

An Integrated Approach for the Co-governance of Sustainable and Resilient Cities: A Focus on Green Infrastructures and Transport Mobility in Catania (Italy)

Luisa Sturiale[1(✉)], Matteo Ignaccolo[1], Vincenza Torrisi[2(✉)], and Alessandro Scuderi[3]

[1] Department of Civil Engineering and Architecture, University of Catania, Viale Andrea Doria, 6, 95125 Catania, Italy
luisa.sturiale@unict.it

[2] Department of Electrical, Electronic and Computer Engineering, University of Catania, Viale Andrea Doria, 6, 95125 Catania, Italy
vincenza.torrisi@unict.it

[3] Agriculture Food and Environment Department (D3A), University of Catania, Viale Andrea Doria, 95127 Catania, Italy

Abstract. Among the Sustainable Development Goals in the UN Agenda 2030, Goals 11 "Sustainable Cities and Communities" aims to "*make cities and human settlements inclusive, safe, resilient and sustainable*". Among the different targets it aims to promote a participatory and integrated transport-land planning; to guarantee accessibility to green areas and safe and inclusive public spaces, especially to vulnerable users; to ensure access to safe and economic living spaces and transport systems. This work presents an integrated approach to consider the role of Green Infrastructures (GIs) and Transport Mobility (TM) as key components in the transition towards a model of sustainable and resilient cities. The analysis of these two components of the urban system, especially in cities with high rates of motorisation and traffic congestion, on the one hand, and with a non-widespread presence of green areas, on the other, becomes strategic for implementing actions aimed at making cities more sustainable.

The analyzed case study focuses on Catania (Italy) at different territorial levels, considering both the urban area and the neighboring municipalities.

The study consists of two steps: (i) first, an interview-based methodology has been implemented to analyze citizen's perception of GIs to tackle climate change and the willingness to pay to sustain the maintenance of these infrastructures; (ii) on the other hand, an extended survey will be performed to evaluate the propensity of users towards innovative shared transport systems and also the willingness to pay for the service. The obtained results from the first round of interviews highlighted the citizens point of view linked to GIs and their interest in the co-management. Research findings will constitute a decision support for administration and stakeholder to guide public investments and achieve awareness among citizens in order to promote co-governance actions and develop climate adaptation strategies and improve the quality of life in urban areas.

Keywords: Climate Change · Urban Green Areas · Transport Mobility · Urban areas · Survey · Citizens' Perception

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2023
O. Gervasi et al. (Eds.): ICCSA 2023 Workshops, LNCS 14105, pp. 213–230, 2023.
https://doi.org/10.1007/978-3-031-37108-0_14

1 Introduction

It is possible to reduce the effects of climate change on society and the environment through specific actions, which can be oriented in two directions: mitigation, which aims to progressively reduce emissions of gases responsible for global warming, and adaptation, which aims to reduce the vulnerability of environmental, social and economic systems and increase their resilience to climate. Clearly, no one option is sufficient on its own, but adaptation and mitigation actions need to be coordinated in order to pursue effective results over time. This can be achieved through governance policies and cooperation between different stakeholders and could be enhanced by integrated responses that link mitigation and adaptation with other societal goals [1].

Assessing the integrated effects of planning and programming choices aimed at reducing climate-changing emissions is a priority theme of the document "*Transforming our world: The 2030 Agenda for Sustainable Development"* The 2030 Agenda sets 17 Sustainable Development Goals (SDGs) and 169 targets to be achieved over the next 15 years. Goal 11, "*Sustainable Cities and Communities*", is specifically dedicated to urban systems, with the goal of *"making cities and human settlements inclusive, safe, resilient and sustainable"* [2].

Cities will play an important role in combating climate change and will be called upon to adopt innovative solutions and rethink urban management and planning [3].

All the targets in Goal 11 are important and complementary to each other in order to achieve the 2030 objective, but it is clear that the related actions must be developed according to the characteristics of the area in question. In particular, in urban realities in which there is a criticality in mobility-related aspects, extreme climate change events are more frequent and there are problems with the use of public green spaces, Targets 11.2, 11.3 and 11.7 will be considered with more attention (Fig. 1).

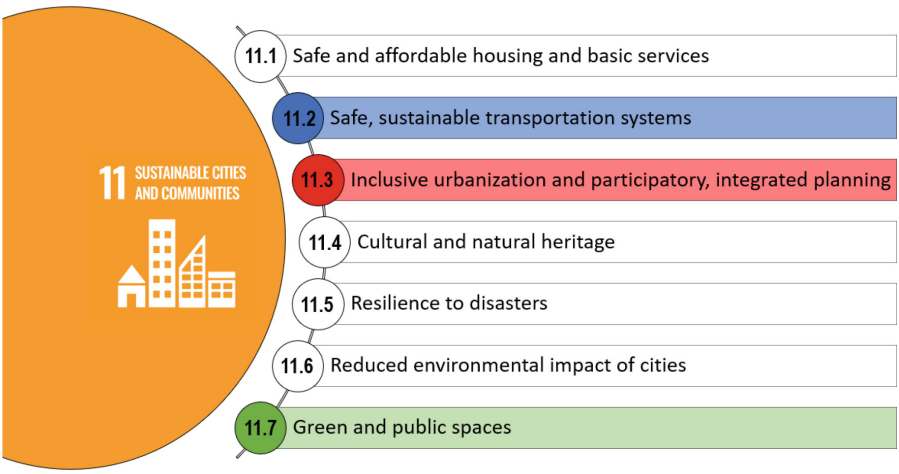

Fig. 1. Targets within Goal 11 "Sustainable Cities and Communities" (author elaboration)

In particular, the Target 11.2. Provides: "By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons". Target 11.3 provides: "By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries". And the Target 11.7 provides: "By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities".

According to the Targets 11.2 and 11.3, it is fundamental to promote an integrated planning approach to foster multi-level sustainability, i.e. environmental, social and economic [4]. Consistent with the three pillars of sustainability, the externalities mainly considered associated with the transport sector concern air pollution (environmental), fuel consuption (economic), traffic congestion and road accidents (social). More widely, the transport sector gives rise to both positive and negative production and consumption externalities [5–7].

