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Can Education Save Money, Energy, and the Climate?—Assessing the Potential Impacts of Climate Change Education on Energy Literacy and Energy Consumption in the Light of the EU Energy Efficiency Directive and the Austrian Energy Efficiency Act

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Abstract: The Austrian Education Energy Initiative ETSIT has been established as a response to the EU Energy Efficiency Directive and the Austrian Energy Efficiency Act. This paper investigates the energy literacy of its young participants, i.e., 6000 primary and secondary school students altogether, on a cognitive, affective and behavioural level, and it compares the putative energy-saving effectiveness of the workshops to that of conventional energy audits.For the current analysis, data from, 640 students who validly answered an online survey shortly after participating in one of the energy education workshops, and 353 students who validly answered the online survey approximately one year after having participated (overall n = 993) were analysed. The results indicate that ETSIT raises students' energy literacy on a cognitive, affective and behavioural level with about three-quarters of participants claiming they will positively change their energy consumption behaviour in the future as a result of workshop participation. This is true shortly after participation in the workshops, and also at the 1-year follow-up. In its second impact perspective, this paper delivers an innovative attempt to look at education from a cost-benefit analysis. A default formula for energy audits is adopted to quantify the kilowatt hours (and thus emissions and costs) saved through workshop participation. Despite limitations, the surprising results show that such workshops can compete with conventional energy audits, and that education can, in fact, help save money, resources, and, most important of all, the climate.

Keywords: energy education; climate education; education for sustainable development; energy literacy; energy consumption; impact assessment; EU Energy Efficiency Directive; Austrian Energy Efficiency Act

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1. Introduction

The depletion of non-renewable natural resources coupled with advancing climate change caused by anthropogenic emissions of greenhouse gases needs to be tackled urgently, effectively, and in a coordinated manner both globally and at a local level. Education can and must play an important role in corresponding strategies and efforts.

Summarizing shortly, the world has been informed about the "Limits of Growth" by the Club of Rome in the 1970s [1]; the 21 Agenda 1990 [2] has coined the idea of "Sustainable Development", and, since then until the present day, many alarming reports have been published by the Intergovernmental Panel on Climate Change (IPCC), with the latest series just out in 2021 [3]. Since 1995, the Conference of the Parties (COP) as the supreme body of the United Nations Framework Convention on Climate Change, with the latest COP26 meeting in Glasgow in 2021, has strengthened the international response to climate change (and, increasingly, also the continuous loss of biodiversity), and highlighted the need for collective action [4]. Yet it is only since the fifth series of IPCC reports [5], the Paris Agreement [6], and particularly the introduction of the Sustainable Development Goals (SDGs) [7], and the latest reports on Education for Sustainable Development [8–10] that the strong interrelation between Sustainable Development (SD) and Education for Sustainable Development (ESD), and thus the importance of SDG4 and ESD for reaching all SDGs [11], have been universally acknowledged in important international agreements [12].

As for climate and energy policy, the European Commission presented a legal package in 2008, which was commonly known as the '20-20-20 goals' [13]. It addressed climate change by focusing on a restrictive climate and energy policy, and aspired that, by 2020, the EU should have cut greenhouse gas emissions by 20%, increased the share of energy from renewable sources by 20% as well as increase energy efficiency by 20% in comparison with 1990 levels. The Energy Efficiency Directive by the European Union in 2012 was adopted in response to the fact that EU Member States were not on track to reduce primary energy consumption by 20% by 2020 and necessitated a change in consumer behaviour and energy consumption practices [14–16]. Among other important changes, education was put high on the agenda. This is even more evident in the latest strategies and efforts by the EU in the so-called European Green Deal, adopted in 2019. The wording of the proposal context says it all as "the Commission set out a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use. It also aims to protect, conserve and enhance the EU's natural capital, and protect the health and well-being of citizens from environment-related risks and impacts. To reach these objectives, energy efficiency must be prioritised" [17]. As a consequence, the European Commission has also issued a new proposal (not yet agreed upon) for yet another directive on energy efficiency in 2021, increasing the efforts of "reducing greenhouse gas emissions to at least 55% below 1990 levels by 2030" [18]. Within this document, it becomes clear that "energy efficiency is (still) a key area of action, without which the full decarbonisation of the Union's economy cannot be achieved" (Article 6), that "the provision of education, training and specific information (. . .) on energy efficiency" still plays an explicit role (Article 5), and that "Member States should take into account the fact that the successful implementation of new technologies for measuring energy consumption requires enhanced investment in education and skills for both users and energy suppliers" (Article 77). Consequently, it has been valued in the past years that energy education could be key in bringing about changes in consumer behaviour and energy consumption practices in rather a bottom-up approach.

