THESIS

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The Need and Opportunities to Reduce Energy Usage in Public Sector Buildings

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Gödöllő

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1. Introduction and objectives:

Reducing energy consumption has been a concern due to the continuous rising demand and the quick Fluctuations in the resources supply chain in recent crises as Covid-19 and the Russian aggression on Ukraine. This study focuses on the measures taken by the EU in order to reduce energy consumption in general and in the public sector buildings in particular, along with presenting the needs beyond those measures and what achievements can be reached through the European green deal and its sub-programs in regard to solve the energy poverty problem and to reach the climate neutrality which is a goal to be achieved in Europe by 2050.

It also highlights the public sector share of the European countries plans to reduce energy consumption and increase the renewable resources, and focuses more on how Covid-19 and the Russian aggression on Ukraine affected the energy sector in regard of energy prices and insecure availability of resources and how the previous European efforts took place as mitigating factor against the impact of those crises. By the end of this study, a survey was made to evaluate the participants point of views about the public buildings in terms of their energy usage and to monitor different effects of the recent crises on the participants energy usage and their reactions where the results came aligned with the hypothesizes assumed that the public sector energy consumption had decreased during Covid-19 on the contrary of the consumption of the household sector, but in total the usage has increased as the decrease in public sector was much less than the increase in the household's one.

The majority of the participants shared that their consumption of energy increased by 40% to 60% during covid-19 and it the increase was 55% because of electricity appliances and lighting and around 40% due to heating and cooling and only around 10% considered their work place or educational institution energy efficient. The third hypothesis assumed that the renewable energy usage has increased after the Russian aggression on Ukraine which was illustrated in the survey results as 35% of participants mentioned that they only started using renewable energy resources after February 2022 and 80% of them said their motive was to reduce energy costs, and for those who didn't, 65% of them said the reason was the high cost of installing them. And that make us believe that the direct impact on consumers makes the biggest motive for them to go for renewable resources.

It was important to measure how the participants reacted to those two crises in regard to their energy consumption in order to have a closer understand of how Covid-19 and the Russian war on Ukraine affected the energy sector which are two important matters to research due to how recent they are due to their temporal intersection which was a serious test for the energy sector in the world in general and in Europe in particular, which the sector succeeded with minimal and unavoidable effects.

Hypothesis 1: COVID-19 led to reduction in energy consumption in the EU in the public sector considering the more time the people spent in their houses rather than public buildings.

Hypothesis 2: Even though there was a decrease in energy consumption in the public sector due to Covid-19 but the total energy consumption was more because the household sector energy consumption has increased

Hypothesis 3: the crisis in Energy sector supply chains after the Russian aggression on Ukraine pushed for faster actions and was confronted by an outstanding reaction by the EU member states represented by more dependency on renewable energy resources.

2. Literature review:

2.1 Energy poverty definition

As one of the recent rising challenges facing the world in general and the European Union in particular, Energy poverty is one big problem itself followed by many other challenges which should be solved before finding a solution to it, because of the obstacles in determining who can be considered -energy poor- and because of the quandary of collecting data of those who experience energy poverty as its broad term and the start would be by defining what is energy poverty (1), the EU directives stated that energy poverty happens when any family has to decrease their energy usage to a point where their health and wellbeing is affected in a bad way and which cause that to happen is the inhabitants low income and their inability to afford sufficient energy consumption, in addition to the state of their residence in terms of insulation and energy performance (2)

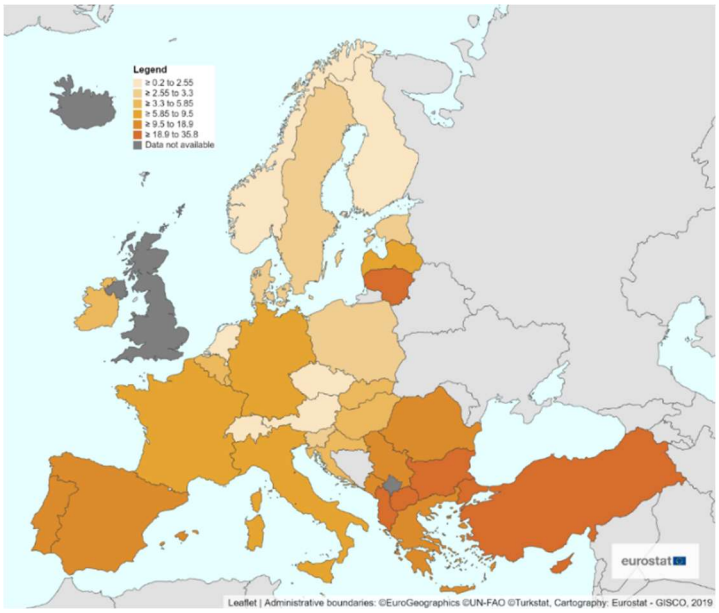
Studies defined energy poverty as the inability of providing a good level of energy relying services for the domestic use which is needed for maintaining a decent level of day to day social needs such as heating, cooling and other appliances (3) but not to forget that there are reasons for energy poverty in under developed countries which mainly are the disconnection from the general electricity network and the inability to deliver this energy to the household, while in high income "developed countries" those who are affected by the energy poverty or the vulnerable consumers are mainly those who are not able to afford their energy consumption due to the reasons mentioned above. (4)

2.2 Energy poverty in the household sector

In the past few years, not having enough energy to meet basic needs has become a big issue in Europe and around the world. It means people are struggling to get the energy services they need for their daily lives. (5)

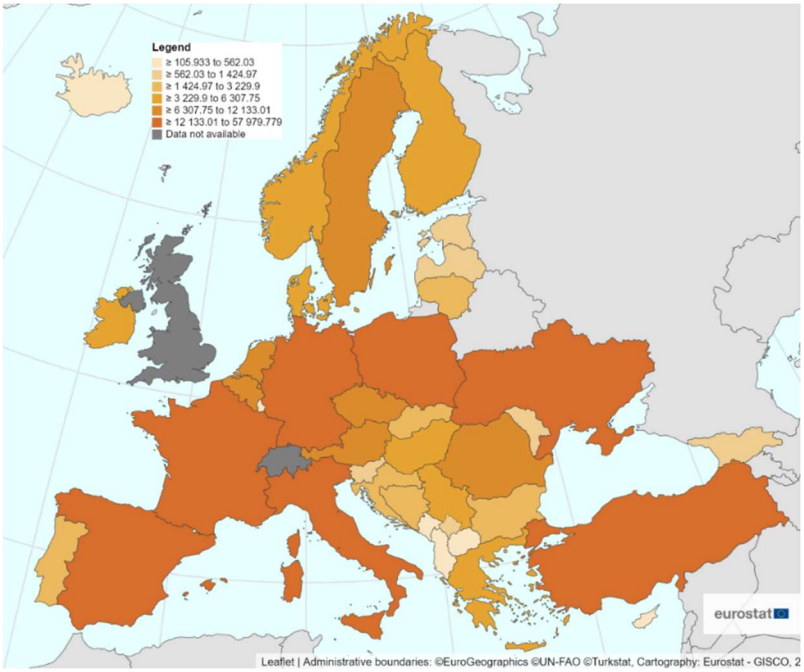
The following figure (6) shows the percentage of population who were not able to keep their homes warm during 2020 in Europe as numbers indicates that the following percentages exceed 50 million families. (7)

Figure 1 Percentage of population who were not able to keep their homes warm during 2020 in Europe Source: Eurostat.com (6)



Even with the fact that a considerable percentage wasn't able to warm their residence enough, but the building sector was responsible of 35% of the total greenhouse gases emissions consuming over 42% of the total energy consumption in Europe (8)

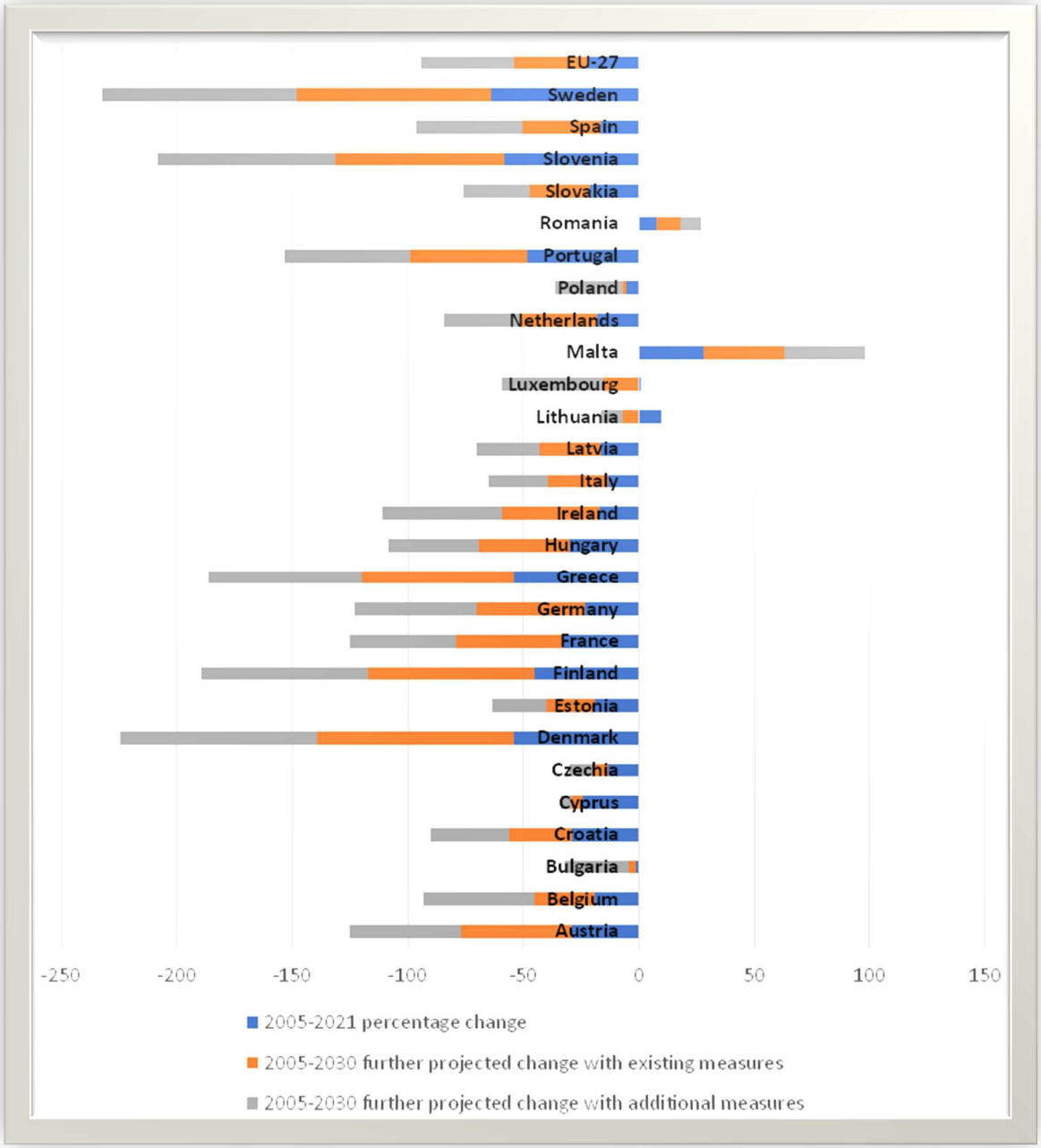
Figure 2: The energy consumption for the household sector in Europe equivalent to how many thousand ton of oil in 2020. Source: Eurostat.com (9)



