sustainability

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Review

Gaps in Regulation and Policies on the Application of Green Technologies at Household Level in the United Kingdom

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Abstract: Green technologies (Green-Tech) are solutions aiming to mitigate or reverse the effects of human activity on the environment. The United Kingdom (UK) government established a Ten-Point Plan and over GBP 5 billion to support Green-Tech to lay the foundations for a green industrial revolution and reduce emissions by 180 million tons of carbon dioxide equivalent (CO_2e) by 2032. Households and buildings contribute around 40% of the UK's total GHG emissions, which implies that key actions are needed in all areas around the building sector (Point 7). This study provides an overview and analysis of the existing regulation and standards in the UK building/household sector, to understand the current state-of-the-art and identify gaps preventing Green-Tech wider implementation and use. Discrepancies in regulation and standards were identified. Given that households bring together and adhere to numerous standards and regulations, the analysis highlighted that it is critical to formulate relevant actions starting from the individuals with engagement and information. Complete and clear guidelines addressing environmental awareness, the performance and economical convenience of Green-Tech implementation and related regulations, are required to come to a consensus on the best way to move forward to achieve sustainability and NET-ZERO targets.

Keywords: green technologies; green industrial revolution; GHG emissions; UK building sector; environmental awareness

Citation: Bortone, I.; Sakar, H.; Soares, A. Gaps in Regulation and Policies on the Application of Green Technologies at Household Level in the United Kingdom. *Sustainability* **2022**, *14*, 4030. https://doi.org/10.3390/su14074030

Academic Editors: Baojie He, Ayyoob Sharifi, Chi Feng and Jun Yang

Received: 17 February 2022
Accepted: 23 March 2022
Published: 29 March 2022

1. Introduction

The world is currently dealing with multiple inter-connected crises, such as climate change, unprecedented loss of biodiversity, resource limitation, food insecurity, mass refugee displacement, and spread and control of infectious diseases, to name a few. The main causes of climate change relate to carbon dioxide equivalent (CO_2e) emissions from human activities. We use vast amounts of fossil fuels such as coal, petroleum, heavy oil, and natural gas to produce electricity, run cars and other forms of transport, and power industries, all generating greenhouse gases (GHG). Biodiversity losses can also be attributed to human influence on the world's ecosystems, which have deeply altered the environment and overexploited natural resources. Both represent dangerous and irreversible situations that require accelerated transition to sustainability with significant changes necessary at social, economic, and political levels [1].

To tackle climate change, 194 countries signed the Paris Agreement (PA) in December 2015. This is the most significant pact for international cooperation, where states commit to lower their total GHG emissions and aim to limit the planet's temperature increase by 1.5 °C by the year 2050 [2]. After the PA, in June 2019 the UK government emitted key legislations to reduce the country's GHG emissions by 100%, by 2050, considering as reference the GHG levels of 1990. This was aligned with previous obligations, although the NET-ZERO targets are more ambitious, by gathering significant traction [3]. Additionally in 2015, a collection of 17 interlinked goals named the Sustainable Development Goals (SDGs) were set to be achieved by the year 2030 and designed to be a blueprint for a better

and more sustainable future [4]. The UK is among those countries legally engaged to the SDGs and to reach NET-ZERO emissions by 2050, via committing financial investments to lower GHG emissions and initiating climate-resilient development to tackle climate change. Specifically NET-ZERO emissions refer to the balance between the amount of GHG emissions produced and the amount removed from the atmosphere. NET-ZERO emissions are reached when the amount added is less than the amount removed.

The UK most recent GHG territorial emission measurements showed a 3.2% decrease since 2018 to 480 million tons of CO_2e (i.e., CO_2 equivalent corresponding to the amount of CO_2 which would have the equivalent global warming impact, for any quantity and type of gas). In reference to specific sectors, such as surface transport, industry and buildings, there was a decrease in 1–2% from 2018. To achieve NET-ZERO, an average GHG emissions of around 15.5 million tons of CO_2e must be removed every year, over the next 30 years, similar to the 16 million tons of CO_2e reduction accomplished in 2019 [5]. To add to this, more recently, the UK government published a Ten-Point Plan (TPP), leading toward a green industrial revolution [6]. Specifically, the TTP plan mobilises public funding of GBP 12 billion, and conceivably three times this amount from the private sector, to enhance green jobs and green technologies (Green-Tech), considered as the basis of UK economic revival.

2. Green Technologies

Green technologies (Green-Tech) are solutions that meet society's every need without depleting or damaging the natural environment. Specifically, they refer to services or products that improve the operating performance of existing technologies whilst also reducing their energy consumption, costs, and waste without influencing product quality or ways of life. There is numerous Green-Tech, which can be applied across different markets, e.g., green energy, sustainable agricultural practices, green nanotechnology, green chemistry, etc., [7]. Furthermore, there are Green-Tech that anyone can incorporate into their houses leading to the concept of green living and buildings. A concept that refers to cost-effective, as well as, healthy and comfortable living conditions, requiring minimum energy and water inputs, that is also aligned with conservation of natural resources, and consequently generating less waste. Different Green-Tech can be applied in the whole process of delivering green buildings, with typical examples including renewable energy solutions (i.e., solar energy recovery systems, and heat pump), green roofs, sustainable materials for building foundation, walls, insulation, etc. The Green-Tech concept also relates to the use of smart solutions to reduce energy consumption. Some examples range from highly efficient LED lights, smart meters, and autonomous appliances to the use of artificial intelligence (AI) building management systems and services [8]. Emissions from buildings contribute around 40% of the UK's total GHG emissions [5,9] and despite their recent decrease by 1.3%, they remain higher at present than in 2015, hence there is need to focus in this sector.

