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Perspective

What does Horizon 2020 contribute to? Analysing and visualising the community practices of Europe's largest research and innovation programme

Oleksandr Husiev [a,*], Olatz Ukar Arrien [a], Marta Enciso-Santocildes [b]

[a] Faculty of Engineering, University of Deusto, Avda Universidades 24, 48007 Bilbao, Spain
[b] Faculty of Law, University of Deusto, Avda Universidades 24, 48007 Bilbao, Spain

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ABSTRACT

Decarbonising the world's energy system requires integrated and concise incentives to encourage citizens to participate actively in the energy transition. This article explores community-addressed practices within highly competitive energy projects of the Horizon 2020 framework programme. Compared with bibliometric research, analysing projects' open-platform databases in connection with academic literature can leverage the review and identification of practices in state-of-the-art research projects. In this regard, by applying methodology based on natural language processing techniques to a publicly available Horizon 2020 knowledge database, this paper generalises community-oriented approaches and solutions described in high-impact energy projects. The findings illustrate and characterise disproportions in generalised practices directed to energy consumption reduction, low-carbon energy generation, social economy, policy and strategy actions. Furthermore, the results discuss and exemplify specific projects in the context of the high-impact framework program's technical, socio-economic and socio-cultural matter. Finally, this research work has demonstrated the implementation of language processing within the custom implementation and certain limitations. Given its flexibility, the complex approach can be used as an easy-deployable lens to epitomize the thematic study and facilitate a discussion of trends in social and energy field research.

1. Introduction

As one of the parties to the Paris Agreement, the European Union has an evolving ambition for meeting climate targets and has introduced a policy with the overarching aim to make the EU an economy with net-zero greenhouse gas emissions by 2050 [1]. The resolution on the European Green Deal places energy efficiency and renewable energies in a prominent place among solutions toward the net-zero greenhouse gas emissions objective and outlines their role.

Climate change mitigation also has repercussions on the social sphere—in particular, energy justice and equity [2,3] and energy poverty [4–6] —discussed by scholars across and outside Europe. It increases the potential for creating a more equitable society that highlights the synergies between the dual goals of keeping the temperature below 1.5 °C global warming and achieving the Sustainable Development Goals [7].

As an ambiguous phenomenon for framing and definition, renewable energy transition has sparked the scientific community and policymakers to re-conceptualise an energy system focusing on opportunities for decentralisation [8]. Naturally, such a process requires reconfiguration of responsibility between participating actors. One critical development to spread renewable energy technologies is seen in the emergence of citizens as engaged stakeholders in energy transition through so-called energy communities [9]. In general, an explosion of research in the field is accompanied by literature reviews, with an essential part of research produced for broadening energy research and used throughout a variety of energy-related studies [10–16]. To comprehensively identify the relevant literature, bibliometric analysis is utilised as a widely-used and rigorous method, alongside similar techniques such as meta-analysis and systematic literature reviews, to explore and analyse large volumes of scientific data [17]. In addition, the study of language-in-use (i.e. discourse and discursive practices, narratives, and frame analysis) has become increasingly popular among those scholars interested in researching the intersection between science, technology, society, and politics [18,19].

* Corresponding author.
E-mail addresses: oleksandr.husiev@deusto.es (O. Husiev), olatz.ukar@deusto.es (O. Ukar Arrien), marta.enciso@deusto.es (M. Enciso-Santocildes).

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Despite an active contribution being made by many scholars, extensive publicly available information on community-addressed initiatives found in grey literature, reports, news, community websites, and open platform databases remains somewhat disconnected from the scientific literature discourse. The literature reviews primarily deal with a scientific database (such as Scopus or Web of Science) and the cross-disciplinary pollination of the bibliometric methodology from information science to business research. In contrast, framework programmes are highly competitive and research excellence initiatives, and to this end, the stock of current and past projects presents an essential knowledge database from different perspectives. Thus, research is inspired by the EU framework programme Horizon 2020 (H2020) as a highly competitive research and innovation (R&I) initiative. The importance of augmenting traditional social science methods with computational analysis and guiding principles from computational research is gaining traction (such as concepts of using text-mining methods) [20], with an emphasis on the dramatic growth of social science and energy computational research from subject area classifications that outline the importance of the role of computation in assisting the textual analysis results interpretation. Considering H2020 dashboard solutions [21,22] that can help understand some programme's parameters and indicators within main pillars, thematic proprieties remain not a trivial process due to the volume and versatility of research in energy transition. Moreover, advancements in Natural Language Processing (NLP) have made it possible to contribute knowledge extraction for organising, pursuing, and understanding a vast amount of information in different research areas with combinations of existing tools [23].

Hence, this paper aims to generalise the methods, approaches, and solutions in the H2020 energy projects addressed to communities by building a state-of-the-art review in the context of the European high-impact framework programme. The study scope built upon a cross-disciplinary intersection between technological and social aspects by concentrating energy projects within the H2020 knowledge database aimed at implementation in communities from two concepts: "carbon zero" as a community activity that results in minimal greenhouse gas emissions and "positive energy" accepted as local energy generation exceeds the energy consumption of the community [24]. However, this work does not provide a policy assessment of the EU programme's success or evaluate its efficacy as a policy instrument. Given these circumstances, the study has three objectives: (1) an objective to adopt a combination of NLP techniques as a heuristic approach applied within the thematic analysis of H2020 projects' public data; (2) to propose a particular classification and allocation of the projects' generalised methods, approaches, and solutions by means of categorisation within the heuristic approach of the methodology; and (3) to conduct quantitative analysis of generalised approaches and solutions within specific parameters of categorised projects discussing the trends and their exemplification throughout energy projects.

The rest of the paper is structured as follows: After the introduction, within the following sections, the analytical framework guiding the research motivation is presented in Section 2. Subsequently, the proposed methodology that addresses the NLP application is described in Section 3, followed by Section 4, where results and discussion are reflected. The main conclusions are detailed in Section 5.

2. Analytical framework

In this section, the energy communities are discussed within their definition and perspectives in conjunction with the literature research techniques applied to understand the considered topic for knowledge curation, thematic relationships, and the governing and planning of trends.

The phenomena of energy communities arise among solutions within energy transition as a "way to organise collective energy actions around open, democratic participation and governance and the provision of benefits for the members or the local community" [25]. By now, energy communities within member states were considered in numerous publications as an actively developed but still quite limited phenomenon [26–28]. The potential for emergence and replication has been limited so far, while it is agreed that the real potential is supposed to be discovered in scale [25]. The authors [29] point out that it can be that high-potential structures act as drivers of local, sustainable development despite the idea of up-scaling successful concepts as overly simplistic, and that thus acquiring knowledge about the mechanisms underlying energy transitions may be useful. Consolidation and cooperation are already appearing among community energy projects [30,31], in the sense that projects become more professional, ambitious, versatile, and tend to diversify their activities. By 2050, around 45 % of renewable energy production could be in the hands of citizens, about a quarter of which could involve participation in a cooperative [32].

Understanding the definition of energy community phenomena has a variety of interpretations that evolve with time. For example, Walker et al. [33] investigated renewable energy projects within their diversity to understand distinctive features that make them different from just a renewable energy installation. As a result, three interpretations of community initiatives were specified as projects open and participatory in their process, projects that look at collective outcomes, and projects that do both, allowing for a wide range of possible configurations. Recently, Blasch et al. [34] explored energy communities within polycentric governance theory within a review of definitions specified in the research as "associations of actors engaged in energy system transformation through collective, participatory and engaging processes, seeking collective outcomes" [34]. At the same time, the EU *Clean Energy for All Europeans* package [35] brings into the EU legal framework a conception of *energy community* as a prominent way for citizen as well as community involvement. The goal is to make the energy system more sustainable, with group stakeholders invested in collective energy actions within open, democratic participation towards the decarbonisation of the energy sector. The terms *Local Energy Community* and *Citizen Energy Community* are included in legislation referring to common rules for internal electricity markets within the recast of the Energy Directive [36], while the term *Renewable Energy Community* is contained in the Renewable energy Directive [37].