All the above justify the efforts took place in order to find feasible solutions for the energy crisis in Europe in regard of the household sector including but not limited to, the green deal, clean energy for all package and the renovation wave. (10)

The next figure shows the current percentages changes in GHG emissions resulted by the EU efforts to reduce energy consumption by the buildings sector starting 2005 until 2021 and it represent what are the expected changes in case the current measures are kept as they are without any addition and it also shows the possible ability for even better change in case other plans which are already set theoretically were implemented.

Fig 3: Greenhouse gas emissions from energy use in buildings by country. source: EEA (11)



2.3 Energy efficiency

Energy efficiency is an important factor in this matter as it can be defined as the ability to make an optimal use out of the consumed energy which will result to the reduce of the energy consumption and consequently the costs which make it a crucial factor from both environmental and economical point of view.

And that was clearly mention in the EU directives as mention in the Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955

"Energy efficiency should be recognized as a crucial element and a priority consideration in future investment decisions on the Union's energy infrastructure. The energy efficiency first principle should be applied taking into consideration primarily the system efficiency approach and societal and health perspective, and paying attention to security of supply" (12)

While the energy efficiency first principle was defined in Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council.

"To consider, before taking energy planning, policy and investment decisions, whether cost-efficient, technically, economically and environmentally sound alternative energy efficiency measures could replace in whole or in part the envisaged planning, policy and investment measures, whilst still achieving the objectives of the respective decisions. This includes, in particular, the treatment of energy efficiency as a crucial element and a key consideration in future investment decisions on energy infrastructure in the Union" (13)

In order to understand the energy efficiency deeper than the previous broad explanation and on a scientific level, we need to differentiate between primary energy consumption and the final energy consumption.

PEC: the total energy consumed to produce the final energy (not including other reasons of energy consumption) e.g. the oil burnt to produce electricity is considered part of the primary energy consumption

FEC: the energy consumed by the final consumers e.g. residents consume the electricity and gas in their houses and that energy is considered final energy

So, the subtract result between PEC and FEC is inversely proportional with the energy efficiency (14)

The following table represent the PEC and FEC in the European union from 2000 till 2022 and it shows that the loss of energy while transferring the primary consumption into useful final consumption in 2000 was almost 30% (loss of the primary energy) which is decreased by around 5% in 2022 and that represent an improvement in the energy efficiency during the last two decades.

But looking at the targets for 2030 to have the PEC equals to 992.5 MTOE and FEC equals to 763 MTOE (14) the loss of primary energy while converting it to final useful energy shouldn't exceed 23% by 2030.

Figure: 4: Primary and Final energy in the EU between 2000 and 2022 consumption Source: Eurostat (15)(16)

TIME	|PEC: European Union Primary Energy Consumption (MTOE)	FEC: European Union Final Energy Consumption (MTOE)	Difference (loss) Million tons of oil equivalent
2000	1,396.4	979.9	416.5
2001	1,434.3	1,002.9	431.4
2002	1,436.5	996.2	440.3
2003	1,474.8	1,026.2	448.6
2004	1,493.5	1,036.3	457.2
2005	1,497.7	1,041.3	456.4
2006	1,511.4	1,045.9	465.5
2007	1,490.1	1,028.5	461.6
2008	1,488.7	1,036.7	452.0
2009	1,403.3	980.8	422.5
2010	1,458.3	1,025.2	433.1
2011	1,412.8	985.2	427.6
2012	1,397.0	983.2	413.8
2013	1,384.8	981.0	403.8
2014	1,330.8	939.2	391.6
2015	1,353.4	958.6	394.8
2016	1,364.9	977.6	387.3
2017	1,384.8	989.8	395.0
2018	1,377.8	992.5	385.3
2019	1,354.3	986.5	367.8
2020	1,235.7	906.3	329.4
2021	1,311.2	967.4	343.8
2022	1,257.1	940.5	316.6

By revising the trend and the aimed number for PEC and FEC by 2030 more measures should take place as fast as possible in order to increase the reductions for both PEC and FEC (14)

And as the construction sector is one of the most energy consuming sectors, there is a big potential of reducing the energy use by adopting new technologies and designs which will lead to a great advantage environmentally and economically (17). Which made property owners already integrating energy considerations and cost planning during the building's design, and there's a growing trend towards benchmarking consumption and costs during the usage phase. (18)

Taking into consideration that the energy efficiency in buildings is influenced by various factors. External conditions like wind speed and outside air temperature impact how much cold air affects a building's interior temperature. Key factors affecting a building's heat load include wall heat transfer coefficients, coating material properties, inside and outside temperatures, and external surface temperature. (19).

2.4 European Green Deal goals and opportunities

As one of the most ambitious and important efforts conducted by the European union is presenting the green deal as a response to the biggest challenge of the climate change and the resulted consequences of it.

The term “green deal” or “green new deal” was presented many times in Europe and internationally by various groups and activists and all of them encourage the efforts to more sustainable solutions and pro-environment policies, (20) but on the official European level, the green deal goal is to reduce the greenhouse gases emissions by 55% in 2030 compared to 1990 (which is also referred to as fitfor55) and zero emissions by 2050 to achieve climate neutrality by adopting policies and strategies to separate the economic growth from the resource use (21)

One of the green deal programs is the new green deal industrial plan which consist of four important general strategies

A. Create straightforward rules that professionals can easily understand and follow.

B. Speed up the process of acquiring funding for projects

C. Support professionals in learning new skills.

D. Encourage open trade to strengthen supply chains. (22)

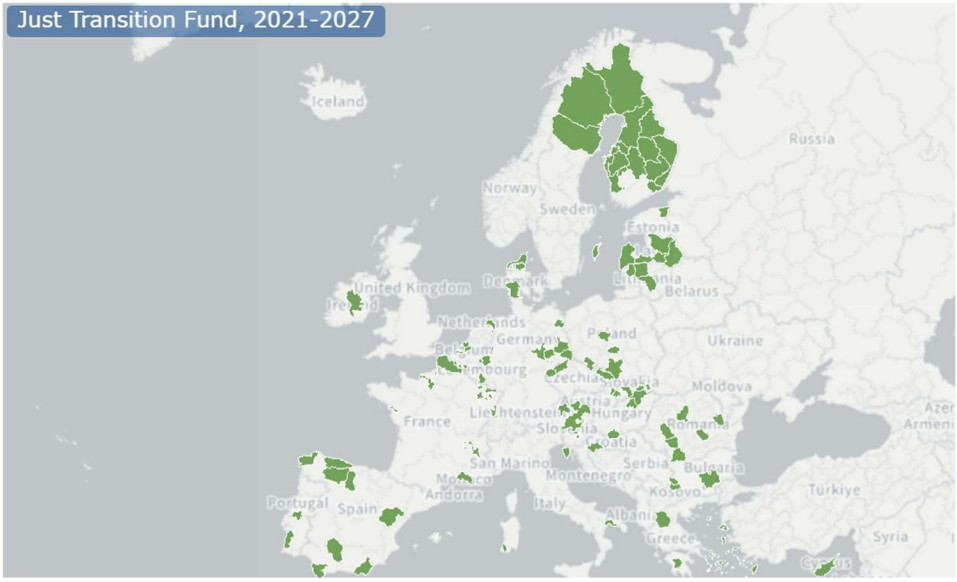
Figure 5: The European Green Deal Goals and ambitions. source (21)

As it's one of the most important priorities in the green deal is to achieve the goals with the utmost feasibility and provide the support in a fair way, the just transition mechanism was announced along with the green deal, which gives what is needed for facing the challenges which might occur due to the transformation to the new phase on climate neutrality and it was under the name of "Leaving no one behind". (23)

The Just transition mechanism will provide support to the territories and communities which are likely to be affected by the environmental and economic effects of the climate change and will aim towards economic support, job vacancies special for communities that rely on fossil fuel and non-renewable energy sources. (24)

The following map demonstrates the regions which their inclusion under the just transition fund has been already approved.

