportion between the consumer and commercial acceptance of the renewable source of energy. The commercial zone has installed cumulatively 11 times more mWh of photovoltaics than end consumers.

This study will focus on calculating the possible financial surplus of the family living in Zero energy house equipped with solar installation in chosen European countries. The multi factor optimization analysis will find the potential multi factor simulation that allows the family living in ZEB Def.6.0.5 to produce energy.

Tested hypothesis therefore is - Zero Energy Houses can substantially decrease social housing overburdening of dwellers with certain market parameters.

In the following chapter the equations to calculate the potential family surplus and saving potential for each European country will be devised.

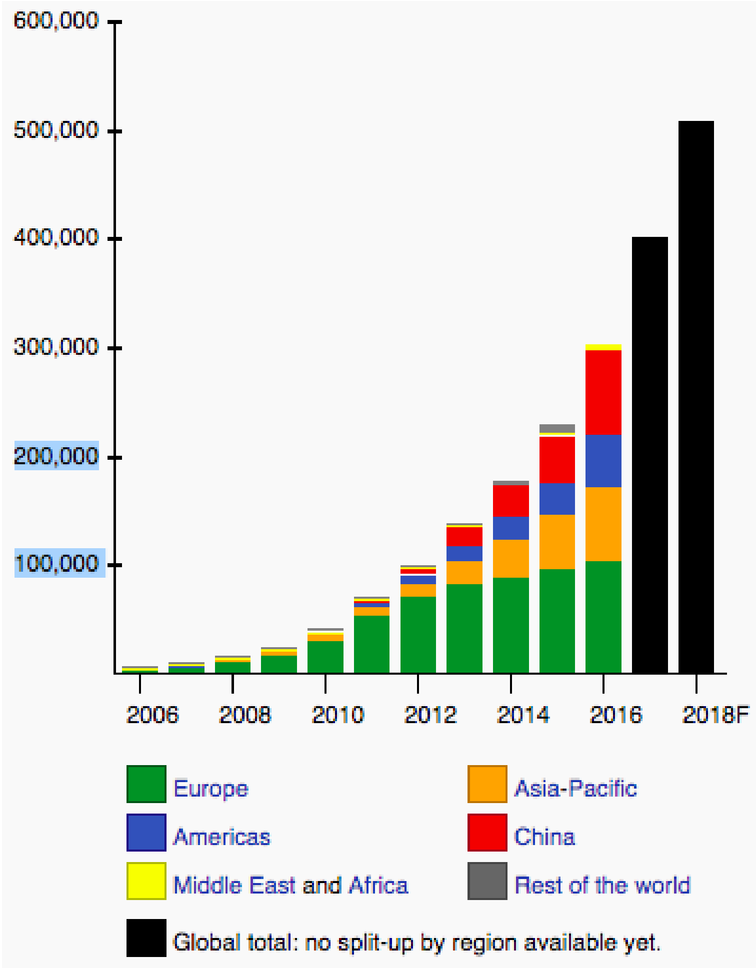

Figure 1.1: mWh of PV installed by continent 2006-2016, Eurostat

1.2. The means of the problem

According to Eurostat, housing overburden rate stands for the percentage of the population which lives in households where the total costs of housing represent more than 40% of disposable income. Housing overburden is a problem which is still growing in Europe. Due to several economic and social issues, emerging housing costs are becoming a serious concern for an increasing number of Europeans.[Eurostat, 2014]

Up to 33.8% of Europeans admit they have to face disproportionate housing costs. Common perception states that housing affordability has worsened compared in past five years and is expected to further decrease. Finding an accommodation at reasonable price is especially difficult in large cities and capitals. The average costs of dwelling for the overall EU population equals 22.5% of disposable income, but housing costs hit the poor population much harder. Those costs represent up to 41% of their income. The gap between those above and below the poverty line is widening all the time. In 2010 up to 10.1% of European households (and 36.9% of households with an income below 60% of median equalized income) spent over 40% of their disposable income on housing costs. Housing expenditures stand for 22.9% of total household consumption expenditure. This is an increase from 20.4% in 2000. Housing affordability differs significantly across the EU. Whether the overburden rate or share of housing costs on income are considered, the situation of the poorest households is especially hard in Greece, the UK and Denmark[Baxter et al., 2008b].

Worsening affordability stands for increasing house prices and rent levels over the past decade, increasing expenditures over domestic energy consumption as well as lack of choice in terms of tenure options, with a particular shortage of affordable rental housing. The consequences of worsening affordability can be seen in the high level of indebtedness over housing mortgages in several countries and on utilities bills. [European Parliament, 2013] Moreover, the phenomenon of energy poverty is spreading. Right now there are already 52.08 million people in the EU who are unable keep their home adequately warm.

Several countries (especially in Eastern Europe) have a relatively bigger problem in terms of overall affordability of housing (price to rents ratio)[Zubi et al., 2018]. In many of these countries inadequate housing quality is still a huge issue, with potentially significant negative impact on residents health. In CEE countries there is a phenomenon of 'poor home owners' which implies that a big part of the existing stock in apartment buildings is in the need of modernization but their residents cannot afford on their own (for instance in Bulgaria, Estonia, Romania). Those residents need public support to live in decent conditions again. Energetic performance of housing has a significant impact on the costs of utilities and contributes to fuel poverty. For example, in the UK the average social rented home is of significantly higher energy efficiency than any other tenure. In spite of that, with 22% of social rented households admitting that they are unable to keep their home adequately warm the proportion is higher than among home-owners or private renters reflecting the concentration of low incomes in social housing.[European Parliament, 2013]

9.4% of EU households admit that are unable to keep houses adequately warm. The proportion of households in fuel poverty across EU remains stable at around 10%, but there are significant differences both across countries as well as in terms of the changes over time. The highest degree of fuel poverty may be observed in countries of South and South East Europe. For example, in Bulgaria, Greece, Cyprus and Portugal over 20% of all households admit they are unable to keep dwelling sufficiently warm. Some of these high rates are obviously the outcome of the quality and energy efficiency of houses, but the growth in fuel poor households in countries such as Spain, Greece or Italy can partially be explained with the worsening social and economic conditions, caused by the financial crisis and austerity measures taken. Lower levels of fuel poverty may be observed in Scandinavian and Northern and Central European countries. In these countries, less than 5% of all households report that they are unable to keep house sufficiently warm [IEA, 2002].

Prices of houses are crucial determinants of housing affordability and monitoring their changes is important to identify potential risks for the overall economic and financial stability. Data released by Eurostat in 2017, show that house prices rose by 4.1% in the euro area and by 4.7% in the EU in the fourth quarter of 2016 compared with the same quarter of the previous year. It was the highest annual growth rate since 2009, as house prices have overall recovered since the crisis in last decade. Data show different trends across EU countries. Among the Member States, the highest annual increases in house prices in the fourth quarter of 2016 were recorded in the Czech Republic (+11.0%), Hungary (+9.7%) and Lithuania (+9.5%), while prices remained nearly stable in Italy (+0.1%). In the majority of countries prices of houses are the highest in capital city areas[2018, 2018].
The most common tenure for in EU is owner occupation, with an average 69.4% of the population living in owner-occupied housing against 30.6% tenants. It masks wide differences in tenure distribution across countries. The majority of former communist countries of Central and Eastern Europe show big amount of home-owners without any mortgage, because after the fall of the communist regimes tenants were offered the dwellings they lived in at a low price. In most English-speaking and Nordic countries, Belgium and the Netherlands owners with outstanding mortgages are the most common tenure type. Only in Switzerland and Germany renting is more common than owning a dwelling [OECD, 2016]. Several countries observed a decrease in the share of owner-occupation since 2000, corresponding to an increase in the share of tenant households in the private rental market - for instance in Ireland and the United Kingdom. This trend can be reflected in the EU average. Despite of significant cross-country variations, since 2007 the share of owners with a mortgage increased slightly (from 25.6 to 27%), that of owners outright decreased (from 47.2 to 42.2%). Over the same period, the proportion of tenants at market price increased significantly (from 12.6 to 19.9%) and that of tenants paying a reduced rent decreased (from 14.6 to 10.9%) [IEA, 2002].

Taking into consideration the rental sector, in the following countries tenants spend more than one fourth of their income on rents alone: the Czech Republic, Finland, Norway, Sweden, Greece, Denmark, the UK, Belgium, Spain, and Luxembourg [IEA, 2002]. Considering the evolution of rents over income, since 2010 the biggest increases were observed in the Czech Republic (21.73% to 29.56%), Greece (24.8% to 28.57%), Luxemburg (from 21.18% to 26.37%), the Netherlands (24.7% to 28.8%), and Portugal (10.58% to 18.08%) (OECD,

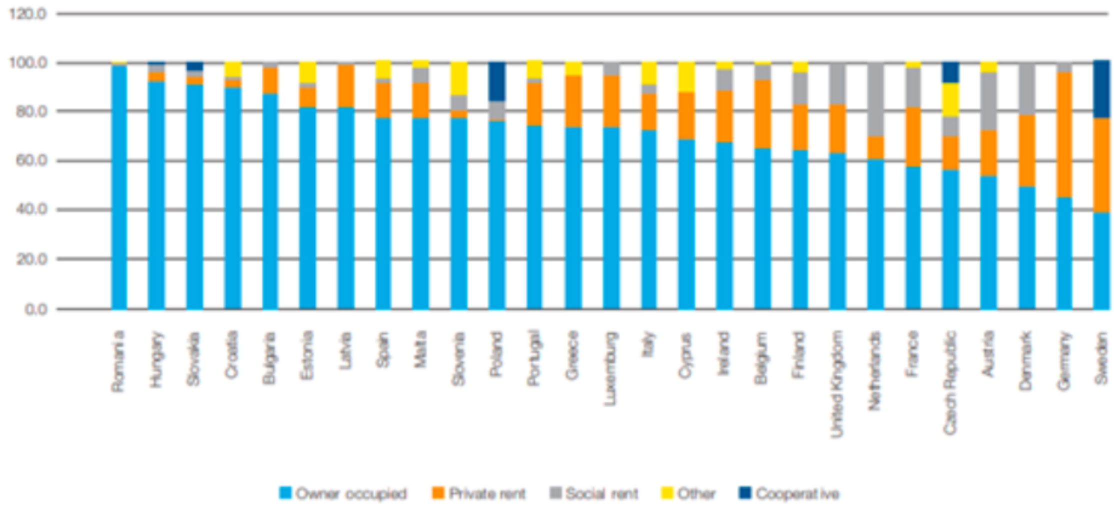

Figure 1.2: Tenure split inEU Member states 2018, Eurostat

2016). Social and affordable housing providers still offer rents at much lower prices than the market (e.g. rents in social housing are about 60% of market rents in the UK and France), but they are facing a double challenge which is increasing number of people registered on waiting lists and decreasing income of current residents. A consequence of the lack of affordable housing solutions is that the social housing sector is under growing pressure to deliver additional social dwellings. In several countries social housing construction played a crucial role in the aftermath of the crisis in 2008. Social housing providers in Austria, Belgium, the UK and France managed to increase the yearly production of new dwellings during the period 2005-2015, but now the supply of social houses is shortened because of budget cuts. For example, in Spain it went from over 15 thousand in 2005 to 2.5 thousand in 2014[Daly, 1990]. Social housing providers must cope with smaller public funding and base more on private finance. Even in countries with a relatively large share of social housing there may be seen a trend towards more residual role (i.e. a stronger focus on lower incomes), either through regulatory changes (e.g. in the Netherlands), or as the sector tends to house increasingly poor households (France). There is a growing trend of the emergence of an intermediate or 'affordable' housing segment. The idea is that this intermediate sector should cater for people who need affordable housing options but they do not fall into the typical criteria for the allocation of social housing. This presents both a challenge and an opportunity and the role to be played by different providers/stakeholders in this segment, which is often a subject of debate[Poggio and Whitehead, 2017].

Another aspect of housing overburden rate stand for the social issues, and changes in lifestyle of Europeans. On average 42% of young people (aged 16-29) who are at risk of

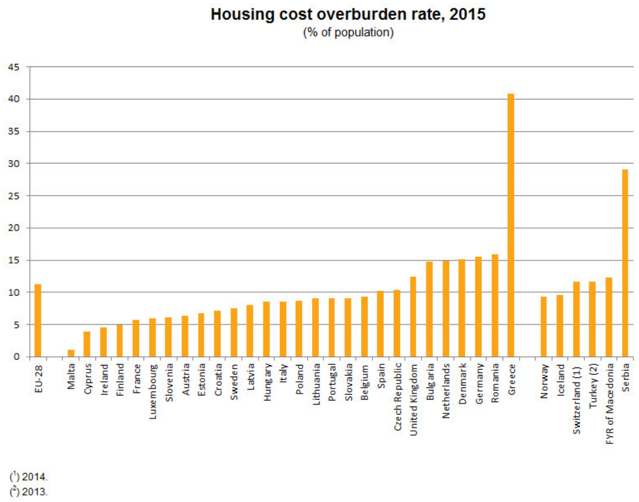

Figure 1.3: Housing cost overburden rate in Europe 2015, Eurostat

poverty spend more than 40% of their income on housing. Moreover, they are more likely to live in overcrowded homes. Excluding one-person households, on average 20% of young Europeans (aged between 16-29) live in a situation of overcrowding. Lots of young people postpone leaving the parental home for several reasons, like the difficulty in securing an accommodation elsewhere. On average, almost half of young people aged between 18 and 34 in the EU lives at home with their parents. On average, around 47% of young adults (aged 18-34 years old) keep living at their family home with their parents since the crisis in 2008. For example, around 70% of young Slovaks and 20% of young Danes still live with their parents. In last ten years in Greece and Spain the number of young adults living with their parents increased around 10% [Dalgleish et al., 2018]. This situation is caused by the fact that young people can not afford buying a dwelling on their own and due to high rental costs is seems more reasonable for them to stay at parental house to save some money for the future own house.

1.3. Housing overburdening calculations

To conduct the study of a potential economical surplus on dwellings financial situation by living in a net zero energy house there is a necessity to understand the burden the house is inflicting on its dwellers. Finding the components of the burden allows to quantify the family budget and compare their cost structure before and after changing to zero energy house.

In the calculation of the housing cost burden all annual costs connected with the household's right to live in the accommodation are included (housing and mortgage interest payment, rental payments, structural insurance, regular maintenance and repairs, services and

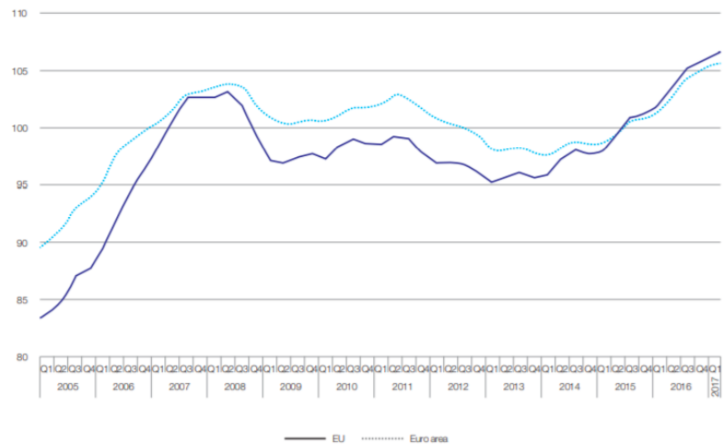

Figure 1.4: House pricing index 2005-2017, Eurostat

charges - sewage removal, refuse removal and the costs of utilities - water, electricity, gas, heating, etc.), net of housing allowances. Housing cost burden (the share of housing costs in the total disposable household income) is the same for all of the persons in the same household.[Eurostat, 2014] The above methodology is used to conduct a widespread research called SILC (Statistics on Income and Living Conditions) to compare the living standard and citizens condition in European Union countries.