As a direct consequence of the EU Energy Policy from 2006 onwards, EU countries were required to transpose the binding measures into their national laws. Austria passed an Energy Efficiency Act, which turned legally binding in 2015. The Austrian Energy Efficiency Act aims to bring about a cost-optimized, secure and sustainable energy supply by increasing energy efficiency and the share of renewable energy in the energy mix, as well as reducing greenhouse gases [19]. According to Austrian law, energy suppliers have to execute energy efficiency measures directed at their clients' consumption. The measures have to annually reduce emissions by the amount of 0.6% on their previous year's consumption level. In order to be legally accepted and 'offsettable' as an effective energy efficiency measure, energy suppliers have to prove that the measure results in verifiable and measurable or, at least, estimable energy efficiency improvement or primary energy savings [14]. While the impact of energy efficiency measures in sectors like housing (e.g., thermal insulation), transport (e.g., electro mobility) or industry (e.g., retrieval of industrial waste heat) is relatively easily quantifiable, there is not yet an equivalent understanding of the impact of cross-sectorial measures like information and awareness-campaigns, or training and energy conservation programmes on the actual energy consumption. In Austria, most energy suppliers (directly or indirectly) make considerable investments in energy information and education initiatives.

Despite these hands-on efforts, not enough research has been done in the evaluation and impact assessment of such activities. This is particularly true for studies examining the actual energy savings in kilowatt hours or avoided carbon dioxide emissions triggered by educational programmes [20–22]. Sharygin [23] calculated the carbon effects of an educated future and reached the conclusion that each year of education could be associated with an average reduction in CO_2-equivalent emissions of -466 kg/year, thus concluding that education can translate into fewer emissions per household. Apart from these (rather general) analyses, and despite objections by critics of cost-benefit analyses involving environmental parameters [24], several energy efficiency programmes in the housing sector have been examined through a cost-benefit-analysis lens, e.g., [25–30]. More holistic projects and evaluations did not only look at energy saving on the financial benefit side but expanded it to environmental benefits and health and comfort improvements [31,32], or they emphasised the positive effects on energy literacy, and, at the same time, the quality of life of the participants and their communities [33].

Despite all efforts, however, DeWaters et al. [34] compiled an extensive review in which they state that there is neither an equivalent understanding in the field of assessing the effectiveness of energy literacy education nor a holistic tool to measure all attributes–a view still regarded as valid today (e.g., in the 2nd Handbook of Climate Communication [35]). In contrast to the environmental literacy domain, evaluation tools for energy literacy are either outdated [36–41], limited on cognitive outcomes [42–44], or measure content-based knowledge only [45–47]. The few existing holistic evaluation tools are, due to their length and complex wording, mostly inappropriate for students. Responding to this research gap, with “The Energy Literacy Questionnaire”, DeWaters et al. [34] developed an extensive evaluation tool, which contains of 17 affective, 10 behavioural and 30 cognitive items. Thus, a systematic procedure was introduced to create a valid, reliable measure of energy literacy (however limited to the use with English-speaking students in the United States).

Undoubtedly, content knowledge, awareness and self-efficacy are regarded to be important domains of energy-literacy, yet, only actual behavioural changes have an impact on the climate. Therefore, legal frameworks, such as the Austrian Energy Efficiency Act, have a high interest in the measurement of the actual impact of behavioural change on the energy consumption triggered by a particular measure, e.g., by an information campaign or an educational initiative [19].

There are acknowledged standards for the estimation of the impact of energy audits conducted by an energy consultant at a private household on the actual energy consumption of the private household in Austria [48] as well as meta-studies about the impact of different energy audit formats on cognitive, affective and behavioural aspects [49]. However, an equivalent for energy education programmes does not yet exist. The study at hand addresses this research gap by outlining basic information regarding the Austrian Energy Education Initiative ‘Die Energiewende–Schulinitiative Tirol’ (Engl. *Energy Transition–School Initiative Tyrol, short ETSIT*) [50], and by presenting the methodology used to evaluate this initiative at cognitive, affective and intentional level.

Secondly, due to a lack of existing methodology in this pioneering field, the authors apply a monitoring default formula borrowed from energy advisory evaluation in order to demonstrate a cost-benefit analysis of ETSIT. In order to successfully convince policy makers and state officials that educational interventions paid by energy suppliers should be legally accepted and ‘offsettable’ as an effective energy efficiency measure in Austria, we decided to apply a robust and widely applied model used in Austrian energy auditing (see Section 3.2). This model was developed by the official Austrian Energy Agency by order and on account of the former Austrian Ministry of the Economy and Families BMWFJ (now the Austrian Ministry of Digital and Economic Affairs). The methods published in a 120-page document by the Austrian Energy Agency [48] are all directed at complying with EU legislation and the consequent Austrian Energy Efficiency Act. In a bottom up-approach, the main types of energy saving potentials are presented, e.g., for buildings, illumination, energy audits for businesses and private households, and various technological possibilities, always in connection with the question of how to measure and calculate the savings in compliance with legal requirements and specifications. It is the most comprising and professional attempt to describe this connection in detail and for the Austrian situation within the time of the study period (and beyond), and the models and formulas presented are widely applied in Austria. The default formula used in our study originates from this publication, and thus delivers a solid base (politically, but also scientifically) for our argumentation.

As a result, the authors present assumptions about a spectrum of potentially conserved kilowatt hours through the education workshops, identify and discuss perils and pitfalls of such an evaluation methodology, and draw further conclusions on what can be learnt from both a cost-benefit and educational perspective.

