Politická ekonomie 2025

Volume 73 (6)
https://doi.org/10.18267/j.polek.1468
Open Access

VŠE / PRAGUE UNIVERSITY OF ECONOMICS AND BUSINESS

Sustainable Buildings and Subsidy Policy: Challenging the Energy Transition Context

Šárka Tomanová, Marian Piecha

Šárka Tomanová (*corresponding author*, email: sarka.tomanova@cluedin.eu), Faculty of Economics, Prague University of Business and Economics, Czech Republic

Marian Piecha (email: piecha@post.cz), Ministry of Trade and Industry; Faculty of Economics, Prague University of Business and Economics, Czech Republic

Abstract

Reduction in energy demand, application of circular economy principles and implementation of sustainable policies are the key pillars of sustainable development. Buildings and the construction sector are significant consumers of both energy and resources. Therefore, a crucial policy objective is to mediate investments in sustainable renovations to make buildings more energy-efficient, less water-reliant and constructed with less waste. The EU Taxonomy, the bible of sustainability, sets the technical criteria for defining sustainable investments. However, do the criteria introduce a new approach, or is it more of another European attempt to improve the governance of sustainability? This article evaluates the impact of the EU Taxonomy regulation on Czech subsidy policy. It uses a comparative analysis of building renovation programmes with a focus on energy efficiency conditions. The article presents a correlation model and mathematical formula for calculating the impact rate. This can be widely used to evaluate financial tools in terms of sustainability. The study reveals that building renovation programmes have made significant progress in reducing the energy demand and managing the waste streams during the construction phase. However, progress in water management has been limited. The impact of sustainability policies on investments in building renovations is noticeable. Moreover, the level of technical detail of European policies is constantly increasing, and this trend is likely to continue. This will have a further effect on national public administration and budgets.

Keywords: EU Taxonomy, subsidy, sustainability, building renovations, regulatory impact

JEL Classification: E61; L74; Q56

Citation: Tomanová, Š., Piecha, M.: Sustainable Buildings and Subsidy Policy: Challenging the Energy Transition Context. *Politická ekonomie* 2025, 73 (6), 926–947, https://doi.org/10.18267/j.polek.1468

1. Introduction

This article broadly examines the European instruments – regulation and subsidies – through which the EU realizes most of its sustainable development efforts. We, the authors, have a long-standing professional and academic interest in the issue of state aid policy, European policies and regulations and their impact on the competitiveness of Czech industries (especially small and medium-sized enterprises). By studying these instruments using a combination of qualitative and quantitative methods, we aim to contribute to a realistic picture of the current state of the EU system. Through independent research in the field of European policy, we try to bring fresh, unbiased ideas and the opportunity to consider the social impact of the instruments implemented from an inner and outer perspective.

The European Union has operated the carrot and stick method since the European Economic Community was established in the 1950s. The term "carrot" is used to describe a subsidy, which is defined in the Cambridge Dictionary as "money given by the government as part of the costs of something, to encourage it to happen". The term "stick" is used to describe the specific conditions set by the government, which determine the part of the costs of something to encourage it to happen. As the system evolved, the condition-reward structure became increasingly complex. In addition to the state aid regulation and conflict of interests, the environmental aspects have become the prominent issue. This is particularly evident in the context of subsidizing investments.

Since the establishment of the United Nations' International Panel on Climate Change in the 1990s and the signing of the Kyoto Protocol, there has been a gradual evolution of energy and climate policy. The reduction of greenhouse gas emissions was the initial priority, followed by the enhancement of energy efficiency and the deployment of renewable energy sources. To implement these priorities, the EU established a regulatory framework comprising targets and terms designed to facilitate the fulfilment of the obligations. Between 2007 and 2021, three major legislative packages were approved (20-20-20 targets for 2020, Clean Energy for All, Fit for 55), which increased the targets and shortened the terms. It can be observed, however, that recent economic developments indicate that increased regulatory burdens result in higher operating costs for companies, reduced productivity and overall competitiveness of the EU.

The regular and frequent updates to climate and energy legislation result in more detailed technical specifications for regulated sectors. The traditional view of law as a minimum of ethics has been superseded by technocracy, with the goal of unifying the system across member states. However, unification requires expert negotiation between individual member state administrations and the EU administration to ensure that national systems remain functional and as simple as possible. It is not only regulations that are subject to frequent changes, but also subsidy pro-

grammes. The lack of clarity and frequent changes to the conditions of the subsidy programmes create uncertainty and increase the risk of applicants losing out on the subsidy, which requires a considerable amount of money to obtain. In this regard, it was necessary to identify the extent of modifications that had occurred between the previous and the current programming period and to gather pertinent data to assess the impact of the new environmental legislation.

RQ 1: Is there a big deviation between previous (2014–2020) and current (2021–2027) subsidy programmes in terms of sustainability progress?