A growing number of countries are committing to achieve carbon neutrality, *or net-zero carbon emissions*, within the next few decades [38]. In these initiatives, actions toward energy system decarbonisation are required on both the supply and demand sides, including renewable energy sources (RES). The electricity and heat production sector in the European Union leads to about 35 % of CO_2 emissions [1], whereas the building sector heating and cooling in the EU is estimated as half of the energy consumption [26]. Within a discussion about the transition of the building stock and distributed energy resources (DER), concepts were proposed—a positive energy district (PED) and positive energy neighbourhoods (PENs)—as strategic keys for decarbonising the environment built in Europe [39]. The general idea also tends to proceed with a functional unit on the larger scheme, such as a district that produces more energy from RES than what is needed to fulfil its demand, and able to export energy surplus to other sites on demand. The European Commission developed an EU Strategic Energy Transition (SET) plan to develop and disseminate 100 PEDs by 2025 [40]. More than a dozen projects have received funding from the Horizon programme across Europe. The EU framework programme Horizon 2020 stepped up research and innovation. It was supplemented by the special call for proposals under a Green Deal and replaced by the next EU research and innovation framework programme Horizon Europe. Alongside that, key programmes have been developed to supplement these plans, primarily facilitating an economy for the EU that will be sustainable, circular, energy-efficient, renewable energy-based, climate-neutral and resilient—such as LIFE [41] and Interreg [42] —for interregional cooperation serving as a policy learning platform.

Along with that, Lund et al. [43] point out that the transformation into future renewable and sustainable energy solutions sparked research towards the concepts of *Smart Energy* and *Smart Energy Systems* (holistic focus on the inclusion of more sectors—electricity, heating, cooling, industry, buildings, and transportation) as approaches expanding beyond *Smart Grids* (focus primarily on the electricity sector). Comprehensively, this evolves into a variety of promising smart city projects [44] to address a wide range of urban problems, including traffic congestion, energy shortage, and environmental pollution [45]. Also, focusing on *digitalisation* within smart energy transition in work [46], the authors went beyond techno-centralism to investigate the social aspects (i.e. discussing people-centric elements such as justice and equity, social inclusion) of the smart energy transition. The authors [47], while providing conceptual insights and practical applications, looked at energy justice through the prism of three main concepts: as a conceptual tool (fair dissemination of both benefits and cost of energy services), as an analytical tool (looking at energy problems outlining challenges of transition from the point who “gets to make it” and who “pays for it”), and as a decision-making tool (examining decision-makers as ordinary civilians, social categories of status, and the role of policymakers and their guiding principles in the process).

As of 2021, REScoop reports over 1900 energy cooperatives were up and running involving over 1,25 million private citizens [48], whereas the European Commission [25] reports more comprehensive data of 3500 energy communities in the EU. However, a vast majority of examples of this amount of currently existing energy cooperatives in Europe are shared between two nations, Germany and Denmark [49]. It reveals that such a model type has not successfully transferred across all European countries [50]. At the same time, during the last decade, the approach to circularity as a new production and consumption model that ensures more sustainable growth over time shifted to an integrated socio-economic approach to resources, consumption, and waste [51]. All of that enables organisations to achieve results, through social innovation, beyond the energy field on the way to the decarbonisation of economic sectors.

The case study approach is widely applied to investigate local community energy initiatives. It facilitates the search for conceptual patterns, categories, and applied methodologies, which helps us understand a certain phenomenon in different local settings [52]. It is valuable to explore existing research, such as those made on best practices research of local energy communities [29], and the comprehensive evaluation frameworks for projects profiling [53] of initiatives being pioneers in the field. The research [54] describes a situation where city dwellers are rarely the subject of research into future energy plans for energy system decarbonisation. At the same time, a significantly wider variety of publications tends to concentrate on technological innovation for energy production and consumption. The approach often includes multiple methods (such as qualitative interviews, observations during meetings and activities, scale surveys, and mapping) of data gathering [55]. The systematic literature review [56] provided a search based on the Scopus database to examine the current state of scholarly research on government instruments for community energy defining four global categories and functions of 19 governmental instruments. The authors outline the importance of further research on community-focused instruments for renewable energy and suitability analysis of current community-appropriate energy solutions instruments for remote and off-grid communities.

Different approaches and tools focused on text-mining in literature reviews. In the practices of bibliometric study [57], the authors applied summative content analysis of archival data of literature, policies, and projects designed to disclose the framing of “eco-innovation” in the EU programmes. As a result, it was concluded that eco-innovation as a buzzword has been losing relevance in favour of the “circular economy” discourse. In the EU programmes, eco-innovation is constructed mostly around the notion of eco-efficiency. At the same time, authors outline that eco-innovation is formed between state vs private actors’ interactions, and note that stakeholders in the third sector—such as co-operatives, non-governmental organisations, social enterprises, and community-based initiatives—are often neglected by the phenomenon. It focuses on counting specific words or content frequency to understand their contextual use by applying the qualitative data analysis computer software NVivo, which has a visualisation feature set. This software has an analogue such as ATLAS.ti, MAXQDA [58], and non-commercial—Taguette [59], Qualcoder [60], Qcoder—with limited set of features. Other tools such as CiteSpaceII [61], BibExcel, SciMAT [62], and Sci^{2}Tool [63] have been extensively reviewed in Moral-Munoz et al. [64], where the authors point out that despite tools that come with wide functionality available through a graphical user interface (GUI), it still limits the user’s ability to extend it beyond its embedded algorithms.

The visualisation and analysis of citation networks of publications are addressed in Corsini et al. [53]. The authors explore and discuss evidence emerging from the research on community energy against the literature on the smart energy system. The analysis is based on the representative database of literature through a bibliometric map approach. The authors’ approach uses the VOS mapping technique to generate a visual representation of terms occurring multiple times in titles and abstracts [65]. In addition, this software product uses a distance-based approach to visualising bibliometric networks by applying normalisation, mapping, and clustering techniques implemented in the softwares of Gephi [66], Leximancer [67], VOSviewer [65], CitNetExplorer [68].

Alternatively, as pointed out by Lu and Nemet [69], application of the latent Dirichlet allocation (LDA) topic modelling technique within the NLP has been used to identify key topics and themes in various literature on energy and climate change [70,71]. In Nicolas et al. [72], the authors scrapped and selected digital notices issued from governmental portals of a few case studies cities to convert a selection of research data to a set of topics [73] and similarity analysis between the different topics. In this way, based on a set of Python instruments, the performance of smart cities was analysed and evaluated to compare top-down communication tendencies with real-world levels of urban performance.

Other research [74] addresses the EU policy cycles and conducts an exploratory cataloguing exercise concerning the clean technologies perceived as essential to help combat the climate crisis. This study applied the NLP technique combining a deterministic approach of keyword search and a probabilistic fuzzy phrase matching for tagging clean technologies catalogued in the Horizon 2020 projects’ description with further analysis.

Thus, it is essential to be aware of existing projects and to allocate practices and solutions that have been enclosed by high-impact research initiatives—distinguishing a “technology-focused” paradigm, and any form of genuine reconfiguration to social innovation, beyond the field of energy.

3. Methodology

The emerging paradigm that shifts scientific research highlights the necessity of integrated instruments for scientific tools and methods within the messy reality of textual data. Natural Language Processing (NLP) is a general field of computer science, artificial intelligence, and mathematical linguistics [23]. NLP methods allow solving various tasks: from the classification of tonality of texts, machine translation, spam filters, and marking parts of speech to a generation of the text [75–77]. The automated classification of texts into predefined categories has witnessed a booming interest in recent years due to the increased availability of vast amounts of documents in digital form and the need to organise them [72,74,78].