2. Methods

2.1. Energy Education Initiative "Energy Transition–School Initiative Tyrol" (ETSIT)

The Energy Education Initiative ETSIT contains eight 90 min energy education workshop formats which all cover the aspects: (i) climate change and energy nexus at the local level, (ii) private household energy consumption, (iii) energy-saving measures for individuals, and (iv) renewable energy sources (for more information see [50]). The group of workshop instructors, all employed by "Energie Tirol" [50], an independent, but state-financed energy office, consists of energy technicians, educators, architects, and energy auditors who are trained both thematically and pedagogically prior to the workshops. Financed by local energy supply companies, teachers can book the workshops for free. The authors of this study have contributed both to the development of workshops and evaluations from a scientific perspective.

In the period between December 2012 and October 2018, more than 6000 primary and secondary school students participated in around 300 workshops provided by the Energy Education Initiative in 175 schools [50]. Since 2019/2020, the initiative has been put on hold due to COVID-19. All results presented in this study are from the years before COVID-19 and have thus been completely unimpacted by any influences of the pandemic, an important asset during these difficult (research) times [51].

Psychological models show that old habits are a very strong barrier to implement pro-environmental behaviour [52]. Therefore, it is important to prevent the development of such habits as soon as possible by turning pro-environmental behaviour into young people's 'default setting'. From a psychological point of view, all redesigned workshops follow an antecedent strategy, which, in contrast to consequence strategies (e.g., feedback, rewards), aims to influence cognitive, affective and behavioural determinants prior to the performance of environmentally significant behaviours [49].

From an educational perspective, the theoretical and practical approach of all redesigned workshops is firmly based on the assumptions of moderate constructivism [53–57], conceptual change [58–64], and inquiry-based-learning [65–72]. They all consist of hands-on activities making use of and activating the students' prior knowledge and experiences, ensuring a high level of engagement, and aiming at the same target—i.e., raising students' energy literacy at cognitive, affective and behavioural level.

2.2. Assessing Energy Literacy in Online-Surveys

The evaluation of the workshops (ETSIT) is understood in the sense of Döring and Bortz [73] as the systematic application of empirical research methods for the impact assessment of a social intervention. The instruments used to measure the impact of the participation among the students are online-based questionnaires. Kuckartz and Rädiker [74] compiled an overview of advantages and disadvantages of using online-based questionnaires for data collection in educational contexts. One of their main conclusions was that the many advantages outweigh the few disadvantages, and therefore they recommend it, if used according to the DeGEval-standards [75] as a valuable contribution to an adequate observation of the object of investigation.

The data evaluated in this analysis were collected via completely anonymous online surveys. Separate versions, which differ only slightly in length and complexity of the wording, were applied as part of this research to account for differences between the cognitive abilities of the primary school and secondary school students. The online-based questionnaire used in the study and survey one was applied directly after the workshop (S1 in Table 1). It was designed to be a combination of closed and open questions with a total duration of no more than 15 min per student to ensure an increased response rate and to prevent denial [74,76]. The teachers of the participating classes were requested to coordinate their students completing the online-survey two days after the workshop at the latest (participation of the classes was at the teachers' discretion). A second study and survey evaluated the long-term effects of the educational workshops using a subset of questions from the first study survey (S2 in Table 1). It was carried out at a time distance of roughly one year after the students' participation in a workshop. The duration here was designed to take no more than five minutes in order to keep the feedback numbers as high as possible. Given the facts of the time-distance, and that teachers and students had changed classes or left school, and various other difficulties, the response rate in the second study survey was not as high as in the first one.

Table 1. Students' self-reporting about the potential future impacts of participating in an ETSIT workshop (rounded percentage) directly after (up to two days after) and approximately one year after the workshop.

	Fully Disagree		**Rather Disagree**		**Rather Agree**		**Fully Agree**		***p* Value**
	S1⁺	**S2⁺⁺**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	
COGNITIVE ATTRIBUTES:									
	Through participating in the workshop …								
… my knowledge about energy has increased.	10%	10%	16%	12%	35%	38%	39%	41%	0.287
… I have learnt how to conserve energy.	8% a	5% a	13% a	8% b	30% a	30% a	51% a	57% a	0.047
… I have learnt how to contribute to mitigate climate change.	10%	9%	16%	15%	35%	32%	39%	44%	0.545
… I have become aware of my personal behaviour's impacts on climate change.	10% a	8% a	18% a	12% b	33% a	39% b	40% a	41% a	0.040
AFFECTIVE ATTRIBUTES:									
	Through participating in the workshop …								
… my interest in energy and energy conservation has increased.	9%	11%	18%	18%	36%	32%	37%	39%	0.501
… my interest in climate change has increased.	14%	11%	19%	16%	32%	34%	36%	38%	0.478
… I have become aware of the importance of energy for my personal future.	7% a	8% a	14% a	7% b	32% a	31% a	48% a	54% a	0.016
… I have become aware of the importance of energy for the future of mankind. *	6%	6%	10%	9%	34%	28%	50%	58%	0.246
BEHAVIORAL ATTRIBUTES:									
	Through participating in the workshop …								
… I will make wise use of energy in the future. **	6% a	8% a	16% a	9% b	38% a	31% a	41% a	52% b	0.012
… I will try to save energy in my day-to-day life.	11% a	11% a	16% a	6% b	31% a	36% a	42% a	47% a	0.001

N.B.: S1⁺: Survey 1, directly after (up to two days after) the workshop, n = 640; S2⁺⁺: Survey 2, approximately one year after the workshop n = 353; Overall n = 993; * 240 missings; ** 429 missings; Differences between S1 and S2 were calculated using chi-square test (significance was set to $p < 0.05$). Superscript letters (a, b in shaded lines) indicate column proportions for respective answer that differ significantly between S1 and S2 using z test ($p < 0.05$ corrected for multiple comparisons by Bonferroni method).