Examples of positive externalities can be found among those that increase the commercial or residential value of areas within which a new transport service is implemented (e.g. a commercial activity or a residential building served by a new metro stop) [8, 9]. However, if safe, inclusive and sustainable transport systems are not designed, the associated negative externalities outnumber.

A first category of negative externalities consists of those limited to producers or consumers of a specific transport service; these externalities correspond to external costs expressed in monetary terms, since the main components of these costs are subject to market transactions. These external costs include, for example, the greater consumption of fuel inducted by *traffic congestion* [10] among the components that are difficult to estimate there is the *value of time*, included in the calculation of the generalized cost for passengers [11]. A second category of negative externalities caused by traffic includes those for which it is possible to easily estimate the times and costs of the interventions to eliminate their negative effects; these externalities can also be expressed in monetary terms and correspond to external costs. This category includes, for example, *traffic noise*, *environmental pollution* and *road accidents* [12, 13]. A third category bring in externalities for which both the identification of the effects and the evaluation in monetary terms are subjective. This category includes, for example, the effects of road accidents in terms of deaths and injuries and, even more, the monetary assessments of the catastrophic effects resulting from *climate change* [14].

Within this context, decision support models for the transport system choices are fundamental and the problem must be framed with a multi-criteria approach [15, 16]. A system of models needs to be developed, integrating models of land use (strategic/long term) [17–19], agent-based passenger and freight transport demand models (tactical/medium term) [20, 21], and multimodal network (operational/short term) [22], in order to cover and integrate different levels of analysis. All this must be supported by transport and territorial planning strategies within the Sustainable Urban Mobility Plans (SUMPs) [23, 24], to face the transition of the mobility system towards decarbonization. Among these strategies, it is possible to identify new services and technologies

for passengers mobility and transport of goods at an urban, sub-urban and regional level, analyzing their characteristics and requirements [25, 26]. Innovative solutions for sustainable mobility in weak-demand areas are Demand Responsive Transport (DRT) services, integrating Local Public Transport (LPT) and characterized by flexible routes and timetables in order to match the users' requests [27].

In line to the Target 11.7, the Green Infrastructure (GIs), are progressively being included in cities' green plans as part of climate adaptation measures [28–33]. According to the European Union (E.U.), the GIs "*… Are networks of natural and semi-natural areas planned at strategic level with other environmental elements, designed and managed in such a way as to provide a wide spectrum of ecosystem services. This includes green (or blue, in the case of aquatic ecosystems) and other physical elements in areas on land (including coastal areas) and marine areas. On the mainland, green infrastructures are present in a rural and urban context"* [34]. Forms of GIs include green roofs, green walls, urban forests, urban green spaces, urban trees, bioswales, rain gardens, urban agriculture (urban gardens; community gardening; community greening; peri-urban agriculture, agricultural parks), river parks, local produce markets, constructed wetland areas, alternative energy farms, and nature conservation areas, among the most common [35–38].

The growing importance of GIs in the urban context for a new model of resilient and sustainable urban development is acknowledged at a political level and there are many research and studies in the literature [39–42].

This work presents an integrated approach to consider the role of Green Infrastructures (GIs) and Transport Mobility (TM) as key components in the transition towards a model of sustainable and resilient cities. The analysis of these two components of the urban system, especially in cities with high rates of motorisation and traffic congestion, on the one hand, and with a non-widespread presence of green areas, on the other, becomes strategic for implementing actions aimed at making cities more sustainable.

The research presents a co-governance approach that could be a useful tool for carrying out strategic actions to make cities sustainable and resilient. The integrated approach was applied on Catania (Italy), a city characterised by a high rate of motorisation and a low availability of green space per inhabitant. After briefly illustrating the case study from the aspect of the two components considered (GIs and mobility) in Sect. 2, Sect. 3 describes the adopted methodology characterized by an integrated approach and Sect. 4 reports the main results already obtained for the GIs investigation, instead the research related to TM is in progress and the results will be provided in next contribution; finally, Sect. 5 concludes the paper. Research findings will constitute a decision support for administration and stakeholder to guide public investments and achieve awareness among citizens in order to promote co-governance actions and develop climate adaptation strategies and improve the quality of life in urban areas.

2 Case Study

The selected case study coincides with the city of Catania, located in the southeast coast of Sicily (Italy). Is has a territorial extension of 180,000 m^2 and a population of about 300,000 inhabitants [43].

The city of Catania is densely populated in its northern part, while the southern part (corresponding to the VI municipality) is mainly an industrial, airport and commercial area. However, it is necessary to highlight that some populous suburban neighborhoods administratively belong to neighboring municipalities as fractions: this is the case of Canalicchio (Tremestieri Etneo), of Fasano (Gravina di Catania), of Lineri (Misterbianco) and others. There are ten first-crown municipalities which, through urban sprawl processes, have been characterized by a strong increase in population to the detriment of the municipality of Catania, which has gone from over 400,000 residents in the early seventies to around 300,000 nowdays: Aci Castello, Aci Catena, Gravina di Catania, Mascalucia, Pedara, Trecastagni, Misterbianco, San Giovanni la Punta, San Gregorio di Catania, San Pietro Clarenza, Sant'Agata li Battiati, Tremestieri Etneo and Valverde (Fig. 2).

This regional development involves a high commuting phenomenon by users who daily gravitate to the city of Catania for various travel reasons (i.e. study, work and leisure). Therefore, the centrifugal movements of the population have changed the relationship between the city of Catania and the Etna municipalities, which have grown completely spontaneously, which have developed without control and the support of adequate urban planning tools, damaging the landscape and generating an extremely chaotic territory difficult to manage.