To bring the measure to the economical therms we will start with the household economy, beginning with the following equation:

$$Y = C + S \tag{1.1}$$

Equation 1.1 is an basic neoclassical income equation where Y accounts for the income, C accounts for consumption and S accounts for saving.

While focusing on housing cost as one of drivers of social inequality, we will omit the taxes and the securities and rewrite the equation in a form of disposable income Def. 6.0.8 to the family budget. As in each family, there is a breadwinner (one or more) who brings a Disposable Income allowing family to decide on what this income is spent.

$$Y_d \text{ disposable income} \tag{1.2}$$

Therefore the equation will take a form of

$$Y_d = C + S \tag{1.3}$$

than

$$C = C_h + H \tag{1.4}$$

where the equation 1.3 denotation has been made to pull the 'net' of housing allowances H (later referred as housing costs) from the Consumption compound and thus receiving:

$$Y_d = C_h + H + S \tag{1.5}$$

Due to better understanding the overburdening problem the saving oriented approach will be implemented:

$$S = Y_d - C_h - H \tag{1.6}$$

What directly shows, that the higher the H compound of the equation, the lower the family savings S. For the European Commission [Eurostat, 2014] the notion of the Housing Cost H pressing the disposable income to less than 60% of the family income is inducing the situation where family is not able to secure the substantial amount of savings for next period and thus being able to climb the social ladder. Therefore the below cases will be implemented.

$$\text{Housing overburden cases} = \begin{cases} \text{if } S > 0 \text{ than the family is not overburden} \\ \text{if } S = 0 \text{ than the family is overburden} \\ \text{if } S > 0 \text{ than the family is at risk of poverty} \end{cases} \tag{1.7}$$

And while it is well known that:

$$S = I \tag{1.8}$$

That means for the second and third family from the equation 1.7, both can't secure their investments and therefore the level of income and knowledge will stay the same as observed by the [Davidson and Mackinnon, 1983], this measure incline also the falling behind hindering inflation line while in 2nd or 3rd scenario. This in long run builds the tension on family widening within the compounded inflation rates. In theory the only way to grow the $\mathrm{Y_d}$ in the family is to invest in knowledge or other long term assets to build the future higher income to prevent the risk of poverty. While the family is not saving for assets of knowledge at the rate of inflation it is theoretically certain that this family will finally land in a case 3 from the equation 1.7. [Irulegi et al., 2014]

$$\lim_{H \to S} y_d(n) = 0. \tag{1.9}$$

Showing that if the disposition of income on housing overgrows the savings, then the space for disposing the left income is reaching 0 in long run.

To secure dwellers from landing in case 2 or 3, the proposed analysis is to search for possible surplus from the zero energy homes and adjust their disposable income to find the space for the savings and thus the investments. This theoretically would allow leaving the housing overburdening of the family [Baxter et al., 2008b] and allowing the social growth in the society.

The below list shows the sources of cost pressuring dwellers to spend to maintain their dwellings or in other words the sub-components of H:

- rent and mortgage interest payment - H_r- for both own and rented dwellings rent is a monthly fee derived from the market value of the flat. This compound can not be lowered nor neglected and therefore is a fixed value in the compound H. Lowering this compound is connected with the possible replacement of the family dwelling inducing other non measurable costs [Zubi et al., 2018].
- land tax - H_t - as well as above factor, land tax can not be lowered nor neglected and therefore is a fixed value in the compound H [Zubi et al., 2018]
- energy costs H_e
  - electricity cost - the factor derived from the placement of the house in terms of climate, the quality of the house energy systems, habits of dwellers and the local prices for the electricity
  - heating cost - for this study -
  - cost of purchase of warm water -
- cost of services and charges - sewage removal, refuse removal - H_{st} -
- regular maintenance and repairs - H_{rn} -
- additional non quantifiable variables such as - H_{nq} - :
  - cost of living in unhealthy conditions
  - cost of travel to the workplace
  - marginal preference to stay in the current dwelling
  - cost of moving to new dwelling

The important notion for this study is to highlight Energy compound H_e that will be taken as the main possibility to generate the family surplus. The compound usually accounts for 25-35% of the all housing costs [Panagiotidou and Fuller, 2013]. In equation 2.1 this compound be denoted to the D_e, to showcase that the cost of the energy (electricity in ZEB) is equal to the demand on energy (electricity in ZEB) times the local price.

The equation for the total compound H is as follow:

$$H = H_r + H_t + H_e + H_w + H_{st} + H_{rn} + H_{nq} \tag{1.10}$$

	rented flat	own flat	rented house	own house
H_r	- 52%	- 42%	- 29%	- 16%
H_t	- 3%	- 5%	- 6%	- 7%
H_e	- 35%	- 41%	- 51%	- 61%
H_{st}	- 6%	- 7%	- 8%	- 9%
H_{rn}	- 4%	- 5%	- 6%	- 7%
H_{nq}	non quantifiable			

Table 1.1: Percentage mean share of the housing costs in the 'net' of housing allowances mix [Baxter et al., 2008b]

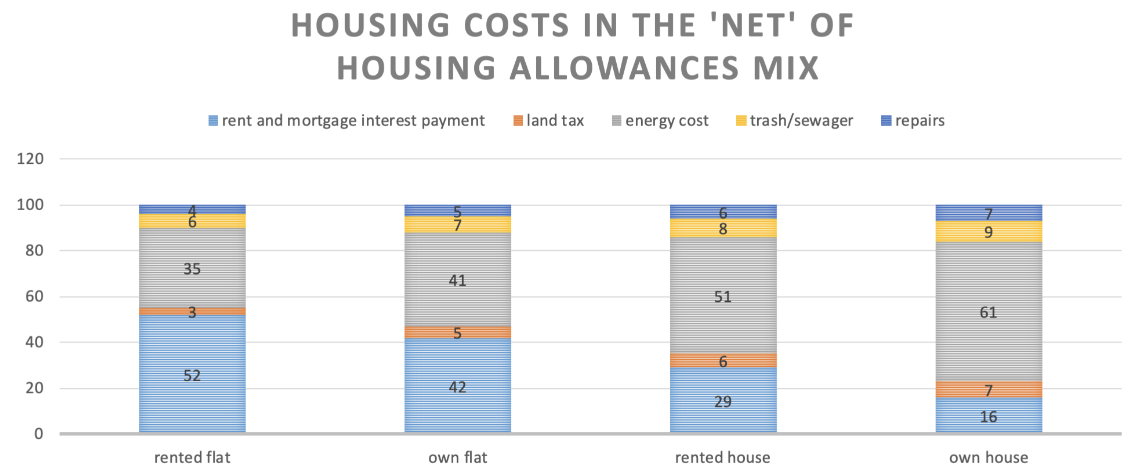

Figure 1.5: Percentage mean share of the housing costs in the 'net' of housing allowances mix as in [Baxter et al., 2008b] - own material

Where the share of each compound on average European household takes:

As visible in the Fig.1.5 the H_e is one of the main drivers of housing costs. The biggest average share is visible in 'own house' sector while the H_r is substantially lowered by the lack of rent (only possible mortgage payment). While on the European level, there are about as many people living in Single Family Houses (58%) as in Multi Family Houses (42%) [IEA, 2002].

The H_e according to Fig 1.6 for European Union shows that the heating is the most important part of the compound. Space heating source may origin from numerous of sources. Gas heating, coal heating, warm water heating and finally electrical heating. For this study we will calculate the required energy to the electrical energy requirement equivalent while ZEB's source of energy can be solely based on internal exergy energy produced on the photovoltaic installation of its roof.

The strategy towards ZEB's therefore should mainly be focused on new houses or renewing

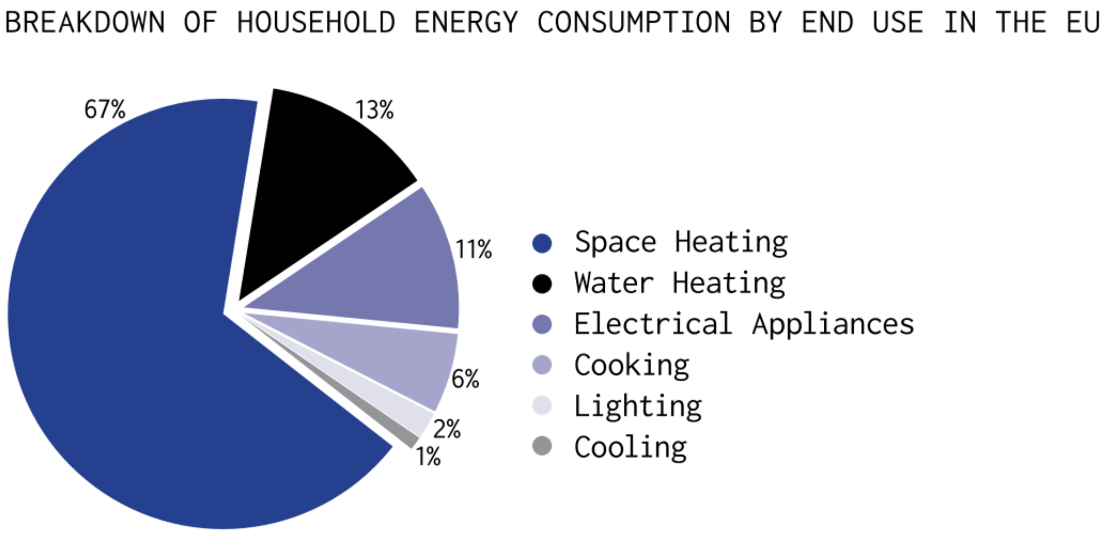

Figure 1.6: Breakdown of household energy consumption by end use in the EU for 2012 (Odyssey database, 2012)

the new houses, while having biggest potential surplus for the family to induce the disposable income. The average 47% h_e will be the main research measure further in study to find the potential family surplus.

1.4. Present value of human life as a method of calculating and ZEB's family lifetime surplus

As a second theoretical base for understanding the ZEB's 6.0.5 potential influence for the family's situation the life valuation of a person/family will be introduced. The notion here is to discuss the potential surplus for the family being introduced to ZEB in terms of life present value.

The value of human life is often expressed in terms of potential lifetime earnings, a measure of the productivity of an individual. This measure is used as a basic tool of the economist, program planner, decision-maker, and others who are interested in measuring the societal benefits associated with investments in particular programs to prevent, treat or cure disease as in [Mcadoo, Harriette Max, Wendy, Ph.D. Rice, Dorothy P Sung, 2005]. The equation to be introduced:

$$PVLE_y = \sum_{n=y}^{85+} P_y(n)Y(n)/(1+r)^{n-y} \tag{1.11}$$

Where

- $PVLE_y$ is the present discounted value of lifetime earnings for a person of age y
- $P_y(n)$ is the probability that a person of age y and gender g will survive to age n y is the age of the person at present
- n is the age of the person
- Y(n) is the annual earnings of an employed person at age n
- r is the real discount rate

While the [Mcadoo, Harriette Max, Wendy, Ph.D. Rice, Dorothy P Sung, 2005] focuses on the valuation of ones life expected valuation the noted $Y^h(n)$ is the same disposable income from equation 1.5. The study To introduce this to the study the method from equation 1.11 will be adjusted and the equation will be rewritten in simpler way highlighting the household valuation with regard to the expenditures of a person or a household. While imputing the 1.4 to the equation we are achieving the valuation of the one's life in regard of what he spent the disposable income of its life. It may look as:

$$PVLH_y = \sum_{n=y}^{85+} P_y(n)(C_h + H + S)(n)/(1+r)^{n-y} \tag{1.12}$$

Where

- C_h Is a consumption without the 'net' of housing allowances H
- H is the 'net' of housing allowances
- S is a family savings

This directly shows, that the higher the value of our consumption the higher the valuation of a household. This is though counterintuitive while the notion of consumption is not directly evoking one's intuition as value. With the regard of [Mihaylov et al., 2019] the possible decrease of the H compound with the ZEB's ability to reduce the H_e will affect positively the PFLH while increasing the potential savings. Taking the Eurostat notion of the housing overburdening as inability of securing the savings [Eurostat, 2014] the equation that would be interesting for this study will look as follow:

$$PVS_y = \sum_{n=y}^{85+} [P_y(n)Y(n))(n) - P_y(n)H(n)]/(1+r)^{n-y} \tag{1.13}$$

Where PVS_y is a present value of lifetime savings of the household with regard to the housing costs. This equation will later be simulated with the Monte Carlo method while checking the underlying dependencies of an ZEB's functioning (as building physics, energy production etc.) and its influence on the family. The result of simulating this would show weather the distribution of the population using the ZEB strategy to secure their financial and decrease their overburdening factor can be viable in our changing world.

To move further with the study, the ZEB's theory has to be introduced.

Chapter 2

Social and economical conditions of self sufficiency of dwelling

Chapter 2 of this study is devoted to draw the picture describing the self sufficiency and its components to bring the closer understanding of how to measure economical surplus of a ZEB's dweller. The chapter will firstly devise the coherent analysis of ZEB micro economical characteristics and parameters to better frame the later devised simulation. Second subchapter will lay over the base equations to understand the energy usage inside the dwelling and introduce the demand - supply terms to the ZEB physics. Than the macro economical argument will be introduced to point out the exogenous metrics of the energy price and its availability and how those may influence the end user of European union. Than the renewable support mechanism at European countries will be introduced, to better test the viability of ZEB's in European Union. The final chapter shows the global motivation of ZEB's and the potential influence on environment as a whole.

2.1. Rationale behind the study of economical surplus of zero energy building for its dwellers - ZEB's economy

From the emotional to the architectural value, buildings occupy a key place in our lives and a society as a whole. The characteristics of a building, its design, its look and feel, and its technical standards not only influence our productivity, our well- being, our moods and our interactions with others, they also define how much energy is consumed in and by a building, and how much heating, ventilation and cooling energy is needed to create a pleasant environment. Below chapter is to lay the ground underneath the study of economical financial surplus of a family unit that obtains the house with the net zero energy or net plus energy characteristics. Def. 6.0.9. The underlying though is to decrease the accumulated cost of housing via decreasing the costs of usage of the house and thus allowing dwellers to move away from the housing overburden. [Rognlie, 2014]

Option Number	ZEB Supply-Side Options	Examples
0	Reduce site energy use through low-energy building technologies	Daylighting, high-efficiency HVAC equipment, natural ventilation, evaporative cooling, etc.
	On-Site Supply Options	
1	Use renewable energy sources available within the building's footprint	PV, solar hot water, and wind located on the building.
2	Use renewable energy sources available at the site	PV, solar hot water, low-impact hydro, and wind located on-site, but not on the building.
	Off-Site Supply Options	
3	Use renewable energy sources available off site to generate energy on site	Biomass, wood pellets, ethanol, or biodiesel that can be imported from off site, or waste streams from on-site processes that can be used on-site to generate electricity and heat.
4	Purchase off-site renewable energy sources	Utility-based wind, PV, emissions credits, or other "green" purchasing options. Hydroelectric is sometimes considered.