The building sector emissions are mostly related to the use of electricity combined with oil, coal, and natural gas for heating and cooking. Electricity consumption in building operations exceeds the 50% of global electricity consumption [9]. To be on the trail of accomplishing the NET-ZERO carbon building stock by 2050, the International Energy Agency (IEA) estimated that a minimum of 50% reduction in both direct and indirect building CO_2 emissions (i.e., from electricity and heat production) is necessary by 2030. This means that the building sector should reduce its annual emissions by approximately 6% until 2030 [9]. Initiatives towards more sustainable buildings were observed both in the public and private sectors. In this regard, the UK government set a series of actions in the attempt to tackle improvements for GHG emission reduction in the building sector [5].

These aim to:

- Develop a strategy to fully decarbonise UK buildings in line with the NET-ZERO goal;
- Strengthen new-build standards;
- Introduce tangible and clear standards across the building sector and firm policies;
- Tackle performance and compliance issues both for new and existing buildings;

- Publish a plan for high-carbon fossil fuel heating installation.

However, despite the release of building regulations and consultations in 2019, the latest progress report of the Climate Change Committee showed that none of these actions have been fully accomplished yet and only a few have been partially completed [5]. Change is also being observed in private consumers, with an increasing demand and preference for sustainable products in their homes [10]. In general, there is a growing interest in product life-cycle, such as design, production, consumption; re-use, recycling, and waste, and in how companies can achieve green sustainability and certifications under the current demands. In response to this, the Financial Conduct Authority recently assisted in the development of a mobile app, called CoGo, created by world leading carbon footprint specialists and data scientists to connect consumers with businesses. The CoGo app calculates personalized carbon footprint (i.e., GHG emissions) in real time, linked directly to the individuals' spending transactions and lifestyle choices (https://www.cogo.co, accessed on 21 November 2021). The International Trade Centre (ITC) acknowledged similar initiatives across Europe. According to the ITC 2019 report, 85% of retailers reported an increase in sales of sustainable products during the past years, and among these, 65% stated that such increase was above 10% [11].

Despite Green-Tech's innovative and advantageous aspects, studies have highlighted that various barriers affect their adoption in the buildings development process and private sector, mostly due to their uncertain costs combined with lack of information and awareness of their benefits, limited government incentives, and an interrelated resistance to change [12]. Therefore, Green-Tech development for households needs proper government guidance with policies and strategies to be reinvented to overcome those barriers. It is not clear how UK policy efforts are moving forward mainstream household innovation and technologies and what the challenges are regarding their implementation [7].

This study aims to provide a thorough review of the existing regulation and policies on Green-Tech implementation at the household and commercial level to understand the current state-of-the-art, but most importantly to identify gaps, bottlenecks, and loopholes that prevent the wider use of Green-Tech.

3. Green Buildings and Incentives for Their Wider Implementation

The green building technologies market is expanding, and widely supported by many governments. Consequently, this has encouraged the growth in adopting green building certification schemes, such as the Leadership in Energy and Environmental Design (LEED) certification, the Green Star rating system, and the Code for Sustainable Homes. Likewise, there is a wider interest in how buildings can have low environmental impact and comply with a low-energy and affordable future [13,14]. For example, studies have shown that using high energy-efficient windows and green walls in houses can save 14–20% and 33–60% of energy, respectively. Furthermore, retrofitting existing buildings with high energy-efficient wall materials and technologies can lead to 25% energy savings [12].

The UK government's attempts to mainstream Green-Tech at household level started around the 2000s, when the first world's established method to assess, rate, and certify the sustainability of buildings, called the Building Research Establishment Environmental Assessment Method (BREEAM), was introduced. Implemented in more than 70 countries, BREEAM is a building evaluation carried out by independent licensed assessors, by referring to scientifically-based sustainability metrics and indices to assess a range of environmental issues. BREEAM categories estimate energy and water use, materials, waste, transport, health and well-being, ecology, pollution, and management processes, according to which buildings can be rated and certified by referring to a scale ranging from 'Pass', 'Good', 'Very Good', 'Excellent', and 'Outstanding'.

As part of the BREEAM family of schemes, a series of technical standards for the evaluation and certification of new and existing homes were successively launched, including Home Quality Mark (HQM), Code for Sustainable Homes (CSHs), BREEAM Domestic Refurbishment, and BREEAM International New Construction, summarised in Table 1 [15,16].

Table 1. BREEAM family of schemes.

Home Quality Mark (HQM)	2005	UK Certification Scheme for high quality and sustainable new homes.
Code for Sustainable Homes (CSH)	2008	UK Government standard and environmental assessment method for new houses rating and certification.
BREEAM Domestic Refurbishment	2014	UK standard to improve the environmental performance and sustainability of existing residential houses.

The Home Quality Mark rates new houses on their overall quality standards and environmental impact. HQM provides two elements, such as a five-star rating system representing the overall depiction of house quality, and a group of indicators on individual features of house performance, e.g., building quality and running costs.