This paper contributes to the integration of scientific disciplines and the interdisciplinary approach needed to solve current societal challenges. Sustainability and energy transition in subsidized building renovations show the need for interdisciplinary research. It covers European law, public finance, EU programme funding, environmental economics and technical fields such as building physics or the technical equipment of buildings. Economic research has been relatively silent on the technical effectiveness of programme funding, even though subsidies represent one of the leading implementation tools of the sustainability policy enshrined in the Green Deal plan. Our objective was to fill a gap in the academic literature by evaluating the effectiveness of existing instruments, with a focus on subsidies, in achieving the objectives of new political ideologies.

RQ 2: Are the renovations in current subsidy programmes more sustainable?

The most recent comprehensive change in the field of climate policy and subsidies was the implementation of the EU Taxonomy regulation in ongoing subsidy programmes. The EU Taxonomy regulation, especially the technical annexes, is nowadays the most complex directive affecting the financial markets within the EU. All the programmes under the Recovery and Resilience Facility (RRF), the multi-financial framework and the emission allowances had to be continuously adapted to the current European conditions. It was therefore necessary to assess the extent to which this technical regulation affects subsidies (in a narrow context) and its potential to trigger social change (in a broader context).

RQ 3: Is the impact of the Taxonomy regulation on subsidy programmes perceptible?

This article also aims to explore how the technical parameters of sustainability have changed in recent years. This is a contribution to the current professional, political and academic discourse that relativizes the positive aspects of the European Commission's technocratic approach to regulation and funding programmes. The instability and robustness of laws have a detrimental impact on the continuity of social arrangements and thus have implications for competitiveness.

RQ 4: Which technical parameters of buildings are progressive or regressive compared to the previous subsidy programmes?

2. Literature Review

The political concept of sustainability or sustainable development was first introduced in the Brundtland Report issued in 1987 (Kuhlman, 2010). It highlights that sustainable development should meet the needs of the present without compromising the ability of future generations to meet their own needs. The concept is based on three pillars: social, environmental and economic. It also considers the depletion of natural resources, which cannot be substituted by new technologies. However, according to Solow (1993), development and sustainability are in constant tension. The goal of development is to increase human welfare, which can lead to the loss of natural resources. This loss is mitigated by substituting natural resources with capital. According to Solow, there is an optimum rate of exhaustion where the social benefits, expressed as rent, outweigh the social costs of losing resources. Rents must be invested in productive capital to compensate for the loss to future generations, not consumed.

According to official documents of the European Commission, buildings account for approximately 40% of the total energy consumed within the EU. Consequently, over the past 15 years, buildings have undergone a significant energy transition, driven by various political tools. Regulations and subsidies have been the primary tools used to encourage sustainable investment (Hondeborg *et al*., 2023). In contrast, the new regulation has had a significant impact on the construction of new buildings. However, a more challenging task is to renovate existing buildings in a sustainable way. According to a case study from Spain (Husiev *et al*., 2023), numerous barriers to sustainable renovations lie at the district level. These include a lack of awareness and capacities, resistance to change, the passive role of users, the absence of governance tools for decisions at the district level, incompatibility with other local legislation, *etc.*

The literature review reveals that the European Union is not the only entity grappling with the challenge of energy transition in buildings. Other system-level tools have been developed to enhance the efficiency in the USA, China and Switzerland, among others. In addition to regulation (Ewing *et al*., 2022) and subsidies (Wang *et al*., 2022; Huang and Lin, 2022; Hondeborg *et al*., 2023; Čermáková *et al*., 2023; Zubíková *et al*., 2023), the prevailing trends in implementation of ICT solutions can be observed, such as fintech (Pata *et al*., 2003, 2024; Mahmood, 2024), microgrid systems and decentralised solutions (Ibekwe *et al*., 2024) and market mechanism improvements (Wang *et al*., 2022; Huang and Lin, 2022). This study focuses on the regulation and subsidies, which are currently the most prevalent tools in the EU and require in-depth examination with the objective of enhancing the system.

In the context of the European Union, the regulation associated with the Green Deal continues to represent a pivotal instrument for facilitating the transition to a more sustainable energy system. The publication of the new EU Taxonomy regulation in 2020 was seen as a promising step

towards the unification of disparate systems within member states (Jourdan-Andersen and Brunt, 2022). The EU Taxonomy is designed to regulate financial investment flows through the establishment of specific technical parameters. The executive subjects of the policy are financial market participants, corporate bond issuers and other large companies that are required to disclose their financial statements. Moreover, the European Union has utilized the EU Taxonomy criteria in a multitude of subsidy programmes. However, some studies (Alessi and Battistan, 2022; Norang *et al*., 2023) have demonstrated the uncertainty and implementation risks in the financially and industry-specific construction sector. Furthermore, stakeholders have disputed the technical screening criteria formulation. Lucarelli (2023) highlighted the unambiguous sector specification within the EU Taxonomy, which was verified by over 130,000 EU firms.