After a few general items at the beginning, both online surveys (provided on the platform soscisurvey.de) contained matrices in which the students were asked to self-report the impact of their participation in the workshop on a four-level ordinal Likert scale ranging from 'fully agree' to 'fully disagree' [77,78]. The selection of items (for more information cf. [79]) was based on the cognitive, affective and behavioural attributes of energy literacy, inspired by 'The Energy Literacy Questionnaire' developed by DeWaters et al. [34], but adapted according to the participants' language and needs. Skipping questions was possible and thus resulted in missing answers.

2.3. Sample and Statistical Analysis

Overall, this analysis combines data from two studies, one on evaluating the immediate effects of (max. two days after) the workshops (n = 640, 43% female, 57% male), and a second study on the longer term effects, i.e., a follow-up after roughly one year after workshop participation (n = 353, 53% female, 47% male), adding up to an overall n of 993 students from Austrian primary and secondary schools.

Statistical analyses are performed in EXCEL® and SPSS®. Distributions of students´ answers between the two time points (S1 directly (max. up to two days) after the workshop, and S2 = follow-up, approximately 1 year after participation in the workshop) are analysed using Chi-square test and z-test to compare column proportions for respective answers. $p < 0.05$ is considered significant in all analyses. For z-tests, corrections for multiple comparisons were applied using Bonferroni Method.

2.4. Cost-Benefit Analysis with Default-Formula

The cost-benefit analysis is based on the central findings of the online surveys, which showed how many students reported they would intend to positively change their future behaviour as a consequence of having participated in the workshop. While measuring the financial costs of the workshops is relatively simple, quantifying the benefits of ETSIT in terms of kilowatt hours is a challenging task underpinned with many uncertainties (cf. Section 4.3).

In this study, a *default formula* commonly used to quantify the impact of energy audits between energy experts and private households in Austria (cf. Section 1) is adopted to attempt to quantify the spectrum of energy being saved through the workshops. In general, it is distinguished between three quality levels of energy audits (eQ1–eQ3) according to their duration, intensity and individuality. An eQ1 audit contains a personified (internet-based) consumption analysis with a duration of at least 15 min. If this audit is undertaken face-to-face and lasts at least thirty minutes, it classifies as eQ2 audit. An eQ3 audit contains an on-site assessment, an individual energy concept comprising the entire energy consumption as well as potential saving options at household level, lasts at least 60 min and has to be done by independent energy advisers. The energy saving factor depends highly on the quality level of the energy audit. While an eQ1 audit accounts for an energy saving factor of only 0.25% of the average household's annual energy consumption (31,700 kWh [80]), an eQ2 audit amounts to 1%, an eQ3 audit even to 3% of the annual household energy consumption [48].

In contrast to the well-acknowledged quality level descriptions in the energy audit domain, there is no quantitative equivalent for energy education programmes, and the methodology of this study does not lead to absolute data either. However, efforts are made to approximately define the quality level of a workshop by comparing its characteristics to those of an energy audit. Although young people's scope of action is hard to grasp, there are many arguments for their strong influence on friends and family members, and their increasing possibilities to contribute to energy consumption/reduction [81]. Beyond that, the energy education workshop with its duration of 90 min exceeds conventional energy audits regarding the factor time (although a 90 min programme is considered as rather short in educational contexts).

Referring to the characteristics of the three quality levels, the authors assume that the energy saving factor of the energy education workshops described above could lie in between eQ1 and eQ3. Therefore, in the following calculation with the *default formula*, the authors use an eQ1, eQ2 and also an eQ3 level audit as a baseline to generate a range of potential impacts.

3. Results

3.1. Results of Self-Reporting Online Surveys about Energy Literacy Attributes

The results of S1 and S2 self-reporting (see Table 1) show that the workshops lead to an increase in the participating students' energy literacy.

Looking at the cognitive attributes of energy literacy induced by workshop participation in the first survey (S1, directly after the workshop), 74% (39% fully, 35% rather) agree that their knowledge about energy increased and 81% (51% fully, 30% rather) agree that they have also learnt how to save energy. The follow-up survey (S2, roughly one year after workshop participation) confirms these strong results: Knowledge increase from workshop participation is still substantiated by 79% (41% fully, 38% rather), 87% (57% fully, 30% rather) confirming that they have learnt how to save energy.

Strikingly, the group of students stating that they rather disagree that they have learnt how to save energy through the workshop has fallen significantly between S1 and S2, and so the group of students stating that they rather or fully agree they have learnt how to save energy grows by 6%. Even more striking is the positive outcome as to students' awareness of their own behaviours' impacts on climate change with 73% (40% fully, 33% rather) agreeing on the increase triggered by the workshops in S1. S2 with 80% (41% fully, 39% rather), again, shows a significant positive increase one year later.