Successively, the Code for Sustainable Homes (CSH) was launched in 2008. The CSH introduced an environmental assessment method to certify and rate new houses performance, and aimed at creating more sustainable dwellings, encouraging continuous improvement, and reducing carbon emissions [15]. It was part of a series of measures also including "Building A Greener Future" and "Planning Policy Statement: Planning and Climate Change" [17,18].

More recently, the BREEAM Domestic Refurbishment and BREEAM International New Construction schemes were released. The first sets standards for the refurbishment existing houses and provides market-focused labels of reference for sustainable and higher quality improvements. The second scheme assists house developers and builders in enhancing the quality of their built products, making them more attractive for investors and homeowners.

The UK's evolution to a green building sector is delayed in contrast to other national contexts [7,19]. Some model examples of urban sustainability can be found in Europe, such as the City of Freiburg in Southern Germany, internationally recognized as a model of environmentally sustainable urban development and leader in energy efficiency; and 'The Walkable City', a progressive environmental and sustainable urban plan in Sweden [20]. Canada is instead an example of international policy design, with the Australian NABERS scheme as good practice policy for decarbonising commercial buildings [21].

This delay in the UK, might be associated with the unknowns and uncertainty still surrounding costs to design and build sustainable buildings compared with those that simply follow existing regulatory requirements. Although clear information is hard to find, research developed by the Sweett Group into projects using BREEAM, demonstrated that green building options add only a small amount or often no capital cost to new housing projects. However, despite the eventual additional costs, these measures showed the high advantage of a life-lasting economical return through lower running expenses, and led to consistent energy saving. Other studies have also underlined the enhanced value and quality of green buildings, and how their greater efficiency made this building concept more commercially attractive. There is high evidence that BREEAM-rated buildings increase both return rates for investors, and rental rates and sale premiums for developers and owners. Maastricht University documented the effect of BREEAM certification on office buildings in London from 2000 to 2009 and reported an achievement of 21% premium on sales prices and an 18% premium on the rents of these buildings [22].

A recent example of green building in the UK promoting best practices, which highly contributes to influence government policy on zero carbon building, is the BedZed development in South London. Completed in 2002, BedZed is a large-scale eco-village with 100 homes, office spaces, a college, and community facilities. It was designed to achieve significant reduction in GHG emissions, water use and car-free streets. For a three-person BedZed household (using a car sharing scheme), it was estimated a total annual saving of GBP 1391 in water, transport, and energy bills, compared with an average London household (with owned car), corresponding to approximately GBP 4 per day. One of the BedZed's biggest successes is the creation of a great community, with car-free areas for children to play and people to socialise.

4. Regulations and Policies

4.1. Buildings

In England and Wales, the Building Act 1984 represents the basis framework for buildings while the rules and procedures currently required for building works are collected in its Building Regulations. In inner London, building control is governed by the London Building Acts and associated byelaws (i.e., Building (Inner London) Regulations 1985) while a separate system applies in Northern Ireland and Scotland.

Depending on the procedural matters, the regulations currently applied are:

- The Building Regulations 2010 (amended);
- The Building (Approved Inspectors, etc.) Regulations 2010 (amended);
- The Building (Local Authority Charges) Regulations 2010.

Most of these regulations were subsequently revised, amended and, further updated over the years and consultations are still ongoing [23]. For this, particular attention is needed to ensure that the most recent modifications are being considered. The Building Regulations, in general, do not contain technical details, which can be found in the related Approved Documents, providing "practical guidance" and an additional other non-statutory guidance. All of them link to "other non-statutory documents" such as National Standards, European Technical Approvals or Technical Specifications and European Standards (e.g., British Standards, Certificates, Agreement). This policy organisation, schematised in Figure 1, aims to simplify the system consultation and eventual modifications.

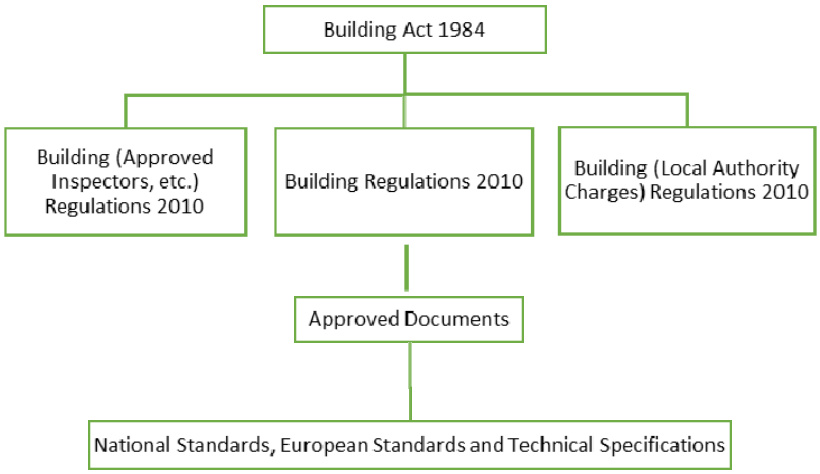

Figure 1. Legislation scheme for buildings in England.

The Building Regulations agenda contributed to a broader low carbon transition to stimulate economic progression, ensure a future proof housing sector, by improving the construction sector [24].

The objectives of the Building Regulations aimed to:

- Secure people's safety, health, welfare and convenience in or about buildings and "of others who may be affected by buildings or matters connected with buildings";
- Enhance fuel and power conservation;
- Prevent waste, unnecessary consumption, misuse, or contamination of water.