The existing literature indicates that further discussion and refinement of EU regulation is necessary. Nevertheless, it has been demonstrated that a more rigorous technocratic approach to legislative revision is not the optimal solution.

3. Research Gap

The literature review revealed several tools that could be employed to facilitate the energy transition. It was found that regulation and subsidies continue to be the prevalent instruments in shaping the landscape of sustainable investments in the present-day EU. The EU Taxonomy has emerged as the primary directive for determining the level of sustainability in investments.

Nevertheless, the impact of this regulation on future sector investments has not yet been sufficiently described in the academic literature. This is particularly evident in the context of subsidised investments in building renovation. It remains unclear whether the EU Taxonomy has had a significant impact on the shape of subsidised investments, whether the Directive merely seeks uniformity for renovations across the EU or it is more of another European attempt to improve the governance of sustainability.

Further research is required to ascertain whether the regulation in question has indeed a key influence on shaping the building renovation subsidies. Furthermore, the research should comment on whether this regulation introduces fundamentally new insights or merely expands the bureaucratic influence through direct regulation.

4. Methods and Data

4.1 Data

The study examines the impact of regulation on subsidised investment in buildings (Taxonomy impact as the dependent variable). In this context, three explanatory variables are considered:

linkage (Figure 1), sustainability deviation (Table 4) and impact on sources. The data used for this investigation consist of energy efficiency percentage (*EE*), construction and demolition waste percentage (*CDW*) and water savings (*WS*) in Table 2. These data were gathered from the technical screening criteria set out in Annexes to the EU Taxonomy and from the Czech subsidy programmes, namely the Recovery and Resilience Facility (RRF), Operational Programme Environment (OPE), Operational Programme Technology and Application for Competitiveness (OP-TAC), Integrated Regional Operational Programme (IROP), Modernisation Fund (ModFond) and New Green Savings (NGS). The study commenced with data for the period 2014–2021.

4.2 Quantitative methods

The study applied the hypothetical-deductive approach, which comprises five key steps, as outlined by Hendl (2023): (1) theoretical description of reality through an economic model; (2) deduction and definition – creation of a hypotheses using research questions; (3) observation and measurement; (4) testing of hypotheses; and (5) verification.

In the first step, an economic model (Figure 1) was created based on an empirical analysis of the relationship among EU Taxonomy conditions (DNSH and significant contribution) and other related conditions, as outlined in the EU guidelines (green tags) and EU informal communication (ad-hoc conditions). The EU guidelines comprise Annex I of the Construction Products Regulation (CPR) and Annex VI of the RRF. Ad-hoc conditions were considered from the European Commission communication, which were held with Czech ministries (mainly the Ministry of Trade and Industry) during the negotiation of the National Recovery Plan. Both the green tags and the EC conditions are considered as instruments for implementing the significant contribution condition. These were incorporated prior to the finalisation of the technical screening criteria, and in retrospect, were intended to ensure a significant contribution to the environment rather than simply avoiding harm.

In the second step, the research questions were created assuming correlation between (at least) two variables.

The third step commences with a comparative analysis of reference data from 2014 and current (defined) data from 2021. The objective of the analysis is to determine the sustainability deviation variable, which is expressed as the difference between the reference data and defined data (Table 4). Subsequently, a formula based on a correlation model was developed. The formula expresses the Taxonomy impact on each financial source and the total Taxonomy impact on subsidy programmes for building renovations.

In last two steps, the research questions are tested and verified (in the Results and Discussion sections).

5. Impact of Regulation on Subsidies – Model

5.1 Sustainability levels

EU Taxonomy determines economic activities which have the potential to be environmentally sustainable. The sustainability of each economic activity is defined by six environmental objectives: climate change mitigation, adaptation to climate change, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, and protection and restoration of biodiversity and ecosystems.

These objectives are further described at two sustainability levels. The first level, which is defined as "substantially contribute", represents a high level of sustainability. In contrast, the "do no significant harm" (DNSH) level represents a minimum level of sustainability. At both levels, technical screening criteria have been established for each economic activity.

The construction and real estate sectors encompass a range of economic activities including renovation of existing buildings (7.2). Renovation of existing buildings is significantly subsidized through a variety of subsidy programmes.

5.2 Funding sources

The data originate from the R&D project "Preparation of tools for the implementation of the optimal scenario for the renovation and adaptation of buildings by 2050", conducted by the Chance for Building Association. The data indicate the amount of finance available for the construction and renovation of buildings between 2021 and 2030. An in-depth analysis of the programming documents was conducted, and consultations were held with the relevant ministries to clarify the amounts that change during the programming process.

According to data in Table 1, support programmes allocate at least CZK 135.23 billion, which accounts for 21% or one fifth of the total allocation for building construction and renovation. It is important to note that this information is presented objectively without any subjective evaluations. The programmes are mixed, making it impossible to determine the exact amount of money that will be invested in construction versus renovation. However, OPTAC focuses solely on renovation and also implements savings in buildings and technology. For the investigation, we consider the investment share in renovations to be half of the mixed allocation.