Table 2.1: ZEB Renewable Energy Supply Option Hierarchy, [Torcellini et al., 2006]

ZEB in detail is a house that generates more energy than uses as mentioned completely deleting H_e compound from the housing cost mix from Table 3.1. The way to achieve this is to both reduce the energy that radiates from the building [IEA, 2002] and to introduce any mechanism of energy production or energy preserving, achieving the exergy situation called Sustainable Energy balance [Torcellini et al., 2006]. The basic distinction of those has been introduced in Table 2.1.

While Option 0 is not directly inducing the energy to the system, it reduces the demand on energy while having the same thermal and usable comfort of dwelling. This is substantially influencing the house in terms of the net energy needed to import to the house. Options 1 and 2 are the local On-Site Supply mechanisms to bring the energy to the house and requires some primary investment to be take while introducing to the dwelling.

An important question has to be asked here. Whether the preservation systems from Option 0 are actually of any use while introducing an ZEB strategy to dwellers as showed in the Option 1 and 2. The answer is not as simple as it may seem. The building by the radiation disposes the energy to the atmosphere and therefore increases the demand on heating or cooling inside the house. This therefore increases the demand on the energy and thus increases the investment for the renewable on site production method. The simple correlation is that the higher the energy output the higher the investment cost[Ramirez Camargo et al., 2018]. Therefore number of Reduction mechanics are being introduced by the designers and dwellers of ZEB's. The building thermal insulation can vary from 10 W/m2/a to even 200 W/m2/a of energy required to heat cool and ventilate the meter of the house.[Zubi et al., 2018]

With options 3 and 4 the theoretical ZEB strategy will be achieved while using the renewable energy to run the ZEB but the Family Surplus hypothesis may not be achieved while currently the green energy is still more expensive in the market than the traditional one. [Manrique Delgado et al., 2018]

The net zero energy building concept is widely adopted by the legislations concerned mainly by the environmental quotas and green limits introduced. Recently approved the Energy Performance of Buildings Directive by The European Parliament proposes that all buildings newly build in EU should be 'net-zero energy' by 2019. [Hernandez and Kenny, 2010]. In order to induce the market shift towards the more sustainable economy the legislators has been introducing the multi leveled incentive programs to induce the demand on energy efficient solutions and technologies - described in detail in Chapter 2.4.

The next thing to be determined is what amount of energy is required to build ZEB or transform an existing home into ZEB. The important notion is that both of those operations - erection or transformation requires some investment cost in the period N_1 (regarding on site renewable production). Traditionally the return on this investment is calculated to the time of substantial exploitation of the energy production method called amortization period.

Production method	Amortization period
photovoltaic	25y
solar hot water	20-30y
low impact hydro	30y
low impact wind	25y

Table 2.2: Average amortization period of most popular on site energy production methods [Marino et al., 2013]

As visible in table 2.2 the amortization of the on-site renewable energy sources are to be lasting for around 25 years. Each of the solution would require some additional reinvestment to be made to acquire the same efficiency after the Amortization time, but for the simplicity of the study the calculated simulation time will be set at the level of N_{25} and check the potential family surplus in that period. Renewable energy installation now accounts for efficiency improvement and on average return of investment takes 5 - 10 years. [Gesell, 2016] Understandably the period between the ROI period and Amortization period (on average 25 years) is a profitability period. Therefore the sum of returns to be calculated will translate to the direct family surplus coming from the energy generating installations.

What's more, the possible production ratio of ZEB also brings the question, what kind of net zero energy buildings are out there. What is the ZEB's formal definition and what kind of influence the building would have on the dwellers.

According to the [Torcellini et al., 2006] and [Panagiotidou and Fuller, 2013] there are 4 ZEB classes with characteristics of its kind. The characteristics will be evoked to check what kind of ZEB is the most beneficial for the people in the housing overburdening state.

The term ZEB can be used to denote either a Zero Energy Building or a Zero Emissions Building. Although both terms are often used and understood synonymously, in reality the definitions differ fundamentally. The Zero Energy Building term refers to the energy a structure consumes in its day-to-day operation while a Zero Emissions Building refers to the carbon emissions that are released to the environment as a result of its operation. It signifies that the structure produces at least an equivalent amount of emission-free energy to the fossil-fuel based energy that it consumes. Therefore, in the context of a response to the problem of human-induced climate change, emissions are implicit in the energy definition but explicit in the carbon definition."[Panagiotidou and Fuller, 2013] This definition though is not giving the precise answer on weather the exergy situation would actually benefit in the monetary way the family. The ZEB is a theoretical notion for the building using same amount of energy as produced from the renewable sources. But this is not sufficient to measure the impact in residential terms as impact for its dwellers. Therefore the classification has been introduced:

Life Cycle ZEB (LC ZEB)

The building producing more energy than uses and takes into account its embodied energy when calculating the energy needs. This results with producing more energy than being used in the Life Cycle situation (from production of raw material to disposal) [Laustsen,2008]

Energy Plus Building (+ZEB)

The building producing more energy than uses within the year. In the regional therms building of such is exporting more energy than is importing from the grid [Laustsen,2008]

Autonomous Zero Energy Building (Autonomous ZEB)

The building does not require any import or export of energy from or to the grid while being able to store the energy in any form. The grid connectivity is sometimes utilized for the safety reasons or as a backup [Laustsen,2008]

Net Zero Energy Building (Net ZEB)

This building is a theoretical one. It is the boundary case of Exergy (energy balance) and thus importing exactly same level of energy from the grid as its exporting. Most basic form of ZEB used to set the equation limitation for the ZEB criterion [Laustsen,2008]

Near Zero Energy Building (Near ZEB)

Producing extended number of energy on site while not sufficient to fully depend on this and requiring to import energy from the grid. [Laustsen,2008]

Ordered from the one producing most net energy to the one with the least net energy produced. While exporting highest number to the grid - the LC ZEB is the most sustainable in terms of societal surplus. The net energy production is surpassing the entire energy required during the erection and usage process - Life cycle - though the feasibility of solutions as such is not rational from the perspective of a family without any governmental or local support. [Tan and Chow, 2016]

As the sub-chapter conclusion, the simulated period will correspond with the actual time of the energy generating installation amortization an be N_1 to N_{25}. Secondly the border case of nZEB will be targeted by the simulation model. nZEB while setting the last kWh produced to acquire Exergy sets the H_e to the 0 showcasing the exact placement of the required size of energy generating installation (lowest Investment) to the highest Exergy of the house. As a final conclusion the 0, 1 and 2 ZDB option will be taken into consideration while only those will cause the direct financial surplus for a family rather than being the socially responsible as options 3 and 4.

2.2. Energy usage of zZEB

The feature that determinate a net zero energy house is the assumption that the annual production of the energy equals the annual house demand for the energy as shown in equation 2.1.

$$\Delta D_e(t) \leq \Delta E_p(t) \tag{2.1}$$

The empirical validation of this hypothesis is only possible after a year of operational house being used and power generated from renewable sources. The energy production is than compared to the energy used, to check the net zero energy hypothesis as shown in a [Hernandez and Kenny, 2010]. For this study the *ex ante* approach will be used to determine the theoretical viability and financial surplus for a users of the net zero energy house.

To acquire the understanding of left side of the equation 2.1 the demand variable is introduced:

$$D_e(t) = \text{demand on energy in time t} \tag{2.2}$$

Variable 2.2 shows the value of the demand of the energy in the time t in the dwelling. This demand changes throughout the day and year according to e.g. season. This variable is a theoretical variable and is impossible to integrate *ex ante*, while it would require the empirical data of the continuous demands on energy in all given discreet moments throughout the year. Therefore the second variable is introduced.

$$\Delta D_e = \sum_{t=1}^{365} D_e(t) = \text{ annual dwelling demand on energy} \tag{2.3}$$

This variable integrates the annual demands on energy in dwelling and is usually calculated *ex post* in every single dwelling via the electricity meter inside the dwelling. This Is the annual *ex post* demand on energy for dwelling usually named Annual Energy Use (AEU) [Hernandez and Kenny, 2010] from the physics standpoint. From the economical perspective the annual energy demand shows better the users to whom this demand belongs to and puts the perspective of energy as a commodity resource necessary for the dwellers.

While the study aims to analyze the zero energy house's influence on budget of a single family the *ex ante* values has to be introduced to calculate the projected costs and demanded energy of the zero energy house. Acquiring the result of equation 2.3 can be than calculated via:

$$\Delta D_e = \sum_{t=1}^{365} D_e(t) \approx \sum_{i=1}^{n} \sum_{t=1}^{365} D_i(t) \quad \text{(for n devices inside dwelling used throughout the year)} \tag{2.4}$$

where D_i is a demand for power for an "i" device used in a house. The integrated calculation takes into account annual demand for energy of every single device in a dwelling.
To calculate the each D_i the nominal power of the device has to be multiplied by the time of usage. The demand for energy for the single device inside dwelling will take a form of:

$$D_i = W_i * T_i(t) * F_i \quad (forF_c < 1) \tag{2.5}$$

where D_i is a demand for power for an "i" device used in a house. W is a nominal power of the device from nameplate capacity of device, such as vacuum cleaner or hairdryer, and is determined by measuring the electric current and voltage in a circuit, when device is turned on. T_i is time of device being used throughout a year. F is a coincidence factor ratio, expressed as a numerical value or as a percentage, of the simultaneous maximum demand of a group of electrical appliances or consumers within a specified period, to the sum of their individual maximum demands within the same period. As per this definition, the value is always bigger than 1 and can be expressed as a percentage. [Electrical-installation.org, 2018]
Final form of the dwelling demand calculation will look as follow:

$$\Delta D_e \approx \sum_{i=1}^{n} \sum_{t=1}^{365} W_i * T_i(t) * F_i \quad \text{(for n devices inside dwelling used through the year)} \tag{2.6}$$

This is a final equation form used in the study to estimate the annual demand for energy for a model net zero energy house. The modeled data has been calculated and shown in table 2.6.

The primary equation's 2.1 right side takes into account the power generated by the renewable energy sources. The power generated in time t equals"

$$E_p(t) = \text{energy generated} \tag{2.7}$$

This is a power generated in a time t and to calculate the annual supply of power produced from the renewable energy source installation one have to integrate the annual power production as follows

$$\Delta E_p = \sum_{t=1}^{365} E_p(t) = \text{ annual supply of energy} \tag{2.8}$$

Similarly to the demand, the above equation 2.8 is possible to calculate by the empirical *ex post* analysis of the integrated power production via e.g. two-way energy meter to receive the $\mathrm{E_p}$ in the annual perspective. Again to attain the *ex ante* values to conduct the following study the approximated value will be calculated.

$$\Delta E_p = \sum_{t=1}^{365} E_p(t) \approx \sum_{j=1}^{n} \sum_{t=1}^{365} E_i(t) \quad \text{(for n energy producing devices installed and used throwout the year)} \tag{2.9}$$

$\mathrm{E_i}(t)$ is a energy produced in a time t via single energy producing device (solar panel, electric wind turbine or other). For this study the energy production source will be solar panel installation while of highest accessibility and usability.

As well as previously, $\mathrm{E_i}$ is composed of lower level component variables as follow:

$$E_j(t) = A_j * r * h(t) * PR \tag{2.10}$$

Where $\mathrm{E_i}$ is energy produced in kWh, A = solar panel Area (m^2) r is a solar panel yield or efficiency, d is an annual average solar radiation on tilted panels and as previously there is a constant PR calculating the performance ratio with coefficient for losses range between 0.5 and 0.9 with the default value on the level 0.75 for the current solar installation technological advancement. [Photovoltaic-software.com, 2018]

The final energy output equation after transforming looks as follow:

$$\Delta E_p \approx \sum_{j=1}^{n} \sum_{t=1}^{365} A_j * r * h(t) * PR \quad \text{(for n energy producing devices installed and used per annum)} \tag{2.11}$$

Both side of our primary equation determining the house net zero energy has been simplified the final equation on net zero energy looks as follow:

$$\Delta D_e(t) \leq \Delta E_p(t) \tag{2.12}$$

The equation for the net zero energy house will look as follow:

$$\sum_{=1}^{n}\sum_{t=1}^{365} W_i * T_i(t) * F_i \leq \sum_{j=1}^{n}\sum_{t=1}^{365} A_j * r * h(t) * PR \tag{2.13}$$

and can be simplified to the:

$$\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{t=1}^{365} W_i * T_i(t) * F_i - A_j * r * h(t) * PR \leq 0 \tag{2.14}$$

The equation 2.14 will later be used for the model to determine the possible family surplus of obtaining the zero energy house. What is more this equation have three possible case solutions.

$$\text{Cases} = \begin{cases} \text{if } \Delta E_p - \Delta D_e S < 0 \text{ than not net zero energy house} \\ \text{if } \Delta E_p - \Delta D_e S = 0 \text{ than net zero energy house} \\ \text{if } \Delta E_p - \Delta D_e S > 0 \text{ than net plus energy house} \end{cases} \tag{2.15}$$

First solution describes all traditional houses that sources the energy from the grid as well as a houses of renewable energy generation of smaller size than demanded, causing necessity to still source the energy from the local grid on level of the size of the difference between the Energy output and the Demand. This condition are met by the two upper cases plotted case on the Fig, showing that both standard building and Low energy building are both in the same situation in witch the energy have to be delivered from the grid. 2.1.

The second solution describes the net zero energy house, as described above in definition 6.0.5. The house will therefore generate no requirements for the energy from grid lowering the H compound from the equation 1.3.

The third solution can be described by the production of higher amount of the energy than demanded by the dwellers living in a house. This makes the dwelling a net plus energy house and makes its owners a prosumer [Mihaylov et al., 2019] allowing management of the excess energy depending on the local legislation and regulation described in a sub chapter 2.4. This is the lowest plotted case on the Fig. 2.1.