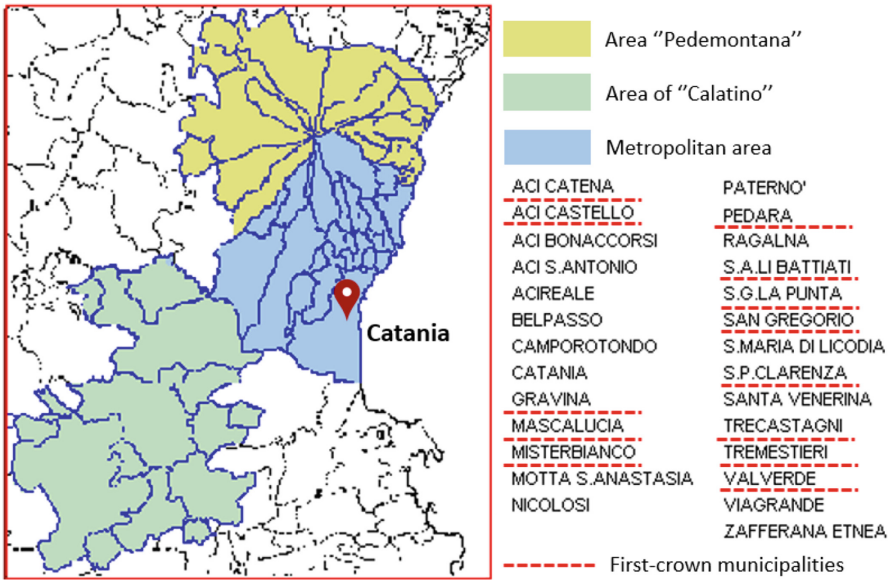

Fig. 2. Regional planning of Catania (Author elaboration from [44])

The functional imbalance, the "disorderly" distribution of the population over a vast and uneven territory, and often the lack of adequate transport systems, also cause serious livability issues. In fact, the municipality of Catania occupies the 91st position out of 107 in the annual ranking on the quality of life drawn up by the "Sole 24 Ore" and the

worst index is reserved for the urban ecosystem, within which the urban transport is considered [45].

Data provided from the National Institute of Statistics (ISTAT) allow to have an overview about the situation of transport sector in Italy, with particular reference to circulating cars and motorcycles in Italian municipalities, and also their emission characteristics (in accordance with the "Euro" categories and types of fuel used). These "numbers" determine the " pressure" on the urban environment, in terms of polluting emissions and noise, as well as traffic congestion and, therefore, the "state" of air quality and the "impact" on people's health.

The map shown in Fig. 3 represents the data relating to circulating cars and motorcycles in Italy, at the provincial level. The national average is 660 cars and 128 motorcycles (for a total of 788) circulating for every thousand inhabitants [46].

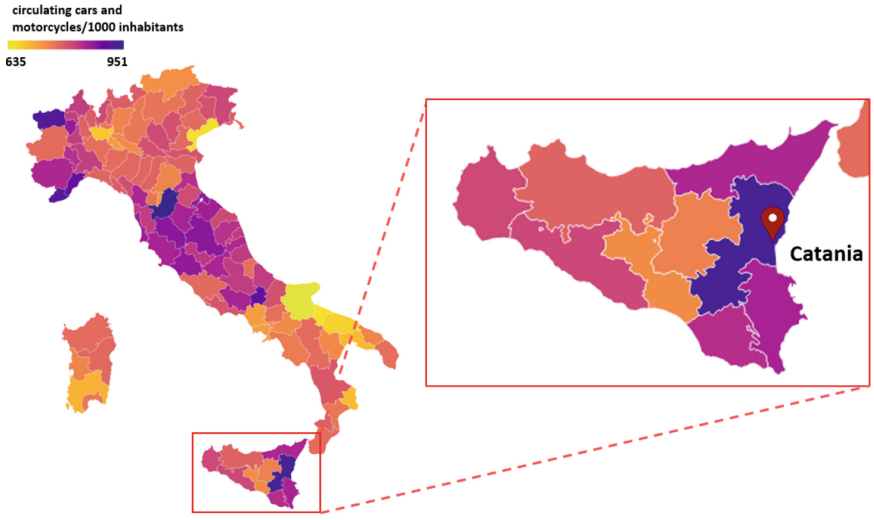

Fig. 3. Density of circulating cars and motorcycles in Italy in 2019 (Author elaboration from data provided by [46])

In particular, Fig. 4 shows the data relating to circulating cars and motorcycles per 1,000 inhabitants, in some major Italian cities. It is evident that the phenomenon of private mobility centrality in our lives and in cities has reached extremely high levels. In Catania there are 1,001 cars and motorcycles per 1,000 inhabitants, i.e. on average each person has a vehicle (including infants and the elderly over 80 years of age) [47].

Furthermore, observing the characteristics of these vehicles, it can be seen that the share of low-emission vehicles is still just over 10% of the total. More in detail, even more than 30% of them have an emission class equal to Euro 3 or less and over 54% is equal to Euro 4 (mandatory for new cars registered since January 2006) or less. The share of zero emission vehicles is equal to 0.2% (Fig. 5) [48]. This evidently means that there is an enormous quantity of motor vehicles which generate very high levels of pollutants and thus the transport decarbonisation is really challenging. Within this

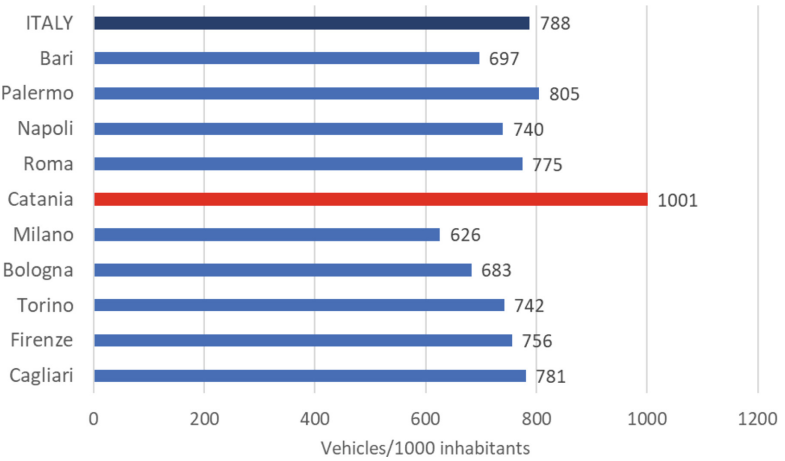

Fig. 4. Circulating cars and motorcycles per 1,000 inhabitants in some major Italian cities in 2019 (Author elaboration from data provided by [47])

context, especially for weak-demand areas and where the LPT is not efficient (cities in Southern Italy often have high motorization rates for this reasons), the implementation of DRT services can be a succeeding strategy.