Table 1: Overview of funding by building type (November 2022)

Programme	*Allocation (bn CZK)*	*Public and state buildings (bn CZK)*	*Residential houses and buildings (bn CZK)*	*Private buildings (bn CZK)*	*Share of investments on allocation (%)*	*Of which renovation (%)*
RRF	179.1	32.15	16.08	5	29.7	14.86
OPE	61	14.2	5	–	31.5	15.74
OPTAC	81.5	–	–	19.6	24	12.02
IROP	117.7	8	–	–	6.8	3.4
ModFond	154	10.2	–	9.2	12.6	6.3
NGS	39	–	15.8	–	40.5	20.26
TOTAL	–	64.55	36.88	33.8	**21.39**	10.69

Note: For the specification of the building renovation, we have drawn on Act no. 406/2000 Coll. on Energy Management, which defines a major change to a completed building as "a change to the completed building of more than 25% of the total building envelope". Therefore, we did not include building interior renovations for the purposes of the study.

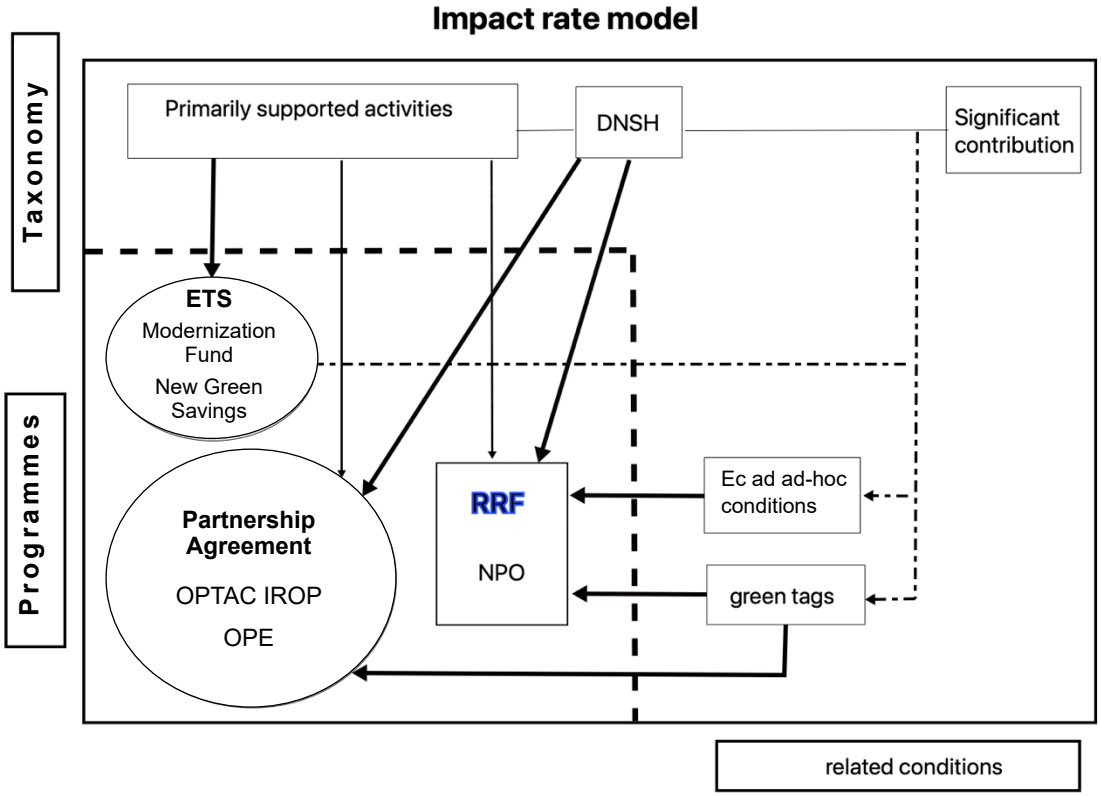
Source: Authors' own calculations

For the purpose of modelling, the subsidy programmes were merged into three sources:

1. Resources from emission allowance revenues (ModFond, NGF) = ETS source
2. Resources covered by the Partnership Agreement 2021–2027 (OPE, OPTAC, IROP) = PA source
3. Recovery and Resilience Facility (RRF) resources = RRF source

5.3 The model

Figure 1: Economic model[1]



Source: Authors' own elaboration

The model identifies three types of linkages ($Link_Y$) between conditions and resources, categorized based on their impact rate:

- exclusive (100% impact of the condition to the programme – Link $_{exclusive}$),
- crucial (condition shapes the programme from 40% – Link $_{crucial}$),
- specific (moderate (15%) impact of the condition – Link $_{specific}$).