Overall, the results demonstrate that ETSIT workshops have the potential to trigger a considerable increase in students' fundamental cognitive base needed to become more energy literate.

Examining the affective level feedback resulting from workshop participation opens another avenue for consideration and deeper insights. In S1, 73% (37% fully, 36% rather) agree that their interest in energy and energy conservation has increased (roughly the same numbers for the item interest in climate change), while 80% (48% fully, 32% rather) agree that they have become aware of the importance of energy for their personal future (similar percentages for the item awareness of the importance of energy for the future of mankind). In S2, the numbers speak a similar language with 71% (39% fully, 32% rather) and 85% (54% fully, 31% rather) agreeing. As to the latter item awareness of the importance of energy for their personal future, there is a significant decrease in those rather disagreeing, and thus a striking increase in the group of agreeing students, which is yet another very positive outcome for the ETSIT energy education programme.

This positive view is also, and even more strikingly, confirmed by a look at the behavioural attributes in Table 1. S1 results show that 79% (41% fully, 38% rather) of the students agree on the statement that, through participating in the workshop, they will make wise use of energy in the future. The same is true in S2 with even 83% (52% fully, 31% rather) agreeing. Likewise, 73% (42% fully, 31% rather) in S1, and, notably, 83% in S2 (47% fully, 36% rather) agree that from now on they will try to save energy in their day-to-day life. The latter item shows a significant decrease in those rather disagreeing (and thus quite an increase in the group agreeing) between S1 and S2, the first a significant increase in those fully agreeing.

Acknowledging that, at the end of the day, it is behavioural (and not cognitive and affective) attributes and changes which are needed for energy-efficient and climate-friendly action in everyday life, the results of ETSIT impact on energy literacy are promising. Combining the two behavioural attributes of energy literacy in particular, it can be concluded that roughly three-quarters of the participants claim they will change their future behaviour in a pro-environmental manner. This central result is used for the simulation of a cost-benefit analysis in the next step.

3.2. Results of Cost-Benefit Analysis with Default Formula

Without taking the limitations of this study into consideration at this point (cf. Section 4.3), and based on the findings presented above, we assume that approximately 75% of the total 6000 participating students, i.e., 4500 students, may be regarded as the number of young consumers who will make wise use of energy in the future, and try to save energy in their day-to-day lives.

Since there is no equivalent for the impact assessment and quantification of energy education programmes, the following energy audit *default formula* (see Table 2 for explanations) is used to constitute the amount of energy saved through the energy education workshops:

$$\text{EStot} = (\text{nQn} - \text{fr1}) \times \text{EECHH} \times \text{eQn} \times \text{rb} \times \text{so} \times \text{cz}$$

Table 2. Overview of *default-formula* elements.

Abbreviation	Description
EStot	total energy savings (kilowatt hours per annum)
nQn	number of energy audits per quality level n
Frn	number of energy audits per quality level n, which would have taken place without measure (free rider) (=0)
EECHH	average household end energy consumption (kilowatt hours per annum)
eQn	saving factor of an energy audit per quality level n (%)
Rb	rebound effects (=1)
So	spillover effects = multiplier effects (1)
Cz	safety margin (=1)

The quality level of the respective energy audit plays an important role in the *default formula*. As previously discussed, the ETSIT workshops cannot be clearly labelled according to the quality level categories of energy audits (cf. Section 2.4). However, comparing the characteristics of the audit and the educational workshops, it can be assumed that the quality level of the workshops lies in between an eQ1 and eQ3 audit (see details in Section 2.4). By calculating minimum, medium, and maximum energy savings (just like in Austrian household energy audits), we thus do not conclude by giving a fixed amount of energy saved (in kWh) or fixed costs for saving 1 kWh in our energy education workshops, but always present a range of energy savings or costs in the following calculations.

Assuming that the workshops have the same impact as an eQ1 energy audit, they account for the conservation of:

(1) $\text{EStot}_{\text{min}} = (4500 - \text{fr1}) \times 31{,}700\ \text{kWh} \times 0.0025 \times 1 \times 1 \times 1$
(2) $\text{EStot}_{\text{min}} = (4500 - 0) \times 31{,}700\ \text{kWh} \times 0.0025 \times 1 \times 1 \times 1$
(3) $\text{EStot}_{\text{min}} = 356{,}625\ \text{kWh}$

Assuming the workshops are equal to the quality level of an eQ2 audit, they account for the conservation of:

(1) $\text{EStot}_{\text{med}} = (4500 - \text{fr1}) \times 31{,}700\ \text{kWh} \times 0.01 \times 1 \times 1 \times 1$
(2) $\text{EStot}_{\text{med}} = (4500 - 0) \times 31{,}700\ \text{kWh} \times 0.01 \times 1 \times 1 \times 1$
(3) $\text{EStot}_{\text{med}} = 1{,}426{,}500\ \text{kWh}$

Using an eQ3 energy audit as the benchmark, it can be assumed that the amount of energy conserved through the workshop initiative accounts for:

(1) $\text{EStot}_{\text{max}} = (4500 - \text{fr1}) \times 31{,}700\ \text{kWh} \times 0.03 \times 1 \times 1 \times 1$
(2) $\text{EStot}_{\text{max}} = (4500 - 0) \times 31{,}700\ \text{kWh} \times 0.03 \times 1 \times 1 \times 1$
(3) $\text{EStot}_{\text{max}} = 4{,}279{,}500\ \text{kWh}$

Hence, the spectrum of the actual energy conservation through the entire Energy Education Initiative ETSIT (300 workshops) ranges approximately from 0.36 GWh over 1.43 GWh to 4.28 GWh. The amount of energy saved through one of the 300 workshops thus lies in the range of ca. 1189 kWh and 14,265 kWh.