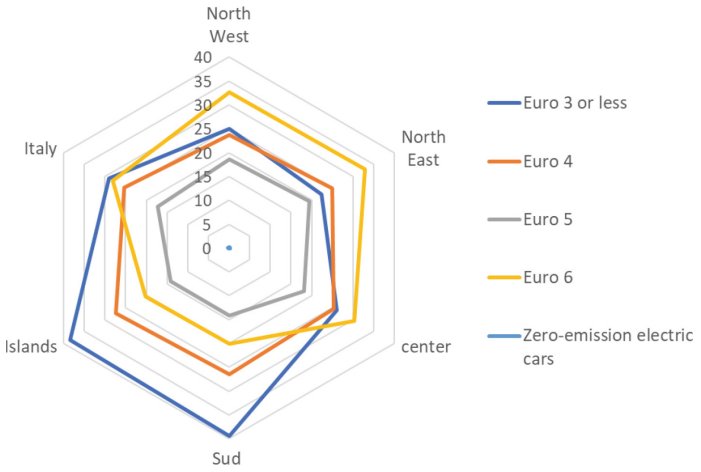

Fig. 5. Vehicles circulating by emission class in Italy in 2020. (Author elaboration from data provided by [48])

The city of Catania has been chosen as a case study both for the high motorization rates, but also for the reduced presence of GIs. Furthermore, in Catania the green areas have represented a sensitive issue in the last thirty years for their maintenance, cleaning and livability. Table 1 reports the GIs in the city of Catania, categorized by type:

Table 1. The Green Infrastructures of Catania (author elaboration from data provided by [49])

Green Typology	Mq
Urban Parks (>8,000 sqm)	513,577
Green Equipment. (<8,000 sqm)	431,270
Urban Design Areas	715,500
Urban Forestation	–
School gardens	350,000
Botanical Gardens and Vivai	20,000
Zoological Gardens	–
Cemetery	50,000
Urban Gardens (mainly managed by families)	2,500
Sports areas/Outdoor play	100,000
Bosch areas (>5000 sqm)	972,769
Uncultivated Green	1,688,044
Total Urban Green	**4,843,660**

The public green is made up of the parks located within the city. There are six characterized by size and relevance shown in Fig. 6.



Fig. 6. The GIs in Catania (the green zones in the picture) (our elaborations).

The Bellini Garden or Villa Bellini, called ‘a Villa, which is dedicated to the musician Vincenzo Bellini; the Pacini Garden or Villa Pacini, named Villa ‘e varagghi (ie “of the yawns”) dedicated to the musician Giovanni Pacini; among the most extensive there is

the Gioieni Park (located north of the Borgo district); the Falcone and Borsellino Park (north of Corso Italia), dedicated to the homonymous magistrates; and the Plaia Grove (the largest by extension, in the area between the south of the city and the Vincenzo Bellini airport, the former Municipal Fruit and Vegetable Market and the Plaia district). Due to its historical importance and for the conservation of biodiversity, the Botanical Garden of Catania in the Mercede district should be mentioned. As evident from the image shown above, the GIs in Catania have a reduced extension (4,843,660 Kmq) compared to the entire city (183 Kmq), with an availability of urban green per inhabitant equal to 18.1 Mq/inhabitants (Fig. 7) [50]. However, considering the availability of "effectively usable" urban green areas, in the city of Catania the available square meters per inhabitant are reduced by more than 50%, with a value equal to 8,2 Mq/inhabitants, significantly lower than the minimum threshold indicated by the World Health Organization (WHO) equal to 9 Mq/inhabitants [51].

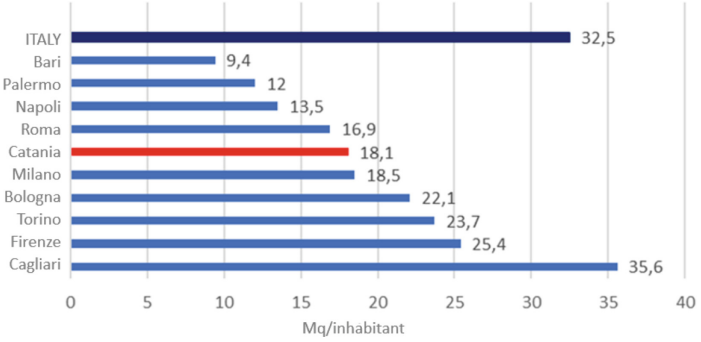

Fig. 7. Availability of urban green within Italian Municipalities in 2021 (Author elaboration from data provided by [50])

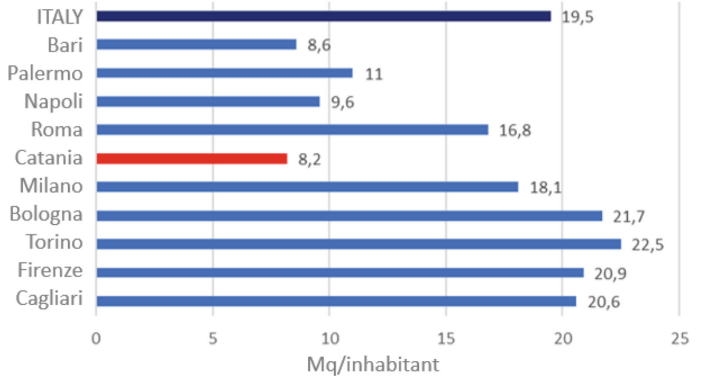

Fig. 8. Availability of "effective usable" urban green within Italian Municipalities in 2021 (Author elaboration from data provided by [50])

3 Materials and Methods

3.1 Methodological Framework

The main goal of the research focuses on the topic of sustainable and resilient cities, presenting an integrated approach characterized by an interview-based methodology, which consists of two step analysis: (i) first, a questionnaire has been implemented to analyze citizen's perception of GIs to tackle climate change and the willingness to pay to sustain the maintenance of these infrastructures; (ii) on the other hand, an extended survey will be performed to evaluate the propensity of users towards innovative shared transport systems and also the willingness to pay for the service. This methodological approach is applied to the case study of Catania, described in the previous section, and the obtained data from the interview are processed through statistical and cluster analysis in order to obtain a meaningful interpretation (Fig. 9).