Researchers working in the field of information theory and neural networks highlight the utility of the bag-of-words (BoW) method [79], consequently investigating novel approaches, which are quite complex techniques based on neural networks [80], deep learning, and sentiment analysis in classification [81]. Meanwhile, BoW is a near-standard technique applied in various natural language processing and information retrieval tasks for text. It is widely applied within different studies in the field within a variety of a scale, combinations, and complexity. A systematic review [77] denoted the growing interest in the NLP application in urban studies since 2015 as a promising tool applied in five main areas: urban governance and management, public health, land use and functional zones, mobility, and urban design. Fu et al. [82] applied the tool to process georeferenced Twitter data in order to analyse activity types of urban residents' perceptions in living environments. The topic modelling approach was used by Benites et al. [83] for analysis of social media posts, documents in text format scraped from newspapers, and certain reports, to analyse social actors' discourses on climate change, food and energy. A case study [84] denoted the utility of "Term Frequency—Inverse Document Frequency" (TF-IDF) to summarise the selected review data. Many researchers used open-sourced libraries such as the Natural Language ToolKit NLTK [85] or the Python/scikit-learn [75], and some use a shallow neural network to determine semantic and syntactic meaning by word co-occurrence, such as word2Vec, to build a model of various complexity that performs a specific task.

In this research, BoW is applied alongside TF-IDF within the designed approach for categorising public data sources for further state-of-the-art discourse on methods and approaches within a specified aim. The model presents the text as a disordered collection of words (to be exact, tokens) without considering grammatical rules and the order of their placement in a particular section of the text, with further manual labelling of terms and categorisation of community energy projects according to developed classification.

Fig. 1 shows a schematic framework that was established to develop the projects' categorisation within their methods, approaches, and solutions used in the descriptions for achieving stated goals. The proposed framework consists of five main steps: (1) database extracted information preprocessing; (2) text data processing; (3) terms generation; (4) classification process; (5) results in analysis.

The dataset was uploaded from CORDIS, the primary public repository and portal for disseminating information on all EU-funded research projects and their results in the broadest sense. At the time of this present research, the imported dataset holds 35,326 projects funded under Horizon 2020 from 2014 to January 2022 (the latest available whole month at the time of the study, end of January 2022).

The appropriate data preparation involves project filtering and is described in a few steps (Fig. 2). Primarily, the imported database was filtered by the keyword "energy" in the title and objective description, resulting in 6020 projects. Following that, the second step was formed in the form of keywords search list query logic: *['communit*' 'building*' 'neighbor?rhood*' 'district* 'cit*' 'living lab*' ('carbon' (AND 'positive' OR 'zero')), 'net?zero' ('demand' OR 'consumption') 'climate' 'smart' 'urban' 'housing']*. Additionally, the specific abbreviations and terms were included in the literature review, such as: 'NED', 'PED', 'ZED', 'ZEB', 'ZEDs', 'ZEBs', as well as 'social innovation', which finally generated 1229 results- The realised query procedure included a count of specified keyword co-occurrence frequency for each project as a *ranking label*. The resulting dataset was obtained in the form of a table where the following fields were of primary interest: *status, title, objective, start date, end date,* and *budget*. This stage was implemented by deploying a keyword-finding algorithm using the Python library FlashText that automatically scans each project description and title and compares it with the string list.

Working with the filtered dataset, the project's "objective" field was considered as a corpus for further processing. The tokenisation procedure applied to the corpus was facilitated by the functionality of Python NLKT library and included removing of stop words and application of stemming procedure to obtain a part of a word responsible for its lexical meaning, named *stem.* Moreover, it allowed generating a list of n-grams—a contiguous sequence of items (stems) for each considered accurate description of the project, specified in the form of uni-, bi-, tri-, and four grams.

The final step before terms-tagging involved a procedure for numerical weightage of n-grams to reflect how important the word is to a document in a corpus. Such weightage was made by applying the basic functionality of the Python sklearn library, such as the frequency of each unique n-gram co-occurring, considered within the approach by TF-IDF score [86], as well as term frequency (TF) parameter.

The manual heuristic approach to categorisation has been applied to label a particular bigram as a term. Within the methodology, the bigrams are considered as a central meaningful semantic unit for further tagging of tokens, a cloud of terms based on the TF-IDF parameter, as shown in Appendix A. The scheme of bigram terms categorisation tagging is presented in Fig. 3.

Tagging involved manually labelling a sequence of terms based on the TF-IDF/TF ranking parameter by attaching a subcategories' tag to a bigram into which it can be referred and limiting the number of such possible categories within 1 to 3 items. After the categorisation, the subcategory that received the highest count of tagged subcategories within matched bigrams was considered a potentially dominant (primary) subcategory of the project. In contrast, the rest matched subcategories were treated as supplementary or secondary.

The approach to the specification of the categories and subcategories and their classification (Fig. 4) is best described as both inductive and deductive. The inductive way comes from some of the considered terms specified above as initially ready subcategories. Namely, while considering the term "energy efficiency" as a bigram according to TF-IDF scores, it was considered in conjunction with top scored trigrams such as "improv energy efficiency", "increase energy efficiency", "energy efficiency build", "energy efficiency measures", "deep ener renow", and in this interpretative way the subcategory was formed.

As for the inductive part, the primary decision for forming upper layer categories came by subcategory grouping, considering the main pillars of the H2020 framework programme: excellent science, industrial leadership, and societal challenge [87], alongside a focus on societal challenges within six key areas: health, food and agriculture including marine sciences, energy, transport, climate and raw materials, and inclusive societies and security [88]. As a final contribution, referencing the categories was done by addressing two paradigms: the first as "technology and energy", where the categorisation naming was built around the discussion of the authors' approach to interpretation within

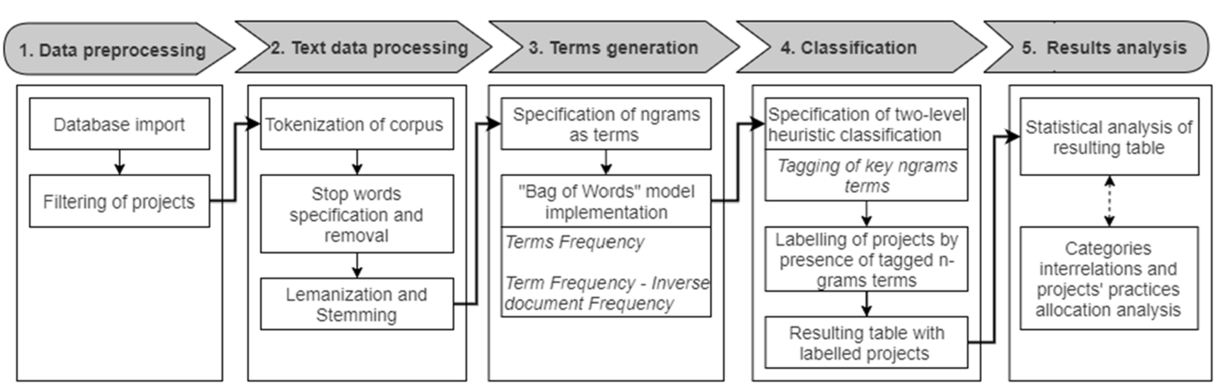

Fig. 1. Overview of research framework (Graphical abstract).