While the energy-saving (and thus the financial) benefits of the initiative can so far only be vaguely estimated with the calculation presented above, the financial costs are easy to add up. The average total costs per workshop are given at EUR 350, including the costs for instructors and administration, which adds to EUR 105,000 for 300 workshops. Since the development of the workshops concepts and evaluation was third party funded, these costs have not been considered in this analysis.

Comparing the financial costs of the workshops on the one hand with the amount of energy saved on the other, it is possible to define a spectrum which demonstrates the costs of saving 1 kWh.

Maximum costs for conserving 1 kWh = total costs of initiative/$EStot_{min}$

= EUR 105,000/356,625 kWh = ca. **0.29 EUR/kWh**

Medium costs for conserving 1 kWh = total costs of initiative/$EStot_{med}$

= EUR 105,000/1,426,500 kWh = ca. **0.07 EUR/kWh**

Minimum costs for conserving 1 kWh = total costs of initiative/$EStot_{max}$

= EUR 105,000/4,279,500 kWh = ca. **0.02 EUR/kWh**

Summing up: The costs for saving **1 kWh** with the Energy Education Initiative ETSIT range from EUR **0.02** to **EUR 0.29**.

4. Discussion

4.1. Discussion of Results of Self-Reporting Online Surveys about Energy Literacy Attributes

The results of both surveys (see Table 1) show that the workshops lead to an (even longer lasting) increase in the participating students' energy literacy and change of behaviour. However, the relationship between cognitive, affective and behavioural aspects remains a controversy. Although early models of environmental behaviour claim a linear correlation between knowledge, attitude and behaviour [82], many recent studies disagree with these findings, e.g., [52]. Instead, the relationship can be characterised as very complex, not at all mono-directional, and certainly influenced by many additional factors, such as feedback, social norms, economic situation, values, and beliefs [83–89]. However, there are several studies which provide evidence that support the relationship between cognitive knowledge of and affective attitudes toward environmental issues [90–94].

Although there are many controversies about the correlation between the attributes, many authors (e.g., [95]) found that the correlations between affective and behavioural subscales are significantly higher than those between cognitive and affective as well as cognitive and behavioural [52]. Therefore, high achievements in the affective attributes increase the probability that the students will change their behaviour, and it indicates that they might possess a general understanding and acceptance for measures tackling climate change (e.g., legal regulations).

Children and teenagers' actual use of energy and their potential to reduce it has not been examined comprehensively enough to determine whether a change in their behaviour has a similar environmental impact to that of an adult. However, homes with children, and particularly with teens, have been evidenced to be high energy consuming households (e.g., for the UK [96]), and from studies on children's and teenagers' environmental attitude and behaviour we know that until they are 14 years of age, both increase, and then (esp. without further educational support) decline until they are 18 [97]. Besides the use of electronic devices, which accounts for only a small amount of an average Austrian household's energy consumption, children and teens are also likely to have influence over lighting use, heating, hot water use, mobility behaviour and general consumption.

It also remains unclear whether or not the Energy Education Initiative ETSIT also affects the behaviour of the participants' families and friends [81]. Indeed, taking into account the energy-saving factors of free-rider effects [98], rebound effects [99,100] or spillover effects [101–104], the carbon savings could be significantly higher.

4.2. Discussion of Results of Cost-Benefit Analysis with Default Formula

The results of this study should not be seen as the solution, but rather as a starting point for any further approximations in this matter. Let us not forget: The annual costs of climate change consequences in Austria at this time and age are estimated at about 15–20 billion Euro, tendency ever increasing [105], which would be reason enough to step up efforts for climate mitigation at almost any cost. However, it also makes a lot of sense to look at soft measures like information, awareness or education campaigns from a cost-benefit analysis perspective.

This study contributes to the discussion of measuring allegedly unmeasurable parameters. Without underestimating the uncertainties in the impact assessment, it can be stated that energy education initiatives such as ETSIT can have a considerable impact on reducing the actual energy consumption of individuals and private households. Although the range of energy potentially saved through one workshop is wide, the impact on the energy consumption could be as high (or possibly higher) as that from a conventional energy audit. In a current spillover-approach, Arimura et al. [104] (p. 761) look at "seemingly unrelated interventions", i.e., the impact of environmental education at firms on the electricity consumption at the employees' houses. By measuring the education intervention effects with the help of an environmental management system, they can prove that those who face ISO14001 at workplace actually also save electricity at home. This finding strongly reinforces the approach taken in the present manuscript.