Figure 6: The countries included In the Just transition funds until 2027.
Source:(25)



"The Just Transition Platform puts people and communities at the center of the transformation, by listening to their aspirations and giving them the tools to realize their ideas"

Elisa Ferreira, Commissioner for Cohesion and Reform

2.5 The legislation of the green deal - fitfor55

The current diagram illustrates how the legislations of the green deal laws took place

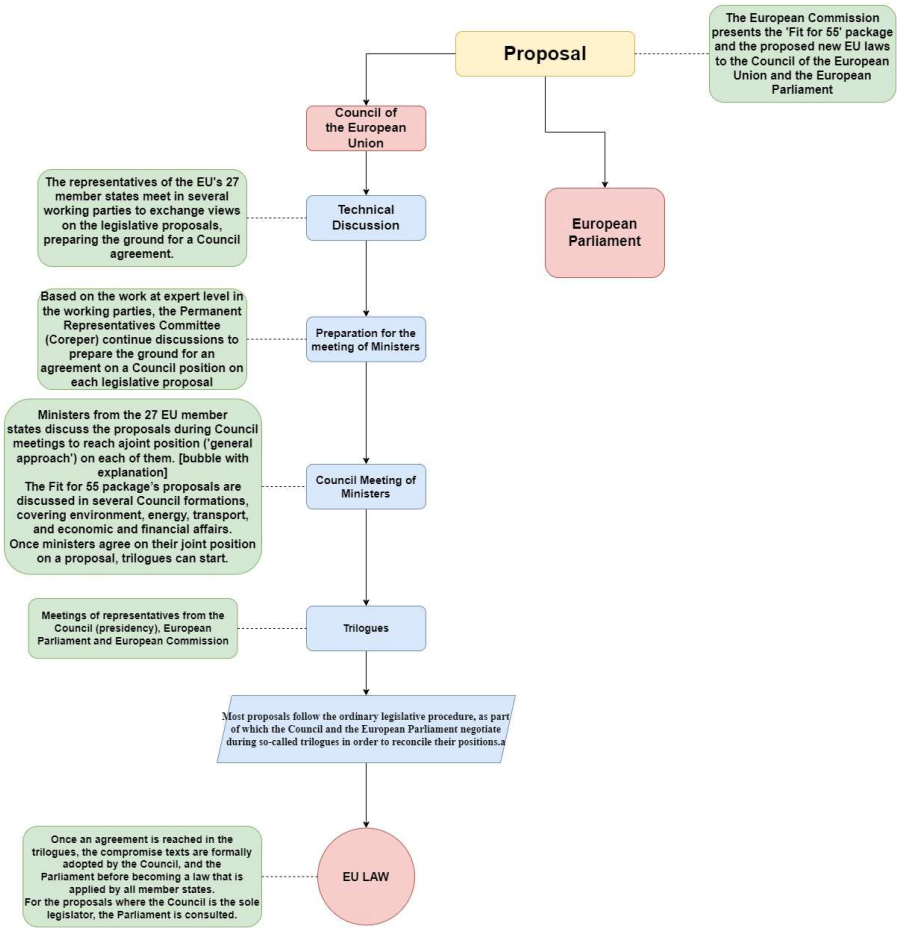
through the European Union official channels.

As we can see in figure 7, the first legal step is taken by the European Commission which presented the Fitfor55 package to both the EU parliament and Council, the latest conducted technical discussion that includes members from each EU member state to prepare what we can describe as a - draft proposals - preparing for the ministers' meeting.

The assigned ministers of the EU member states discussed the previous proposals until they reached a general approach and that will be negotiated further in the "Trilogues" meetings which included the ministers along with EU parliament and council.

After the "Trilogues" negotiations, an EU law successfully emerged.

Figure 7: The legislation of the green deal- fitfor55. Source: (26)



2.6 The renovation wave

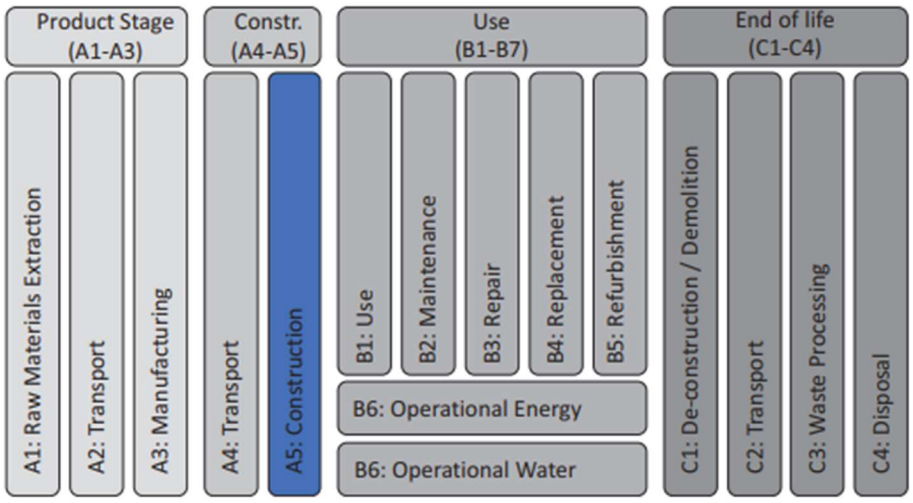
Europe's architectural inventory stands as a testament to the richness of the cultural heritage and its historical evolution. Still, it's not deniable that most of those architectural masterpieces are old and have been developed in a slow pattern over time.

Number indicate that approximately 220 million buildings which means over 85% of the wholesome number of EU's Buildings were established before 2001, and around 90% of them will remain functional by 2050 (27) and as mentioned previously In 2.1 (Energy poverty in the household sector) the building sector was responsible of 35% of the total greenhouse gases emissions consuming over 42% of the total energy consumption in Europe (8) and for both reasons and more, the renovation wave is one of the most important -if not the most at all- actions within the green deal initiative.(27) Specially that until 2022, only 12% of household sector buildings and 9% of non-residential buildings were renovated to meet the goals aimed by 2050, with a very low rate of only around 1.3% annually (28) even though it was suggested in 2010 that each member state should plan a strategy on the long term to meet the goals of 2050 by supporting the renovation of private and public sector buildings by a clear road map for that and taking into consideration that the steps should be feasible on the technical, economical and functional aspects. (29)

During the renovation wave which aims to reduce energy usage in the first place, it's important not to miss the factor of the embodied energy which is the energy spent in order to reach the status of a 'renovated' building which starts from the extraction of the raw materials, transporting them and the usage of energy consumer in the process of the renovation and last but not least, the last phase of the building operation which is the end of its life (30)

The following figure explain the phases of a building lifecycle which include consuming energy and the Embodied energy is the energy used in any time of the life cycle except the stages B1 to B7 in the figure.

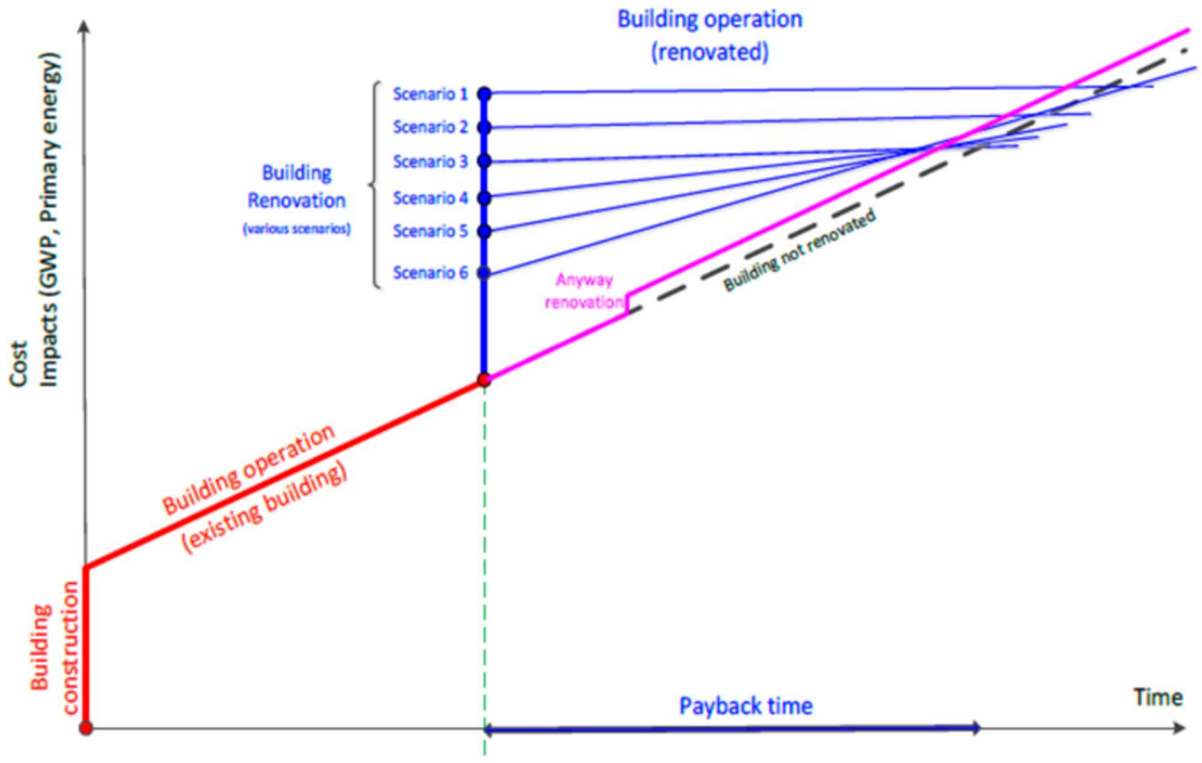
Figure 8: The phases of a building lifecycle. Source: (31)



And because the emissions resulting from the embodied energy consumption are approximately 5% to 10% of the total energy consumption in advanced world countries and might reach up to 30% of that total in third world countries (31) then the embodied energy in renovating should be monitored in order to decide how efficient the renovation is from an environmental – energy consumption point specially that the costs and embodied energy are more likely to be higher when renovating for the purpose of reducing energy rather than normal renovating.

The following figure demonstrate the comparison between the primary energy consumption in the operation phase of the building in case was renovated for the purpose of reducing energy usage (In different six EU countries) and in case it wasn't renovated at all or renovated for different purpose "anyway renovation" and it shows how the "payback" time is connected to each type and we can clearly notice that the payback time in cases of energy renovation is much shorter that the anyway renovation or not renovated at all.(32)

Figure 9: Comparison between different scenarios of renovations payback time
Source: (32)



2.7 definition of a public sector building

A public building definition can vary between different countries and different laws or regulations and might also be subjective to the context and, for example it was clarified by Cornell law school in the USA as "a building, whether for single or multitenant occupancy, and its grounds, approaches, and appurtenances, which is generally suitable for use as office or storage space or both by one or more federal agencies or mixed-ownership Government corporations". (33) But it was defined by the city of Vincent health services as a the area where people gather usually or occasionally with prior intention of gathering rather than coincidence with an annex of a list which included schools, (34) and as a clear example of not having a general definition of a public building which can be always used officially, the department of education in GOV.UK website considered schools as private properties since not all people have a default permit to have access to the school premises, for instance parents have that right in certain times or by appointments (35).