To introduce the variables to describe the excess power to further calculation the following equation is introduced:

$$\Delta E_p = \Delta E_l + \Delta E_g \tag{2.16}$$

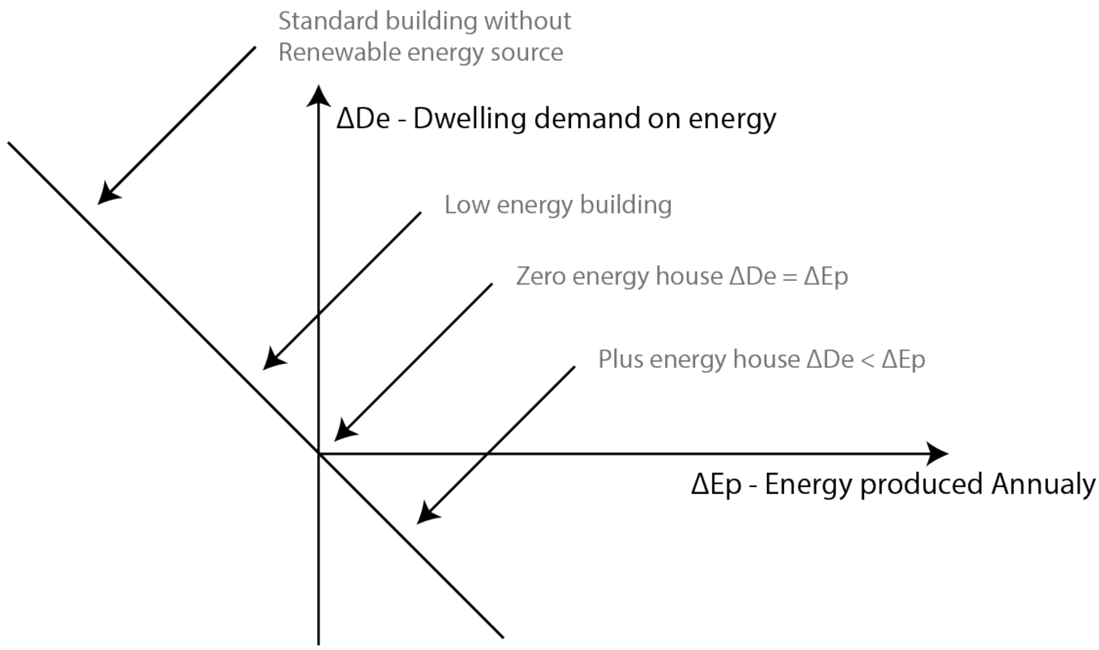

Figure 2.1: plot of the case solutions of Energy Demand and Production, own material

Equation 2.16 shows the possible two usages of the power generated from renewable sources. E_l is the energy used immediately while being produced. This energy is used live, meaning it does not leave the building to the grid nor is stored in any form of a battery. It is the energy produced and used in a time t. All the excess power unused at a time t is sent to the storage for future use. One option of storage are batteries or other energy storing devices. The most popular storage way is to inject the energy to the local power grid and thus is called E_g. While the renewable support mechanisms differs for each of the countries, the final benefits of the energy injected to the grid are to be elaborated. [Mihaylov et al., 2019]

For the further analysis the following equation have to be introduced

$$\Delta E_g = \Delta E_f + \Delta E_s \tag{2.17}$$

where E_f is energy stored to be used in future and than:

$$\Delta D_e = \Delta E_f + \Delta E_l \tag{2.18}$$

the demand for power at any given point in time have a form of two compounds: the life production and usage of power E_l plus the energy stored for later use E_f than:

$$\Delta E_s \tag{2.19}$$

is an excess energy to be injected further to the grid. Therefore the case 3 of the equation 2.15 can be rewritten in a form of:

$$\Delta E_p - \Delta D_e = \Delta E_s \tag{2.20}$$

The introduction of those variables is crucial while different European local support mechanisms promotes different measures to stimulate different decisions of households concerning the sustainable housing. [Mihaylov et al., 2019]

As an example, if a Government A promotes the E_s, with a monetary bonus for each kWh of excess power injected to the grid for the installation owners, those owners would be incentivised to build as big installation as possible, having the option to benefit for each kWh of excess power. But if a Government B promotes the household only with the $E_p = D_e$, those households will try to obtain the instillation of the exact size of their annual power needs. [Mihaylov et al., 2019]

2.3. Energy costs and macro-economical value of self sustainability

What seems as a potential to reduce the spendings of a family may actually be one of the necessities of a future man. The prices of energy grows with the faster pace than the price depreciation and therefore its relatively more expensive for Europeans than it was in the past.[European Parliament and European Council, 2012] The tempo of energy growth is reaching 4% annually as an average European growth. [IEA, 2002]

As visible in the fig. 2.2, since late 90 there is a visible change in the relations between the inflation index and the electricity price index. This will certainly not change, while there is more and more evidence that the societal cost of producing an energy from non renewable sources is higher than the prices[Alexei Barrionuevo, 2016]

Te figure 2.4 directly shows the relationship between the price of the energy and the development of the country mentioned in [Carey et al., 2014]. The underlying factor is that more developed country can better and sooner adjust the prices of the electricity to the actual societal cost of producing 1kWh of energy and understand that the cost is higher due to saving our planet and environment as well as to preserve and distribute more sustainable sources of energy. The cost of coal energy in Poland for a consumer weights between €0.14 to €0.16, while calculated societal cost of production ow 1 kWh of coal energy weights between €0.3 to €0.35 [European Parliament and European Council, 2012] It is visible that the cost of countries calculating the full cost of using unsustainable energy has been rising taxes on usage of this energy.

One of those are the green subsidies, bringing up the prices of mix energy by the value of the societal cost of transitioning into renewable energy. This solely counts for around 13%

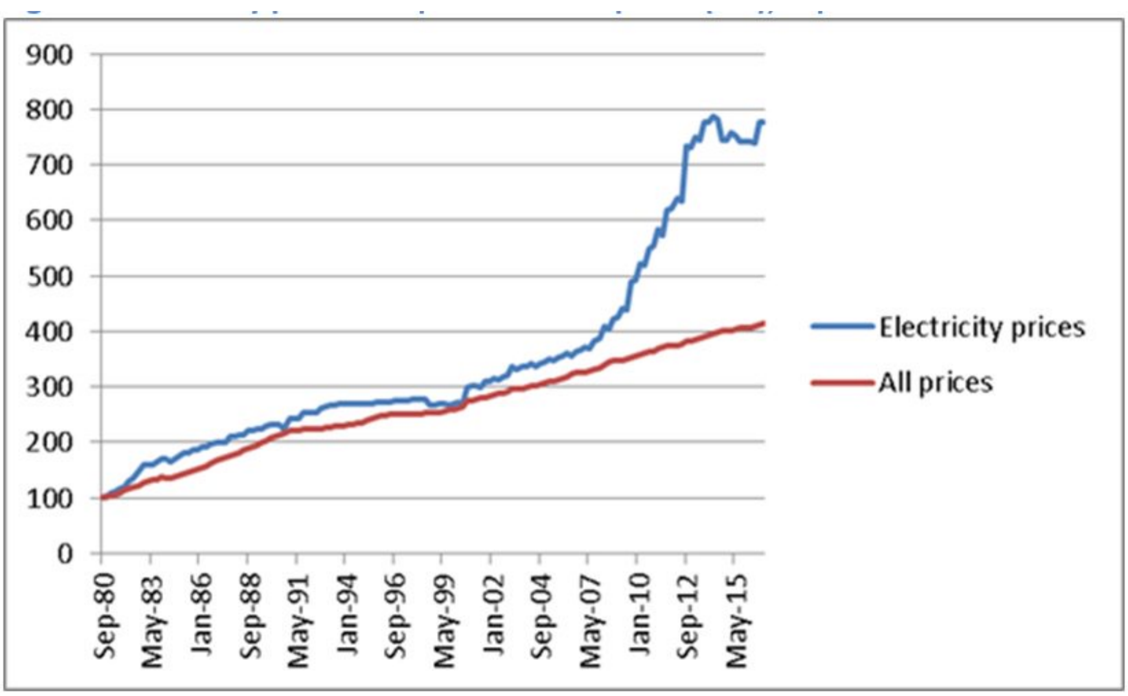

Figure 2.2: Electricity price per MWh compare to the price index, [IEA, 2002]

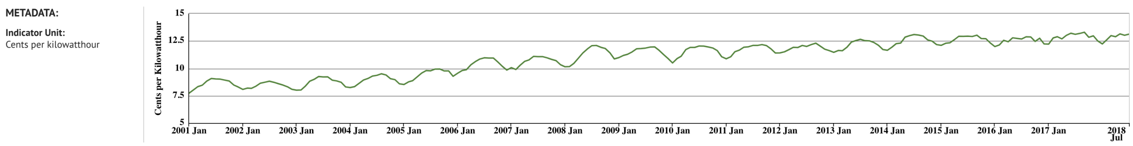

Figure 2.3: House pricing index 2005-2017, U.S. Energy Information Administration

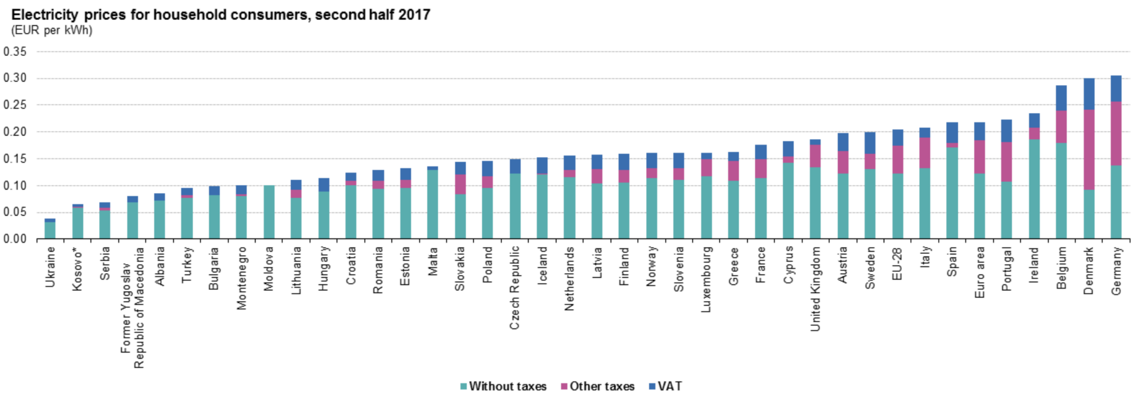

Figure 2.4: Electricity pricing 2017, Eurostat

higher energy tax in Germany.[ScienceDirect (Online service), 2017] Whats more, extreme temperatures can drive up the demand for electricity, as more energy is needed for heating and cooling, among other operations. As global climate change progresses and extreme weather becomes more widespread, this higher demand will likely drive electricity prices higher.[Moseley and Bruhin, 2018] What has an influence for the family of nZEB is that the higher the prices of the energy on the tested market, the higher relative family surplus derived from not covering the H_e. This may be counter intuitive, but while a single family is using an nZEB on a low price market it may actually never bring the return on investment. To make this more tangible lets take the potential situation, when the 1kWh of energy costs the family €0,03. Cost of installing PV installation an installation producing around 3000kWh costs around €5000. That would mean, that within the 25 years of amortization, the installation would finance:

$$25(years) * 3000kWh * €0.03 = €2250 \tag{2.21}$$

Which is obviously lower than investing into the on-site electricity production, Therefore there is a market dependent marginal cost of electricity on which the PV installation is feasible for the family. May this theoretical value of energy price be called the On-site, of witch price can be calculated as follow:

$$\frac{\text{Investment Cost}}{\text{Amortization Period* Annual Energy Production}} = \text{On-site Price} \tag{2.22}$$

than we can observe 3 cases:

$$\text{Cases} = \begin{cases} \text{if On-site price} < \text{Market Price, than market actors choose grid power purchase} \\ \text{if On-site price} = \text{Market Price, no market actor is changing its current power source} \\ \text{if On-site price} > \text{Market Price, than market actors choose on-site power generation} \end{cases} \tag{2.23}$$

As a reflection on the data evidence of this chapter the notion of rising prices of power may seem as something of negative influence for a society. Growing prices on electricity pressing the disposable income and adding to the housing overburdening and energy poor citizens. Though with the well organized societal support, installation of the on-site production while the prices are high can generate substantial comparative family surplus while installing the Installation. The new mechanics can be introduced to support those pressed by power prices.

If the difference between the on-site electricity price and market price is high enough to cover both the On-site installation and the cost of crediting a family to take this investment, than the family can basically become price independent. This would look as follow

$$\frac{\text{Investment Cost + Credit Cost}}{\text{Amortization Period* Annual Energy Production}} = \text{On-site Adjusted Price} \tag{2.24}$$

Again if a On-site Adjusted Price be lower than the current market price of the energy, then there is no economical reason behind not installing the on-site electricity production. The ones could be solely assigned to believes and convictions of citizens being weary about those technologies and their efficiency.

As the sub-chapter conclusion, the simulated period of 25 years will try to reflect the current price change, and account for the probable 4% year to year growth of energy in European union. The way to simulate the probability of the price growth by the Monte Carlo simulation be the Brownian motion methodology described later in detail.

2.4. European renewable support mechanisms influencing net zero energy housing

The below sub-chapter is solely devoted to analysis of the renewable support mechanisms in European countries. The aim is to derive the zero energy house dwellers economical surplus equations for each country. The countries chosen are the ones with already introduced renewable support mechanisms of different forms. The European countries propose many subsidies for energy efficiency, energy generation, and responsible supply chain and sourcing. Such co-funding can significantly reduce initial costs of obtaining the zero energy house and bring the dwellers away from the housing overburden.

The European Commission's aim of lowering the environmental impact of human activities has strongly grow through the recent years. The legislations become strongly opposed to high carbon economy both in a commercial and consumer space[Baxter et al., 2008a]. One of the biggest focuses is to pressure European consumers to comply with environmental targets in the housing area while buildings cause a significant amount of greenhouse gas emissions, mainly CO2, altering our planet's climate. They account for around 40% of total energy consumption and 36% of CO2 emissions in Europe [**?**]. Dwellings are responsible for 29% of total electricity demand in Europe [Hayn et al., 2014] The reduction of energy consumption and the use of energy from renewable sources in the buildings sector is important to reduce energy dependency and greenhouse gas emissions. EU energy consumption can be reduced by 5%-6% and CO2 emission by 5% by improving energy efficiency of buildings [EMF-ECBC, 2015]. This direction is visibly supported by EU via current directive on the energy performance of consumer buildings [European Parliament and European Council, 2012] that requires all new buildings to be net zero-energy by the end of 2020.

One of the key fields of the policy makers applications are the support policies motivating residential prosumers to inject excess energy produced to the grid[Butler and Neuhoff, 2008]. There are five most popular support policies supporting electricity from renewable energy sources (RES-E) and they are as follow:

1. Feed in Tariffs (FIT)
   The mechanics of the FIT policies mainly allows the prosumer to benefit from the energy injected to the grid in the period of calculation. At the end of the period the prosumer is compensated at a fix rate for each kWh of energy injected to the grid. The optional for of feed in tariffs may promote the nominal power of the RES-E installation to reduce the bureaucracy between the prosumer and the promoting units. [Mihaylov et al., 2019]

2. Net Metering (NM)
   The mechanics of the NM guarantees the injected energy balancing with the grid. The energy exported by a prosumer will be compensated from the grid to the point it does not exceed the production of the prosumer demanded energy.[Mihaylov et al., 2019]

3. Premium Tariffs (PT)
   The PT are direct demand generators in form of supply or price lowering to the installation of the RES-E guarantees that the injected energy will be compensated to the point it does not exceed the production of the prosumer demanded energy.[Mihaylov et al., 2019]

4. Tax Reduction (TR)
   The mechanics behind the Tax Reduction (TR) may vastly vary from country to country. The most popular is the reduction on the part of tax for the energy imported devoted to sustainable development for the prosumers to the level of the energy produced (for example in Great Britain). [Mihaylov et al., 2019]

5. Tendering schemes (TS)
   The mechanics behind(TS) is a competitive mechanism for allocating financial support to RES projects on the basis of the cost of electricity production via auctions. The price is the criterion to be evaluated and the system is closest to the free market while bot prosumers and commercial RES-E's take part.