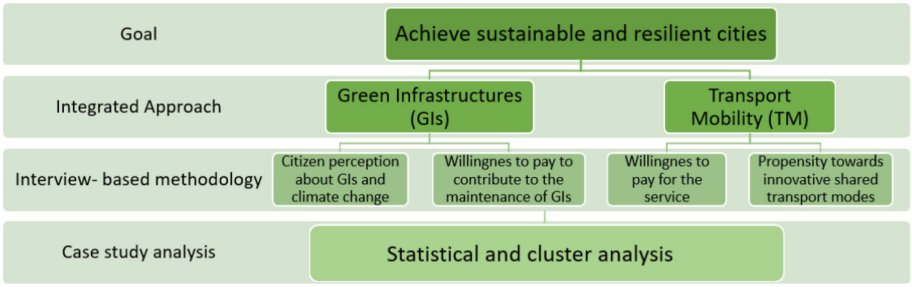

Fig. 9. Methodological framework

3.2 Interview-Based Survey

The questionnaire carried out to investigate the degree of perception of GIs and the impacts on climate change involved a sample of 500 citizens of Catania. The sample size has been fixed a priori for some significant variables (e.g. gender and age), according to the non-probabilistic sampling method, which allows more flexibility [42, 52, 53]. The structure of the questionnaire consisted of an introductory part to shortly introduce the research objective and five following sections. It envisaged no. 20 questions and a section with pictures to be evaluated. The questionnaire allowed to obtain mixed survey data, both from online GoogleDocs and face-to-face interviews and provided quantitative and qualitative information on:

- socio-demographics characteristics;
- behaviour towards GIs;
- level of knowledge and perception of quality of life;
- willingness to pay for GIs;

– perception of climate change problem.

As for the TM investigation, the main aim is to investigate the propensity to use DRT services in Catania. Therefore, two work phases will be envisaged: a *Desk Work* for the analysis of citizens' transport supply and demand and the study of the segmentation of mobility behaviors and a *Field Work* for the detection of the knowledge degree and potential use of DRT services in Catania and neighboring municipalities. More specifically, a structured questionnaire will be implemented on a sample reasoned using Computer Assisted Telephone Interviewing (CATI) and Computer Assisted Web Interviewing (CAWI) techniques to detect the following quantitative and qualitative information on:

– Socio-economic characteristics of the sample;
– Degree of knowledge and propensity to use DRT;
– Willingness to pay for the DRT service;
– Choice experiments.

The choice experiments will be based on travel costs and times values, analyzing short and medium distance scenarios and comparing the DRT with other transport alternatives (e.g. car; metro; bus).

4 Results and Discussion

This section reports the main results related to the performed research on GIs [42], as already mentioned in the reminder of the paper. The analysis of the socio-demographic structure through the performed questionnaire allowed to obtain the composition of the interviewed sample according to these characteristics: gender, age, residence, educational qualification, working sector. The results are summarized in Table 2: the sample is mainly made up of women; the prevailing age is over 51 years, while the remaining part of the sample is equally distributed among the other age groups. Consistent with the research aim, most of the sample has their residence within the Municipality of Catania. All respondents have a High School Diploma, and among these over 70% have a bachelor's or master's degree. As regards the employment, over half of the sample is employed by the Public Administration (PA); another part belongs to the service sector; and even if in a small percentage, the preferences of employees in the industrial sector, students, health care, etc. are also detected.

This paper reports the results relating to two significant aspects emerging from the analysis carried out, respectively relating to: (a) adaptation measures to climate change through urban GIs; (b) use of urban green areas.

For the first one it has been investigated Q1: *"What types of measures/actions to be primarily implemented in Catania or in the neighborhood to face climate change through urban GIs (evaluation based on provided pictures)"*. Figure 10 summarized the obtained results according to which the emerging measure/action is represented by the *increasing green spaces in areas of public use* (i.e. 33%), followed by the *improvement of the maintenance of existing GIs* (i.e. 27%), and finally, comparable in the evaluation by the interviewees, the *design of usable green areas* and the *greater protection and care of green spaces* (i.e. both 20%).

Table 2. Socio-demographic structure of the interviewed sample relating to GIs

Gender		Working sector	
Male	26%	Agriculture	3%
Female	74%	Industry	10%
Age		Public Administration (PA)	53%
18–25 years	20%	Services	20%
26–35 years	17%	Students	6%
36–50 years	23%	Health	6%
Over 51 years	40%	Associations	2%
Residence		**Educational classification**	
Catania	83%	High School	23%
Outside Catania	17%	Bachelor	47%
		Master	30%

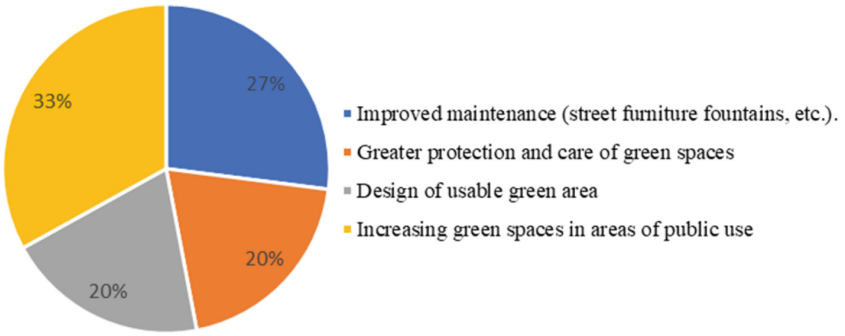

Fig. 10. Percentage evaluation of initiatives proposed by citizens to implement GIs

For the second aspect it has been investigated Q2: *"Motivation and frequency degree of urban green areas; recognized benefits to urban green spaces"*. Figure 11 represents through a bar diagram the subjective assessments provided by the interviewees, reported to a numerical value ranging from 1 to 5 using the Likert scale.

There is a general attention from users to the benefits given by GIs. In fact, for none of the considered benefits there are answers "not at all important", except for the benefit *increase in property value*. The main benefits recognized to GIs are the *temperature control* and the *carbon dioxide uptake*, considered as a much important benefits by more than 70% of the sample, followed by the *promotion of physical and mental wellbeing* much important for about 67% of the sample and by the *use for leisure activities* for about the 65% of the sample. On the other hand, the benefits considered less influential are the *increase in property value*, the *rainwater regulation* and the *noise reduction*, all considered much more important benefits for more or less 40% of the interviewees.