The results presented above show that a workshop which costs EUR **350** might amount to an energy saving of between ca. 1189 kWh and 14,265 kWh, and the expenditures can thus be summarized as being invested wisely also from a cost-benefit perspective. The actual costs of a conventional energy audit in Austria differ depending on quality level but exceed EUR 350. Based on this analysis, one could assume that energy education workshops could compete with conventional energy audits, although costs and benefits of behavioural intervention programmes are not very well studied in general. Allcott and Mullainathan [106] found that the cost-effectiveness of energy audits with behavioural interventions range from .016 USD/kWh to .064 USD/kWh. However, a precise cost-benefit comparison of energy audits and energy education programmes clearly requires further research.

A further point of critical reflection could also consider that, in the energy audit domain, it is assumed that the impact of an energy audit lasts for approximately two years [48]. As the survey results show a fairly lasting effect on the participants through the ETSIT workshops (although very time-restricted and only a one-time exposure), it could be assumed that the impact might last equally long. Yet this clearly has to be investigated further in future studies.

4.3. Discussion of Limitations

There are limitations and uncertainties involved at different stages of the study. The following explains how the authors have dealt with and attempted to reduce them.

4.3.1. Survey Instrument Validity

In order to ensure survey instrument validity and reliability whilst endeavouring to prevent measurement errors, a variety of measures have been undertaken in the development process of the questionnaire [107]. First of all, the survey was co-developed together with different primary and secondary school teachers, and also with the workshop instructors for pedagogic and content appropriateness. Before it was applied to the sample, the questionnaire had been pre-tested with a group of students in non-participating schools. Before the actual participants filled in the survey, they were informed of the importance of responding honestly rather than giving answers that might be deemed desirable by the workshop instructors as well as their teachers. In order to minimize experimenter expectancy effect, the authors of the study prevented any interpersonal contact with the study participants [108]. Alongside the standardised online survey for the students, the teachers were provided with a feedback form with open questions about their general impressions of the workshop. This complementary qualitative survey instrument was applied to compare the results of teachers and students, and to examine whether the teachers' general feedback was in line with those of the students. This procedure follows a mixed-methods approach [109] focusing on the mutual verification of empirical insights. We have not included further information on the teacher survey in this study as the semi-standardised feedback has never been intended to qualify for further detailed analysis. However, these surveys draw a generally positive and affirmative picture about the workshops and their impacts on the students, and thus further confirm our results from the students' surveys S1 and S2.

4.3.2. Knowledge-Action Gap and Self-Reporting

In this study, one major uncertainty requiring discussion is the phenomenon that there can be a considerable knowledge-action-gap, i.e., between knowing about the possibilities of efficient energy use and applying it in the real world [110–115]. So, unfortunately, there is a possibility that self-reported behaviours (as requested in the surveys) might not correspond with the study participants" real action. This conflict is discussed intensely in the literature, and some argue that self-reports are notoriously unreliable [116–119], that self-reported behaviour reflects perceptions or beliefs about people's own behaviour rather than their actual behaviour [119–121], or that people are not even aware of the actual environmental consequences of their individual behaviours [122]. In contrast, it is argued that socially desirable responding is not so much a problem when assessing environmental attitudes and self-reported ecological behaviours [123]. In some studies, observed energy-related behaviours are compared with self-reported measures, and no significant differences between them can be found [49,124,125].

The survey in this study asks for self-reporting of intentions to change actual behaviour. According to the Theory of Planned Behaviour [126,127], human behaviour is guided by three kinds of considerations (behavioural beliefs, normative beliefs, control beliefs), which produce an attitude toward the behaviour, subjective norm and perceived behavioural control. These aspects have been examined in the items about cognitive and affective attributes in the survey. In combination, this leads to the formation of a behavioural intention. According to Ajzen's theory [126] (p. 438), intention is "assumed to be the immediate antecedent of behavior". In this sense, Abrahamse and Steg [128] show that there is a positive relation between attitudes towards energy conservation and actual energy use. There is no doubt that a truly reliable solution to this problem does not yet exist, yet there are various measures which can be, and in the study at hand have been taken in order to reduce the effect of social desirability. In order to further minimise uncertainty, and to examine whether two test items measure the same construct, Cronbach's α, a statistical estimate for internal consistency, was calculated for the items which address the students' intention.

4.3.3. Young People's Influence on Energy Consumption

Young people will be affected by challenges connected with climate change and energy-related topics longer and more intensively over their lifetime than any generation before [129]. However, another uncertainty worth being mentioned here is the question as to whether and how much young people can actually influence energy consumption/reduction. Again, there are opposing scientific arguments: On the one hand, young people's scope of action seems limited, since they are not responsible for energy bills in their household (e.g., electricity, heating) or (technical) energy-intensive investments (e.g., heating, car, insulation). However, reducing heating energy and electricity as well as increasing use of public transport, bicycles or car-pooling and choosing products with a smaller environmental impact are actions that lie within their scope of action and, all in all, have a considerable impact [130]. Most of all, the childhood and teenage years seem important for transferring energy related saving habits into adulthood, whereas changing habits at a later period in life seems clearly more difficult [131]. Furthermore, different studies indicate that, increasingly with age, children and adolescents can actively influence their parents' and friends' values, attitudes and decisions [81,132,133]. Environmental education programmes for children or teenagers can thus result in spillover effects [102]. However, these have not been considered in the study in order to reduce uncertainty. It should also not be forgotten that adolescence—a period of transition–is the second major window of development for human beings [134]. It is of great importance to enable teenagers to deal with environmental challenges, since change is often driven by young people as they explore the world, put societal behaviours to the test, and develop their own values [135]. Thanks to compulsory school attendance in the industrialised world, there is hardly a target group that is organisationally more accessible than students. Thus, young people qualify as a desirable target group for programmes leading to the increase in energy literacy at cognitive, affective and behavioural levels.