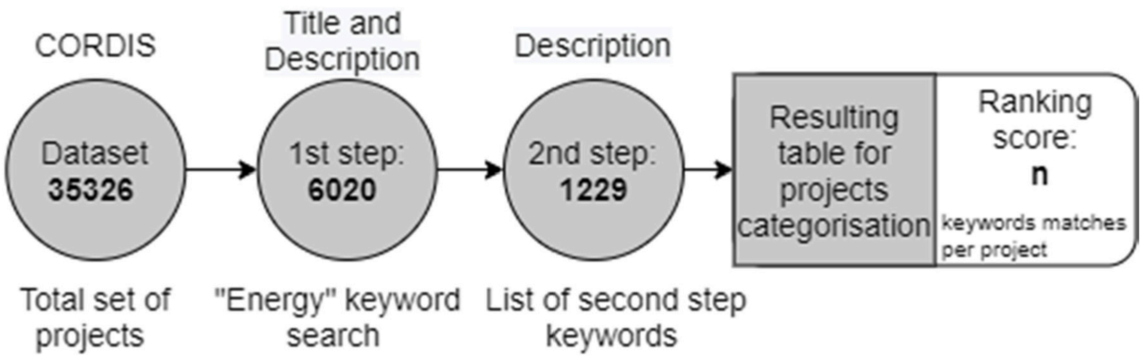

Fig. 2. The keyword search process used to specify the pool of projects.

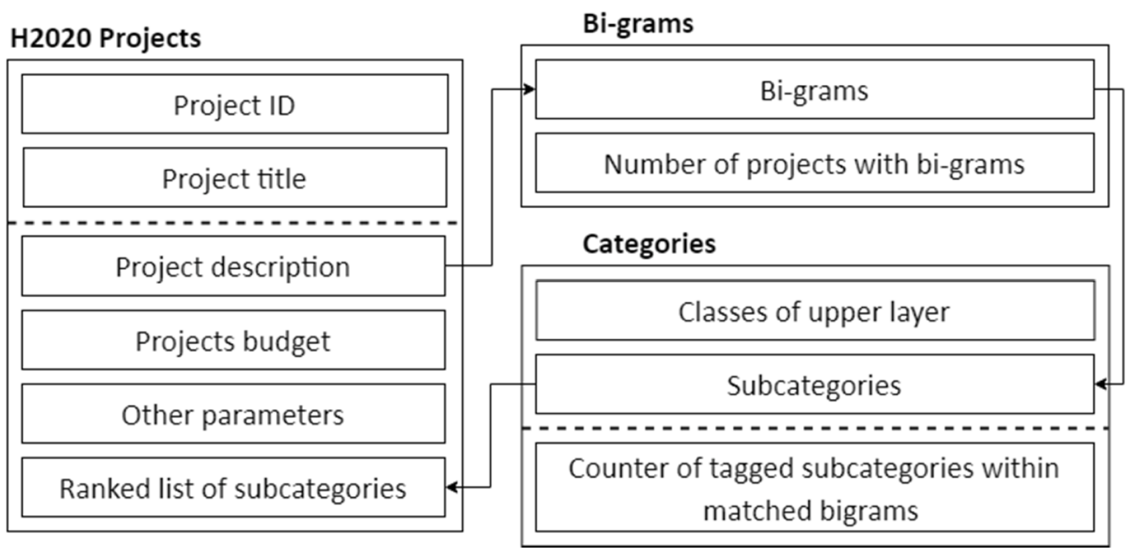

Fig. 3. Scheme of the project's categorisation.

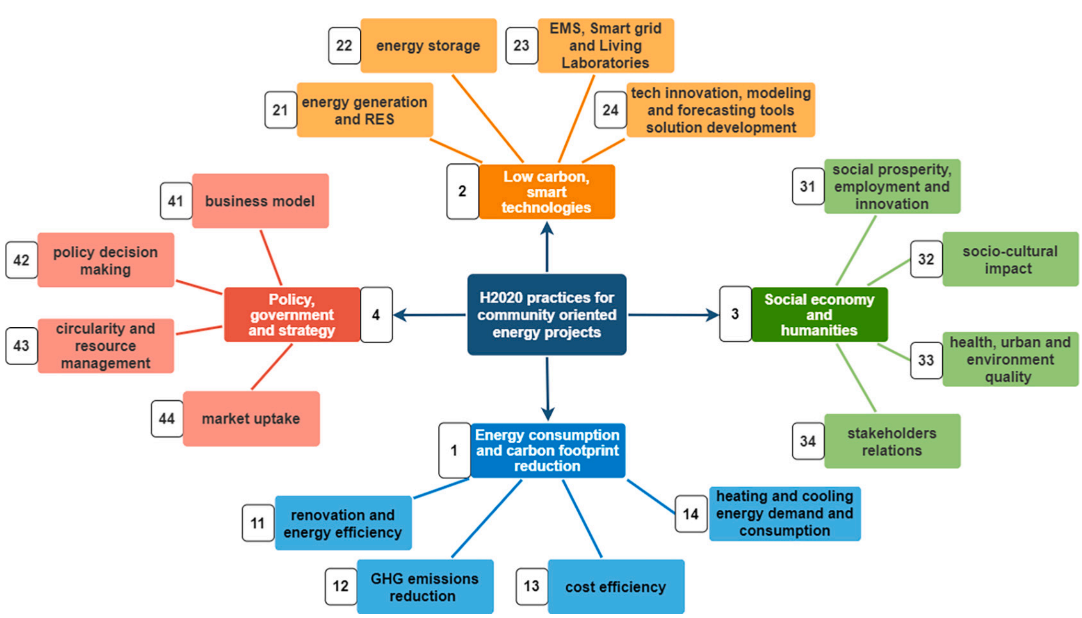

Fig. 4. Specified classification of H2020 practices for community-oriented energy projects.

[12,89,90] topic modelling study [69] and as a result formed into the upper layer categories: 1) energy consumption and carbon footprint reduction, 2) low carbon, smart technologies. The second build considering policy and societal issues [47], addressing socio-economic landscape antecedents discourse in Knox et al. [91] resulted in the specification of 3) social economy and humanities, and 4) policy, government, and strategy. Additionally, to present the hierarchy, in Fig. 4, categories are depicted with a decimal digit identifier (1, 2, 3, 4) and correspondent subcategories with the tens.

The results, in the form of labelled projects, showed overlap between the considered categories. Thus, in line with the methodology, a counter of tagged subcategories within matched bigrams was introduced as an element in the ranking of subcategories. The categorisation of the projects was distinguished by the single custom analytic tool, which allowed to allocate the project by its parameters. Namely, filtered projects were positioned by parameters such as budget, duration of the project, and ranking for a particular subcategory. While considering the budget, the EC contribution has been taken instead of a total cost for the calculations since total costs can sometimes include spending by non-EU actors. The results are summarised and analysed in the following section.

4. Results and discussion

This section presents the results built upon the quantitative parameters of categorised projects. Furthermore, it discusses practices addressed within the H2020 energy-related projects facilitated by visualizing categories and allocating the resulting projects within the proposed classification.

4.1. General characterisation

The statistical analysis of the energy projects' budget and duration parameters showed that the mean duration of the projects is three years with the 1.9 M€ budget. The first and third quartiles within the duration data are 2 and 4 years, and the budget quartiles are 0.19 M€ to 4 M€, correspondently. The "lighthouse" projects are specified for 4 to 6 years with outlier points of budgets between 10 M€ to 29 M€ of European Commission contribution. The quantitative reflection is depicted in Fig. 5, where projects within four primary ranked categories are presented by years.