And since public sector buildings are part of the buildings included in the renovation wave the EU advised that by October 2025 the member states need to keep an up to date database which list the public buildings with the ability of access for private sector energy companies in order to suggest renovation plans for the buildings that might be conducted. (36)

Figure 10: Examples showing difference in the definition of a public building Source (33) (34) (35) (36)

Country	Public Building defintion - various interpretations
USA	A building, whether for single or multitenant occupancy, and its grounds, approaches, and appurtenances, which is generally suitable for use as office or storage space or both by one or more federal agencies or mixed-ownership Government corporations
Australia (Vincent City)	the area where people gather usually or occasionally with prior intention of gathering rather than coincidence with an annex of a list which included schools
UK	Department of Education considered schools as private properties since not all people have a default permit to have access to the school premises, for instance parents have that right in certain times or by appointments
EU	EU advised member states to keep an up to date list by each state public buildings

2.8 Public sector Buildings energy goals across the EU member states

Buildings sector is one of the primary energy consumers in the European union and since the public buildings -"buildings owned by public bodies"- represent a considerable percentage of the total buildings, it's highly convenient for the member state to aim for a higher renovation rate in order to achieve the EU goals by playing an ideal role in this regard (36) and in order to be in that position

and as a part of the renovation wave (check 2.5 the renovation wave) the EU directive stated that starting from 2014 each member state should renovate the minimum of 3% out of the entire floor are which is managed by the government and being warmed or cooled artificially should be renovated (37)

The goals and methodologies vary between different EU member states, In Hungary's national recovery and resilience plan, the roadmap is ready for the renewal of public buildings including educational buildings, nurseries, universities and health institutions but the budget in not yet allocated. (37) While in Austria the goals for non-residential buildings are to support at least a thousand company or institution in order to decrease the energy consumption for cooling and heating and that to be achieved by the first quarter of 2025 and 250 municipalities in central locations by the second quarter of 2026. (39) And in Belgium, the minimum of 30% decrease in primary energy need in public building by 2030 is the target while it worth to mention that the hopes for social housing renovation in Brussel alone are to achieve 53% reduction in primary energy consumption and Belgium plans are to renovate at least 1.25 million square meter of public buildings area by 2030. (40).

the same as Belgium in terms of primary energy savings, Bulgaria's aim to reduce consumption by 30% by 2030 and aiming to for public buildings to be classified in category (A) in terms of EPC (energy performance certificate). (41)

Croatia on the other hand, set the goal of 3% renovation rate with an increase of 2.7% as it used to be 0.7% with the decrease of 50% in energy demand for both public buildings and multi-family buildings. (42) And the Czech Republic plans for public and state buildings are clear and aim to save 0.6 PJ annually (equivalent to almost 19 million cubic meter of natural gas) and that's starting from the fourth quarter of 2025. (43).

Denmark projected plan is to increase the energy performance in 40% out of the public buildings which are currently rated between Grade G and Grade D (EPC) scale and it adopts "whole building" renovation plans for public buildings while supports renovation of specific parts for other sectors. (44), In France, the renovation of the buildings owned by the local authorities and the state takes the biggest portion of the renovation projects , as 2900 Buildings were renovated in the fourth quarter of 2021 and 1954 in the second quarter of 2022, the upcoming buildings to be selected will be based on what provide the fastest result in terms of environmental, economic and energy wise impact. (45)

Even though Germany would for sure include public buildings renovation plans within its total 140 Billion euros budget for reducing energy consumption and renovation plans, but it doesn't specify exactly what would be the public sector share or plans of the renovation (46)

Greece's Public buildings goals follow the general target of reducing greenhouse gases by 30% and they have the share of 10% out of the energy renovation plans (47).

Ireland program focuses on the public building significantly, 5400 square meter of public office buildings already finished renovating by the second quarter of 2023 achieving 50% increase in energy efficiency, in addition to Tom Johnson house renovation which finished by the last quarter

of 2023 and that by itself included retrofitting of over 10000 square meters of office area increasing the energy efficiency in it by 75% (48)

Italy worked on speeding up the renovation process in the non-residential sector to reach 2.9% of the total building area each year including 48 judicial buildings and 195 schools noting that for public buildings in Italy the renovation as per the plan doesn't require to be at least medium renovation in order to be eligible for funding by the European Regional Development Fund (ERDF) (49)

Latvia aim to renovate 838 Public building by 2030 (over 0.5 million square meter) and the current projects showed average energy savings of 51% (50) while the schools in Poland are one of the top priorities to be renovated among the public sector buildings as the NRRP's section in regard of the building set a goal of renovating 320 schools in Poland working on improving the floor area of over 130 0000 square meters.(51)

Slovakia's Plan aims to achieve 30% or primary energy savings in the public building sector and one of the ways to achieve that is the renovation of over 117000 Square meters of historical pubic buildings by modernized insulation techniques and instalment of renewable energy resources (52)

Not very different than others, Romania's plan also aim for 30% energy savings by renovating share of its residential and non-residential buildings but without going into details about how deep the renovations would be, but the plan encouraged on renovations goals within acceptable budget. (53)

Slovenia's future plan for 2050 is subjectively ambitious as it sets the goal to reduce final energy consumption by 45% and CO2 emissions to be 25% of what it was in 2005, and it stress on the public sector buildings renovation as it aims to achieve the renovation of 0.16 Million square meter in public sector buildings which represent 17% of the narrow public sector that has the total of 0.9 Million square meter and 1.6% of the wider public sector that has the total of 8.8 Million square meter as it includes all the educational institutions , administrational buildings , hospitals and many more. (54) While Spain's plan focuses on the residential sector but it also estimates that 17 TWh lifetime saving of the final energy expenditure will be saved in the non-residential sectors and 1.5 TWh of them from the renovation of the administrative buildings in the public sector. (55)

The above can be summarized as follows, if we want to reach a general understanding about the NRRP plans, most of the plans focus on the same goal of reducing primary energy consumption by at least 30% before 2030, while the methods and ways differ depending on each member state feature and situation as most of the plans focus on renovation mainly while other specify how deep the renovation would be and in which sector (residential or non-residential) and what percentage should be achieved annually.

Other have set targets related to reducing Co2 emissions or to the area which should be renovated but the first step for most of countries was to set the roadmap towards 2030 with different varieties of detailed steps.

2.9 EU Member states NRRPs (National Recovery and Resilience Plans) between 2021 and 2026.

* Hungary

Even though there is no clear plan for the renovation in the public sector but the plan set the target of almost 35000 residentials houses to be renovated by the end of 2026, 15000 of them to be finish before the end of 2024, in addition to 2500 buildings renovation and 600 new built social rented homes to be done before 2026. (38)

* Austria

Over 2500 thermal renovation projects were approved and planned to be done before the end of 2024 while 1000 of them were planned to be finished by the last quarter of 2023, and it's worth to mention that oil and gas heating systems were exchanged in more than 31000 residence already, in the companies sector, around 1000 firms out of those who invested in the thermal renovation are to be renovated by the first quarter of 2025, in addition to the re-creation of environment-friendly centers in over 250 towns (check 3.2) starting the second quarter of 2026.(39)

* Belgium

The plan set annually targets to be achieved on the second quarter of each year starting 2023 and till 2025 reaching the number of 200264 residence (social and private) to be renovated while it sets clear plans for the public sector buildings based on the floor area to be renovated as following , 523852 square meter by the second quarter of 2024 and to reach 650 097 square meter after a year and the total of over 1.1 Million square meter by the middle of 2026. (40)

* Bulgaria:

Bulgaria's plan in residential sector includes the amount of primary energy to be saved by achieving a renovation based on floor area, as it aim to renovate over 67622800 square meter by the second quarter of 2026 which will reduce the primary energy consumption by 1070 GWh/year , in addition to 250 commercial buildings to be renovated by that time as well, in regard to the public sector buildings, over 600 Building with the floor area of almost 1.4 Million square meter to be renovated by the same time in Q2-2026. (41)

* Croatia:

The plan in Croatia set a very promising energy renovation of buildings as it aims for 37000 square meter in 2024 and 10 times more to be done by the second quarter of 2026 with 370000 square meters (check figure 9 for energy renovation) and following the same rate, 35000 square meter in 2024 and over 350,000 square meter to be rebuilt as part of the damages resulted from the recent earthquakes in the country, and it focused on the public heritage buildings renovation as it sets the goal of 35000 square meters to be done by the second quarter of 2026 and Croatia's plan include the human resources sector as well since it also plan the training of over 500 experts in the previously mentioned fields (42)

*** Czechia**

The upgrades in the residential sector included over 35,000 buildings started in 2023 and it aims the saving of 3.2 PJ (petajoule) of energy and 512 KT (Kiloton) of CO2 emissions per year while the renovation of public sector building by itself will save around 0.6 PJ of energy annually starting 2026 (43)

*** Denmark**

Denmark already has set the legalization side related to the energy efficiency goals in the industry and public buildings renovation rules back in 2021 and they aim to save 16 PJ(petajoule) by the end of 2024 while the renovation of public buildings (check 3.2) is to be done by the end of 2025, and by the start of 2026, the beneficiaries of the funds allocated for the project of replacing gas and oil boilers will be selected. (44)

*** France**

Even though There are no clear plans for the next years but already 700 thousand private buildings benefited from funding for the purpose of renovation, in addition to over 40 thousand social houses were renovated along with more than 20 million square meters of the public sector buildings. (45)

*** Germany**

Germany's plan focuses on funding and supporting the scientific research as it created "Municipal living labs" that are specialized in creating new authentic methods In energy transition sector and testing it in the real world which lead to the creation of 10 neighborhoods in 2023 which will be set as an idol example for future wider projects, in addition to that the plan aim to provide the funds to renovate over 30,000 residential property by the second quarter of 2026. (46)