As of 2015, 52 countries have adopted NM incentives, while 110 jurisdictions at the national or state/provincial level have implemented FIT incentives [Tan and Chow, 2016] Below the comprehensive analysis of representative European country will be devised. The aim is to derive the country support scheme equation as a comparative method to asses the countries approach to grow the demand on RES-E.

For the easiness of reading the below the metric signs will be again introduced: Where:
r - Nominal efficiency of the on-site RES-E

Y_s - Energy generated by on-site RES-E
D_e - Dwelling demand for energy
I_o - Investment required to plant the on-site RES-E

2.4.1. Germany

In Germany renewable sources are mainly supported through a FIT scheme. For installations, up to 100 kW the FIT generates the margin for the prosumer injecting the excess energy to the grid. The criteria for joining the support scheme and the tariff levels are regulated by the Renewable Energy Sources Act [Bundesministerium der Justiz, 2014].It came into effect in 2000 and has been adapted by many other countries around the world. It was amended several times and triggered substantial growth of the production in solar electricity production. This success is largely due to the creation of favorable political framework conditions.[ENERGY, 2012] Moreover, low interest loans for investments in new plants are provided for by different KfW-Programmes (Renewable Energy Programme–Standard, Programme offshore wind energy, Consortium Loan Energy and Environment, Renewable Energy Programme Premium). [ENERGY, 2012] There are many support schemes but one applicable to the study, and therefore connected with housing and zero energy housing will be:

1. The KfW Renewable Energy Programme "Storage" supports the usage of stationary battery storage systems, related to a PV installation, which is connected to the electricity grid.[ENERGY, 2012]

2. Grid operators are legally obliged to pay producers of solar electricity a fixed remuneration FIT for solar generated electricity injected into the grid, depending on the size and type of the system, as well as the year of installation. The tariffs vary to account for the different costs of rooftop or ground-mounted systems in accordance with the size of the system and system cost reductions over time. Since the EEG guarantees the FIT payments for a duration of 20 years, it provides sustained planning security for investors in PV systems. Grid parity for large installation and small roof-top systems was already reached in 2011 and 2012, respectively.

   As of now, feed-in tariffs for photovoltaic systems range from 0.13 €/kWh for small roof-top system to 0.09 €/kWh for large utility scaled solar parks. Feed-in tariffs are restricted to a maximum system capacity of 10 MW. The feed-in tariff for solar PV is declining at a faster rate than for any other renewable technology.[ENERGY, 2012]

Renewable Energy Sources Act has been accepted in late 2014. This is a first comprehensive European national legislation covering the end to end transition from non renew ables to renewable sources of energy. What is surprising that (feed-in tariffs) will no longer be fixed by the government, but will be determined by auction. Also Germany provides policies for the promotion of the renewables in form of trainings, certifications and research programmes, as a self-commitment of public zone to the support of districts pushing with the obligations to use the heat from renewable energy sources.

While both the battery output and the FIT are at place for the prosumer support in Germany, the surplus equation of the German dweller obtaining on-site energy production will have a form of:

$$€0.13 * (\Delta Y_s - \Delta D_e) + 0.1 * I_o \tag{2.25}$$

2.4.2. France

In France, renewable energy is promoted via feed-in tariff schemes - similar to Germany, as well as premium tariff and tenders for the premium tariff level. Also tax benefits are available. Support which will be denoted in a country equation are

1. Feed-in Tariff. - generation of electricity is promoted through a feed-in tariffs. Energy operators of renewable electricity are legislatively trusted against the suppliers to pay for the electricity exported to the grid. The tariffs are shaped as follow: €0.23 per kWh during the first 10 years and then between €0.5 €0.23 per kWh for the next five years.[LEGAL, 2015]

2. Premium tariff - additional one time benefit from a premium tariff additionally to the sale price in order to cover the investment required to install the on-site energy production and ensure the profitability of the installation (so-called "compensation mechanism").[LEGAL, 2015]

3. Tax regulation mechanisms - Electricity generated is additionally promoted through internal tax incentives for the dwellers, who are eligible for an income tax credit discretion (Crédit d'Impôt). What's more, investors who install photovoltaic installations on roofs of the buildings are eligible for a reduced VAT tax.[LEGAL, 2015]

Therefore cumulative surplus of On-site energy production in France looks as follow:

$$€0.23 * (\Delta Y_s - \Delta D_e) + 0.2 * I_o + 0.23 * I_o \tag{2.26}$$

2.4.3. United Kingdom

England is one of the most reach in support mechanisms country obtaining:

1. combination of a feed-in tariff system
   FIT is only accredited to installations below 5 MW and their owners can sell their electricity at fixed rates by the Gas and Electricity Market Authority (Ofgem). Applicable

to all England, Wales and Scotland. Additionally as an encouragement to install the on-site energy production the feed in tariff to the nominal power is funded by the same unit. This generates around €10 per kW nominal power installed per month during first 10 years of operation. [Electricity, 2016]

2. quota system in terms of a quota obligation
Suppliers of more than 5 MW installed of energy nominal power are obliged to supply a proportion of production (”quota”) to their customers in form of renewable energy. A supplier's quota is deemed if he presents a certain number of green certificates.[Electricity, 2016]

3. certificate system and a tax mechanism. Furthermore, in Great Britain commercial and industrial users of traditional energy sources are subject to Carbon Price Floor (CPF), a 13% tax on fossil fuels used for electricity generation. Electricity from renewable sources is exempt from this tax.[Electricity, 2016]

Therefore cumulative surplus of On-site energy production in France looks as follow:

$$€10 * r + €\text{FIX rate} * (\Delta Y_s - \Delta D_e) + 0.12 * \Delta Y_s \tag{2.27}$$

2.4.4. Spain

In Spain, very high growth of RES-E was observed in a commercial zone in the past years. Growth observed was beyond the goals set by the country, due to the huge disproportion between the commercial an private RES-E sector, support schemes for RES-E were blocked.

In 2015 the new regulation came to life - Real Decreto 900/2015, establishing charges on existing and new self-consumption RES plants, both on capacity and generation levels. According to RD 900/2015 these are no taxes or compensation for utility losses, but contributions to overall system costs. Self-consumption installations under 10 kW and plants located not on the Spanish mainland will be spared the generation charge, but will still be a subject for a fixed charge per kW of capacity. The only existing prosumer program on the Spanish market is a Net-Metering resulting in no existing surplus equation. [ENERGY, 2012]

2.4.5. Netherlands.

In the Netherlands, the promotion electricity from renewable energy sources is promoted in one of most intensive form and mainly as a premium tariff. RES-E also promoted as an investment subsidy for PV on-site installation with net-metering and benefits from tax. Support schemes available:

1. Loan - green fund tax reduction. Banks offers loans at lower interest rates to 'green' projects. The qualification for such a loan is regulated with the Gereen Project 2016 regulation. All positively affecting the environment projects, can apply for this.

2. Net - metering - standard net metering as described in
3. Premium tariffs - Premium to the market price is proposed to the big producers of renewable energy.Not applicable to the consumer sector.
4. Reduction of environmental protection tax - the consumption of electricity with the natural gas is main interest of the Act on the Environmental Protection Tax. A consumer is than exempt from this particular tax if the electricity used comes from RES-E and was generated solely by the consumer.
5. Energy investment allowance - benefit enabling entrepreneurs to write off investments in renewable energy plants against tax. Not aplicable for the end consumer.

Therefore cumulative surplus of On-site energy production in France looks as follow:

$$€\text{FIX rate} * (\Delta Y_s - \Delta D_e) + 0.18 * \Delta Y_s \tag{2.28}$$

2.4.6. Poland

In the Republic of Poland, electricity from RES is promoted mainly through a net metering system with addition of locally supported premium tariffs. It's also supported through a tax discount as well as subsidy schemes from the National Fund for Environmental Protection and Water Management (NFOŚiGW) distributed locally through municipalities or local communes.

1. Net metering
   The owners of micro-installations (with capacity up to 40 kW) are allowed to exchange the surplus of energy produced by favorable conditions for gaps in energy production in the future in relation 1 to 0.8 (in the case of micro-installations with capacity up to 10 kW) or 1 to 0.7 (in the case of micro-installations with capacity above 10 kW).
2. Tax incentive
   Tax incentives. Producers of electricity from renewable sources are exempt from the tax on the sale and consumption of electricity.
3. Premium Tariff
   The National Fund for Environmental Protection and Water Management (NFOŚiGW) grants low interests loans together with subsidies up to 60% of the installation of RES to support the purchase and installation of small and micro-RES installations for the needs of residential single-family or multi-family houses

Therefore cumulative surplus of On-site energy production in France looks as follow:

$$0.6 * I_o + 0.12 * Y_s \tag{2.29}$$

Chapter conclusions:
All discussed European countries have multiple options available to diminish cost of the future prosumer population installed RES-E's. Specific numerical values of return and subsidies available will be simulated in Monte Carlo simulation for each individual country surplus equation on the same random set of simulated agents. These conclusions make those regions very lucrative markets and perfect locations of RES-E installations and nZEB's from the energy efficiency co-funding point of view.

2.5. ZEB's important Building physics parameters

To acquire more precise solution to our study the sophistical parameters of the house have to be added to the model. To understand better the demand on energy for the house one have to understand the nature of the buildings itself. The energy required is divided to 4 different sections:

1. demand for energy on heating
2. demand for energy on ventilation
3. demand for energy on water heating
4. demand for energy on devices and lightning

The first is directly connected with the loss of heat through the walls of the house. To calculate the energy loss and match it with the energy input required to heat and cool the space within the year, the calculation on the wall thermo-insulation, roofing and windows would be required. While the exact value of the thermal permeability of the walls in perspective of the dwelling surplus may be of interest, the complexity of the building materials and building shapes would get in the way to obtain the optimization values for the plus energy houses.
For the study simplification the higher measure have been implemented. This measure averages the demand on energy for the entire building and brings it to a compounded measure of energy per square meter of the dwelling. The targeted by the European Union standard of the energy loss consumer house market is set on the level of 40kWh/m^2/annum. [European Commisiont, 2018] For the below study the values tested to check the dwelling surplus of the zero energy house will be set between the 15kWh/m^2/annum. and 150 kWh/m^2/annum.

Therefore the new variable will be introduced:

$$D_h \text{ demand on the energy for heating per m2 of the building per annum} \tag{2.30}$$

and to calculate the energy required for the entire dwelling the equation will looks as follow:

$$\Delta D_h = D_h * M_2 \text{ demand on the energy on heating per annum} \tag{2.31}$$

Where M is a size of the house in m^2

The second measure is connected directly with the energy required with the ventilation of the house. The exchange of the air inside the building is one of the most crucial parameters for the dwellers well being while mostly influencing the demand on energy. The reason behind this is that during the exchange of used air from inside the house with the fresh air from outside the energy is being lost. The warm air from inside is being exchanged with the cold one from outside with the substantial energy loss for the house. The fresh cold air has to be heated again to attain the temperature of comfort.

To prevent this process, the heat exchanges has been introduced as shown in Fig. 2.5

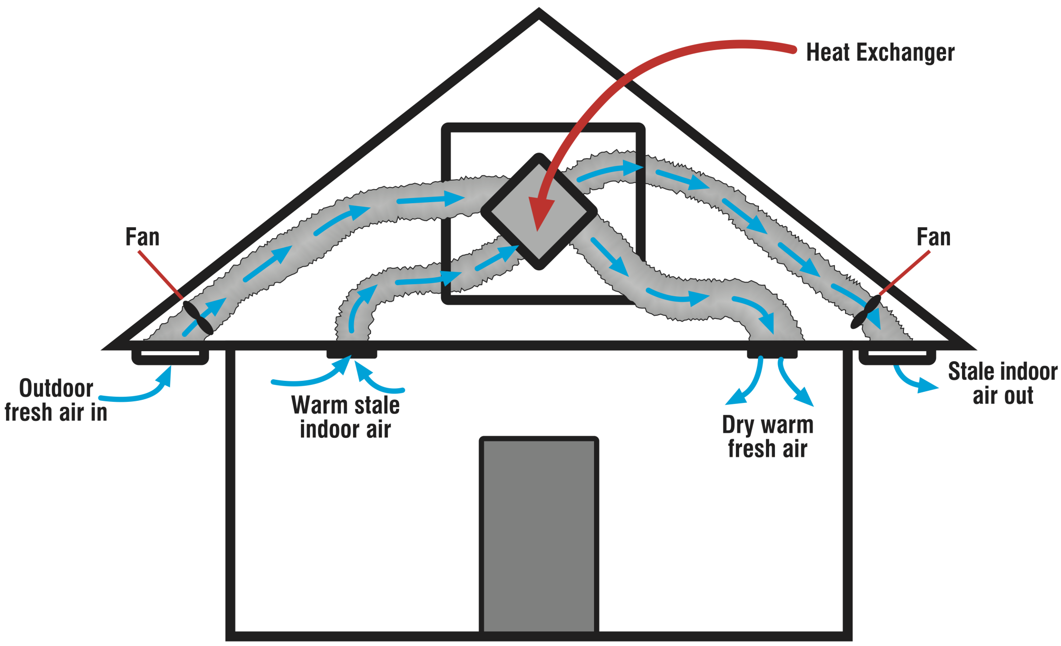

Figure 2.5: illustration of the heat exchanger inside the house, own material

The warm used air is heating the cold air from outside on the heat exchanger, changing the means of the problem from calculating the energy lost during the process to the energy required by the heat exchanger to secure the same temperature before and after the heat exchange. The demand on the ventilation therefore will be described as:

$$D_v \text{ demand on the energy for ventilation per m}^3\text{of the building per annum} \tag{2.32}$$

and to calculate the energy required for the entire dwelling the equation will looks as follow:

$$\Delta D_v = D_v * M_3 \text{ demand on the energy on heating per annum} \tag{2.33}$$

Where M is a size of the house in m^3

The third measure is added to the model while the additional assumptions have to be made to calculate the demand for water. The average need for the warm water per capita in Europe is 30l/day. For the model we will be using a 4 member family and thus the requirement for daily water heating per dwelling will be set on the level of 120l per day. According to previous two, the equations looks as follow:

$$D_w \text{ demand on the energy for water heating per l of the water heated} \tag{2.34}$$

and to calculate the energy required for the entire dwelling the equation will look as follow:

$$\Delta D_w = D_w * L \text{ demand on the energy on heating per annum} \tag{2.35}$$

Where L is a annual need for warm water in liters

The forth measure is the compound of all demands of each subsequent device inside the house as shown in the equation 2.6. The potential list can go as follow: house lightning, induction plate, oven, dishwasher, washing machine, kettle, TV, phone charger, notebook, hair dryer, iron, refrigerator, router, vacuum cleaner, and others.

The equation 2.6 will suffice to integrate all devices by the *ex ante* values of their demanded electricity as follow.

$$\Delta D_e \approx \sum_{i=1}^{n} \sum_{t=1}^{365} W_i * T_i(t) * F_i \quad \text{(for n devices inside dwelling used through the year)} \tag{2.36}$$

The remark has to be made at the end of this sub-chapter, that each of the dwellers have different habits and daily routines using different values of the electricity daily. One can have very long baths and second can never turn off the lights. There are also dwellers with special needs for the energy like disabled people with additional life supporting devices. There are also hobbies or interests that generate additional demand for electricity and thus changing the final D_e. The emergency occurrences may also generate some substantial one-off needs for the power, changing the final balance.