One of the key principles of integrated strategy involving a wide range of sectors, "energy efficiency first" [92], is reflected by the identified project quantity and investment category. With these remarks in mind, category 2—low carbon, smart technologies—is dominated by the number of potentially primarily addressed projects (46 %), followed by energy consumption and carbon footprint reduction (26 %), social economy and humanities (16 %), and policy government and strategy actions (12 %). However, the concise trend is demonstrated by generalised subcategories (Appendix C). The total share of energy projects identified as community-oriented, within generalisation of their method, activities solutions, and allocation throughout it represented as 5.85 % (3.95 B€) of the H2020 net EU contribution (67.62 B€) [22]. Implementation of energy management systems (EMS) and a variety of "smart" solutions (subcategory 23) dominates a number of projects and budgets, followed by the "energy generation with RES" and "renovation and energy efficiency", which is evidently looking throughout the years of the projects' start date looking at subcategory distribution by a number of projects and budgets (see Appendix C). Firstly, the projects potentially oriented to primary renovation and energy efficiency actions used to have much lower budget projects. This becomes evident looking at two times the higher ratio of project quantity to budget compared to energy management and smart grids (subcategory 23). The socio-economic, policy, and strategy issues primarily oriented to the project take a minor portion from the quantitative evaluation of projects. In an explicit way, the socio-cultural issues within the H2020 projects take on a minor role compared to the abovementioned subcategories. Nevertheless, a notable amount of projects and budgets potentially addressing social prosperity, employment, and innovation (subcategory 31) grew from the second half of the programme in 2019 (15 projects with a total budget 45.5 M€) and reached the highest number by investment and quantity of project in 2021 (28 projects with 166.5 M€ budget).

As was outlined before, so-called "lighthouse" projects were mentioned as well-defined, measurable projects that serve as a model and, consequently, a substantial portion of investment holders. Consequently, lighthouse projects have a versatile conceptual pillar—demonstration sides with focus areas. Some of them are specified, mentioning a conception of innovative living laboratories. It is defined by the Joint Research Centre (JRC) as "a modern way to user-centred environments that integrate research and innovation processes in real-life communities and settings" [93]. Such projects are implemented in conjunction with PED/PEN creation which refers to the realisation of SET Plan: such projects as oPEN lab, SMARTER TOGETHER, and PROBONO are based on existing or planned construction projects for the whole neighbourhoods or single-type buildings clusters. Along with them appear PED/PEN-addressed lighthouse projects such as MAKING-CITY, ATELIER, Smart-BEEjS, POCITIF, CityxChange, SPARCs.

Another side of topical actions that follow out from the living laboratories approach is implementing or testing certain complex solutions within the community for a topical and urgent problem such as energy

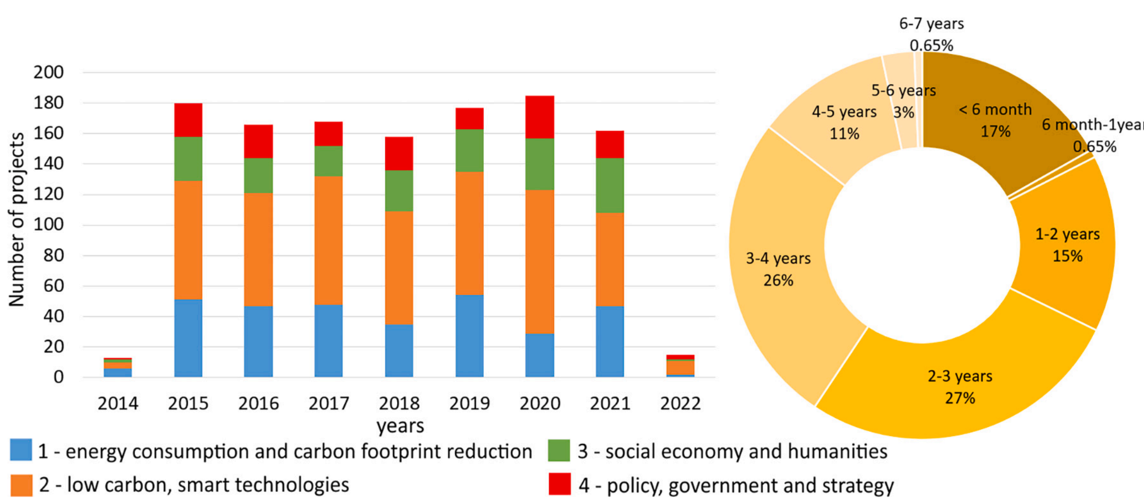

Fig. 5. Quantitative representation of the resulting characterised projects. Left–Number of projects in primary categories by year (x-axis), quantity (y-axis) and primarily referred category. Right–projects' duration (within months shares).

poverty. As an integral part, a number of projects explicitly address guiding actions aimed at inclusiveness, focusing on addressing energy poverty and creating affordable housing. Those actions follow out from the living laboratories approach in the form of implementing or testing certain complex solutions within the community. Here, some projects with lower budgets contribute through examples of digitalisation solutions for global methodology development, to bring together local experts and stakeholders with energy poor consumers (such as STEP-IN project), or to understand how digitalised daily life impacts climate change (e.g. iDODDLE). They intend to demonstrate and validate how attractive, resilient, and affordable solutions are integrating energy renovations (such as DREEAM, INSUPanel, ABRACADABRA, ComAct), with special attention to historical areas (e.g. GEO4CIVHIC) or complex architecture (e.g. Svelte), as well as digital tools (e.g. domOS), PV generation (e.g. HyTile), and circularity under the deployment of energy and climate measures for communities.

The focus is naturally put on replicable, commercially viable packages of solutions enabling the achievement of positive energy within existing urban contexts. They are seamlessly integrated into the local energy system as an active micro-energy hub, testing these technologies and packages as an integrated solution at a neighbourhood scale. At the same time, some small projects that address a particular issue of cost reduction, circularity, and well-being within communities have been outlined. Thus, the collection of community planning, management, and capacity instruments all serve to support a set of case studies within the lighthouse projects (e.g. social and economic components as integral parts to the application of validated technologies in a scale of the building, neighbourhood, etc.); yet, in some cases, local socially connected capacity building is indirect or secondary. At the same time, some projects fall under one umbrella as a sister research project, specified on an international level.

With a specified visualisation tool (Fig. 6), the top-ranked projects were allocated by specified parameters based on the resulting projects' subcategory mapping matrix shown in Appendix B. The project's index used for identification throughout the study was accompanied with a project's acronym, used for visualisation and further exemplification in Section 4.2. An introduction of filtering made by custom visualisation allowed us to distinguish projects by year and duration, budget (such as low-, mid-, or high-budget projects by changing the scale of the budget (x-axis) amount). In addition, allocation by subcategories and primary categories (as presented in the example of Fig. 6) along the ranking axis (y-axis) was an integral interpretative part of the discussion. It facilitated the discourse process by specific goals with potentially lower scale, and already mentioned high budget, involving highly innovative and versatile multi-stakeholder projects with their integral approach. The notable practices reviewed among the top-ranked projects primarily address mobility and the energy sphere combining socio-economic issues promoting entrepreneurship, platforms aimed to connect stakeholders, engaging customers to become prosumers with hybrid storage (Section 4.2.2.), and providing a market uptake and trading platform (Section 4.2.4).

At the time of research (end of January 2022), 45 % of the ranked resulting projects are active ongoing projects. Research organisations predominantly have the highest share among coordinator activity types within the top list of ranked projects (28 %). In total, considered projects are complex multiparter activities involving many stakeholders. This is followed by a private for-profit entity type (excluding higher or secondary education establishments) (27 %). This group is notable since it involves a low-scale budget project addressing a small-scale feasibility study project. The third activity type for coordinators presented by higher or secondary education establishments is 24 %. The remaining types of entities referred to the categories of public bodies (excluding research organisations and secondary or higher education establishments) and the type specified as "other" shared in 10 % and 11 %, respectively. The coordination institution within the mentioned shortlisted projects (see Fig. 6) in a significant share includes three countries of the Mediterranean region: Spanish (22), Italian (15), and Greek (9) entities. The central and Northern Europe institutions are led by the Netherlands (7), Norway (6), Germany, and France with four institutions.