1 The model shows the linkages of sustainability principles and conditions under the Taxonomy regulation (primarily supported activities are economic activities that are defined to be sustainable; DNSH principle; substantially contribute principle, green tags conditions, European Commission ad-hoc conditions = rectangles) on different subsidy sources and programmes – RRF source, emission allowance (ETS) source and sources under the Partnership Agreement = circles. This model relates to the EU programming period 2021–2027.

Exclusive linkages are prescribed conditions with a significant impact on the formulation of the programme and individual projects. DNSH is an illustrative example of an exclusive linkage. The DNSH conditions were directly incorporated into the regulations for the Partnership Agreement and the Recovery and Resilience Facility. Moreover, the exclusive links establish a connection between the primarily supported activities and the Modernisation Fund. This is due to the fact that all revenue generated from emission allowances is allocated to support Taxonomy-related economic activities.

There are *crucial* connections between the primarily supported activities and the RRF and Partnership Agreement programmes. A 40% impact is attributed to this link, reflecting the level of green investments that must be reported in the programmes.

It is challenging to predict the specific linkages, as their fulfilment is not clearly defined. Furthermore, some indicators are taken over by the EC's green tags or ad-hoc conditions. The impact rate for specific linkages was determined on a scale of 1–39%, with the impact categorised as negligible for 1–10%, moderate for 10–20%, medium-high for 20–30% and high for 30–39%. The impact of specific linkages can be described as moderate; therefore, the rate was quantified as 15%.

5.4 Comparative analysis

To define a sustainable renovation, data from the EU Taxonomy Annex were gathered. These indicators correlate with the environmental assessment indicators from the 2014 Communication on Resource Efficiency in Construction.

The following indicators were considered:

- Building energy efficiency (*EE*) – as a percentage
- Construction and demolition waste management (*CDW*) – as a percentage
- Water savings (*WS*) – as a value

To facilitate the comparison, the reference data (Ref) from 2014, as defined by the Ministry of the Environment Operational Programme Environment and Rainwater Programme (2014–2020), were utilized. These indicators were established in 2014 and may be considered a suitable reference point, despite being nine years old.

Table 2: Data for comparative analysis – indicators and parameters

INDICATORS	Energy efficiency (*EE*)	Construction and demolition waste management (*CDW*)	Water savings (*WS*) parameters
Defined criteria and conditions (*Def*)	**PARAMETERS**		
DNSH in technical screening criteria (Def_{DNSH})	Not specified	70% of *CDW* is ready for reuse, recycling and other types of material recovery, including backfilling	Water flows on sanitation: – Basin and kitchen taps: 6 litres/min. – Showers: 8 litres/min. – Toilets: maximum flush volume 6 litres and maximum average volume 3.5 litres – Urinals: maximum total volume 1 litre
Significant contribution in technical screening criteria (Def_{SC})	Major renovation or 30% primary energy savings	– 90% of *CDW* is ready for reuse, recycling and other types of material recovery, including backfilling – GWP calculation in every life cycle stage – At least 50% of the original building is preserved – At least 50% of the materials used are recycled, reused or renewable materials – Renovation is digitalised – *etc.*	Not specified but must comply with DNSH
Ad-hoc EC requirements (Def_{A1})	90% of the project costs will be dedicated to energy efficiency (which can be also interpreted as 30–60% energy savings)	70% of *CDW* is ready for reuse, recycling and other types of material recovery, including backfilling	Not specified
Green Tags (Def_{A2})	30-60% PE savings or 30% greenhouse gas savings	Not specified	Not specified
Reference document (*Ref*)	**PARAMETERS**		
OPE 2014–2020 (*Ref*)	More than 20% PE savings	Not specified	Not specified (Rainwater programme was on a voluntary basis)

Source: Authors' own elaboration

5.5 Variables and formula

To calculate the impact of the Taxonomy ($Impact_T$) on the subsidy programmes, two variables will be used: the sustainability deviation ($Sustain_x$) and the linkage ($Link_y$) where x is the condition and y is the linkage type.

5.5.1 Sustainable deviation calculation

The explanatory variable "sustainability deviation" ($Sustain_x$) is the difference between reference indicators (Ref) and defined indicators (Def_x) on the parameters.

The deviation is measured on individual parameters and has five levels, which can be positive or negative.