Knowing this, the study will describe the dwellers of the average European use of energy and average demand for the energy produced. This will allow assessment of the potential of zero energy homes to generate surplus for the dwellers rather than solve the individual dweller situation.

2.6. Energy consumption

The *ex ante* analysis of the demand referred in equation 2.6 requires enlisting all possible devices used via dwellers trough the annual usage of the house. The *ex ante* demand analysis has been devised and the results are visible in the table 2.6

	Nominal power of the device	hours per day	days used per year	factor simultaneity [kj]	Energy consumption for a year [kWh]
	W	h/d	d/y	kj	kWh
Heating					4615
Space hating / air conditioning	1000	24.00	365	0.38	3329
Water heating	1550	24.00	365	0.056	760
Ventilation	60	24.00	365	1	526
Electricity					2163
Induction hubs	7400	1	365	0.25	675
Roaster (oven)	2200	2	52	0.75	172
Lighting	240	6	365	0.50	263
Dishwasher (widht 45cm)	2200	3	365	0.10	241
Washing machine	2200	2	182.5	0.20	161
Kettle	2000	0.25	365	1.00	183
TV LCD (40")	60	3	365	1.00	66
Phone charging	5	3	365	1.00	5
Notebook	25	3	365	1.00	27
Hair dryier	1600	0.10	365	1.00	58
Iron	2200	0.5	52	0.50	29
Refrigerator (120 l)	225	24	365	0.10	197
Router	6	24	365	1.00	53
Vacuum	2000	0.33	52	1.00	34
				TOTAL	6,777.95

Table 2.3: *ex ante* demand for electricity for a model dwelling, own material

For the current study the certain approximation of reality has been made. The function of the total demand for electricity will be derived from both physical parameters of the house as well as an average electricity output per dweller. The calculation can be presented in such way:

$$\Delta D_e \approx \sum_{i=1}^{p} D_e(p) + H_e * H_m \quad \text{(for n devices inside dwelling used trough the year)} \quad (2.37)$$

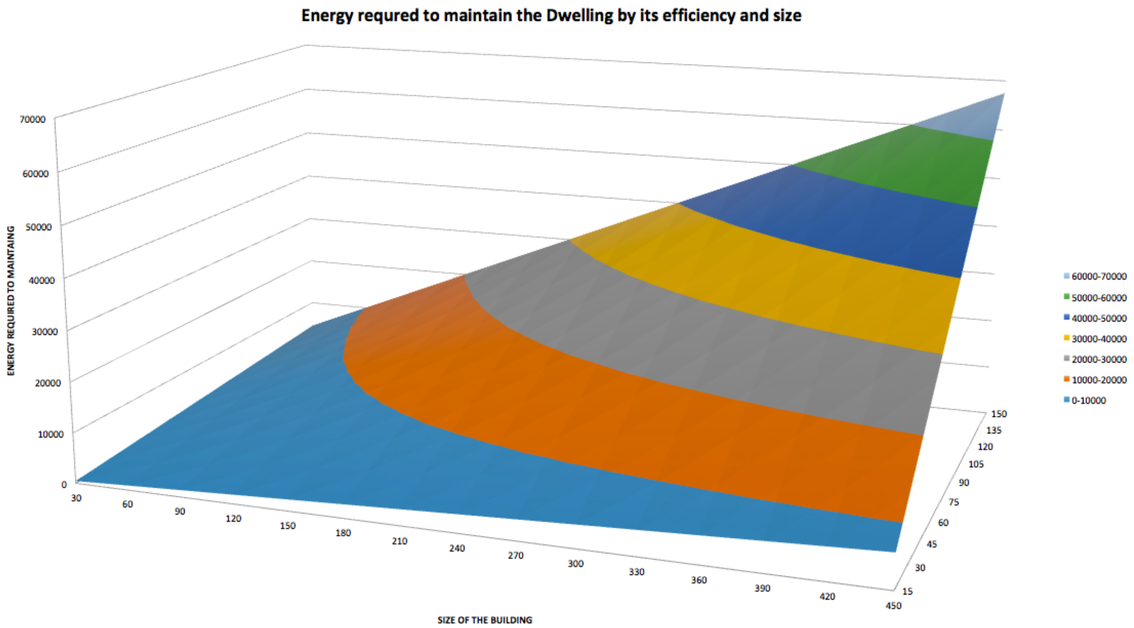

Figure 2.6: Demand on energy for household by its energy efficiency and size, own material

Where

$$D_e(p) \quad \text{is cumulative demand of a single dweller on electricity} \tag{2.38}$$

$$H_m \quad \text{(size of the house in meters)} \tag{2.39}$$

$$H_e \quad \text{(is house efficiency parameter in kWh/m)} \tag{2.40}$$

This equation will be used to describe the final demand of the modeled household to acquire the best approximation of the household demand, having possibility to entangle the size of the house with the demand output. While the average European household nowadays requires the 100 kWh/m^2. The analyzed data scope will be broaden to the string between 15 - 150 kWh/m^2 to have a wider perspective on the plus energy housing potential. In graph 2.6 the size and house efficiency has been plotted acquiring the delta $\mathrm{D_e}$ plot on the all possible houses in size between 30-450m^2. Those values will be increased in model by the size of the family multiplied by the average European demand for electricity of the level of 623kWh/$_{\mathrm{annum}}$ [BPIE, 2011]

2.7. PV installation economics

The photovoltaic installation is one of the options for calculating the surplus of the net plus energy house. The alternatives are wind turbines, water turbines, solar water panels and many other options that would induce the surplus energy to the house and achieve the net plus energy parameter.

The basic economics of the PV installation consists the present down payment for all the costs connected with investment and the future reduction of the energy bills connected with the energy production from PV. The EPBT Def.6.0.10 will define the time of the return of the investment and begin the period of collecting the economical surplus for the owner. The important measure from this sub-chapter would be the possible monetary output as a present value of the photovoltaic installation.

$$PV_{PI} = \sum_{i=1}^{t} PI_{cos} - PI_{ret}(t)/(1 + r(t)) \quad \text{(for n devices inside dwelling used trough the year)} \tag{2.41}$$

Where

$$PV_{PI}\text{(is a present value for installing the photovoltaic installation)} \tag{2.42}$$

$$PI_{cos}\text{(Is a full investment cost for the PV installation)} \tag{2.43}$$

$$PI_{ret}(t)\text{(is the return from the installing the PV on the year t)} \tag{2.44}$$

Approximately about half of this investment would be for the PV modules and the inverter, PV array support structures, electrical cabling, equipment and installation would account for the rest. Please note that BOS and installation costs can vary significantly. For example: when costs for site preparation, laying a foundation, system design and engineering, permitting, as well as assembly and installation labor are higher, total installation costs are higher too. The life cycle cost (LCC) of a PV system may also include costs for site preparation, system design and engineering, installation labor, permits and operation and maintenance costs. Photovoltaic systems have an anticipated 25-years lifetime.[Manrique Delgado et al., 2018]

The return on the factor PI_{ret} is determined by the following parameters [Manrique Delgado et al., 2018]

1. solar insulation in the location of the installation in the W/m^2
2. Installed Capacity - efficiency of the photovoltaic installation
3. Capacity Factor - as the ratio of energy generated over a year divided by the installed capacity

4. MandO - Annual Maintenance (and operation costs)
5. System Degradation Rate

2.8. Additional benefits of net zero energy housing - Environmental rationale to introduction 0-energy housing

Buildings cause a significant amount of greenhouse gas emissions, mainly CO2, altering our planet's climate. They account for around 40% of total energy consumption and 36% of CO2 emissions in Europe[European Commisiont, 2018]. Residential buildings account for 75% of the total stock in Europe[BPIE, 2011] and they are responsible for 29% of total electricity demand in Europe[Hayn et al., 2014].

The reduction of energy consumption and the use of energy from renewable sources in the buildings sector therefore constitute important measures which are needed to reduce energy dependency and greenhouse gas emissions. Therefore, the recast directive on the energy performance of buildings[European Parliament and European Council, 2012] requires all new buildings to be nearly zero-energy by the end of 2020. This means that in less than one decade, all new buildings will demonstrate very high energy performance and their reduced or very low energy needs will be significantly covered by renewable energy sources. This very ambitious commitment fully supports the radical cuts in greenhouse gas emissions identified by the 4th report of the United Nations Intergovernmental Panel on Climate Change[IPCC, 2014] as being necessary to avoid the risks of irreversible climate change.

The move towards very low-energy buildings will trigger a deep market transformation of the construction sector, which is very material-intensive and thus very carbon-intensive and requires an important market deployment of very efficient technologies. This market up-scaling has important employment potential and, according to the estimates, hundreds of thousands jobs may be created and induced across Europe.

Chapter 3

Description of model

In this chapter the chosen method to test the hypothesis will be presented in detail. Firstly the Monte Carlo methodology will be explained and provided with the base model assumptions. The reason behind choosing the method will be provided. In the second step the model parameters influencing the net zero energy housing and their influence on family financial surplus will be enlisted, and probabilistic methods to simulate their behavior in time will be described in detail. The model parameters are derived from the findings in previous chapters and the reference will show what is the final math behind the required parameters.

3.1. Modeling methodology - Monte Carlo simulation

As Monte Carlo model definition say:
"Monte Carlo simulation, or probability simulation, is a technique used to understand the impact of risk and uncertainty in financial, project management, cost, and other forecasting models." [Woodhouse et al., 2011]

Indeed the problem of obtaining the probabilistic family surplus from obtaining the nZEB is a forecasting model with the financial uncertainty and involves the risk of never reaching an return of investment. While willing to model the *ex ante* net surplus of the family obtaining the plus energy home, the Monte Carlo simulation will suffice to reason on the parameters given above in both chapter 1 and chapter 2. This is the reason of choosing this to validate the paper thesis.

While building a forecast model - the model that tries to predict the future the assumption has to be made. The assumptions may be about the ROI of the portfolio or the cost of the construction project. While those are only a future projections the best is to estimate the expected value. The value is not certain but basing on historical data and expertise in field, the researcher can make an estimate of the expected future. The important notion is that while this estimation is useful, the inherent uncertainty and risk will be engraved in the methodology because it's an estimation of an predictive values. [Woodhouse et al., 2011]

While Monte Carlo is a simulation of the outcomes it will not bring the certain answer to the given problem but rather it will tell how likely some of the possible futures are. The role of the researcher therefore is to pick the assumed base values and approximation of the reality in the most precise way. By doing so, the risk of obtaining highly improbable values of simulation is being decreased. The Monte Carlo simulation be as good as the estimations that are approximating observable reality. It's important to remember that the simulation only represents probabilities and not certainty. Nevertheless, Monte Carlo simulation can be a valuable tool when forecasting an unknown future. [Woodhouse et al., 2011]

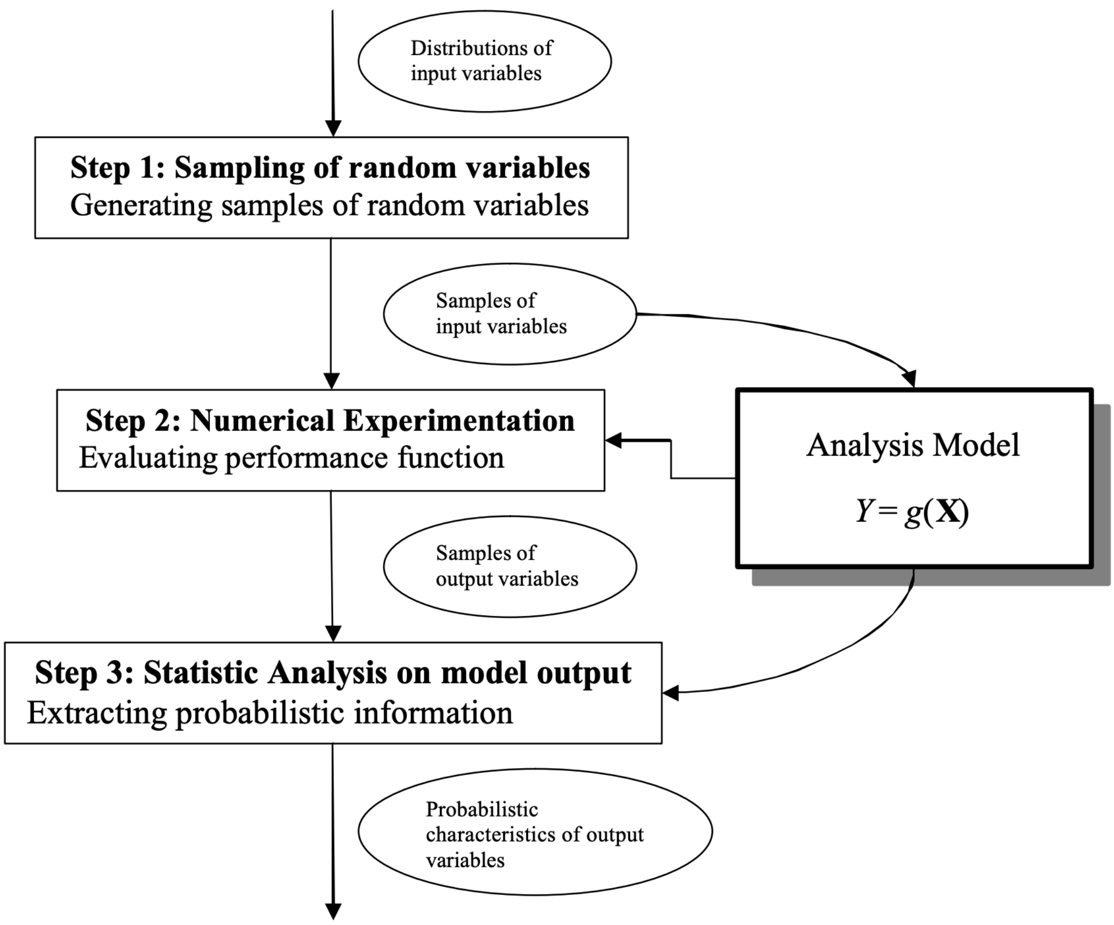

Figure 3.1: Monte Carlo simulation - research process [Mooney, 1997]

Accordingly with the graph 3.1 in the first step undertaken was to generate 10.000 agents with two random variables each. Both the variables has been generated for each of the agents separately generating 20.000 individual data samples. First is solar insulation, that can be estimated by normal distribution (described better in sub-chapter 3.2). Second variable describes market price for electricity, estimated by multi-period Weiner process(also described better in sub-chapter 3.2). Additionally to the randomized parameters the discreet parameters and constants has been added to the simulation. They are as follow: the efficiency of the RES-E/ demand on energy of dwelling, country surplus equation, size of the southern roof exposition, price of RES-E and a constant r.

The step 2 from fig 3.1 calculation is based on the Present Value formula:

$$PV = V_0 + V_1/(1+r) + V_2/(1+r)^2 + ... + V_n/(1+r)^n \tag{3.1}$$

As a second part of the model formula a simple photovoltaic budget calculation derived in a equation 2.41 has been used . At the end of this chapter the final tested formula will be given.