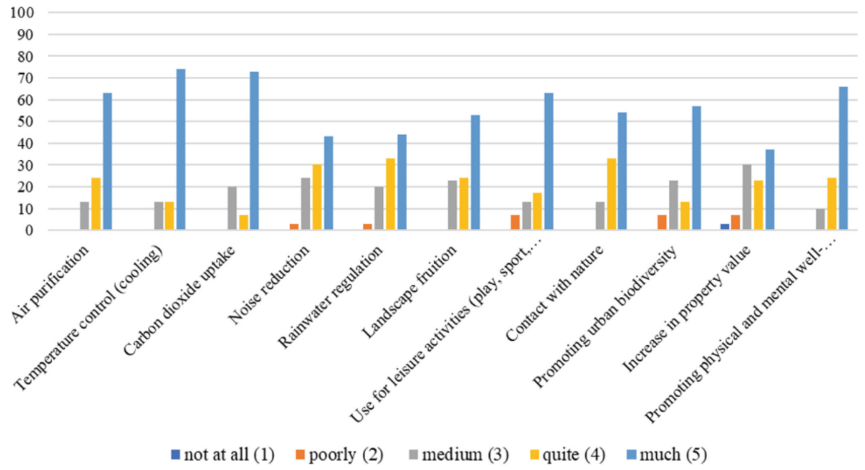

Fig. 11. Recognized benefits to urban green spaces

The graph represented in Fig. 12 compare the willingness to pay for GIs by citizens in two different situations: (i) without tax reduction and (ii) with tax reduction. The first one considers the willingness of citizens to contribute for maintaining GIs with no boundary condition; in this case a high percentage of citizens is not willing to pay anything (i.e. 26% of citizens answered 0 €) or a very low amount (26% of citizens answered 1–10 €), instead only 7% of citizens are willing to pay more than 100 €. This last percentage increases in the second considered situation (the number of citizens triples from 7% to 22%) for which citizens are given the opportunity to contribute to the maintenance of the GIs by considering a municipal tax reduction thanks to a crowdfunding among neighborhood residents. In this case, the percentage of citizens willing to pay for GIs rises from 74% to 86% of the interviewees.

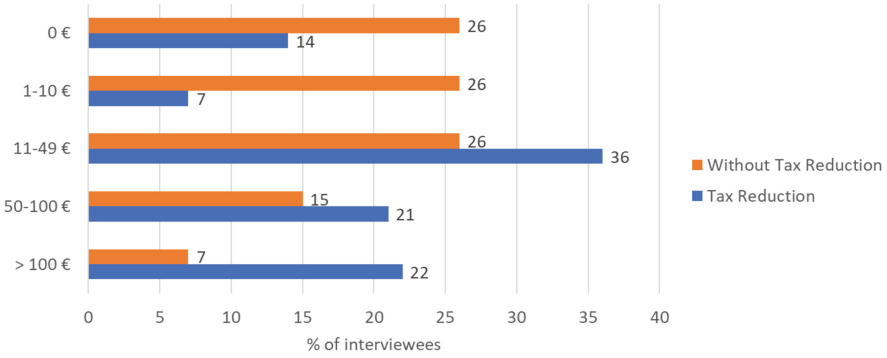

Fig. 12. Willingness to pay for the maintenance of GIs with and without tax reduction

The cluster analysis highlighted the predominant one for 40% of the sample is made up of users belonging to the middle class, who use green spaces only for socialization

and not for other benefits (above mentioned). Therefore, it follows that these users are not willing to pay for the maintenance of GIs, but the fundamental element is their free use. These results match those relating to the willingness to pay, which is almost equal to zero. However, if it is possible a tax reduction of the costs for the maintenance of the GIs, then users are more positively predisposed to the willingness to pay for GIs. This demonstrates that individuals respond to the proposed incentives and from a co-governance perspective, this research allows administrations to know what to do.

5 Conclusions

This paper provided the main results obtained from the first step of a wider research dealing with GIs and TM to gather useful information for supporting stakeholders and local authorities to develop shared strategic actions in order achieve climate change reduction and promote sustainable and resilient cities in accordance with the SDG 11 "Sustainable Cities and Communities".

The expected impacts of climate change in urban settlements are very different: impacts on health and quality of life (in particular for vulnerable users), impacts on the buildings, on water, energy and transport infrastructures, on cultural heritage (due to landslides, floods and heatwaves), impacts on energy production and supply. Thus, to deal effectively with these impacts, it is fundamental the coordination of a very broad institutional network (i.e. multilevel governance) [54–56]. Therefore, the research highlighted the usefulness of involving citizens in the implementation of strategies and actions to reduce climate change.

The research, although in process, provided preliminary information on the importance attributed to urban GIs by citizens and their relationship with climate change. A key element for future co-governance actions has been the surveying of citizens' willingness to pay to contribute for the management of urban GIs, both in terms of participatory planning and monetary contribution (one-time or in the form of crowdfunding). The research also made it possible to highlight the need to promote awareness-raising actions on benefits that GIs offers on climate change. Thus, it is important to promote collaboration with citizens to support long-term actions towards climate adaptation and to obtain information about the perception of urban green, which is strategic for urban policies.

Future research developments will focus on integrating the results with the ongoing TM survey, which will certainly be useful in building a comprehensive framework on the strengths and weaknesses on which local governments will need to act in order to promote sustainable and resilient cities.

Author Contributions. This paper is the result of the joint work of the authors. 'Abstract', and 'Conclusions' were written jointly by the authors. LS and VT wrote the 'Introduction', 'Case Study', "Materials and Methods"; LS, VT and AS wrote "Results and discussion"; LS, VT and MI coordinated and supervised the paper.