Table 3: Deviation levels

Level	Positive value	Negative value
Zero	0	0
Low	2.5	–2.5
Medium	5	–5
High	7.5	–7.5
Significant	10	–10

Notes: $Sustain_{DNSH} = Ø\ Ref - Def_{DNSH} = (–7.5 + 5 + 2.5)\ /3 = 0$; $Sustain_{SC} = Ø\ Ref - Def_{SC} = (5 + 7.5 + 2.5)\ /3 = 5$; $Sustain_A = Ø\ Ref - Def_{A1(2)} = (10 + 5 + 0)\ /3 = 5$.
Source: Authors' own calculations

Table 4: Sustainability deviation calculation

	Ref	Def_{DNSH}	**Sustainability deviation ($Sustain_{DNSH}$)**	Def_{SC}	**Sustainability deviation ($Sustain_{SC}$)**	Def_{A2}	**Sustainability deviation ($Sustain_A$)**
EE	≥20%	0	–7.5	≥30%	5	30–60%	10
CDW	0	70%	5	90%	7.5	70%	5
WS	0	1	2.5	1	2.5	0	0

Source: Authors' own calculations

5.5.2 Impact on source calculation

Once the sustainability deviations have been determined, the effect of the Taxonomy on each individual source ($Impact_{Isource}$) needs to be calculated. This is done by adding the deviation (*Sustain*) and the impact linkage (*Link*) variables, which are then multiplied by each other.

$$Impact_{I\ source} = \sum Sustain_{(Ref-Def_x)} Link_y \tag{1}$$

5.5.3 Total impact calculation

The total impact ($Impact_T$) of the EU Taxonomy on the subsidy programmes, using the building renovation as an example, will be calculated as the average of $Impact_{I\ source}$ multiplied by the percentage $Impact_{€source}$ invested in building renovation within the source (*Source*/2) relative to the total allocation of the source (Σ *Source*).

$$Impact_T = Ø\ Impact_{I\ source}\ Impact_{€\,source} \tag{2}$$

$$Impact_{€\,source} = \left(\frac{\frac{Source}{2}}{\sum Source} \right) \tag{3}$$

Final formula:

$$Impact_T = Ø\ (\Sigma Sustain_{(Ref-Def_x)}\ Link_y) \left(\frac{\frac{Source}{2}}{\sum Source} \right) \tag{4}$$

6. Results

In the comparative analysis of defined and reference parameters on each indicator, we found deviations. To further verify the identified deviations, expert consultations were held with Chance for Building Association analytical team and working group sessions were conducted with representatives of construction enterprises. The level of deviation in energy efficiency is contingent upon legislative requirements. The absence of a value for the DNSH defined condition for building renovations indicates compliance with the liberal Czech legislative parameters that do not prioritize energy-efficient reconstruction. Energy savings of 30–60% require a deep and complex renovation that should be rated as significant. The "70% of construction and demolition waste" is a novel phenomenon, yet its assessment is only at a medium level. According to the expert consultations, to recycle a large amount of waste is a common practice, with the exception of do-it-yourself renovations. The condition of 90% is rated high. The water saving measures are not sufficiently ambitious, given that the sanitation parameters employed during the reconstructions are not novel.

$$Impact_{I\ ETS} = Link_{exclusive} + Sustain_{SC} Link_{specific} \tag{5}$$

$$Impact_{I\ ETS} = 1 + 0 \times 0.15 = 1 \tag{6}$$

$$Impact_{I\ DoP} = Link_{crucial} + Sustain_{DNSH}\ Link_{exclusive} + Sustain_{A} Link_{exclusive} \tag{7}$$

$$Impact_{I\ DoP} = 0.4 + 0 \times 1 + 5 \times 1 = 5.4 \tag{8}$$

$$Impact_{I\ RRF} = Link_{crucial} + Sustain_{DNSH}\ Link_{exclusive} + Sustain_{A} Link_{exclusive} \tag{9}$$

$$Impact_{I\ DoP} = 0.4 + 0 \times 1 + 5 \times 1 = 5.4 \tag{10}$$

$$Impact_{T} = Ø\ Impact_{I\ source} \left(\frac{\frac{Source}{2}}{\sum Source} \right) \tag{11}$$

$$Impact_{T} = Ø 1 \times \left(\frac{\frac{35.2}{2}}{193} \right) + 5.4 \times \left(\frac{\frac{53.23}{2}}{179.1} \right) + 5.4 \times \left(\frac{\frac{46.8}{2}}{260.2} \right) \tag{12}$$

$$Impact_{T} = \frac{0.091 + 0.802 + 0.486}{3} = 0.46 \tag{13}$$

Table 5: Impact rate levels

Level	Scale
Low	< 0.25
Noticeable	0.26–0.5
High	0.51–0.75
Significant	> 0.75

Source: Authors' own elaboration

The results of this study provide insight into the perceptibility of the impact of the EU Taxonomy on subsidy programmes. The result of 0.46 indicates a noticeable to high level of impact.

7. Discussion

This research was prompted by the reluctance of state administration bodies to implement sustainability principles across subsidy programmes between 2020 and 2023. The primary rationale provided was that the proposed changes would be too noticeable for applicants, thereby rendering the subsidies less attractive. We engaged in communication with the individuals responsible for the development of energy-saving programmes in buildings. This empirically derived premise originating from Czech state officers could be initially discussed with the findings from broad quantitative research conducted on the building stock in Switzerland (Hondeborg *et al*., 2023). The research indicated that subsidised renovations (retrofits) do not result in deeper renovations than unsubsidised ones. Nevertheless, to establish a comprehensive correlation between subsidies and renovation depth, it is essential to gain a thorough understanding of the Swiss energy efficiency policy and subsidy policy. It should be noted that these may diverge from the regulatory framework of the European Union and the Czech Republic, respectively.