Such regulations address the technical areas shown in Table 2 [23].

Table 2. Key technical requirements of the Building Regulations [23].

Technical Areas	Description	Building Regulations Specific to Each Part
A: Structure	Ground movement, loading, and disproportionate collapse.	
B: Fire safety	Internal and external fire spread, access and facilities for the fire service, fire warning and escape.	Regulations 7, 38
C: Site preparation and resistance to moisture and contaminants	Subsoil drainage and resistance to weather, interstitial and surface condensation, and ground moisture, preparation of site and resistance to contaminants.	
D: Toxic substances	Cavity insulation.	
E: Resistance to the passage of sound	Sound protection from	
other parts of a building and adjoining buildings.	Regulation 41	
F: Ventilation	The people living in the building must be provided with an "adequate means of ventilation"	Regulations 39, 42, 44
G: Sanitation, hot water safety and water efficiency	Water efficiency, hot water supply and systems, cold water supply, sanitary conveniences and washing facilities, kitchens and food preparation areas, bathrooms.	Regulations 36, 37
H: Drainage and waste disposal	Water drainage, rainwater drainage, wastewater treatment systems and cesspools, building over sewers, separate systems of drainage and solid waste storage.	
J: Combustion appliances and fuel storage systems	Air supply, protection of the building, discharge of products of combustion, warning of release of carbon monoxide, protection of liquid fuel storage systems and protection against pollution.	
K: Protection from falling, collision, and impact	Stairs, ladders and ramps, protection from falling, protection against impact with glazing, vehicle barriers and loading bays.	

According to the Sustainable and Secure Buildings Act 2004, still in use, the Department for Communities and Local Government are required to publish reports to Parliament every two years, to justify whether and how the building regulations and other related policies have helped to improve the environmental sustainability of building sector.

These reports must include any changes in:

- Building regulations and their expected related impact;
- Any strategic legislation, and proposals for targets setting to sustainable buildings;
- Estimation of dwellings number in England;
- Carbon and energy efficiency of the building standard;
- Level to which buildings have their own facilities for energy generation;
- Reuse and recycling of construction materials over the period of reference.

In addition, the UK Green British Council (UKGBC) produced a new home policy playbook to assist local authorities in implementing sustainability of new houses [25]. This is intended to be a hands-on resource, which can be used and adjusted to endorse the 'day job' of officers with responsibilities for sustainability and planning within local authorities. Together with this playbook, UKGBC also provided an interactive UK policy map, which shows important examples of new build policies from local and combined authorities across the country.

Differing initiatives attempted to reduce the environmental impact of the building sector and its related GHG emissions. In order to analyse the variation in policy design for green buildings and the sectors involved, in the following subsections, specific details to the actions taken for energy, water use, transport, materials, nature-based solutions and smart living are discussed.

4.2. Energy

The UK's buildings and housing standard are acknowledged as being among the most energy inefficient in Europe as 70% of buildings do not meet current energy efficiency standards [7]. New targets set for domestic energy efficiency require that, by 2025, homes should reduce CO_2 emissions by 75–80% compared with current levels.

As heating and electricity powering currently account for 40% of the UK's total energy usage, policies to encourage Green-Tech in the energy sector have been an essential part of UK government commitments for climate change mitigation in the past years. This aimed to have more proficient and sustainable old and new houses in order to reduce CO_2 emissions and improve building energy efficiency [26].

In 2012, following the European Energy Efficiency Directive which provided member states the responsibility to encourage and simplify efficient energy use by domestic customers, in the UK household sector, the Green Deal (GD) and the Energy Efficiency Obligations (ECO) were delivered. Their aim was to retrofit insulation measures and promote energy-efficient heating systems and appliances [27].

Since then, a range of key initiatives promoting energy efficiency in homes, together with instruments, such as non-regulatory policies, access to finance, fiscal incentives, grants, information provision, representative projects, or workplace activities, are also increasingly being implemented (Table 3). The main policies for energy efficiency are chronologically described in the following and reported in Table 3.

Table 3. Energy efficiency measures for households.

Initiative	Date	Main Content
The Energy Company Obligation (ECO)	2012–ongoing	Energy efficiency obligation on large energy suppliers (gas and electricity), working with the Green Deal to provide energy-saving home improvements for those in need.
Green Deal: energy saving for your home	2012–2015	Finance scheme for homeowners to install new energy-saving measures in their homes (i.e., new boilers, insulation, or double glazing).
Smart meter implementation program	2017	Program to support gas and electricity meter installation for real-time data on energy use in households and small businesses.
Domestic Renewable Heat Incentive (RHI)	2018	Government financial incentive to promote use of renewable heat.
Green Homes Grant	2020	Funding (vouchers) available to homeowners to realise energy-efficient home improvements.
Electricity Demand Reduction project		Assessment on available support and incentives to households, businesses, and organisations.
The Central Heating Fund		Authority competition supporting installation of first-time heating systems in low income households.

The Green Deal (GD) relates to sustainable improvements for England, Scotland, and Wales's homes with energy-saving measures and electricity meters.

The different energy-saving measures include:

- Fenestration with energy-efficient glazing and doors (e.g., double glazing windows, fiberglass doors, etc.);
- Use of energy-efficient lighting (e.g., lighting LED, lighting control etc.);
- Upgrade heating (e.g., underfloor heating, condensing boilers etc.);
- Novel hot water systems (e.g., water efficient taps and showers);
- Generation of renewable energy from natural sources such as wind or solar power.