Acknowledgements. This work is financed by the MIUR (Ministry of Education, Universities and Research [Italy]) through a project entitled WEAKI TRANSIT: WEAK-demand areas

Innovative TRANsport Shared services for Italian Towns (Project code: 20174ARRHT, CUP: E44I17000050001), financed with the PRIN 2017 (Research Projects of National Relevance) programme. We authorise the MIUR to reproduce and distribute reprints for Governmental purposes, not with standing any copyright notations there on. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors, and do not necessarily reflect the views of the MIUR. The work of V. Torrisi was supported by European Union (NextGeneration EU), through the MUR-PNRR project SAMOTHRACE (ECS00000022).

References

1. Intergovernmental Panel on Climate Change (IPCC). Climate Change 2014; Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change[Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 (2014)
2. United Nations. Transforming our World: The 2030 Agenda for Sustainable Development; United Nations: New York, NY, USA (2015)
3. United Nations. Revision of the World Urbanization Prospects; United Nations: New York, NY, USA (2018)
4. Purvis, B., Mao, Y., Robinson, D.: Three pillars of sustainability: in search of conceptual origins. Sustain. Sci. **14**, 681–695 (2019)
5. Santos, G., Behrendt, H., Maconi, L., Shirvani, T., Teytelboym, A.: Part I: externalities and economic policies in road transport. Res. Transp. Econ. **28**(1), 2–45 (2010)
6. Sovacool, B.K., Kim, J., Yang, M.: The hidden costs of energy and mobility: a global meta-analysis and research synthesis of electricity and transport externalities. Energy Res. Soc. Sci. **72**, 101885 (2021)
7. Chatziioannou, I., Alvarez-Icaza, L., Bakogiannis, E., Kyriakidis, C., Chias-Becerril, L.: A structural analysis for the categorization of the negative externalities of transport and the hierarchical organization of sustainable mobility's strategies. Sustainability **12**(15), 6011 (2020)
8. Banerjee, A., Duflo, E., Qian, N.: On the road: access to transportation infrastructure and economic growth in China. J. Dev. Econ. **145**, 102442 (2020)
9. Kelobonye, K., Zhou, H., McCarney, G., Xia, J.C.: Measuring the accessibility and spatial equity of urban services under competition using the cumulative opportunities measure. J. Transp. Geogr. **85**, 102706 (2020)
10. Afrin, T., Yodo, N.: A survey of road traffic congestion measures towards a sustainable and resilient transportation system. Sustainability **12**(11), 4660 (2020)
11. Litman, T.: Measuring transportation. traffic, mobility and accessibility. ITE J. **73**(10), 28–32 (2003)
12. Marques, J., Batista, S.F.A., Menendez, M., Macedo, E., Coelho, M.C.: From aggregated traffic models to emissions quantification: connecting the missing dots. Transp. Res. Procedia **69**, 568–575 (2023)
13. Cabrera-Arnau, C., Prieto Curiel, R., Bishop, S.R.: Uncovering the behaviour of road accidents in urban areas. R. Soc. Open Sci. **7**(4), 191739 (2020)
14. Albuquerque, F.D., Maraqa, M.A., Chowdhury, R., Mauga, T., Alzard, M.: Greenhouse gas emissions associated with road transport projects: current status, benchmarking, and assessment tools. Transp. Res. Procedia **48**, 2018–2030 (2020)
15. Ortega, J., Moslem, S., Palaguachi, J., Ortega, M., Campisi, T., Torrisi, V.: An integrated multi criteria decision making model for evaluating park-and-ride facility location issue: a case study for Cuenca City in ecuador. Sustainability **13**(13), 7461 (2021). https://doi.org/10.3390/su13137461

16. Garau, C., Annunziata, A., Yamu, C.: A walkability assessment tool coupling multi-criteria analysis and space syntax: the case study of Iglesias, Italy. Euro. Planning Stud. 1–23 (2020)
17. Levine, J., Grengs, J., Merlin, L.A.: From Mobility to Accessibility: Transforming Urban Transportation and Land-use Planning. Cornell University Press (2019)
18. Annunziata, A., Desogus, G., Mighela, F., Garau, C.: Health and mobility in the post-pandemic scenario. an analysis of the adaptation of sustainable urban mobility plans in key contexts of Italy. In: Computational Science and Its Applications ICCSA 2022 Workshops: Malaga, Spain, July 4/7, 2022, Proceedings, Part VI, pp. 439–456. Cham: Springer International Publishing (2022). https://doi.org/10.1007/978-3-031-10592-0_32
19. Garau, C., Desogus, G., Maltinti, F., Olivo, A., Peretti, L., Coni, M.: Practices for an integrated planning between urban planning and green infrastructures for the development of the municipal urban plan (MUP) of Cagliari (Italy). In: Gervasi, O., et al. (eds.) ICCSA 2021. LNCS, vol. 12958, pp. 3–18. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-87016-4_1
20. Calabrò, G., Torrisi, V., Ignaccolo, M., Inturri, G.: Improving inbound logistic planning for large-scale real-word routing problems: a novel ant-colony simulation-based optimization. Eur. Transp. Res. Rev. **12** (2020). https://doi.org/10.1186/s12544-020-00409-7. ISSN: 1867–0717
21. Torrisi, V., Ignaccolo, M., Inturri, G.: The microsimulation modeling as a tool for transport policies assessment: an application to a real case study. In: AIP Conference Proceedings, vol. 2611, no. 1, p. 060006. AIP Publishing LLC (2022 November)
22. Elbert, R., Müller, J.P., Rentschler, J.: Tactical network planning and design in multimodal transportation–a systematic literature review. Res. Transp. Bus. Manag. **35**, 100462 (2020)
23. Torrisi, V., Garau, C., Inturri, G., Ignaccolo, M.: Strategies and actions to-wards sustainability: encouraging good ITS practices in the SUMP vision. In: AIP Conference Proceedings, vol. 2343, no. 1, p. 090008. AIP Publishing LLC (2021 March). https://doi.org/10.1063/5.0047897
24. Torrisi, V., Garau, C., Ignaccolo, M., Inturri, G.: Sustainable urban mobility plans: key concepts and a critical revision on SUMPs guidelines. In: Gervasi, O., et al. (eds.) ICCSA 2020. LNCS, vol. 12255, pp. 613–628. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-58820-5_45
25. Torrisi, V., Ignaccolo, M., Inturri, G.: Innovative transport systems to promote sustainable mobility: developing the model architecture of a traffic control and supervisor system. In: Gervasi, O., et al. (eds.) ICCSA 2018. LNCS, vol. 10962, pp. 622–638. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-95168-3_42
26. Campisi, T., Cocuzza, E., Ignaccolo, M., Inturri, G., Torrisi, V.: Exploring the factors that encourage the spread of EV-DRT into the sustainable urban mobility plans. In: Gervasi, O., et al. (eds.) ICCSA 2021. LNCS, vol. 12953, pp. 699–714. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-86976-2_48
27. Zhao, J., Sun, S., Cats, O.: Joint optimisation of regular and demand-responsive transit services. Transportmetrica Transp. Sci. **19**(2), 1987580 (2023)
28. EC. Towards an EU research and innovation policy agenda for nature-based solutions & renaturing cities. 2015. Towards an EU research and innovation policy agenda for nature-based solutions & renaturing cities - Publications Office of the EU (europa.eu). Accessed 28 Jan 2022
29. Economides, C.: Green Infrastructure: Sustainable Solutions in 11 Cities across the United States. Columbia University Water, New York, NY, USA (2014)
30. EEA. Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction. EEA Report 01/2021. Luxembourg: Publications Office of the European Union (2021)