3.2. Model parameters with descriptions

1. Demand on energy / efficiency of the house energy conservation (discreet)
   The Model will be tested for most common photovoltaic efficiencies in a discrete manner. 3 Types of Installation will be tested for 3 sizes of house:

Energy supply/demand	Family unit	House characteristics
3000 kWh/annum	two-person family	passive house
6000 kWh/annum	four-person family	passive house
9000 kWh/annum	four-person family	non passive house

   Table 3.1: Monte - Carlo tested house units

   The amount of energy to be produced from PV installation equals the energy quantity that suffices the nZEB equation 2.14. Tested model follows the assumption mentioned in equation 2.1 that the delta $\mathrm{D_e(t)}$ is equal to $\mathrm{E_p(t)}$. This will therefore equalize the consumption with production with the regard of building parameters and features such as air heating, ventilation, water heating and utility devices usage and simplify the model.

2. Country Surplus Equation (bool)
   The devised European support mechanics for the RES-E installations has brought very promising results for the profitability potentials. The legislation and benefits of energy

reception via the network will be calculated. Surplus equation will be taken from the 2.4 chapter to determine the additional monetary surplus for the RES-E. While determining the current Polish family situation, the equation 2.29 will be used as a version of the model. The only remark to be added is that the support mechanics can change at immediate and therefore both simulation will be devised - with and without the country equation.

3. Surface in m^2 of the southern roof exposition (discreet)
   The parameter has been added do determine some of the external limitations of the model that may not be dependent on the family decision but rather the prior building situation the family obtains. The southern side is the one, that brings up to 97% of annual insulation on the double roofs in Europe. Therefore the market standard is to install PV RES-E's only on southern exposed roofing. The below discreet values shown in table 3.2 will be tested.

southern roof exposition	descriptive size
10 m^2	s
20 m^2	m
30 m^2	l
40 m^2	xl

Table 3.2: Monte Carlo tested southern roof exposed sizes

4. Price of Installing the RES-E (constant)
   the data derived from the efficiency parameters on the average price tag for installing the photovoltaic RES-S has been revised. The 280W modules will be used while currently being most cost efficient solutions in the market [pvXchange.com Martin Schachinger, 2018]. The installation cost will be assumed to comply with the standard average price tags for the installing the RES-E photovoltaic on-site productions to be €1500 per kW of nominal value of the installed power of the on-site RES-E [pvXchange.com Martin Schachinger, 2018].

5. Annual solar radiation in W/m^2/annum (continuous, randomized)
   One of the simplest method simulating the solar radiation with known geographical longitude and latitude and available empirical evidence data is to follow the normal distribution as a baseline of TAG solar insulation probability model[Linguet et al., 2016]. While testing homogeneous zone (Poland, Germany Netherlands), both the mean and variance has been chosen from the solar radiation map for Europe prepared for those purposes [European Commision, 2017]. The parameters has been revised and the mean has been set on level 1050 kW/m^2/annum while variance on the level of 100 $kW/,^2$/annum,

therefore the simulated solar radiation will be characterized by the following:

$$X \sim \mathcal{N}(\mu, \sigma^2) \text{ for } \mu = 1050, \sigma^2 = 100 \tag{3.2}$$

6. Power price (randomized, Brownian motion)
According to chapter 2.3, the average growth of the electricity in EU is a 4%/annum. To check the probable outcome on a global population in Monte Carlo simulation the individual price of the agent has been simulated within the Brownian motion process assuming the change of price in time with the unknown probability output for each price. [Morters and Peres, 2018]
The Investopedia brings a good visualization of this with the figure 3.2.

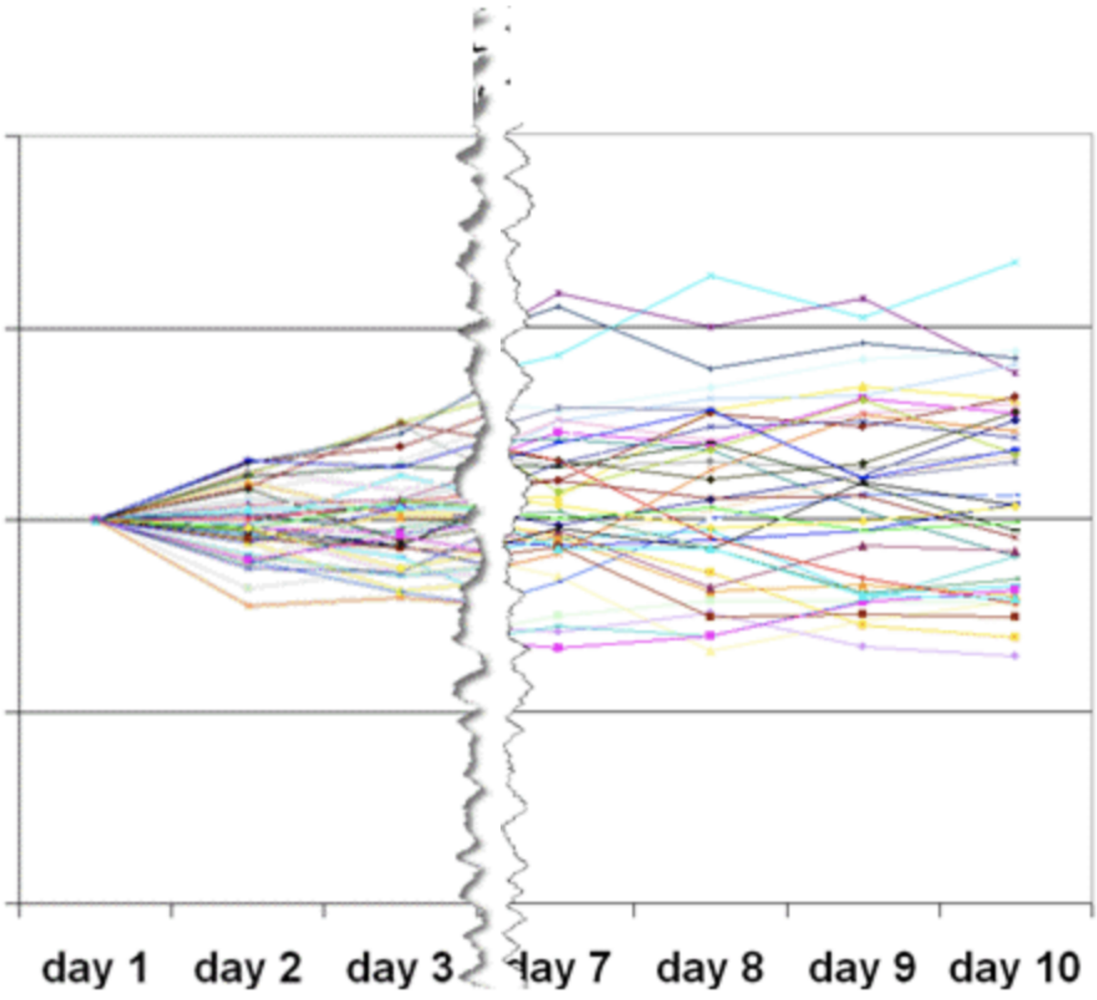

Figure 3.2: Exemplary of simulated random Brownian motion random paths [David R. Harper, 2018]

Assuming that,

$$B(t) : t \geqslant 0 \quad \wedge \quad t_0 > t_1 > ... > t_{25} \tag{3.3}$$

the base criteria of the Weiner process are satisfied. The choice of the t = 25 period simulation is based on the findings from table 2.2 from chapter 2. The period of simulation is equal to the amortization of the on-site photovoltaic RES-E. The Weiner process will than follow the equation:

$$B(t) = B(t-1) * t\mu \tag{3.4}$$

The process is than a stochastic one while the result of the period t_n is equal t_{n-1} multiplied by the probability of the electricity price increase by the 1.04 or other words by 4% as derived in chapter 2.3. The probability of the price increase in a t_n has been set on constant for all 25 periods level of 0.5 (50% chance) to resemble the potability of electricity price uncertain growth with potential to finally stabilize on level of inflation. The parameters of the process will be as follow:

$$P(\mu) = 0,5 \ , \ \mu = 1.04 \ , \ B(t_0) = 0.64 \tag{3.5}$$

To better visualize the Weiner process the below graph shows the multi period probabilistic model in action where 25 periods where the random value be selected on each agent randomly.

$$B(t_0) \Longrightarrow B(t_1) = B(t_0) * t_1\mu \Longrightarrow B(t_2) = B(t_1) * t_2\mu \Rightarrow ... \Rightarrow B(t_{25}) = B(t_{24}) * t_{25}\mu \tag{3.6}$$

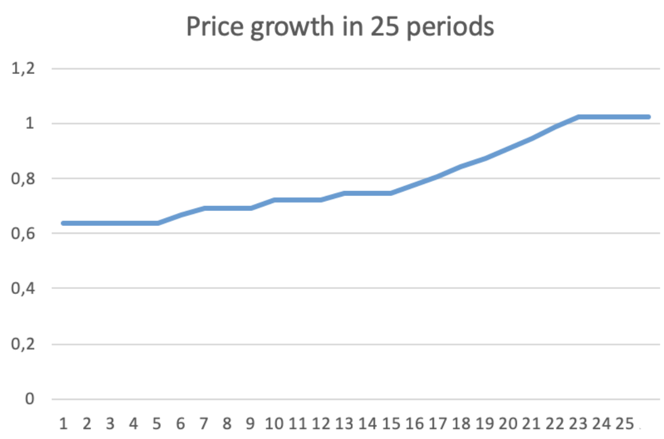

Figure 3.3: exemplary price random growth with process from equation 3.4

The graph plots one of the agent's simulated 25 period price growth of the electricity price, where the $B(t_{25})$ price have reached the level of PLN 1,02.

In the Monte Carlo simulation each of 10.000 agents will have it's own random price curve and therefore own monetary surplus depending on the level of price curve shape.

3.3. Final tested multi-period simulation equation

The final form of simulated equation is therefore formed as:

$$PV = -I_0 + D_e * N * B_0 + D_e * N * B_1 * t_1\mu/(1+r)^1 + ... + D_e * N * B_{25} * t_{25}\mu/(1+r)^{25} \quad (3.7)$$

$$\text{for } N = \mathcal{N}_0(1050, 100) \quad (3.8)$$

The tested value of the simulation is formed as the final surplus for installing the RES-E PV installation with the regard to all previously mentioned factors. The final distributions will be formed mainly by multiplication of tho random variables - the solar insulation and the Weiner process shaped prices of the electricity.

Chapter 4

Implementation of the Monte Carlo simulation

The model has been implemented in MS Excel as the most simple and efficient tools to simulate the Monte Carlo model. The imputed Formulas for the random variables presents as:

- Solar insulation

Figure 4.1: Solar insulation simulation command

- Solar insulation

Figure 4.2: Electricity price simulation command

4.1. Simulation results

To begin with the simulated prices shaped itself in a similar to normal distribution after being simulated randomly for 25 periods with the Weiner process. The distribution of the prices in t_{25}, hence can be shown in a form of a below histogram figure 4.3

The results of the Weiner process has reached a below parameters:

- The Average Price = 1,065 -¿ 64% higher than at price t_0
  Or 12 successful price increase in 25 periods

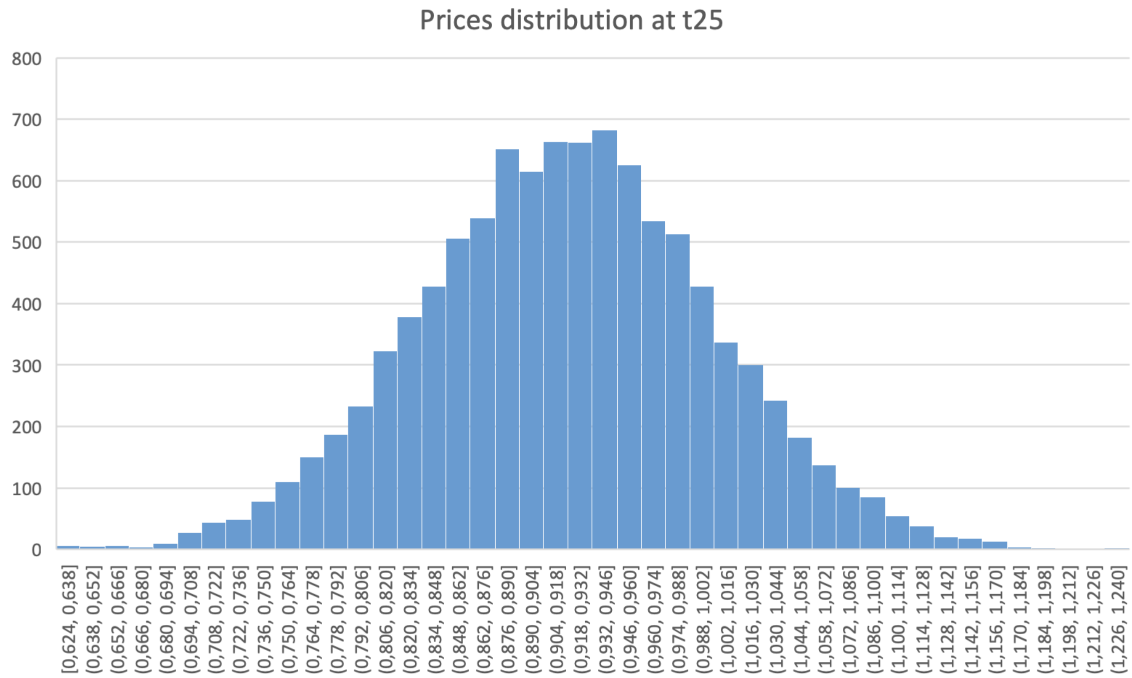

Figure 4.3: histogram of all simulated prices at t_{25}

- The Minimum Price =0,76-¿ 17% higher than at price t_0
  Or 4 successful price increase in 25 periods
- The Max Price = 1,48 -¿ 228% higher than at price t_0
  Or 21 successful price increase in 25 periods

Taking the average prices the accumulated spendings on energy without the RES-E has been calculated The results of the NPV of the 25 years of usage a non nZEB is shown in a table 4.1.