The Green Deal was set up in 2012 but the application process is difficult to follow and to implement both for the costumers and the providers, as such, the government

funding for loans were stopped in July 2015. This was also because the interest rate was too high and ultimately the amount of finance made available was often insufficient to cover the installation costs of some of the energy-saving measures. In 2017, the scheme was resurrected and still in use via private investors; however, loans are not easily accessible, as limited home specifications allow to be qualified and only refer to selected companies.

As mentioned, the ECO was also launched in 2012, and underwent significant amendments in recent years. ECO is a subvention from energy suppliers that, combined with the Green Deal, offers home improvement options for energy-saving to the most in need customers and for those older buildings more difficult to upgrade. Its basic concept is the obligation on large energy suppliers (gas and electricity) to deliver heating and energy efficiency measures to domestic households. Part of the ECO scheme was the Carbon Emissions Reduction Obligation (CERO). CERO was a free energy assessment designed to help households pay for solid walls and hard to treat cavity wall insulation.

Successively, the Energy Act 2013 introduced several consumer protection provisions, which included:

- Limitation on the energy tariff number presented to domestic consumers;
- Automatic change in customers to cheaper deals;
- Supplier obligation to inform consumers on the best alternative deals available to them.

In 2014, the Big Energy Saving Network delivered a broad programme helping vulnerable consumers to reduce their energy costs and energy consumption. Between 2014 and 2015, a new "fuel poverty target" was set for England, by publishing a strategy to cut the fuel costs for heating in the long term [28]. The Central Heating Fund launched an English Local Authority competition assisting in the installation of central heating systems for the first time in those low-income households not using main gas as primary heating fuel source.

The smart meter implementation program followed in 2017. This was a programme to introduce electricity and gas meters providing near real-time information on energy consumption for both households and small businesses. Smart meters (SMETS2) were successively considered as gas and electricity meters, offering a range of smart functions. For example, these inform customers on how much energy is being used and showed on an In Home Display (IHD). These smart meters communicate directly to the energy supplier, by allowing the costumers to have accurate bills, without the need for the energy supplier to be on-site. Therefore, IHD helps to keep track of energy usage and kilowatt hours (kWh) and allow to switch off appliances when possible.

In 2018, the Clean Growth Strategy (CGS) emitted policies to promote clean growth, and improve UK homes energy efficiency. A new ECO3 scheme, running until March 2022, was also approved. This scheme's targets relate to energy efficiency, fuel poverty and bill savings. ECO3 aims to provide support to low-income, vulnerable, and fuel poor households, and to substitute the previous CERO.

Additionally, the Green Homes Grant was set out in September 2020, also running until March 2022, for homeowners to apply for funding and realise energy-efficient home improvements. Depending on eligibility, the government committed to provide two-thirds funding up to GBP 5000, or up to GBP 10,000 for low-income homes.

The types of improvements fall into two categories:

- Primary measures, which are defined as the home improvements further improving the home's energy efficiency, including heat pumps and insulation. These improvements help thermal home efficiency and at the same time reduce the home heating bills and carbon emissions. They are considered the most worthwhile improvements that homeowners can request under the Green Homes Grant;
- Secondary measures also reduce home carbon emissions, and they include double or triple glazing (where single glazing are replaced), secondary glazing (in addition to single glazing), draught proofing, energy-efficient doors replacement, etc.

A Simple Energy Advice (SEA) website is also recommended to customers addressing on the suitable options and what energy efficiency or low carbon heating improvements may be best suited for different households.

However, some schemes cannot be applied together. In fact, it is not possible for the privilege of a Green Homes Grant voucher to support the cost of a measure which was also funded under the ECO. They can be both claimed only if each one of them is requested for different measures (e.g., cavity wall insulation and loft insulation). On the other end, in case of a renewable heat installation, it is possible to apply the Domestic Renewable Heat Incentive (RHI) with the Green Home Grant.

More recently, in January 2021, the UK government, responding to a consultation on the Future Homes Standard (FHS), introduced further plans to radically improve the sustainability, with all homes to be carbon NET-ZERO ready by 2025 and to change the Building Regulations 2010 from 2021 onward [23,29].

As summarized in Table 4, two-stage consultation to the current building regulations were released, setting new ventilation and overheating standards to improve energy efficiency, called, respectively, the Future Homes Standard Consultation (FHS) and The Future Building Standard Consultation (FBS). To ensure the housing industry is ready to meet the new standards by 2025, new houses need to produce 31% lower GHG emissions from 2021.

Table 4. Latest consultations to modify Building Regulations 2010.

Initiative	Date	Main Content
The Future Homes Standard Consultation (FHS)	2020	Document introducing new overheating mitigation requirement in the Building Regulations for new and existing residential buildings.
The Future Building Standard Consultation (FBS)	2021	Consultation on changes to Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for non-domestic buildings and dwellings; and overheating in new residential buildings.

These consultations propose changes to the energy efficiency standards for new houses, as well as the wider impacts of Part L (conservation of fuel and power), and Part F (ventilation) (Table 4), by improving the 'as-built' performance. As reported, FHS and FBS aim for new housing to not be built with fossil fuel heating, such as a natural gas boiler, but with low-carbon heat sources (i.e., heat pumps, heat networks, direct electric heating, etc.), together with related improvement of home insulation. A full technical specification for the Future Homes Standard will be released for consultation in 2023, with the necessary legislation introduced in 2024, and implemented by 2025.