4.2. Study of categories

The results presented in a matrix with ranked subcategories related to the project index (see Appendix B) were arranged into the intermediate matrix representing the ratio of quantitative projects as potentially dominant (primary) subcategories to secondary by number of tagged projects. It was done considering a quantity of projects within the subcategory (which, after categorisation, was put as a potentially dominant, primary subcategory of the project) referred to the relative quantity of other tagged subcategories (that were tagged alongside primary but as supplementary or secondary). Based on the intermediate matrix, a chord diagram (Fig. 7) represents the ratio of the number of projects with a potentially dominant subcategory (right-hand diagram) and category (left-hand diagram) to the rest of the subcategories and categories. Namely, on the right-hand chord diagram of Fig. 7, the subcategory (11) "renovation and energy efficiency" has a sector width that represents the relative number of projects with generalised actions, methods, and solutions primarily addressed to renovation and energy efficiency. The flows illustrate the number of projects where mentioned primary subcategory met alongside other subcategories tagged as supplementary or secondary.

4.2.1. Energy consumption and carbon footprint reduction

Referring to the energy subsectors reviewed by Lund et al. [43], the building sector with savings relates to concepts of zero carbon and zero emission compiled within net Zero Energy Buildings (ZEBs) and nearly ZEBs (NZEBs). These trends are seen in technological competencies and learning outcomes for training schemes and programmes on deep energy renovation, retrofit solutions, and renovation acceleration (such as projects Fit-to-nZEB, TIGER, EeMAP, DREEAM, THERMLOSS, RenoZEB).

The *smart heating group of the energy subsector* [43] is typified by a heating network with excess or waste heat treatment (e.g. REWARDHEAT) and recovery (e.g. ReUseHeat), low-temperature grids, and low-grade heat sources (FLEXYNETS, RELaTED, COOL DH, LOWUP). Particular attention is a topical connection of thermal storage systems (and technology itself, e.g. Hi-ThermCap) into integrated energy systems mentioned by Lund et al. [43]. This can be elucidated by project CHESTER, which addresses particular compressed energy storage for RES, and SmILES, dedicated to energy mix within district systems. Along with that, heating systems integrated with RES (e.g. Heat4Cool), heat pumps (e.g. CHESS-SETUP), and general improvement of district heating across central Europe (e.g. KeepWarm) are referred to as a synergy mentioned by [94].

4.2.2. Low carbon, smart technologies

As opposed to a single sector approach, the holistic approach to the storage aspects is seen as mentioned by Lund et al. [43]. Thus, the tendency for energy system analysis modelling (e.g. DAMOSET) to be "used synonymously with Smart Grid" [43]. This trend is evident in project SCORES, as seen from the chord diagram flows connection, storage systems related to energy generation and RES, self-consumption, and energy management systems. It can be demonstrated by projects addressing integral parts of hybrid storage systems and their management systems (INVENT, ARMOUR, SEMS), behavioural change by combined ICT-based tools, and modular information services (e.g. MOBISTYLE). This is also to emphasise the trend shifting from smart grids and "smart energy systems", energy and economic efficiency addressing the concept of "smart communities" (with, however, no single consensus inside the scientific community [95]) through integrated multi storage technologies (e.g. NETFFICIENT).

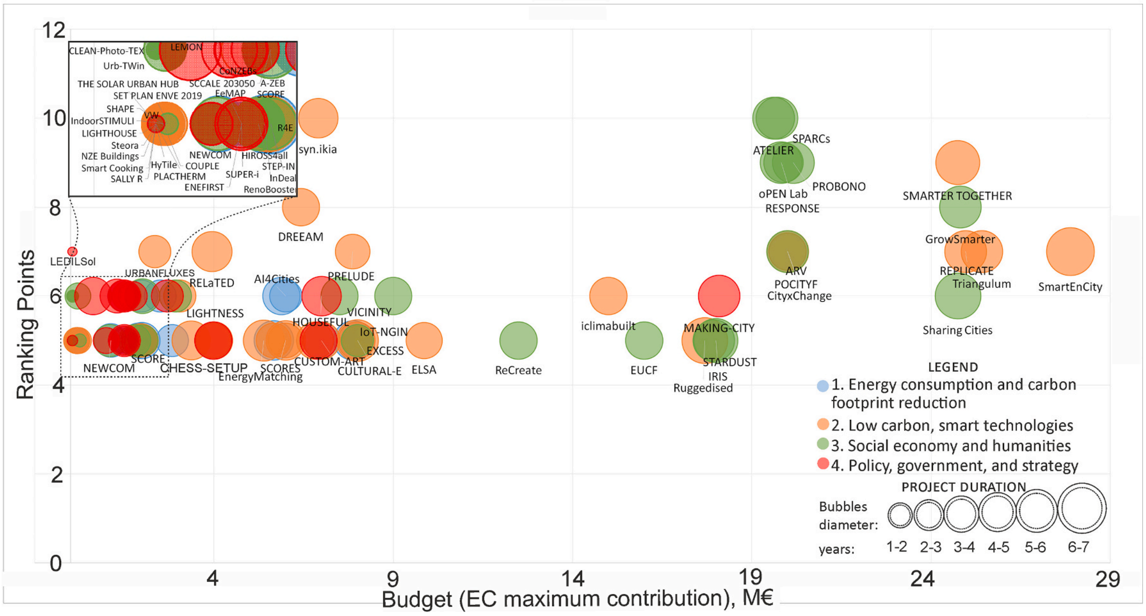

Fig. 6. Example of a visual allocation tool, used for positioning of categorised projects (ranked top 100) within keyword matching and subcategories ranking score by their EC budget contribution (x-axis), ranking point (y-axis), and project duration (diameter of the bubble), the colour of the bubble is a primary referred category of project.

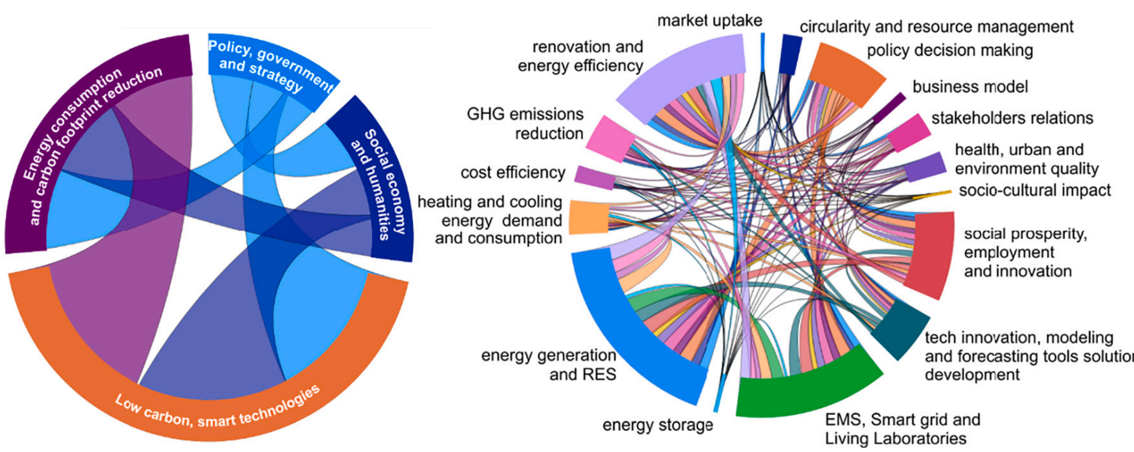

Fig. 7. Chord diagram of inter-relations between the categories and subcategories.

Engaging with citizens as the end-user stakeholders often addresses the combination of ICT-based tools and modular information services on energy use (SUPER-I, domOS, EnergyMate), customer engagement (e.g. REDREAM), and lifestyle. At the same time, levels of engagement with citizens for the big lighthouse projects (also considering island communities, e.g. COMPILE) vary from the provision of information at events and workshops to consultations and interviews and with web and app tools including collaboration.