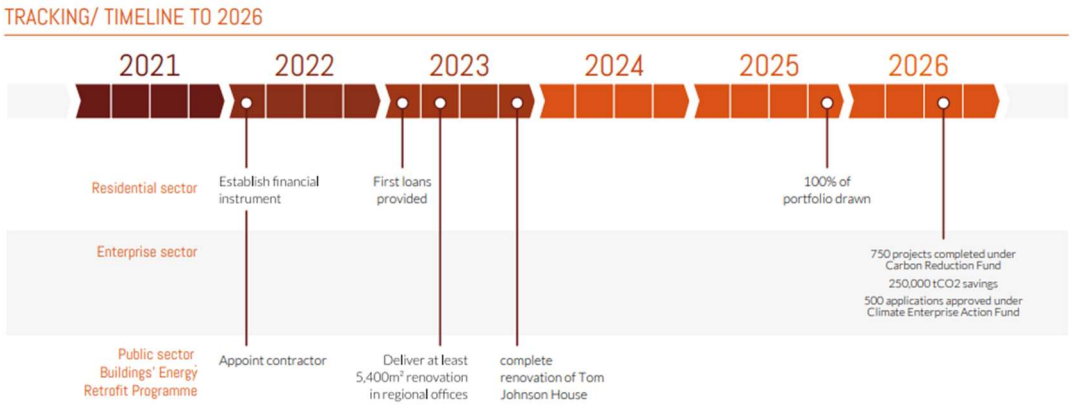
*** Greece**

In regard the residential sector, Greece's plan set the goal of over 150,000 houses which are evaluated as vulnerable energy consumers by the end of 2025, and also the public sector has a fair share of the plan with the total of over 350 improvement for the infrastructure buildings also by the end of 2025 (47)

*** Ireland**

As mentioned before in Ireland plan (check 3.2), the public sector has much attention and the following figure illustrate the time line for the different sectors until 2026

Figure 11: Source (48) Ireland's NRRP timeline from 2022 to 2026



*** Latvia**

By the end of 2026, Latvia's NRRP is expected to have most of its achievements acc which includes upgrades in 183 buildings where multiple families reside, in addition to i in apartment buildings, central government buildings, municipal buildings and comme ings which will achieve an annual savings of primary energy of 14,432 MWh , 4,456 M MWh and 11,498 MWh consecutively (50)

*** Slovakia**

By the end of 2024, Slovakia will accomplish the renovation of 18.000 residential single family houses and apartments and 60.000 square meter of floor area renovation of historical and public sector buildings and with the end of 2026 the progress would increase to reach 30.000 houses and apartments and 117.000 square meters in total based on the condition that those upgrades will achieve at least 30% primary energy saving. (52)

*** Romania**

Romania's plan timeline until the end of 2025 set only the goals of preparation for the actual development including training sessions and certifications and the registration start of each building energy passport , but in 2026 it aims to accomplish the deep energy renovation of the whole targeted public buildings (approximately 2.5 million square meter of floor area) which will lead to 0.07 TCo2 and MTep (53)

* **Slovenia**

Slovenia's Plan timeline clearly differentiated the administrative procedures deadlines from the practical steps as it already announced the call for the tender and had a first funding contracts back in 2022 and by the end of 2024 the projects will be selected to receive the funds and by the last quarter of 2026 it's expected that all investments will be finished, on the other hand on the practical level, 29 000 square meters of public sector buildings (especially those with high social importance and top level administration) are expected to be renovated by the end of 2024 and another 29 000 square meters by the second quarter of 2026, in addition to that, 36 000 square meters will receive technical upgrades, last but not least 10 000 buildings of those owned by the public will be renovated in the second quarter of 2026 (54)

* **Spain**

Spain NRRP's timeline didn't spread the renovation goals over phases but set the deadline on the middle of 2026 to renovate what is between 355 000 and 510 000 dwellings, at least 26000 residential building in areas with population of less than 5000 habitants and the minimum of 1,230,000 square meter of floor area of public sector buildings (55)

Outlining the timelines for the above 16 mentioned countries shows the different aspects and approaches of each as mentioned previously (check the summary of 3.2), but the timeline shows more details about each step taken or planned to be in the period between 2021 and 2026, what can be highlighted as unique measures is that Croatia included training the human resources as part of the plan while Germany has put the scientific research as one of the priorities creating "Municipal living labs".

Regarding the public buildings sector, the following figure is a brief about public sector share of each plan until the end of 2026.

Figure 12: Public sector in NRRPs

Country	Public sector plan
Belgium	650 097 square meter renovation by 2025
Bulgaria	600 Building = floor area of 1.4 million square meter by 2026
Croatia	35 000 square meter of Public heritage renovation
Czechia	0.6 PJ energy savings starting 2026
Denmark	16 PJ energy saving starting 2025
France	20 million square meters renovation
Greece	350 improvement for the infrastructure buildings also by the end of 2025
Ireland	5400 square meter renovation + renovation of Tom johnson House by 2026
Slovakia	60 000 square meter renovation by the end of 2024
Romania	Deep renovation for all buidlings allocated in the plan by the end of 2026
Spain	1.23 Million square meter renovation
Slovenia	58 000 Square meter renovation by the end of 2026 + 36 000 square meter technical upgrades

3. Material and methods

The primary sources are the results collected through a questionnaire which includes a combination of questions that are asked in order to understand the participants evaluation and approach towards public buildings from the energy aspect.

The survey questions the participants opinion about which public buildings should be given the priority to be upgraded and why they think it's important to apply those upgrades, In addition to collecting the related data about their universities or work places if they think they are energy efficient, and what is – in their opinion – the best way to reduce energy usage in the public buildings.

In regard of the first and second hypothesizes, the survey aimed to collect data about how Covid-19's lockdown affected their energy consumption and what was their reaction to that effect and what are the obstacles prevented them from taking an eco-friendly approach towards that, along with questioning the way their public buildings authorities handled that situation.

About the third hypothesis, the questionnaire aimed to collect data about how the participants dealt with the energy prices change after February-2022 and in case the effects reached their educational institution or their work place.

As for the secondary sources used are mainly the official European platforms like Eurostat, the statistical office of the European Union and the Eur-lex which gives access to the authentic Official Journal of the European Union and what related to EU commissions directives, along with other trusted open access scientific journals as MDPI and Science Direct.

4. Results and evaluation

4.1. Covid-19 pandemic and the quarantine effects over the energy sector

Covid-19 virus which was first noticed in Wuhan, China 2019 caused an international pandemic affecting millions around the world on every possible level as the affected people are not only the ones who actually were infected with the virus since the people around the sick person or the holder of the virus would also be affected in many aspects (56). But in order to fight the pandemic, all countries had taken several, different and serious measures and one of most important social regulations including wearing masks, social distancing and most important measures were about isolation of possible virus holders, quarantine and encouraging people to stay home by applying curfews and lockdowns (57).

It wasn't different in Europe as all European countries intervened to protect the population from the circulation of the virus applying similar measures as a response and it was on different levels varying from strict to soft regulations depending on the number of reported cases and based on the social, economic and medical needs and advice.(58)

As a logical consequence to the lockdown, many sectors were affected in the European union and the energy sector was one of them due to the changes in energy consumption, the objective of this section is to investigate the changes happened to the energy consumption before and after Covid-19 in both public sector and household sector.

But the energy usage is not only affected by the lockdown and the time people spent in their houses during Covid-19 lockdowns, even though the need to warming the houses has increased but the green deal package and its sub-program lead to better energy efficiency in all sectors including household (check 2.3 / energy efficiency) which assumes that in case there was no previous up-grades concerning energy efficiency the energy consumption would have increased more.

Another factor should be taken into consideration is the fact that even though there was a larger need for energy in the household sector but not all people were able to keep their houses warm enough and that explains the slight difference in energy consumption between 2019 and 2020 (248,657.991 in 2019 and 248,742.692 in 2020) (Thousand tons of oil equivalent).

(check figure 1 and figure 2 for relevant illustration about the year 2020)

As the percentage of people who weren't able to keep their houses warm in 2020 has increased to reach 7.5% after it was 6.9% in 2019 but with that percentage of people decreased again to be 6.9% in 2021, the energy consumption in the household sector increased to reach 260,167.082 Thousand tons of oil equivalent. (59)(60)

The following figures (13) and (14) show the final energy consumption in household sector and the percentage of people who weren't able to keep their houses adequately warm over the period between 2016 and 2022 and the noticeable change in the results in 2022 can be assumed we can as a consequence of the Russian war on Ukraine and its sub-consequences on the energy sector in Europe.

Figure 13: Household sector final energy consumption from 2016 to 2022. Source: Eurostat (59)

Final energy consumption in Household Sector							
Year	2016	2017	2018	2019	2020	2021	2022
Thousand tons of oil equivalent	251,870.79	252,719.44	250,749.37	248,657.99	248,742.69	260,167.08	242,430.23

Figure 14: Percentage of population who were not able to keep their homes warm from 2016 to 2022 Eurostat Source: (60)

Year	2016	2017	2018	2019	2020	2021	2022
Percentage of people not able to keep their houses warm enough	9%	8.10%	7.60%	6.90%	7.50%	6.90%	9.30%

So as per the above, it's shown that the energy consumption in the household sector stayed steady from 2019 to 2020 and has increased by approximately by 4.6% in 2021 (11510 thousand tons of oil equivalent: Ktoe) comparing between 2019 and 2021.

So, 248657.99 Ktoe was what needed to be consumed by 93.1% of the population to stay adequately warm in 2019

While 248742.69 Ktoe was what needed to be consumed by 92.5% of the population to stay adequately warm in 2020, and by a simple calculation we can assume that if the same percentage of people were able to keep their homes warm in 2020 the same as 2019 and 2021 the energy consumption would have been 250355.461 Ktoe

$\frac{248742.69}{92.5} = \frac{X}{93.1}$ ---> $X =$ 250355.461 (assuming X is the final energy consumption in 2020 if 93.1% of people were able to keep their houses adequately warm to eliminate the factor of people's ability to do that)

and that shows an increased pattern of final energy consumption in the household sector between 2019 to 2020 and reaching 2021.

On the other hand, and by looking at the public sector final energy consumption we can notice a drop of consumption by approximately 5.83% from 2019 to 2020 as it was 128875.741 Ktoe in 2019 and 121,385.640 in 2020 with another increase to 129,372.988 in 2021 as per Eurostat and as seen in figure 15.

Figure 15: Commercial and Public Sector energy consumption from 2016 to 2022Source: Eurostat (60)

Year	2016	2017	2018	2019	2020	2021	2022
Final energy consumption by commercial and public services sector (thousands tons of oil equivelant)	130,187.179	133,883.152	131,976.670	128,875.741	121,385.640	129,372.988	121,671.074

And that lead us to realize that the sum of the final energy consumption in the household sector and public services sector in 2020 has decreased than it was in 2019 from 377533 Ktoe to 370128 Ktoe in 2020 and increased again to 389540 Ktoe in 2021 which means that in 2020 the energy consumption of both these two sectors combined has dropped.