4.3. Water

In the UK, the household water demand and management contribute to 0.8% of the annual GHG emissions. Furthermore, the emissions resulting from heating water in the home increases this amount to 5.5%. Current law specifies that water companies must supply potable water to all houses. Yet on the UK government website, all house owners are encouraged to use water efficiently and the importance to protect water supplies for the future is highlighted. Some examples of the water-saving and efficiency measures promoted are listed in Table 5. For water use in England and Wales, it is important to refer to the Water Supply (Water Quality) Regulations 2018 (SI 2009/3101), playing an important role in safeguarding water supplies, protecting public health, and encouraging the efficient use of water within customers' properties. In the Water Supply Regulations, water is considered to be "wholesome" if it does not contain any microorganism or parasite and any substance at a concentration dangerous for human health. Greywater is, instead, the domestic wastewater (excluding toilet flushing), and it is usually divided into light greywater, which is from bathrooms, hand basins, showers, tubs, and dark greywater, including laundry facilities, dishwashers, and kitchen sinks [30].

Table 5. Domestic water efficiency and saving measures promoted in households.

Kitchen	Turn off tap water between rinsing dishes; fix dripping taps; only fill the kettle with the water needed; use of water-efficient dishwashers and washing machines
Bathroom	Turn off the tap whilst brushing teeth; take shorter showers; fit flow regulators or aerators to taps; put water-saving bags where possible; fit a flow regulator or an aerated shower head
Garden	Utilise water butt in the garden and a watering can or bucket and sponge

The Code for Sustainable Homes (CSHs) provides an environmental evaluation method to rate and certify new homes' performance, and to encourage a continuous upgrading of households also in relation to water sustainability. In this regard, it is also indicated that the daily water usage per person must be maximum 80 L up to 120 L with increasing rating levels [31]. The Approved Document of Part G of the updated Building Regulations 2010 [32] introduced a new requirement that, for any new house, the maximum potential water consumption is 125 L per person per day. It is also suggested not to use drinking water quality for toilet flushing. Green-Tech for water systems can be used to meet this target, as they support sustainable water management, by developing environmentally friendly, economically viable, and energy-efficient processes to treat and preserve water resources (Table 6). Water reuse technologies have the potential to save considerable water amount when used in a targeted way. For instance, 24% of household water is used for toilet flushing whilst 4% is used externally in the garden. This means that by using such systems it is possible to save at least a quarter of water use demand. Additionally, depending on the outlet water quality and the system installed, it can additionally save 12% of water used for washing clothes [33]. Among these systems, the water reuse systems, such as greywater or rainwater harvesting, summarized in Table 6, which displayed a growing interest over the last years [34]. Greywater recycling systems such as Hydraloop claims to recycle 85% of domestic water used, reduces water consumption by 45%, wastewater production by 45% and carbon footprint with 6%. The estimated return of investment is between 5 and 6 years. These systems provide an alternative water source that can be used as alternative to drinking water for uses that do not require high quality water. They are much supported by many water suppliers.

Table 6. Green-Tech for water reuse.

Rainwater harvesting	Diverting rainwater from roofs or other collection surfaces in underwater tanks; green roofs; green walls; store rainwater in garden water butt.
Greywater treatment	Diverting water from kitchen sinks, wash hand basins, washing machines, showers, baths to a treatment onsite and re-use for the same applications.

No regulations are available for the quality of reused water; however, the British Standards Institute (BSI) launched some guidelines for both greywater and rainwater reuse. These guidelines introduce water quality parameters for water reuse applications, whose standards are referred to those included in the European Bathing Water Directive.

While rainwater can be used for non-potable purposes (e.g., washing vehicles, irrigation, etc.), the suitability of greywater reuse is widely influenced by what it is used for. All systems storing greywater must incorporate some level of water treatment, as untreated greywater tends to rapidly deteriorate when stored. Such deterioration occurs as greywater is often warm and rich in organic matter (e.g., hair, skin particles, detergents, etc.), which are ideal conditions for bacteria to multiply, resulting in poor water quality. Additionally, greywater can contain harmful bacteria, which, without adequate water treatment, represent a serious health risk. However, if the greywater is not stored for long before use, it is possible to reuse it before any treatment. For instance, bath water, once cooled, can be used directly for garden irrigation [35].

Integrated water systems use both treated greywater and harvested rainwater. These systems can be implemented where one or the other of the non-potable sources are insufficient to meet the end uses. An example of water reuse implementation is in BedZed, where water-saving appliances provided of aerated flow taps and shower heads, dual-flush toilets, and water-efficient washing machines were combined. With these solutions, the average home saves approximatively 40% of water compared with average metered homes in the same area.

4.4. Nature-Based Solutions

Nature-based solutions (NbSs) implicate working with nature to address societal challenges, and provide benefits for both human well-being and biodiversity. Specially, NbSs involve the protection or creation of novel ecosystems in the household, the renewal or management of natural and semi-natural ecosystems, and the sustainable management of aquatic systems and lands (i.e., croplands or timberlands) [36].