3000kWh	6000kWh	9000kWh
PLN -59 831	PLN -119 663	PLN -179 454

Table 4.1: PV of accumulation of simulated power expenditures

The demand on energy for all three cases during the 25 year period has generated the demand on financing on the level presented in a table 4.1. While households are progressively subduing the monthly payment for the electricity the accumulated cost is not visible to them as a potential saving. While laying it in a form of accumulated 25 year PV liability to the electric company. The similar exercise is often presented to the smokers, where calculation of smoked cigaret is calculated in form of a potential purchase of the level of saving. In all three cases the present equivalent of those energy spendings can be substantially translated to luxurious car, small flat in suburbs small house in suburbs of Poland. This means, that if possible to apply the nZEB strategy to houses of those potential energy demands the surplus of this size can be made without including the investment sum od the installation itself.

demand	3000kWh	6000kWh	9000kWh
10 m^2	PLN -3418	PLN -23071	PLN -78777
20 m^2	PLN 2314	PLN -5767	PLN -55219
30 m^2	PLN 41222	PLN 17745	PLN -33250
40 m^2	PLN 82710	PLN 45242	PLN 20719

Table 4.2: Present Value of the households energy house financial influence

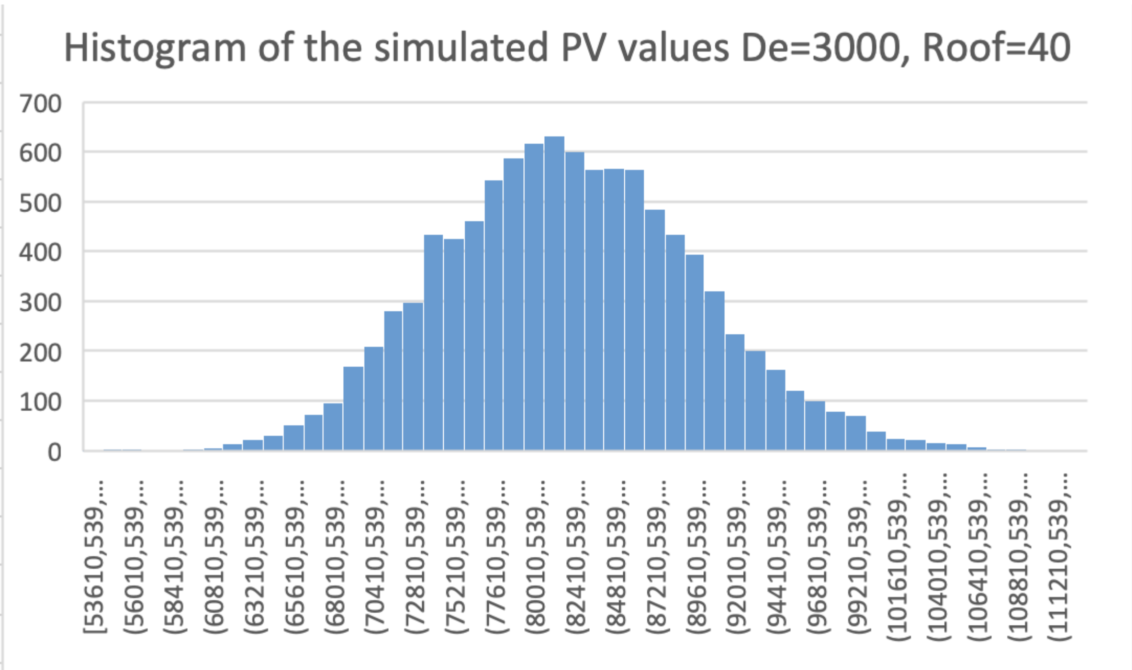

Figure 4.4: histogram of all cumulative present values of model 3000kWh, $40m^2$

The simulated discreet houses with the demands on levels of 3000, 6000 and 9000 kWh, when using a simulated market price would in fact decrease their present value of life of numbers presented in the table 4.2. As visible in the table the underlined cases does not fulfill the nZEB criterion and still generating the burdening for the family.

Table 4.4 has been added to better comprehend the model findings. By setting the price of the energy on certain base level and utilizing the SOLVER function, the border price of efficiency of the RES-E installation has been found. Those prices are indicating the level of the energy price on the market to achieve any return on investment. This threshold price is showing the price range from witch the RES-E or nZEB are feasible to install in dwelling. The

demand	3000kWh	6000kWh	9000kWh
10 m^2	PLN -3418	PLN -23071	PLN -78777
20 m^2	PLN 2314	PLN -5767	PLN -55219
30 m^2	PLN 41222	PLN 17745	PLN -33250
40 m^2	PLN 82710	PLN 45242	PLN 20719

Table 4.3: Single Family surplus of installing the RES-E

important notion is that this price is dependent both on the falling price of the photovoltaic RES-E. The lower the I_o the lower the affordability price. Also the observation that those electricity prices are long gone is worth mentioning. This only means, that all photovoltaic RES-E can currently achieve the return on investment and with growing prices of electricity this return on investment can be achieved even faster.

Roof/demand	3000kWh	6000kWh	9000kWh
10 m^2	PLN 0.32	PLN 0.33	PLN 0.32
20 m^2	PLN 0.25	PLN 0.28	P PLN 0.25
30 m^2	PLN 0.21	PLN 0.21	PLN 0.22
40 m^2	PLN 0.18	PLN 0.19	PLN 0.18

Table 4.4: Price of energy granting affordability of PV RES-E installation or having an nZEB

As the final simulation calculation was the period of return of investment. The calculation has been made as a first year of financial surpluses overcoming the initial investment I_o. The returns has been calculated for each individual modeled values.

Roof/demand	3000kWh	6000kWh	9000kWh
10 m^2	5Y	5Y	5Y
20 m^2	5Y	5Y	6Y
30 m^2	5Y	6Y	6Y
40 m^2	6Y	6Y	7Y

What is interesting is that by adding the financial parameters as price growth and calculating a present value of the surplus of household or nZEB to the discussion of the photovoltaic RES-E ROI, the period has actually decreased than the ones observed in the market. The common calculation being made are not accounting for future prices and thus distorts the true ROI and profitability of the system.

4.2. Discussion of the results

1. Roof size to Energy demand.

   One of the most important notion observed during study of nZEB potential economical surplus for the family was understanding the dependency of the potential of creating the nZEB condition. The ratio of the house demanded energy to possibility of becoming an nZEB is straight forward. The excel solver function has calculated for the polish market a $1m_2$ of southern exposed roof (ready for installing a photovoltaic nZEB) for each 232 kWh of energy demand on year. With this understanding the limitations of the RES-E on-site installations are not derived by the demand on the energy of a household, but rather by the possible size of the roofing with the southern exposition and other exogenous limitations.

2. Price growth

   Current prices of energy and their estimated future growth are on level higher than inflation what allows us to think that installing the on-site RES-E installation will be more and more feasible for any households on the market. Currently on each simulated houses the installation has its ROI, while the prices of energy are higher than the efficiency of photovoltaic installations within its 25 year period of amortization

3. Current price of the energy

   Is making the current RES-E installation a viable solution has been found for all the characterized demands for energy. The price is already higher than the found solutions and therefore all the actors of the market have an incentive to install its own on site RES-E of power allowing reaching the nZEB.

4. Adjusted ROI

   One of the most impressive result is that the market calculation on average is providing a return on investment of the PV RES-E on the level of 8-12 years, while not providing the customer the comprehend financial present valuation of the streams of the potential surplus. The return on investment for simulated data with the randomized growth of 4% annually, has been fluctuating between 5 and 7 years. This only is making the later period of usage after the profitability period a pure mechanics to improve the family financial situation. This only means, that without financial understanding of the surplus in time, the actors of our European market have not see the end to end financial surplus for their dwellings on achieving an nZEB.

As a side note, the possibility to open the financing schemes for the nZEB's should be discussed on the European level. Understanding that the RES-E can have a ROI on level of even a 5 years should pressure the governments, local units as well as creditors as banks and funds. While achieving such stunning possible ROI the family could basically take the loan to bring up the nZEB to their home achieving stabilization of the price and decreasing the risk of price increase with substantial economic influence on a household.

4.3. Author Comment - Micro Housing as a biggest potential nZEB

Micro housing def.6.0.4 trend is a new booming trend in numerous location in the world. Those location can be characterized as highly urbanized modern cities and their outskirts that thanks to their economical success experiences constant inflow of citizens. This inflow leads to increased city density that finally pushing the prices of the dwellings high above the possibilities of young generation. Evolution of our society leads to evolution in terms of housing and one of the answers to this problem is new visible trend in the world - Micro Housing [Gesell, 2016].

Reasons of housing habits shift in Europe[Gesell, 2016]

1. High population densities in (major) cities
2. Urbanization
3. More concentrated use of less space
4. Population growth
5. Rent increase
6. Increased single-person households
7. Mobility needs

This way of living is known already in Japan as "compressed living". Micro house trend is also highly popular in Silicon Valley where young generation of technological millennials are choosing preferred living location over dwelling size. What is more, that housing unit sizes are shrinking across the country opening space for more creative space management [Alexei Barrionuevo, 2016].

Urbanization as a main European metropolis trend takes different forms according to local construction regulations and preferences of consumers. Though one thing is common to all regions is visible - demand for dynamic cities having affordable dwellings for its inhabitants. With increasing population and constant inflow of newcomers to cities this is becoming more and more difficult to secure in reasonable prices. Against this, the housing sector is visibly working its way in the topic of micro homes. With different approaches to Micro Housing we

[h!]

PROS	CONS
Reduce things to their essentials	Small area
Easily financed residential property	Personal restrictions
More room for individuality	Added costs from acquisition of space-saving furnishings
Economic use of resources	Larger gatherings not possible
Economic use of space	External storage of belongings
Modern big-city living	Little storage space
City-centre living, shorter distances	Untidiness quickly becomes apparent
Mobility and expansion options	Accelerated wear of the property
Modern technology and design	Less privacy
Easy maintenance	

Table 4.5: Pros and cons of micro housing - own authorship based on [Gesell, 2016]

can also see different names of products in the trend: single house, nomad home, mini house, micro home, tiny house, etc. - depends on a target group. [Gesell, 2016]

Micro housing external factors:

1. Inequality: according to MIT studies [Rognlie, 2014], lack of housing for people struggling with real-life challenges is the main reason of inequality; people with low income are not able to invest in renewable energy solutions and cannot benefit from the changes happening on the energy market and contribute to low carbon economy transition

2. Sustainable Living Trend: There is a growing number of people who would like to live in sustainable way and reduce an individual's use of the Earth's natural resources. Practitioners of sustainable living often attempt to reduce their carbon footprint by living in sustainable homes, altering methods of transportation, energy consumption and diet.

3. Refugees crisis: the refugees coming to Europe need social housing that is not expensive but long lasting and healthy to live in physically and psychologically.[Carey et al., 2014]

The reason this chapter has been added is to understand, that the potential of building a micro house of witch return of investment is possible while producing a substantial margin for a family, the Micro housing is the biggest potential the author have came upon. The potential return of investment a Net Plus Energy building being build from the ground, with its own RES-E of a substantial size to energy demand, can actually be achieved on the level of 23 years. (own experience of the author)

Chapter 5

Summary

During the process of writing this paper, the company we are building - SOLACE sp.z o.o. has achieved building its first own prefabricated nZEB. We have not only designed it from scratch and built it, but also we have been testing its energy usage as well as its own RES-E installation performance. A SOLACE house is visible on a figure refsolace.

Figure 5.1: Photos of SOLACE house, co-owned by the author

One of the key motivator to write this study of nZEB potential to decrease the housing overburdening was my private agenda to learn and test the offer we are proposing to our client. What is a surplus from the nZEB we are producing and offering to the end customer and how to derive the end to end logical process to achieve the clear understanding of nZEB performance in time of the RES-E amortization period. During the process of writing this thesis, the topics I was reading and testing to put in this paper, were often a topic of discussions and numerous interesting observations by the team members. The notion of being able to write about the work we are actually trying to accomplish was one of the most motivating points of this journey.

As a proposed solution for social problems connected to housing overburdening is a nZEB house, a house that produces more energy than it uses. The study above was build to check the possible outcome to solve recent alerting accumulation of information about the term 'housing overburden".

The proposed hypothesis was to lower the housing burden of a household via zero energy housing nZEB. The hypothesis was that the Zero Energy Houses can substantially decrease social housing overburdening of dwellers with certain market parameters and building characteristics. Method chosen for the study was to first derive the market and building parameters affecting the possibility of obtaining the zero energy house from both economical and technological stand point.

As a result of the model testing, the interesting results have came into the light. The limitations of the RES-E on-site installations are not derived by the demand on the energy of a household, but rather by the possible size of the roofing with the southern exposition and other exogenous limitations. Secondly, current prices of energy and their estimated future growth, on level higher than inflation, allows us to think that installing the on-site RES-E installation will be more and more feasible for any household on the market. What is more, the price of the energy that is making the current RES-E installation a viable solution has been found for all the characterized demands for energy. The price is already higher than the found solutions and therefore all the actors of the market have an incentive to install its own on site RES-E of power allowing reaching the nZEB. One of the most impressive result is that the market calculation on average is providing a return on investment of the PV RES-E on the level of 8-12 years, while not providing the customer the comprehend financial present valuation of the streams of the potential surplus. The return on investment for simulated data with the randomized growth of 4% annually, has been fluctuating between 5 and 7 years. This only is making the later period of usage after the profitability period a pure mechanics to improve the family financial situation. This only means that without financial understanding of the surplus in time, the actors of our European market have not seen the end to end financial surplus for their dwellings on achieving an nZEB.

As the final remark on the hypothesis - can Zero Energy Houses substantially decrease social housing overburdening of dwellers with certain market parameters - my answer is yes. The higher the market price on energy the higher the family relative surplus and possible housing overburdening escape.

Chapter 6

Annex 1 - Definitions

The aim of this chapter is to clarify the definitions used prior in the thesis which are crucial to understand the logic behind the study.

Definition 6.0.1 *Nearly zero-energy building*

A building that has a very high energy performance; the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources.

Definition 6.0.2 *Building NF standard*

*House energy-saving measure that cumulates demand for usable energy for heating and ventilation systems at the level NF level of kWh/(m2*year) or less; technical requirements for energy efficient buildings (lower than NF 40) buildings relate to various issues and building elements, such as: minimal heat transfer coefficients of walls, windows, doors, roof, and floor on the ground and the parameters on the efficiency of mechanical ventilation, the minimum value of thermal bridges and air tightness of the building.*

Definition 6.0.3 *Economical sustainability*

Sustainability is the ability to continue a defined behavior indefinitely.

1. *For renewable resources - the rate of harvest should not exceed the rate of regeneration (sustainable yield);*
2. *For pollution - The rates of waste generation from projects should not exceed the assimilative capacity of the environment (sustainable waste disposal); and*
3. *For nonrenewable resources - the depletion of the nonrenewable resources should require comparable development of renewable substitutes for that resource.*

In shortcut, Environmental sustainability is the rate of renewable resource harvest, pollution creation, and non-renewable resource depletion that can be continued indefinitely. If they cannot be continued indefinitely then they are not sustainable. [Daly, 1990]

Definition 6.0.4 *Micro house*

Small house designed with respect to maximization of usable space and minimization of the home's footprint. Usually micro house is a $500ft^2$ *squared or* $45m^2$.

Definition 6.0.5 *Zero-energy buildings (ZEBs)*

Buildings with on-site generation systems, that generates equal or higher number of electricity than demand on energy of dwellers sometimes resulting in the export of excess electricity.

Definition 6.0.6 *Energy Prosumer*

The final customer, who purchases electricity on the basis of a comprehensive contract and generates electricity only from renewable energy sources in micro-installations for its own consumption not related to running business.

Definition 6.0.7 *The housing cost overburden rate*

The percentage of the population living in households where the total housing costs ('net' of housing allowances) represent more than 40% of disposable income ('net' of housing allowances). [Eurostat, 2014]

Definition 6.0.8 *Equalized disposable income*

The equalized disposable income is the total income of a household, after tax and other deductions, that is available for spending or saving, divided by the number of household members converted into equalized adults; household members are equalized or made equivalent by weighting each according to their age, using the so-called modified OECD equivalence scale. [Eurostat, 2018]

Definition 6.0.9 *Net energy*

Is a balance between the energy produced by a house and its renewable energy generating system and the energy output required by the house and its occupants to sustain [Hernandez and Kenny, 2010]

Definition 6.0.10 *EPBT Energy payback time*

The period of time required for the renewable energy installation achieve the point profit from an investment that equals the initial outlay for the installation.

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