The definite trend in city planning, urban architecture, and policy-making requires simulation models to understand, predict, design, and manage future forms of cities to make them more sustainable, equitable, and efficient. The methodologies of local digital twins (LDTs) are actively developed and implemented as digital replicas of cities that involve not only the physical aspects but also the people and the influence of their decisions and behaviour (e.g. BRIGHT). This encourages the use of technologies that might otherwise not be considered by stakeholders and that, at the same time, move beyond business models as business-as-usual renovation (Section 4.2.3) through creating and operating advanced community energy systems (e.g. in CREATORS). The energy storage systems are one of the less mentioned primary oriented subcategories of community energy projects. One explicit way concerned with social prosperity, employment, and the innovation context (Section 4.2.3) regarding the business models for communities can be exemplified by PEDIA project, where actions are directed to promote energy efficiency and develop innovative approaches in schools.

4.2.3. Social economy and humanities

As pointed out by Sovacool [12], R&I systems are developed only through the unique interaction of technology, people, knowledge, markets, and institutions. The author's framework entails that transformative changes in energy systems proceed through alignment of "niche," "regime," and "landscape levels". The first level is discussed as the stage where similar goals are consolidated and advocated ("niche"). The second aims to challenge the ̈regimes ̈ (exemplified by a decentralised system in contrast to a conventional centralised system); whereas the change (i.e. "breakthrough into the overall external environment" [12]) happens only so much as members of the niche can destabilise regimes, which form a scale—the "landscape" level. Approaches exemplify this concept within projects seen in the engagement of citizens as the end-user stakeholders. It often addresses the combination of ICT-based tools and modular information services on energy use, indoor environment, health, behaviour (e.g. MOBISTYLE), and lifestyle within the urban city context regarding climate change carbon zero, such as project Climate-fit.City. The remarkable project EXCESS promotes a user-centric approach by specifying the concept of "plus energy building", or "sustainable plus energy neighbourhood" by the syn.ikia project. As pointed out by Manjon et al. in their review [6], social aspect research domains represented energy efficiency, retrofitting connectivity (Section 4.2.1.), and social housing (e.g. SUPER-I) as practical solutions to tackle energy poverty (POWERPOOR, ComActs).

It was outlined that the connection of social prosperity, employment, and innovation often met alongside the findings for the business model but rarely with explicitly mentioned circularity issues. Since the readiness to participate in energy projects is determined by several factors—e.g. social norms, trust, and community identity—it poses an important challenge to overall business model development [96]. It can be said that the problem of public participation in most demonstration projects is often related to the lack of trust and transparency combined with technical ignorance about the technology involved [9,97]. The tendency to provide the decision-making tool in the context of societal issues complies with the vision of Sovacool et al. [47] —namely, of high-budget PED/PEN projects tackling city context focus on availability and affordability of energy principles in scale and with connection to policy and strategies (e.g. ABRACADABRA), also specified by Renovation Wave for Europe [1]. In contrast, specific projects demonstrate a trend of moving toward the more controversial or complex ones, such as intragenerational equity and responsibility (e.g. NEWCOMERS, COME RES, COMETS, RECOMS), solidarity (CEES), social innovation in energy (e.g. SONNET), and advancement of social innovation in socio-economic incentives for increased ownership by dynamic modelling of supply chains, companies, and social groups (e.g. SMARTEES).

4.2.4. Policy, government, and strategy

Connecting societal issues (Section 4.2.3) also mentioned previously by Kalkbrenner and Roosen [96] as business model development can be exemplified throughout slogans such as "simple and smart energy communities for all" (e.g. KISS), and market uptake (POWER UP, LIGHTNESS). Also, special attention is paid to projects that study the community's place in a specific scope, such as European context (NEWCOMERS) or particularly within city and citizens' actions (IRIS, SCCALE 203050).

The explicit reference to circular economy principles is worth noting throughout numerous projects addressing water-energy-food nexus research [83,98]. This is evident when considering the AccelWater project, which covers water resources circularity; urban agricultural energy systems (e.g. PROTEAN); solar panels technologies for greenhouses and glass buildings (e.g. PanePowerSW); and various water treatment plant-focused projects (such as WiderUptake, REWAISE, HYDROUSA, ENERWATER, Smart-Plant).

The importance of entrepreneurship, in terms of cases of living laboratories, enables investigating opportunities for buildings to adapt to their surroundings and adopt engineered living approaches applied to further regenerative transition and recyclable holistic waste management initiatives (e.g. HISER). This involves climate adaptation and improved management for the usage of resources in building construction (e.g. RE-CREATE), along with social influence within low carbon innovations (e.g. SILCI) including energy, water, wastes, and food. A general review of the short-listed ranked project confirmed that circularity is indirectly addressed within the objective among the lighthouse projects. The lighthouse projects of the final years 2021–2022, such as the ARV project, specify the systematic way of addressing the circular economy of energy community activities through automated life cycle analysis, digital logbooks, and material banks. However, the HOUSEFUL project identified as top-ranked among the circular economy and resource management category develops five main pillars for circularity in materials, water, waste, energy, and interactive platform for circular services to provide synergy as a holistic pillar.

5. Conclusions

In this paper, the EU Horizon 2020 energy projects knowledge database was analysed to find a way to generalise and discuss high-impact energy project actions directed to communities between 2014 and 2022. The results demonstrated that using the NLP bag of words (with the TF-IDF method) technique for analysis applied through iterative rounds of coding and design of the query is a useful custom tool that can facilitate the thematic study of the social and energy field.

The explanatory analysis allowed capturing the language-in-use of projects' descriptions and building the categorisation of generalised methods and solutions, in combination with literature review and policy discussion. Along that, a quantitative analysis of projects' duration and budget was built based on compiled reference allocation of projects within the categories.

The results outline the connection between renovation and energy efficiency actions, with renewable energy generation and energy management systems for community initiatives towards creating "smart energy systems". Generalised actions for energy storage in communities were found to be less mentioned as primary addressed within projects; however, it is pointed out as an integral part of the renovation, energy generation, and energy management systems. It was pointed out that allocating different tasks within potentially addressed prioritisation of renovation and energy efficiency actions comes not only from a large portion of investments but also from a variety of low-budget initiatives which diversify the actions. The potential socio-economic and policy decision-making involved is integral to many complex and multi-stakeholder projects allocated within the methodology approach. Meanwhile, socio-cultural issues identified as less tackled were noted to primarily orient actions and solutions throughout high-impact R&I energy projects of H2020. Additionally, generalised activities and solutions primarily oriented toward social prosperity, employment, and innovation—being seen as a stable number of projects and funding over the years—demonstrated gradual growth in the second half of the H2020 programme (from 2019 to 2021).

A few words about the limitation of this work must be outlined. NLP opens an exciting new direction for researchers in the cross-disciplinary energy-related field. Still, at the same time, it brings about more challenges that depend on the context and the level of technology application details. The selection is not exclusive and is a matter of initial interpretation and assumptions of the author. Scholars in the information theory field outline that n-gram models are usually preferred for statistical language modelling but may suffer from data sparsity since it neglects the order as well as the semantics of words [79]. Findings represent the extent to which these instruments are mentioned in the research, which does not necessarily reflect how common the instrument is found in practice.