As a summary to the above, the numbers indicate to the fact that the household sector energy consumption increased during Covid-19 in the years 2020-2021 while the public sector buildings consumption had decreased only in 2020, and that decrease is not equal to the increase happened in the household sector. Which lead to the conclusion that the energy consumed in both sectors together has increased in 2020 and 2021. Including the year 2022 in this conclusion might give us false indicators as another big change happened which is the Russian unprovoked aggression on Ukraine and the exceptional change in energy resources prices and that is discussed in the following chapter 5, "The Consequences of the Russian war on Ukraine in the energy Sector in Europe"

The influence of Covid-19 and its consequences as lockdowns, quarantines were for sure negative on the energy sector but the previous measures which were taken by the EU represented by the green deal, fitfor 55, just transition mechanism and the renovation wave established a form of protection against any type of energy insecurity and without those measures we could have whitened even more disastrous crisis than what we went through.

4.2. The Consequences of the Russian war on Ukraine in the energy Sector in Europe.

Energy resources can be categorized into two main categories, traditional and renewable, and a country's dependency on traditional resources can be based on multiple aspects including the availability of the natural resources, their price and secure supply chains and those factors are affected by changes geopolitics and that – in addition to the environmental reason – can be an important reason for more dependency on renewable energy resources (62)

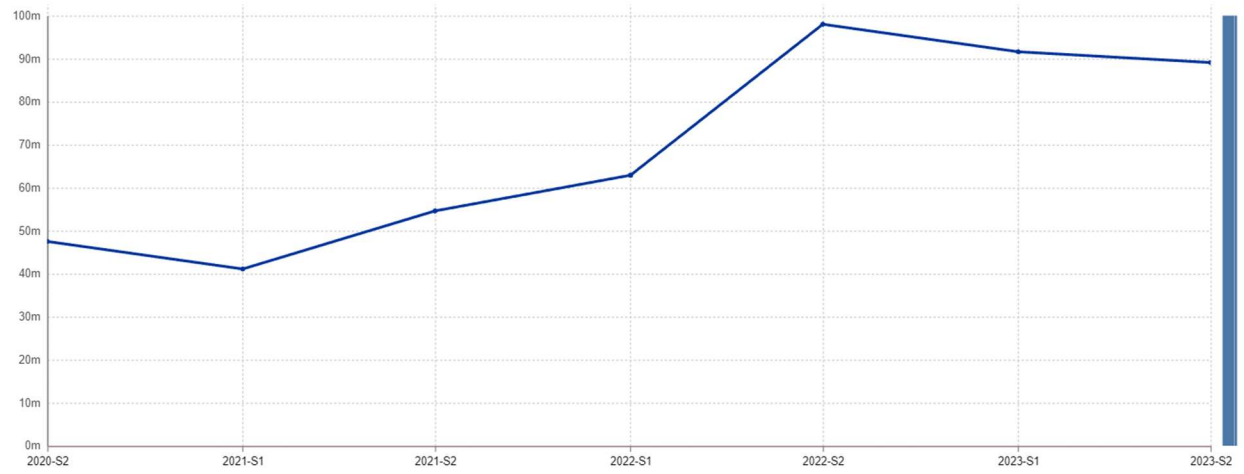
In addition to the EU commissions efforts in reducing energy consumption which are mentioned throughout the whole article, reaching the percentage of 45% dependency on renewable energy resources by 2030 is one of the main goals (63) and one representation of that is the "clean energy for all package" (10)

Since 2009, many studies highlighted the danger around the energy security in the EU countries, especially the ones who rely on limited number of resources which most of them are external sources generating over 50% of the energy consumed in the EU (64) and in 2021 Russia by itself provided over 41% of natural gas, 23% of oil and 47% of coil imports to the EU (65) and with the start of the Russian aggression against Ukraine in February 2022, the unsureness about the supply chains continuity in energy raw resources from Russia to the EU encouraged the member states to act fast towards the goal of providing the energy security for the union's countries taking effective measures were represented in relying on various different suppliers to make sure to reach the start of 2023 with all the Gas storages being almost full, along with the support to small-medium businesses that are dependent on energy, due to the unpredicted increase in energy prices.(66)

On the other hand, and thankfully to previous initiatives taken by the EU such as the firfor55 as part of the green deal which was legislated previously(check 2.5), the first steps of energy security and less dependency on Russian energy supplies were already taken by boosting the renewable sources infrastructures, for example, in 2021 which was before the crisis , 22% of the EU energy consumption was coming from renewable resources (67) but, the goals became more ambitious and the expectations went higher, as the old goal was to achieve 32% of consumption to be coming from renewable resources but now the new aim is 42.5% instead after the fast pace in achieving successful results, for instance, in 2022 the solar energy resources increased by more than 60% than 2021 and kept going up gradually in 2023, while the energy coming from the wind went up by 67% in just two years from 2021 to 2023.(66)(67) And that played a big role in adjusting the energy prices for consumers after they kept going up until they reached the peak in the second half of 2022 and recorded 0.0980 Euro for each Kwh of natural gas.

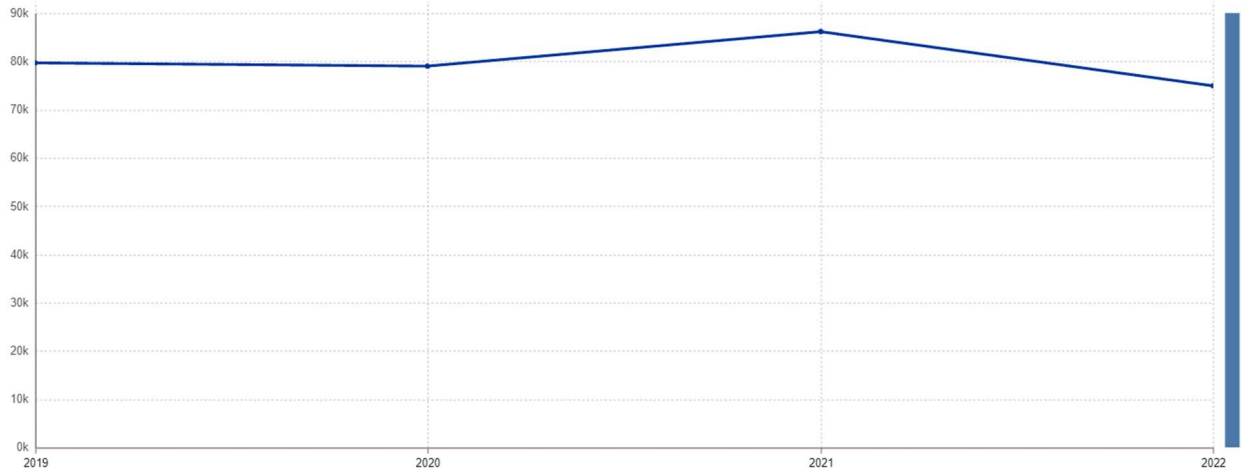
The following figure shows the gas prices starting the second half of 2020 until the end of 2023 and we can notice how they declined starting 2023.

Figure 16: Source Eurostat: Gas prices for household consumers - bi-annual data (68)



With the gas prices were going up in 2021 and 2022 that reflected directly on the household consumers using natural gas as a source of energy in those 2 years as we can see in figure 17 that the final energy consumption based on natural gas went through a considerable decrease in 2021.

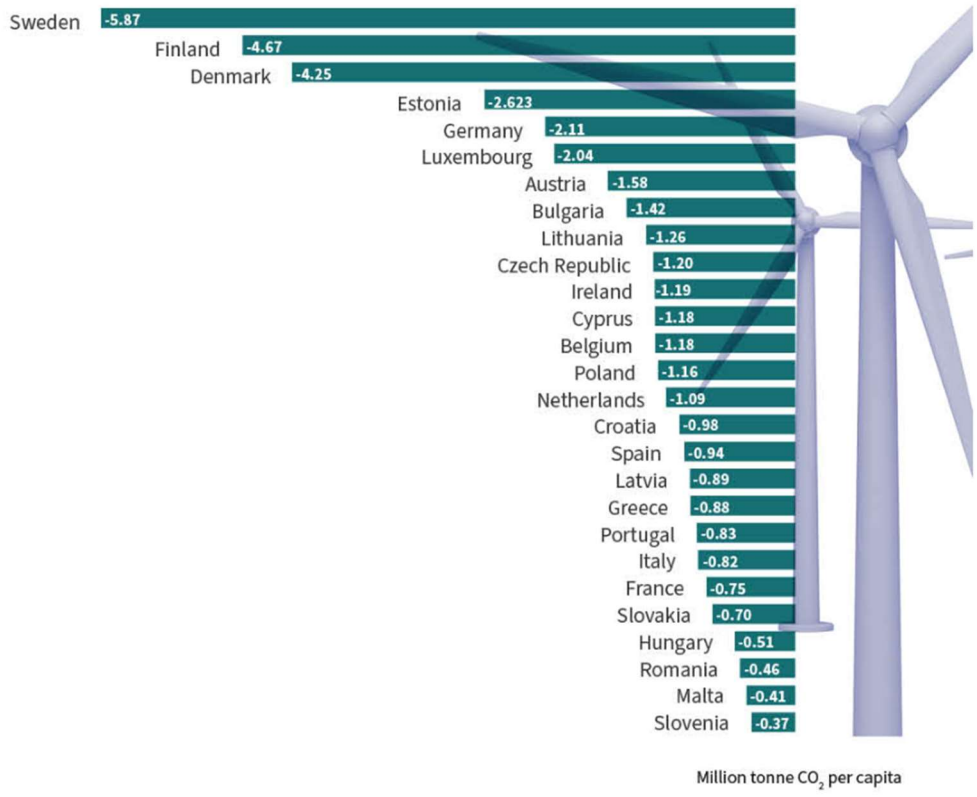
Figure 17: Source Eurostat: Final energy consumption in households by type of fuel by thousand tons of oil equivalent (69)



The less dependency on natural gas was aligned with another decline of relying on solid fossil fuel as the household sector in Europe consumed 6483.464 Ktoe in 2021 and decreased to only 5477.280 Ktoe in 2022 which is around 15 % decrease in one year and it's important to mention that just 10 years ago, In 2011 the consumption of solid fossil fuel in the sector was almost double than now. (69)

Relying on renewable energy not only helped making big steps into energy security but also plays a major role in increasing air quality and improving the environment, the following figure 18 shows the amounts of Co2 emissions avoided per person and that's only in 2021 because of the bigger reliance on renewable resources.