31. Carrus, G., et al.: Go greener, feel better? The positive effects of bio-diversity on the well-being of individuals visiting urban and peri-urban green areas. Landsc. Urban Plan. **134**, 221–228 (2015)
32. EC. Nature-based solutions (2020). (https://ec.europa.eu/info/research-and-innovation/research-area/environment/naturebased-solutions_en). Accessed 13 Sept 2022
33. Wei, J., Qian, J., Tao, Y., Hu, F., Ou, W.: Evaluating spatial priority of urban green infrastructure for urban sustainability in areas of rapid urbanization: a case study of Pukouin China. Sustainability **10**, 327 (2018)
34. Environment Directorate (ED)-General for the Environment. Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Green Infrastructure (GI)—Enhancing Europe's Natural Capital; Environment Directorate-General for the Environment. Bruxelles, Belgium (2013)
35. Escobedo, F.J., Giannico, V., Jim, C.Y., Sanesi, G., Lafortezza, R.: Urban forestry & urban greening urban forests, ecosystem services, green infrastructure and nature-based solutions: nexus or evolving metaphors ? Urban For. Urban Green. **37**, 3–12 (2019)
36. Sturiale, L., Scuderi, A.: The role of green infrastructures in urban planning for climate change adaptation. Climate **7**, 119 (2019)
37. Scuderi, A., La Via, G., Timpanaro, G., Sturiale, L.: The digital applications of Agriculture 4.0: strategic opportunity for the development of the Italian citrus chain. Agriculture **12**(3), 400 (2022)
38. Sturiale, L., Scuderi, A.: Information and communication technology (ICT) and adjustment of the marketing strategy in the agrifood system in Italy. In: HAICTA, pp. 77–87 (September 2011)
39. Bayulken, B., Huisingh, D., Fisher, P.M.J.: How are nature based solutions helping in the greening of cities in the context of crises such as climate change and pandemics ? a comprehensive review. J. Clean. Prod. **288**, 125569 (2021)
40. Brink, E., Wamsler, C.: Collaborative governance for climate change adaptation: mapping citizen-municipality interactions. Environ. Policy Gov. **28**, 82–97 (2018)
41. Sturiale, L., Scuderi, A., Timpanaro, G.: A Multicriteria decision-making approach of tree meaning in the new urban context. Sustainability **14**(5), 2902 (2022)
42. Sturiale, L., Scuderi, A., Timpanaro, G.: Citizens' perception of the role of urban nature-based solutions and green infrastructures towards climate change in Italy. Front. Environ. Sci. **11**, 1105446 (2023). https://doi.org/10.3389/fenvs.2023.1105446
43. National Institute of Statistics (ISTAT). Bilancio demografico mensile anno 2023 (dati provvisori), su demo.istat.it, ISTAT, 7 aprile 2023 (2023)
44. Regional Province of Catania. Ufficio Pianificazione Del Territorio - Sistemi Informativi - Web Gis E Cartografia - E-Government (2003). https://public.cittametropolitana.ct.it/cartografia/index.asp
45. 33rd Quality of Life Survey from Il Sole 24 ore (2022). https://www.cataniatoday.it/cronaca/classifica-sole-24-ore-qualita-vita-catania.html
46. National Institute of Statistics (ISTAT). Density of cars and motorcycles circulating by municipalities (2019). https://www.istat.it/it/archivio/254037
47. National Institute of Statistics (ISTAT). Tavole di dati, Mobilità urbana (2019). https://www.istat.it/it/archivio/254037
48. Ambiente e non solo. Vehicles circulating by emission class in Italy in 2020 (2020). https://ambientenonsolo.com/la-mobilita-nei-109-comuni-capoluogo/
49. Municipality of Catania for Environmental and Green Policies and Energy Management of the Autoparco - Service for the Protection and Management of Public Green, Giardino Bellini and Parchi (2017)

50. National Institute of Statistics (ISTAT). Verde urbano (2022). https://www.istat.it/it/archivio/254037
51. World Health Organization (WHO). Urban green spaces and health (2016). https://apps.who.int/iris/handle/10665/345751
52. Wooldridge, J.M.: Econometric Analysis of Cross Section and Panel Data. MIT Press, Cambridge, MA (2002)
53. Gujarati, D.: Basic Econometrics. 4. New York, NY, USA: McGraw Hill (2003)
54. Wicki, S., Schwaab, J., Perhac, J., Grêt-Regamey, A.: Participatory multi-objective optimization for planning dense and green cities. J. Environ. Plan. Manag. **64**, 2532–2551 (2021)
55. Scuderi, A., Sturiale, L.: Evaluations of social media strategy for green urban planning in metropolitan cities. In: Calabrò, F., Della Spina, L., Bevilacqua, C. (eds.) ISHT 2018. SIST, vol. 100, pp. 76–84. Springer, Cham (2019). https://doi.org/10.1007/978-3-319-92099-3_10
56. Sturiale, L., Scuderi, A., Timpanaro, G., Foti, V.T., Stella, G.: Social and inclusive value generation in metropolitan area with the urban gardens planning. Green Energy Technol. 285–302 (2020)