An increasing number of building developers, city mayors and owners are setting ambitious targets on carbon reduction, climate resilience, and increasing biodiversity. By implementing green roofs and walls in buildings, it is possible to create new ecosystems, renewing biodiversity, helping to protect species that otherwise struggle to survive in urban environments and can be otherwise extinct. Green plants can sequestrate atmospheric carbon, reducing air pollution, of special relevance in large cities. Further to this, green walls have other advantages by contributing to building insulation and a noise barrier. They can also help reduce the impact of heat waves and other climate changes by maintaining and decreasing the air temperature and moisture around them. Buildings that resemble forests are slowly emerging around the world, with a positive visual impact as well as people recognising them as source of well-being and joy.

In March 2020, the UK Government disclosed differing funding toward Nature recovery. Some examples are GBP 640 million Nature for Climate Fund to restore 35,000 hectares of peatland and plant 30,000 hectares of trees in England by 2025, and GBP 25 million towards the Nature Recovery Network in England, that involved collaborating with local communities to safeguard and restore natural habitats. However, no regulations or policies are currently available in the UK for NbSs at household and commercial activities.

4.5. Materials

Green-Tech materials aim to be of sustainable nature and quality, by also fully satisfying the purposes and conditions of their use. Household materials include all those manufactured products (e.g., components, fittings, and items of equipment and systems) connected to building work together with backfilling for excavations.

A range of solutions can be currently used to reduce the embodied GHG emissions of building materials, for example minimising the amount of steel and concrete required when possible and using suitable and environmentally friendly sourced building materials where possible (e.g., recycled products, secondary aggregates, and FSC certified timber).

In the UK, building materials are regulated by the Building Regulations 2010 with its related Approved Document 7, called "Materials and workshop" updated in 2013 to reflect the full implementation of the European Construction Products Regulation of 2011.

The use of recyclable materials is also managed by the Building Research Establishment Environmental Assessment Method (BREEAM), which contains further details on the various environmental aspects of buildings (e.g., energy efficiency and indoor air quality).

In 2018, the Building Research Establishment (BRE) released a database informative of the environmental impacts of building materials, including embodied energy. The BRE database contains 350 datasets that are compliant with the EN 15804 Environmental Product Declarations (EPD). The latter is the EPD standard for the sustainability of construction works and services. Specifically, the EN 15804 describes the products being assessed, their technical performance, as well as material content and provides data on a standardized set of indicators for the products in specific life stages.

Successively, the government released the Construction Products (amendment) Regulations 2020 after EU Exit [37], whose changes apply in England, Wales, and Scotland only, while Northern Ireland relates to the EU requirements for construction products.

4.6. Smart Living

Smart home Green-Tech includes smart appliances and smart systems such as, energy-saving appliances, or remote management of lighting, temperature, appliances, security systems, garden irrigation, etc.

In reference to this sector, in 2016, the UK government set out the Smart Systems and Flexibility Plan (SSFP) as a response of the joint Call for Evidence launched in the same year to collect stakeholders' opinion when transitioning to a smarter, flexible energy system. SSFP delineated a series of actions, which relate to Demand-Side Response (DSR), by also including user view with regulating smart appliances. DSR is a way for consumers to participate with the energy system, by managing their consumption in response to needs and price. This focused on generating benefit to the overall system, which helped to balance supply and demand and to manage consumer bills via offering smart offers, i.e., time of use tariffs.

Successively in 2018, a Consultation on Proposals regarding Smart Appliances was released, proposing to set out DSR appliances [38]. The following decisions entailed to set regulatory supplies for smart appliances and to develop technical standards. The UK government based these standards on principles of data privacy, cyber-security, and consumer protection. In reference to that, the UK is currently planning a new law aimed at improving the security standards of household products connected to the Internet of Things (IoT).

The legislation stipulates that all consumer smart devices sold in the UK (i.e., TVs, smart cameras, wearable health trackers, and connected appliances) must follow three specific requirements:

1. IoT devices must have unique passwords and retuning to universal factory settings should be unable;
2. Manufacturers must provide contact points to enable the customers to easily report any vulnerability;
3. Manufacturers must clearly communicate the timeframe of the security updates for the devices they sell.

These proposed rules are a result of a long consultation period, during which officials explored the potential impact of the growing popularity of connected devices. The government research indicated that, by the end of 2025, there will be over 75 billion devices connected to internet in homes around the world. The aim of this legislation is to avoid piracy attacks.

No current specific regulations address the use and installation of smart living systems.

4.7. Transport

In the transport sector, the UK Government is focusing on Electric vehicles (EVs) as Green-Tech to help to meet the UK long term NET-ZERO GHG emissions by 2050.

In 2011, because EVs were more expensive than the equivalent internal combustion vehicles, the UK government offered plugs-in grants to make EV more affordable (successively updated with the Budget 2020).

However, research studies have highlighted that the lack of charge points is often the main reason why consumers do not buy EVs [39]. In this context, to help this sector evolve, more accessible, affordable, and safe charging EV infrastructure networks were addressed in policies.

In 2019, following the GBP 1.5 billion Road to Zero strategy of 2018, defining a comprehensive package of support to ensure all new cars and trucks to be effective with zero GHG emissions by 2040, the UK government released a public consultation on EVs. This consultation, called "Electric Vehicles Charge points", proposed to fit electric car

charge points in all new-build homes with dedicated car parking spaces and make some changes to the Building Regulations 2010. Additionally, it outlined to transpose three requirements from the European Energy Performance of building Directive (EPBD) to set minimum requirements for EV charging infrastructure.