Figure 18: The amounts of Co2 emissions avoided per person and that's only in 2021 because of the bigger reliance on renewable resources in 2021. Source: (67)



With that being illustrated, the renewable resources share in producing energy in multiple sectors has scored ambitious levels, as more than 40% of electricity produced in 2022 was coming from renewable resource, along with 25% of energy used in heating and cooling and 10% in transportation (70) and relying on various renewable resources was one of the reasons that helped achieving those good numbers as the renewable resources used in electricity production were 37.5% Wind, 29.9% Hydro, 18.2% Solar , 6.9% solid biofuels and 7.5% were from other renewable resources

(71) and checking the details of those numbers as shown in figure 19 as per each member state we can notice an increasing patter with the percentage of electricity produced by renewable resources since 2016 till 2022 with Iceland, Norway and Sweden had the highest share of that with more than 80% and only five European countries had less than 20% of their electricity produced renewably while Finland, Lithuania, Greece, Netherlands and Norway achieved more than 5% increase from 2021 to 2022

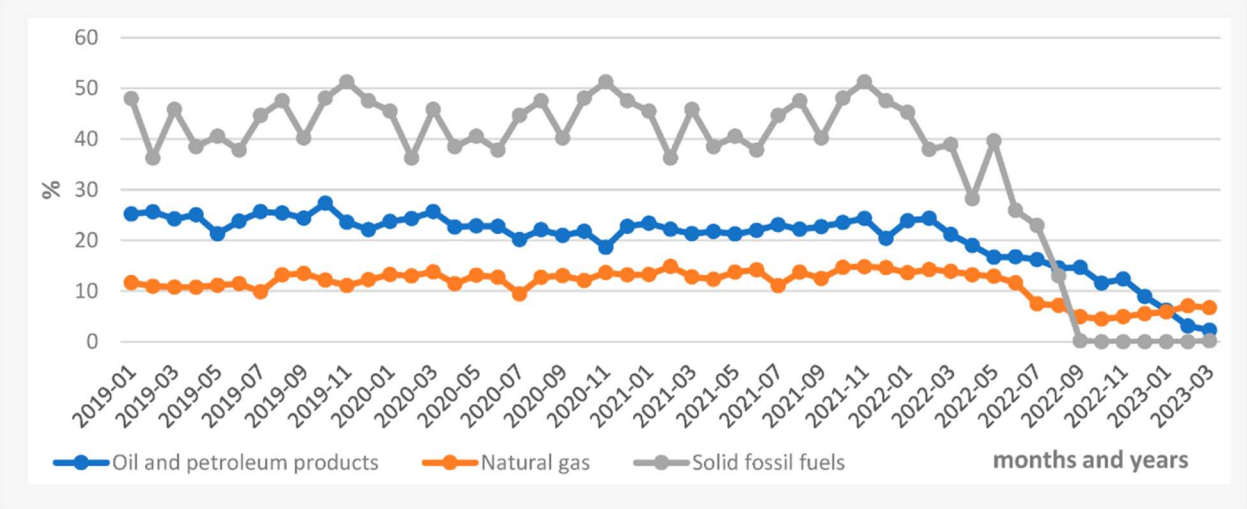
Figure 19: The renewable resources share in producing energy by percentages
Source: Eurostat (72)

	2016	2017	2018	2019	2020	2021	2022
European Union	**30.172**	**31.104**	**32.134**	**34.086**	**37.408**	**37.754**	**41.174**
Belgium	15.834	17.214	18.886	20.817	25.122	26.012	29.106
Bulgaria	19.147	19.022	22.355	23.509	23.586	21.413	20.235
Czechia	13.615	13.654	13.711	14.046	14.81	14.468	15.499
Denmark	53.717	59.94	62.394	65.347	65.323	72.916	77.22
Germany	32.273	34.612	37.591	40.604	44.215	43.88	47.637
Estonia	16.194	17.583	19.679	21.998	28.293	29.188	29.108
Ireland	27.069	30.318	33.317	36.46	39.055	36.375	36.776
Greece	22.657	24.464	26.001	31.295	35.856	35.934	42.408
Spain	36.676	36.465	35.236	37.131	42.944	46.001	50.902
France	19.209	19.933	21.131	22.389	24.819	24.775	27.323
Croatia	46.667	46.437	48.139	49.783	53.816	53.471	55.518
Italy	34.012	34.104	33.93	34.969	38.081	35.996	37.102
Cyprus	8.587	8.911	9.357	9.756	12.041	14.84	16.963
Latvia	51.251	54.352	53.499	53.423	53.357	51.399	53.305
Lithuania	16.872	18.255	18.408	18.79	20.166	21.278	26.461
Luxembourg	6.674	8.055	9.115	10.863	13.887	14.216	15.936
Hungary	7.292	7.513	8.306	9.969	11.904	13.66	15.342
Malta	5.714	6.845	7.702	7.485	9.489	9.649	10.126
Netherlands	12.55	13.812	15.171	18.23	26.407	33.266	39.916
Austria	72.521	71.626	74.189	75.067	78.204	73.97	74.67
Poland	13.342	13.082	13.027	14.356	16.237	17.166	21.009
Portugal	53.99	54.168	52.186	53.774	58.032	58.433	60.959
Romania	42.712	41.965	41.793	42.616	43.374	42.676	43.725
Slovenia	32.056	32.425	32.307	32.632	35.095	34.976	37.005
Slovakia	22.513	21.343	21.499	22.103	23.066	22.403	22.901
Finland	32.716	35.044	36.539	37.969	39.564	39.583	47.925
Sweden	64.869	65.909	66.228	71.234	74.495	75.76	83.34
Iceland	95.31	93.376	98.497	100.64	102.709	99.536	99.193
Norway	105.638	104.85	106.829	110.445	113.802	113.642	120.01

And in 2023 and as per the Union state of energy report 24.10.2023, In May 2023 and for the first time, the share of electricity produced by solar and wind generation was more than the share of it produced from fossil fuel which is considered a big milestone into the goal of terminating any dependency on imports from Russia in raw materials In the energy sector in order to stop using manipulation in gas prices as a pressure tool against the EU. (73)

By looking at figure 20 , the percentage of Russian energy raw material imports to the EU over the last 5 years, we can notice how the fossil fuel imports dropped from 40% to 0 in less than a year from the start of the war, while the oil and petroleum declined steadily to less than 5% in march 2023 while natural gas represented less than 10% in July 2022 for the first time in 4 years and remained under that percentage since then. (64) and that was achieved by relying on renewable resource and the expansion of exports from the US and Norway. (73)

Figure 20: The percentage of Russian energy raw material imports to the EU between 2019 and march 2023 Source: (64)



The above can be briefed in the point that almost immediately after going out from the first challenge of Covid-19, the energy sector confronted a harder one due the Russian aggression on Ukraine and its direct effect on the supply chains of energy resources and gas prices, where prices increased and reached its peak in the second quarter of 2022 and the availability of those resources was under question.

Even though this section focuses on how the EU improved its dependency on renewable resources and their share of the production, along with not letting go of the natural resources but replacing those coming from Russia with more reliable supply chains from the USA and Norway instead of Russia, but what relies beyond those two alternatives is the fact that less energy is being needed year by year thanks to the improvement in the levels which the energy efficiency has reached in Europe.

As a result, to many reasons including, but not limited to, the renovation NRRP plans (revise 3.2 and 3.3) which played a great role in improving the energy efficiency. In 2022 the final energy consumption was 940.5 Million Ton resulting from 1257.1 Million Ton of primary energy consumption (check figure 4).

It's not doubtable that without those plans we would have required more final energy usage and consequently a lot more primary energy and that will make the share of renewable energy is less influential, so relying on renewable resource could be considered the complement part of what was already been done which is increasing energy efficiency and reducing the needed consumption.

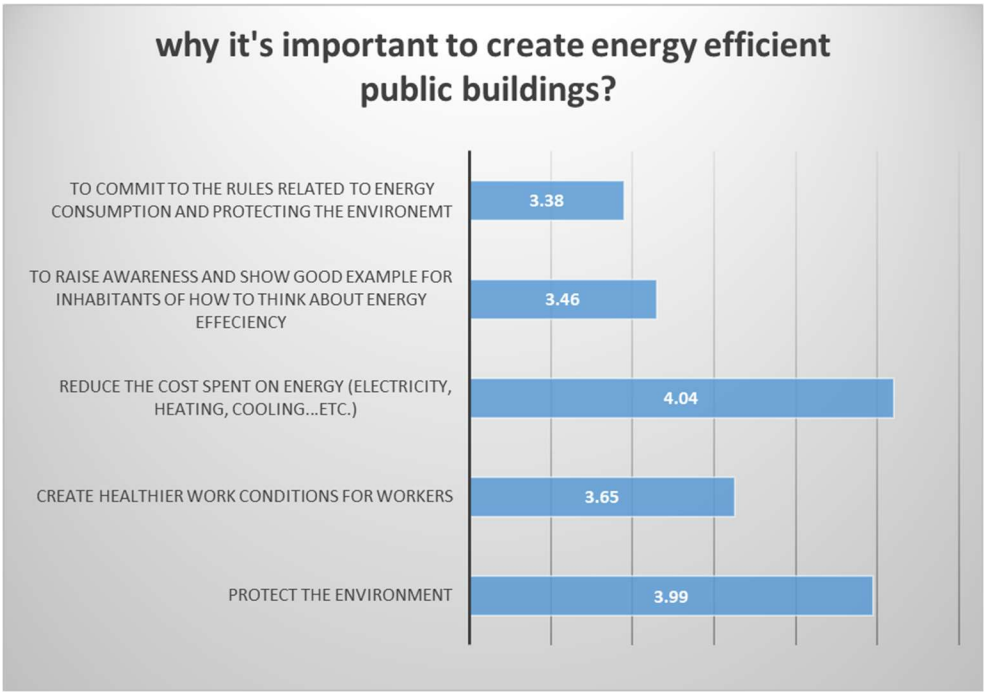
4.3 Results of the questionnaire

Since the survey questions were about specific topic, the answers taken into consideration is preferable to be from high level degrees holders, as around 55% of them hold Bachelors' degrees, around 40% with a master's degree and 5% hold PHD and they also reside in different countries with the majority of them currently live or used to reside in Europe.