The part of the research aimed to analyse the differences between the building renovation conditions in the previous and current programming periods (RQ 1). Significant changes were observed in the field of energy efficiency regarding individual technical parameters. Although the reference programme has set the threshold of 20% for energy savings for renovated properties (Ministry of the Environment, 2015), the new rules do not require this (Commission Delegated Regulation (EU) 2021/2139). The question of whether to endorse new regulatory directions that would halt the increase in saving percentages across the EU financial framework is a matter that requires further discussion. It is crucial to highlight that an increase in the percentage of energy savings results in a financial demand on investors. Husiev *et al*. (2023) mentioned that the cost-effectiveness of renovations depends on several factors such as building location, current HVAC, labour costs, climatic conditions, *etc.* In most cases, the cost-optimal solution presents a low degree of energy savings. This confirms the fact that a higher percentage of primary energy savings will exceed the cost optimum. Čermáková *et al*. (2023) stated that the energy price level is also related to the ability to rent larger, more spacious properties. However, this claim cannot be applied, as the research did not consider technical specifications of properties such as orientation (solar gains), degree of renovation, energy sources and so forth. Increasing the percentage of energy savings in the EU financial framework, regardless of the climate conditions or the technical design of the property, would not be an optimal solution. Regarding reduction of water consumption and recycling of construction and demolition waste, the change has a low or moderate impact. In fact, the common practice was already in place before the conditions were officially set. Consequently, the overall discrepancy is not considered significant. Nevertheless, the sustainability of renovations remains superior to that of the preceding programming period (RQ 2).

Further evaluating progression or regression of individual conditions (RQ 4), it is important to adhere more to the "do no significant harm" principle. This principle has implications for a wide range of investments, including the use of emission trading system finance. Technically, DNSH is regressive in term of energy savings, as it only requires applicants to meet the legislative cost-optimal level of renovation, which does not guarantee any additional energy savings. The implementation of water savings and recycling of construction and demolition waste has made rather low or medium progress in DNSH. The "significant contribution" principle is more progressive in all the monitored parameters. The EC ad-hoc conditions put pressure on deep renovations and energy savings. The achievement of high savings in residential buildings requires a complex reconstruction of the house, including massive insulation of all external walls, replacement of the heat source with the most efficient one, replacement of windows and installation of a photovoltaic system. However, water savings are often overlooked. For example, greywater management is still underrated and there is not even any reference in the technical criteria. The demand for waste recycling is moderately progressive. The principles of circular economy pertaining to construction and demolition waste were rated with a medium to high positive value and made a significant progress in the current programming period. The reason is that it is the first time that investment in building renovation should prove that it deals with waste in a sustainable way (*i.e.*, reducing landfilling, increasing reuse and recycling).

In evaluating the overall impact of new sustainability conditions on investments (RQ 3), it is important to also consider the total volume of subsidized investments to refine the impact. This analysis reveals a noticeable overall impact on programme settings. The economic model (Figure 1) was used to examine the individual impact of sustainability conditions on subsidy programmes. The conditions that exhibited the strongest ties and therefore the most influence (100%) were those directly incorporated into European regulations that establish individual subsidy programmes. The general conditions of the programme exerted a comparatively smaller influence (40%), while ad-hoc conditions connected to the significant contribution principle exhibited the weakest ties (15%). The mathematical formula considered the links and parameters of sustainable investments from the previous subsidy period, as well as the size of the investment support. Furthermore, it is acknowledged that the EU Taxonomy did not build upon point 0. The allocation of funds for renovations, which varies depending on the source, has significantly affected the impact of the EU Taxonomy on investments, particularly subsidy programmes. Excluding the financial component, the impact rate of the EU Taxonomy on the programmes would be more than 1,000% ($Impact_T = 11.8$). However, this result would be highly inaccurate as it is necessary to consider not only the qualitative but also the quantitative component. Upon the inclusion of the quantitative component, the result is 0.46. This indicates that the regulation has a significant impact at a moderate level, which is almost 50% greater than in the previous

programming period. However, the impact rate is highly influenced by the deviation value, which refers to the technical parameters that determine the level of sustainability of the current investment in comparison with the previous (reference) investment. Considering that subsidies will be distributed among all entities, including municipalities, schools, cultural institutions, state institutions and private owners (both natural and legal persons), it can be concluded that the regulation will have a noticeable impact on real estate investment in the Czech Republic.