Secondly, deterministic keyword searches can result in false matches. The resulting scope might be broader and fuzzy due to the semantic context of the terms used in describing the projects in the H2020 knowledge database as input for processing text, as it may have yielded difficulties in understanding the meaning and context of the issue being studied. This issue affects, in any case, the consideration of possible scenarios with advanced methods working with NLP, such as word embedding (with word2vec), or language models based on pre-trained machine learning techniques (e.g. BERT). In the interests of reproducibility, the data have been made public in the following GitHub repository[1]

The NLP approach used within the particular bag-of-words technique (with TF-IDF) has proven to be an appropriate and helpful custom tool for synchronising and allocating different energy projects with an addressed community focus. However, future research can elaborate with a qualitative analysis of selected communities and project administrators to make meaning of the projects and some impacts on the community.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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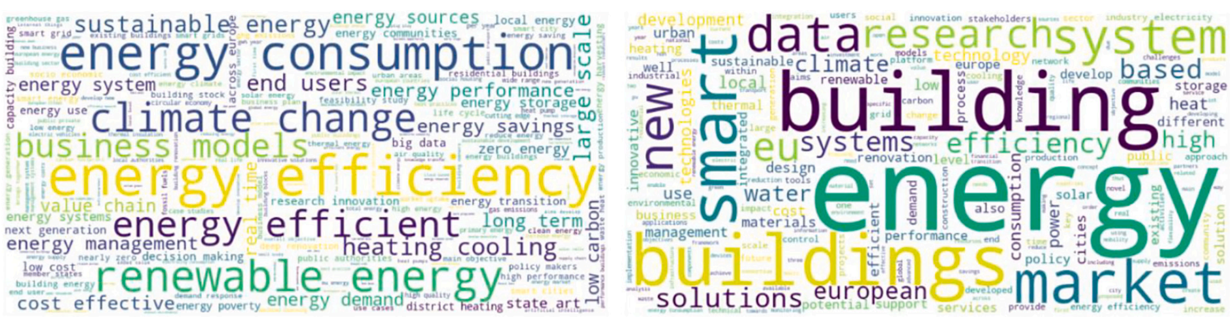
Appendix A. Word clouds of uni- and bi- grams generated for terms labelling procedure



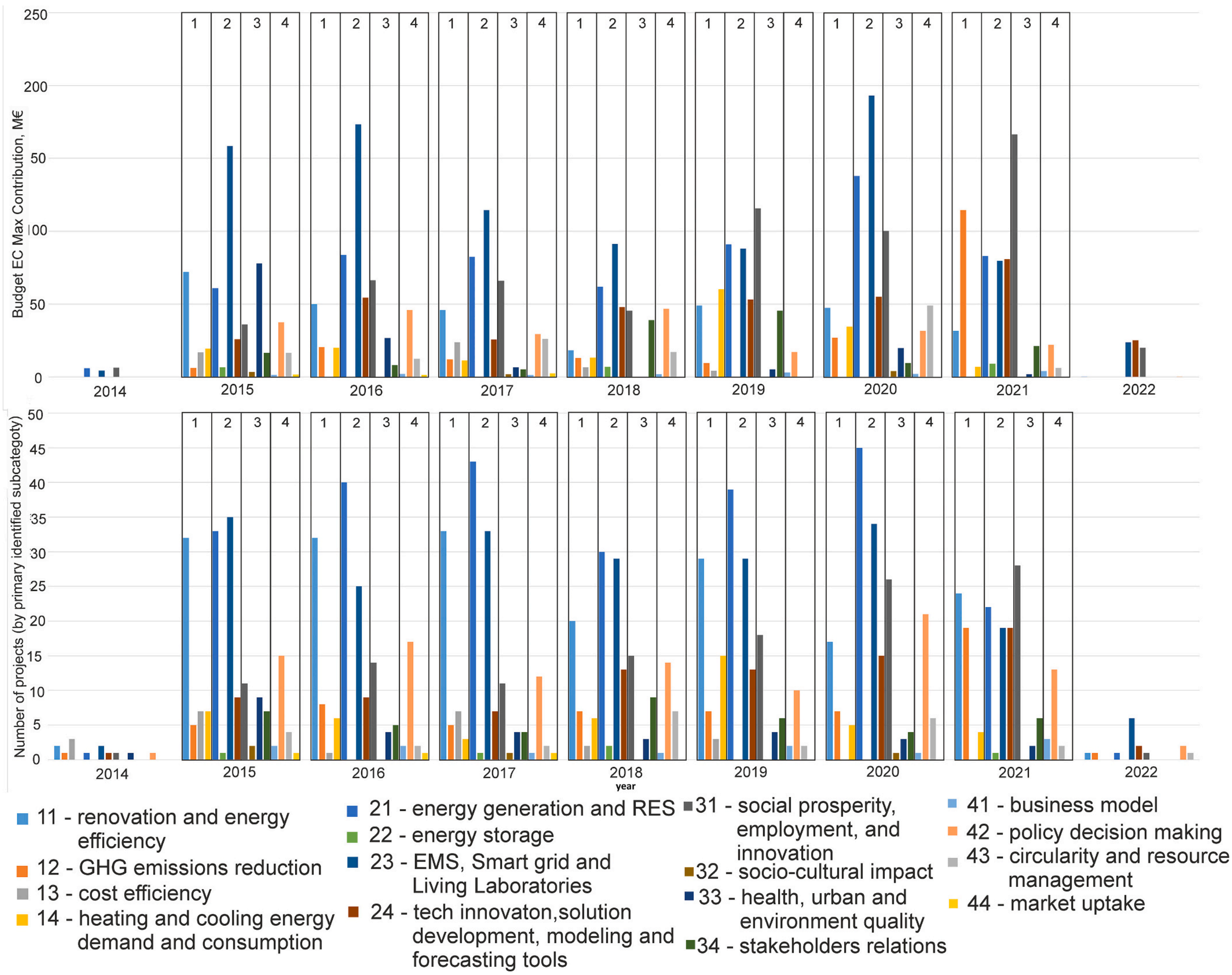
Appendix B. Project subcategory mapping matrix

Project Index

Category ID	58	62	135	228	325	361	428	432	441	443	444	449	463	477	488	533	534	535	635	672	673	691	699	700	714	717	746	747	789	901	91
11	12	1	8	7	0	1	0	2	4	6	2	0	17	1	8	1	7	0	4	0	0	1	4	0	0	2	2	1	5	1	
12	1	0	1	3	0	0	1	0	1	1	1	0	4	1	0	1	0	1	1	0	0	0	0	2	0	0	1	0	0	0	
13	1	1	0	1	0	0	0	0	1	3	0	0	0	0	3	0	0	0	0	2	0	0	0	0	0	0	0	2	1	0	
14	4	1	1	3	0	1	0	14	2	0	1	7	8	0	3	5	3	0	0	7	1	2	5	0	0	1	0	0	0	0	
21	8	1	6	18	0	0	0	5	4	7	2	3	6	0	14	3	7	1	4	5	1	4	3	0	0	4	2	2	1	1	
22	5	0	0	1	0	0	0	4	1	2	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	
23	10	1	3	2	1	1	0	6	4	0	2	7	2	0	4	5	4	1	1	4	4	3	1	1	0	2	1	0	4	0	
24	2	2	1	2	3	2	3	2	1	0	0	1	2	2	4	1	0	1	2	1	3	5	4	0	0	0	7	1	1	2	
31	4	5	7	5	1	3	8	0	3	10	10	4	0	1	7	8	1	1	3	1	4	5	5	5	1	2	7	0	4	0	
32	1	1	1	0	3	0	1	3	2	1	1	1	2	0	0	1	0	0	0	0	1	1	0	0	1	1	1	0	1	0	
33	1	0	2	2	0	2	0	0	0	0	2	0	1	0	0	0	1	0	1	0	1	1	2	0	1	4	1	2	1	0	
34	3	1	1	2	3	2	1	1	2	3	4	0	1	0	1	1	5	0	2	1	0	4	6	1	7	3	4	1	4	1	
41	1	3	0	0	1	1	1	0	0	1	0	0	0	0	0	0	1	0	1	1	1	4	0	0	0	0	0	2	1	0	
42	3	3	7	3	4	1	3	0	0	1	7	3	2	2	15	4	14	2	10	2	2	6	7	10	2	0	5	1	5	1	
43	1	0	0	0	0	0	1	0	0	0	0	0	1	1	0	4	0	1	0	0	1	0	0	0	0	0	0	0	0	0	
44	1	0	0	0	1	1	0	1	2	0	0	0	0	0	1	0	0	0	2	0	0	1	2	1	1	1	3	1	0	0	

[1] The code and data are accessible via the following link: https://github.com/ohusiev/enercomm_h2020_categorisation.git.

Appendix C. Tagged subcategory's distribution by year of start, number of projects and budget



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