The age group which dominated the answers was the one between 26 and 30 years old as more than 45% were from that group, with 25% for those who are younger and around 23% for those in their thirties, with less than 3% for participants who are older than 40 years old, and in order for the answers to cover the variety of households in terms of the number of people, around 45% of household include 3 or 4 people , while around 38% include 1 or 2 and the remaining were 5 people or more in the same household.

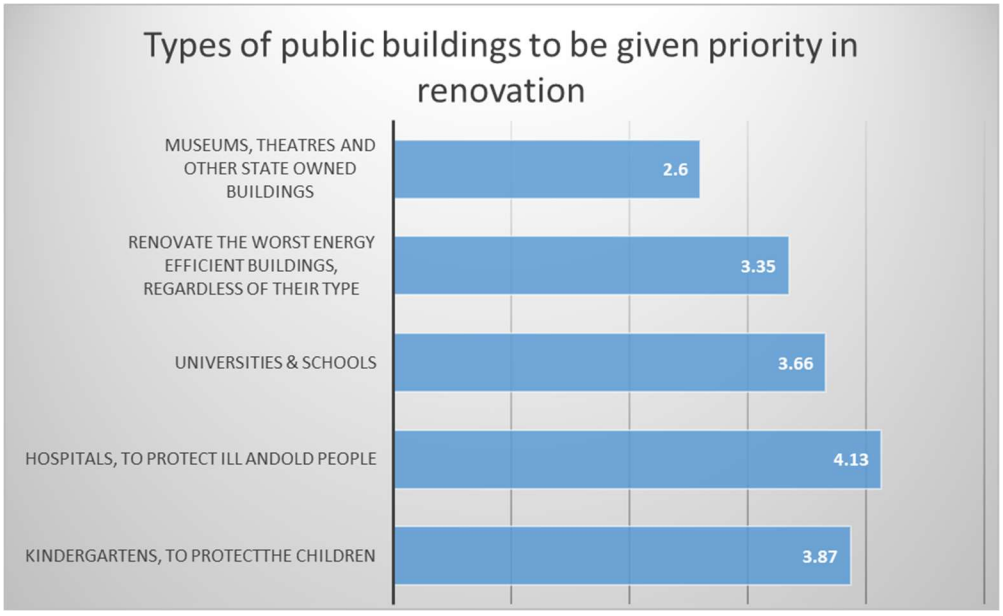
The way the participants looked at public buildings from energy perspective varied as it was important to know why they think it's important to have energy efficient public buildings with 5 reasons to choose from, and on a scale of 1 to 5, by calculating the average importance for each reason – as per the answers – the most reason came for reducing energy cost bypassing protecting the energy, creating a healthier work environment for employees, raising awareness and committing to rules as we can see in the following chart.

Figure 21: why it's Important to create energy efficient public buildings. Source: own work



Using a similar method, the survey asked which type of public buildings should be given the priority in being renovated, and not surprisingly, hospitals were the priority.

Figure 22: Types of public buildings to be given priority in renovation. Source: own work



The above answers for the two questions showed very close results which indicates to not having the same thinking regarding public buildings, but the majority of the participants agreed on the fact that reducing traditional energy consumption must happen by having a complex solution of increasing energy efficiency and relying on renewable resources and not one of them only as over 90% shared that opinion.

In regard to how Covid-19 affected the participants energy consumption, around 33% answered that their consumption increased between 40% and 60%, while around 23% and 26% think that their consumption increased by 20% to 40% and 60% to 80% subsequently.

Lighting and using electricity appliances were the main reasons for that increase rather than heating or cooling or other reasons.

Figure 23: Energy consumption increase during Covid-19. Source: own work

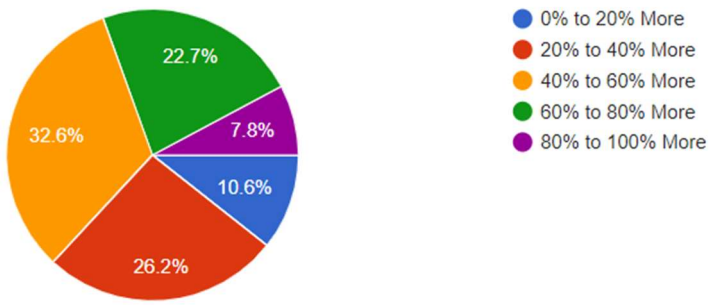
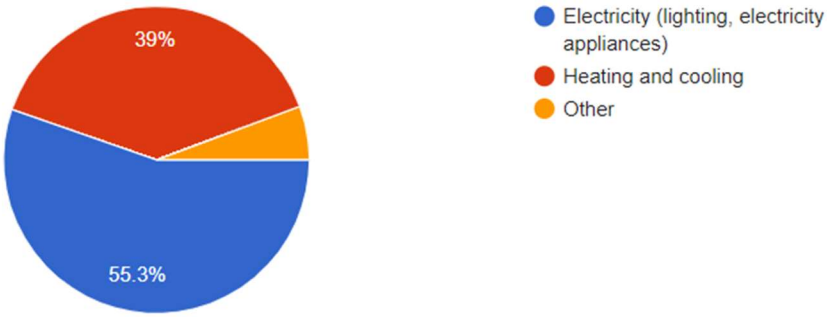


Figure 24: Reason of energy consumption increase during Covid-19. Source: own work



Even with that increase, around 75% answered that neither them or their work or education institution used alternative renewable energy resource during Covid-19 even though the majority answered that were they work or study is not energy efficient building.

But when asking the same question but for a different period (after February 2022) when the Russian war on Ukraine started, the percentage of those who started using alternative renewable energy resource in their houses reached 30% and 35% answered that were their work or educational institution started using renewable energy resource only after February 2022.

And to evaluate the reasons for using or not using renewable resources, the motive behind using them was only 20% for protecting the environment and 80% only for reducing energy cost.

And for those who didn't install renewable energy appliances in their house, the reasons behind that were 65% because of the cost needed to install them while the others reasons were almost equally divided between either because they don't provide sufficient energy for them or their buildings are not well established for that.

5. Conclusion and proposals

The collected results showed a mature understanding regarding public building energy but unfortunately the motives came mainly focusing on the financial aspect and that would raise a concern about important it is to raise the awareness regarding energy efficiency and renewable energy and that only indicate of how critical it was to have the just transition mechanism as part of the green deal which is mentioned in (2.4 European Green Deal goals and opportunities)

The results came somehow aligning with the first and second hypothesis that Covid-19 increased the energy consumption in the household sector by the average of 47.6% in total (for the participants) when the results in the public sector only showed a decrease of 5.83% (check 4.Covid-19 pandemic and the quarantine effects over the energy sector)

As for the third hypothesis, the results indicated a huge harmonization with it, since the major reason for participants to use renewable energy was the high cost of traditional energy and the highest share of them starting using that when they were affected directly after February 2022 and not during covid-19 or before.

6. Suggestions and recommendations

Based on the results of the survey along with the research done within this study, it's important to highlight that each country or community can deal with energy poverty and increase the energy efficiency in all sectors and specially the public one, though various approaches and within different timetables taking into consideration the urgency of the needed actions.

But few common goals and general methods should be taken into consideration either on the personal level for residents and house owners or on the public level in regard of public buildings.

Based the survey along with the third hypothesis assumptions, individuals and also organizations tend to take actions faster when the impact is direct and already happened which push us to understand how urgent it is to be ready in advance for any crisis in the energy sector instead of dealing with the problem after it occurs, and that would demand higher level of awareness regarding energy efficiency and renewable resources, for example for the house owners:

1- Renovation should focus on energy renovation and the payback time would be shorter

2- Establishing the house/apartment to be compatible with renewable energy appliances

As the just transition is one of the green deal applications in Europe, the consumers ability to adapt with the transition in not ignored , but as the survey suggested that most participants found the high cost of being dependent on renewable energy is the main reason behind not using it privately in their residence, more thoughts and efforts should be evaluated as energy loans or aid for example

which can be distributed for the exclusive purpose of renovation or installing renewable energy appliances (e.g. solar panels).

In addition to not relying on one source of renewable energy but various sources to guarantee its security and availability (Hydro, Wind, Solar) and even with that, the renovation – energy renovation – should priority specially for the public buildings in order for the renewable resources be sufficient enough for them.

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9. Table of Figures:

The Need and Opportunities to Reduce Energy Usage in Public Sector Buildings

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Reducing energy consumption, especially the energy that relies on fossil fuels and more dependency on renewable resources has been necessary due to the environmental results caused by generating and consuming it, leading to massive emissions of greenhouse gases. Finding ways to decrease the energy consumption in the public sector, and particularly its buildings will have a major role in accomplishing that since it's one of the most energy consuming sectors. The objective of this study is to highlight the recent efforts taken by the European Union to reach climate neutrality in Europe by the year 2050 through the various measures taken place such as the Green Deal, the renovation wave, fitfor55 and the mechanism of applying those measures in a fair direction by applying the just transition mechanism, taking into consideration how urging the demand is for such measures on the environmental, economic and social aspects and what will be the benefits of increasing the energy efficiency relying on renewable energy in the public buildings. Additionally, to show the effects of the energy sector crisis caused by the Russian war on Ukraine and how the measures taken, helped lead to more dependency on renewable energy sources, especially since it came along with -or shortly after- The COVID-19 pandemic which also caused energy disturbance because of the rapidly increased demand by the household sector due to the quarantines and the supposed reduced energy usage by other sectors such as the public sector comparing the energy consumed in the different sectors throughout the related timeline would help give a better understanding of how the energy sector was affected, while precisely understanding how people from different countries and mainly Europe reacted to that energy crisis on their personal level in their household or how their workplaces or educational institutions through the applied research method.

DECLARATION

Nabky Mehrez (NEPTUN code: **NRHT9A**) as a consultant, **I declare** that I have reviewed the thesis and that I have informed the student of the requirements, legal and ethical rules for the correct handling of literary sources.

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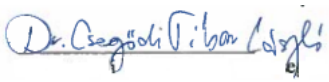

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