Given the focus on the impact of regulation on the financial framework, specifically in terms of investments in infrastructure, it is also pertinent to consider the impact on the quality of the environment and climate. The study by Runguo *et al*. (2024), which examined the impact of environmental regulation, quality of bureaucracy, low corruption and economic growth on environmental quality, confirmed a correlation between all the variables and environmental quality. The economic growth variable has a positive or even negative impact collaterally. The initial impact of economic growth on environmental quality is typically adverse; however, at a certain level of growth, positive effects begin to emerge. Conversely, a study on financial technologies (Ahmad *et al*., 2024), which was conducted on data from EU countries, indicated that economic growth is a significant driver of natural resource consumption, which leads to environmental degradation. The contradictory findings suggest the presence of a research uncertainty that requires further exploration. A promising avenue for future research would be to embrace data applying the concept of sustainable economic growth. This could entail examining the relationship between economic growth and the use of renewable energy, applying circular economy and other characteristics of sustainability and ecological footprint. Such data could extend beyond the period preceding the adoption of the Paris Agreement in 2015.

One topic meriting discussion is the relationship between environmental legislation and the capacity of applicants to utilise EU funding. It is not possible to evaluate the attractiveness of the funds until the end of the investment phase, which is expected to be in 2025 at the earliest. Business entities may be reluctant to draw funds, given that they typically have more equity than individuals or public entities that rely on subsidies. Furthermore, there is a risk that funds allocated for building renovations may not be utilized, which could result in political failure if significant non-utilization occurs. However, subsidies for energy-saving renovations have a lower nominal value and are distributed among a broader range of applicants in comparison with investments in new technologies linked to the energy transition. This reduces the political risk compared to investments in energy technologies. Nevertheless, the uncertainty regarding the eligibility of subsidising the economic activities that are not explicitly aligned with the EU Taxonomy (*e.g.*, the production of specific fuels, specific industries) represents a significant issue that can potentially hinder the use of funds. The legislative uncertainty places a greater burden on programme designers to mitigate risks. If these risks are not eliminated, the uncer-

tainty may have an impact on applicants who are deciding whether to utilize subsidy programmes. This trend is corroborated by the findings of Lucarelli *et al*. (2023) in their study on corporate investments. The firms that exhibited minimal uncertainty regarding the EU Taxonomy eligibility demonstrated a tendency to increase their investment levels. On the other hand, according to Lucarelli *et al*. (2023), the degree of technical precision of requirements tended not to affect investment levels, regardless of the company size. Uncertainty regarding subsidies is further reinforced by state aid regulation on climate, environmental protection and energy. As Jourdan-Andersen and Brunt (2022) correctly observed, the EU Taxonomy and state aid regulation must be complemented by comprehensive climate and energy sectoral legislation compliance, especially within the context of complex projects.

The methodology employed in this article for assessing the sustainability of renovations can be applied to any other subsidised investment. Furthermore, the EU Taxonomy is EU-wide, thus enabling its application in a comparable manner in any member state.

8. Conclusion

The article introduced a novel approach to evaluating sustainable investments in relation to regulation and subsidies. In 2022, the EU Taxonomy Directive affected the design of subsidy programmes by intervention of the European Commission. The study demonstrated the impact of this intervention on building renovation in the Czech Republic in three areas: energy, water and waste management in the construction and operational stages.

The noticeable impact of the regulation on building renovation was demonstrated by a mathematical model. It is now evident that the EU Taxonomy has shaped the subsidised investment significantly, and that the European administration has gained a new tool for a direct impact. In contrast, the regulation does not represent a revolutionary shift in the construction sector. The Commission's observed approach shows more centralising influence not only at the political level but far more at the expert (technical and administrative) level.

This conclusion may be slightly disturbing because it raises demands on national administration and experts. National representatives must be prepared to provide ongoing explanations of the specifics of the Czech system within the context of socio-economic factors. These include the common private ownership of buildings, the country's ageing building stock and the social and historical context in which these issues exist. As legislation becomes increasingly technical, the negotiations are no longer concerned with political work but rather with independent expert work, which represents participation in Commission expert bodies dealing with legislation, such as working groups, expert panels, revision and evaluation groups. Concurrently, responsibility for these initiatives should by shared between national administrations

and independent academic institutions. This is intended to balance the influence of special interest groups.

Future research into the sustainability of buildings and European policies could be diverse and multifaceted. One research stream could continue to examine energy and resources (such as energy efficiency and the circular economy), while another may investigate the potential correlation between sustainability and declining housing affordability. Furthermore, the energy transition in buildings is also connected with the introduction of a new legislative principle, known as the Energy Efficiency First principle. This principle directs towards reduction of energy consumption and implementation of new economic models for energy demand management. One potential modus operandi for future research could be to examine the potential of decentralised energy supply in energy communities in building complexes as a significant means of reducing and managing energy demand at the local and regional levels.

Acknowledgement

Funding: There was no funding, either externally or internally, towards this study.

Conflicts of interest: The authors hereby declare that this article was not submitted no published elsewhere.

AI usage statement: The authors confirm that no artificial intelligence (AI) or AI-assisted tools were used in the creation of this manuscript.

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