The EV Charge points Consultation was linked to a package of statements to support EV drivers and improve the experience of charging, ensuring the convenience and efficiency for drivers, by also including a standardized approach to EV charging equipment. A drafted Approved Document and two impact assessments were also published within the consultation. These latter assessed the impact of the requirements on both residential and non- residential buildings. However, after such Consultation, no updates are available for this sector regulations. More recently, Point 4 of the Ten-Point Plans for a Greener Industrial Revolution, addresses in the further actions to accelerate the shift to zero-emission vehicles, announcing investments worth GBP 500 million to drive to the UK automotive sector electrification [6].

5. Gaps in Policies and Green-Tech Implementation

Buildings are among the most long-living products across the economic sector and highly impact on the GHG emissions.

Their long-term nature automatically implies a low turnover rate of building standards over time, which significantly affects the choice of policies. While new buildings can be designed by implementing sustainable technologies, often technical innovation cannot be easily implemented in existing buildings. This results in many households with obsolete technologies which are costly and difficult to replace for the consumer. Improving household efficiency and sustainability is, in fact, usually connected to extra capital costs. Although these are often recovered during the service building lives, consumers generally discard the efficiency option if the related investment is not recovered via cost-savings within a short timeframe. For this reason, Green-Tech implementation is one of the biggest challenges for households and only clear regulations and policies can help the individuals to overcome such obstacles.

As here discussed, many initiatives have been undertaken in recent years, to implement Green-Tech in the interconnected sectors related both to new and existing buildings, in the attempt to achieve the GHG emission target by 2050. However, most of UK government focus has been on energy policies and only a few funding initiatives have indeed been implemented over the years.

Given that buildings bring together and adhere to numerous different policies, standards and regulations, the analysis highlighted how difficult and confusing it can be to follow all regulations and updates involved [40]. This was observed especially in the energy sector, where energy policies and associated programs failed to be consistent in focus and to help consumers in the long term [41]. The most recent regulations in the energy market tried to simplify the process by making it clearer and fairer for consumers and by allowing them to easily check on their existing deals and understand how changes would benefit them. However, this is not sufficient to fully implement the Green-Tech course of action.

In summary the gaps in policies for Green-Tech implementation identified:

- Most of the UK government's focus has been on energy policies and only a few funding initiatives have indeed been implemented over the years;
- Given that buildings bring together and adhere to numerous different policies, standards and regulations, it can be difficult and confusing to follow all regulations and updates involved. This was observed especially in the energy sector, where energy policies and associated programs failed to be consistent in focus and to help consumers in the long term;
- The lack of knowledge about costs about what these technologies can achieve, a low level of awareness of their benefits, a lack of government incentives, and sector resistance to change is slowing the adoption of Green-Tech in building development.

To address these gaps, there is a need to complete and clear evidence-based guidelines and indications, which address concerns around (a) the performance and (b) the economical convenience of Green-Tech implementation, are required to better incentivise the adoption of green technologies. These should include specific procedures which address each different related sector. The evidenced-based guidelines on the most effective types of household efficiency interventions should be produced, to simplify the performance and standards of Green-Tech. Additionally, policies that tackle the high capital costs involved in improving building and household efficiency and sustainability. It is also recommended that campaigns are launched to increase awareness on how the upfront costs of making efficiencies are often recovered during the life of the building.

6. Conclusions

The building sector has a major impact on UK GHG emissions, and is directly and indirectly interconnected to many sectors, such as energy, water, materials, and smart systems, which affect household efficiency and environmental performance.

Green-Tech can be a sustainable solution to implement in all households. However, the costs remain uncertain to implement and economic barriers are increasing.

Under these circumstances, government policies play an important role in guiding the individuals and addressing on the best solutions to adopt together with supporting funding for their implementation.

In this paper, a holistic analysis of regulations and policies to support Green-Tech implementation for households in the UK was carried out. This specifically included the building sector regulations, and is interrelated with initiatives adopted in energy, water, material, nature-based solutions, smart living, and transport.

The analysis highlighted different aspects for each sector, which are summarized in the following:

- The energy sector has the most attention for the higher GHG emissions correlated. Many regulations and funding initiatives have been released over the years; however, the energy efficiency technologies implementation procedures to follow are often confusing and not economically adequate both for the customers and suppliers;
- The water sector regulations mainly relate to water quality standards and general indications for water saving and reuse. No specific policies and funding actions are shown to be planned to help water Green-Tech implementation in households;
- The nature-based solutions sector has yet to be regulated and addressed. Only funding initiatives have been, released but actions have yet to be undertaken;
- The materials sector regulations and policies are incorporated in the building regulations and have been updated in recent years. Building material technical performance as well as content and environmental impact have been widely addressed;
- The smart living sector was approached via consultations and plans to best approach their use and public consensus; however, no specific regulations address their use and installation;
- The transport sector and EV implementation was initiated with consultations and funding opportunities. However, no regulations have been released yet.

Households bring together and adhere to numerous different policies, standards and regulations, and meeting targets in an efficient way can be onerous and difficult to follow for the consumer. Therefore, complete, and clear guidelines and indications, addressing both the performance and economical convenience of Green-Tech implementation and related regulations, are required to come to a consensus on the best way to move forward.

Author Contributions: Resources, data curation and writing—original draft preparation, I.B.; review and editing, H.S.; conceptualization, methodology, formal analysis, investigation, writing—review and editing, supervision, project administration, funding acquisition, A.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Policy Support Fund (PSF).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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