Meter reading was not part of the study as it would have provided insights only into the electricity and heating consumption of a household (both subject to possibly very different winter situations and thus energy consumption patterns in Austria), and would not cover the weighty areas of mobility, nutrition and general consumption in which the students have a potentially high scope of action. Moreover, young people spend a lot of time, and thus use a lot of energy, outside their family households [133].

Taking all things said into consideration, the authors assume that energy education in general, and the Energy Education Initiative presented in this study in specific can lead to considerable impact on individuals' and households' energy consumption/reduction.

5. Conclusions

In 2021, a Eurobarometer-survey on climate, environment, and energy shows that European citizens see climate change as the most substantial problem the world is faced with, and thus 78% consider it a very serious problem (plus 15% who say it is a serious problem) [136]. All in all, the survey reports on the strong public support for mitigation, adaptation or transformation measures in connection with climate change, environmental protection, and any type of sustainable development. Its results are an encouraging base for further efforts by the European Commission as to becoming "Fit for 55" [137] and reaching ever more serious climate goals. Energy saving and energy efficiency remain high on the agenda, confirming Eurobarometer trends from 2019, where people showed substantial awareness of the energy and climate related problems of our time, and expressed their desire for innovative energy policies, and also said they were personally willing to act as well [136].

In Austria, public awareness and support are similarly high, and it is small wonder that almost countless projects and initiatives take place in ESD, CCE, and also in more specific energy education programmes. This study indicates that the energy education initiative ETSIT contributed to raising students' energy literacy. Directly after and roughly one year after their respective workshop, the vast majority of the participating students reported that their energy literacy increased at cognitive, affective and behavioural level. Despite an unknown degree of social desirability influence on the responses, the results of the online surveys indicate that the Energy Education Initiative ETSIT meets its targets by getting a considerable number of primary and secondary school students closer to becoming energy literate individuals who report their intentions to make wise use of energy in the future and try to save it where possible in their day-to-day lives.

Based on these findings, a number of implications can be formulated:

In the light of the Austrian Energy Efficiency Act, investments in energy education (e.g., through energy suppliers) should, if they result in a measurable or estimable energy saving, be regarded equal to energy audits in private households, and therefore handled as 'offsettable' investments for energy suppliers for the purpose of increasing energy efficiency [19]. Thereby, the results contribute to the debate on the appraisal and the financial perspective of energy education.

However, the aforementioned uncertainties in the evaluation methodology should not be neglected, but implicitly targeted by additional evidence-based research. Special attention should be paid to defining an equivalent to the quality levels used in the default formula for the monitoring of energy audits. Longitudinal studies with an extensive mixed-methodology approach are needed to find out which specific educational approaches produce positive outcomes and to which degree. A combination of meter data and self-reporting surveys in a pre-test-post-test design could deliver helpful information about the actual impact of energy education on individual and household consumption. However, meter data can only account for household electricity and heating and does not provide insights into the weighty areas of mobility, nutrition and general consumption, in which young people have a potentially high scope of action. In addition, spillover effects as well as rebound effects of energy education require further research as they hold a significant potential to inflate or deflate the actual impact on energy use. Self-reporting surveys could also pay more attention to behavioural patterns ranging from electricity and heating usage over individual mobility to consumption in general and take into account aspects of social desirability as well as demand characteristics effects. The behavioural items in DeWaters et al.'s Energy Literacy Questionnaire [34] could be seen as a starting point but should be extended by further energy efficiency as well as sufficiency measures and adapted to different target groups. Especially in the light of climate scientists' warning about the current state of the Earth's climate on global [138] as well as national/regional level (for Austria, e.g., [139]), it is essential that education activities do not only raise awareness for more sustainable lifestyles, but really lead to action on the ground [140]. Although we could show that even 90 min workshops with only a one-time exposure can have lasting energy-saving effects on individuals, it should be considered that multiple exposure measures over a longer period of time might well prove even more successful and sustainable, in terms of measurable energy savings. A comparison of different interventions in their effectiveness would be very interesting. Unfortunately, the current ETSIT initiative workshops are currently on hold due to COVID-19 pandemic restrictions, and it will probably take some time to reinstall them in the future.

Finally, it has to be clear that focusing on quantifying the impacts of educational campaigns on individual and household energy consumption should never lead to any kind of financial or technocratic "fine tuning of education". At the end of the day, it is the individual and collective action as to saving energy and the climate, and thus the transformation of society towards climate-friendly and sustainable development that counts. In light of the post-COP 26 era and the enormous challenges the planet and humanity are confronted with, no goal less important than that should be pursued.

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