

Article

Assessing Multiple Benefits of Housing Regeneration and Smart City Development: The European Project SINFONIA

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Abstract: The urban energy transition towards more sustainable energy production and consumption systems is at the top of the European Union political agenda. Several demonstration projects are dealing with the deep-energy retrofit of real-estate assets to show how technological and societal innovation can provide new investment opportunities while enhancing citizens' quality of life by delivering multiple benefits. In this framework, the EU smart city project SINFONIA has developed and tested a new comprehensive framework to define, identify, and evaluate the main multiple benefits expected from similar initiatives. The present contribution reviews the three assessment exercises carried out in the lighthouse city of Bolzano during the project execution, consisting of an investigation of the users' stated preferences, an evaluation of consumers' revealed preferences and a multicriteria analysis of homeowners' priorities. It offers an overview of the main achievements and sheds light on further investigatory paths applicable to Positive Energy Districts assessment.

Keywords: real estate evaluation; smart energy transition; spatial hedonic price method (SHPM); choice experiment (CE); analytic hierarchy process (AHP)

1. Introduction

About 75% of the European population lives in cities or urban areas, which are considered key places to develop innovative solutions to advance the smartness of the built environment, by improving citizens' quality of life, increasing industrial competitiveness, sharing knowledge to prevent mistakes being repeated, reaching energy and climate targets [1], and, not least, "to ensure a sustainable recovery after challenging times" [2], such as the current Covid-19 crisis.

Dating back to early 2000, the European Commission started to encourage cross-sectorial urban-energy renewal through specific funding calls, within the sixth and seventh European Research Framework Program, by allocating about EUR 169 million and EUR 176 million, respectively [3]. Thus, urban research and innovation projects have depended on a substantial contribution to develop and test groundbreaking solutions to be adapted and replicated on a large scale in the near future. More specifically, a recent review estimated that more than EUR 260 million was invested to carry out refurbishment interventions on buildings under smart-and-sustainable-energy district (SSED) projects from 2005 through 2018 [4]. European SSED projects achieve outstanding results in terms of energy efficiency and the resultant reduced CO₂ emissions; however, their approach may collide with the hard reality of current times, wherein "a significant share of the energy efficiency options are not (or not enough) cost-effective from an investor perspective when only energy savings are accounted as benefits" and, therefore, it becomes crucial for "policymakers [to] frequently justify energy efficiency measures by pointing to co-benefits" [5].

Carried out in the framework of the SINFONIA project [6], this study starts from this premise and defines an innovative framework to analyze the multiple benefits delivered by the European Union (EU) smart city projects and to refine it through individual assessment and three field investigations.

The SINFONIA project has been developed as a multi-annual initiative that conducted from June 2014 to July 2020 to develop large-scale, integrated, and scalable energy solutions targeting mid-sized European cities. In the two lighthouse cities of Bolzano (Italy) and Innsbruck (Austria), local partners have closely worked together to achieve outstanding energy savings (80%/90%), increase the share of renewables in some urban demonstration districts (20%/30%) and contribute to decarbonization. Thanks to an integrated set of measures combining the deep-energy retrofitting of more than 100,000 m² of social housing apartments, the creation of innovative smart infrastructure and the introduction of advanced solutions for district heating and cooling, SINFONIA has brought the two cities onto the pathway to the smartness and paved the way for the replication in five early-adopter cities: Pafos (Cyprus), Rosenheim (Germany), Seville (Spain), La Rochelle (France) and Borås (Sweden).

Since the beginning of the project, it has been clear the need to go beyond the climate–energy goals and to discuss, probe and assess the existence of additional co-benefits that substantially contribute to increasing the quality of life of citizens and constitute resultant added value for involved partners and cities. In fact, despite the consistent research and literature production on co-benefits (or, multiple benefits, as they are called, considering a holistic approach without ranking prejudice) [7], pointing out the existence of positive impacts in the environmental, economic and social areas, and defining methods for quantification [7–10], the various categories, labels and definitions still need to be discussed within a multidisciplinary and heterogeneous working environment (as an international innovation project is), to avoid misunderstandings, raise awareness and enhance familiarity with the concept. Therefore, during the development of the SINFONIA project, within task 2.4, “Integration of socio-economic aspects and analysis of sustainability”, it was decided to sensitize project partners towards the co-benefits paradigm and to adopt it for the assessment of some actions. The task was led by Eurac Research, with the main contribution of the University of Innsbruck.

The present study reports for the first time in a single place the main results obtained from the multiple analysis and assessment exercises performed during the project lifetime that provide at a glance the overall picture and describe the underlying narrative, while the detailed results are extensively reported in properly referenced research works.

It is structured as follows: Section 2 describes the process that led to the definition of the framework through desk research on co-benefits, including the presentation of the priorities identified by the project partners halfway through the project and also compared to the final re-evaluation.

Section 3 presents in a concise way the three assessment exercises carried out in the lighthouse city of Bolzano. The first is an investigation of users’ stated preferences concerning the smart points to be designed and installed as the interface of an innovative urban infrastructure. The second deals with the evaluation of consumers’ revealed preferences concerning energy efficiency in buildings, starting from a residential property-prices spatialized database. The last is a multicriteria analysis of homeowners’ expectations, aiming to better understand how they prioritize co-benefits in refurbishment work.

The final Section 4 discusses the main findings, placing them in the broader context of smart city project evaluation and co-benefits/multiple benefits appraisal approach for urban regeneration.

2. A Dive into the Co-Benefits: Setting the Framework

The following subsections present the key steps of the methodology performed to identify the key urban co-benefits to be further discussed and the main results achieved, while the full description of activities carried out is available in [11,12].

2.1. Desk Research and Mid-Term Evaluation

The scientific literature and extensive knowledge developed about energy projects at the district scale (see, for example, the crucial European initiative “CONCERTO” [13,14]) suggest that multiple co-benefits should arise from the SINFONIA project development and implementation.

To answer the question about which kinds of co-benefits are expected from the development and implementation of SINFONIA and similar SSED projects, a review of co-benefits deriving from energy-efficiency projects and CO₂ mitigation policies has been conducted, combined with analysis of reports and communication materials provided by 36 European SSED project involving local administrations and co-financed by similar programs. To provide a scientifically-based taxonomy for SSED projects’ co-benefits, some major studies have been analyzed: the IEA publication on multiple benefits related to energy efficiency policies [8], the US EPA document on the assessment of multiple benefits of clean-energy policies [15], the EU building-stock renovation scenarios depicted by Copenhagen Economics [16], and the proceedings of an IPCC workshop on ancillary benefits and costs of greenhouse-gas mitigation policies [17], in particular [18]. These sources suggest numerous dissimilar taxonomies, and they group the various benefits into different categories, ranging from five in IEA [8] and Copenhagen Economics [16] to three in US EPA [15]. An iterative refinement and selection process was undertaken, aimed at merging these classifications and, thus, trying to simplify and avoid repetition (see Figure 1). By linking the expectation of SSED EU projects to literature findings, a list of 19 key urban co-benefits has been obtained (see Table 1), fitting them into the seven smart-city dimensions previously defined by [19]. It will be noted that in the final step of the process the smart city dimension, “mobility” resulted in a lack of co-benefits because of the little attention paid by the analyzed projects to this topic, and therefore it was not further considered. The detailed description of the research steps, sources, and results are available at [20,21].

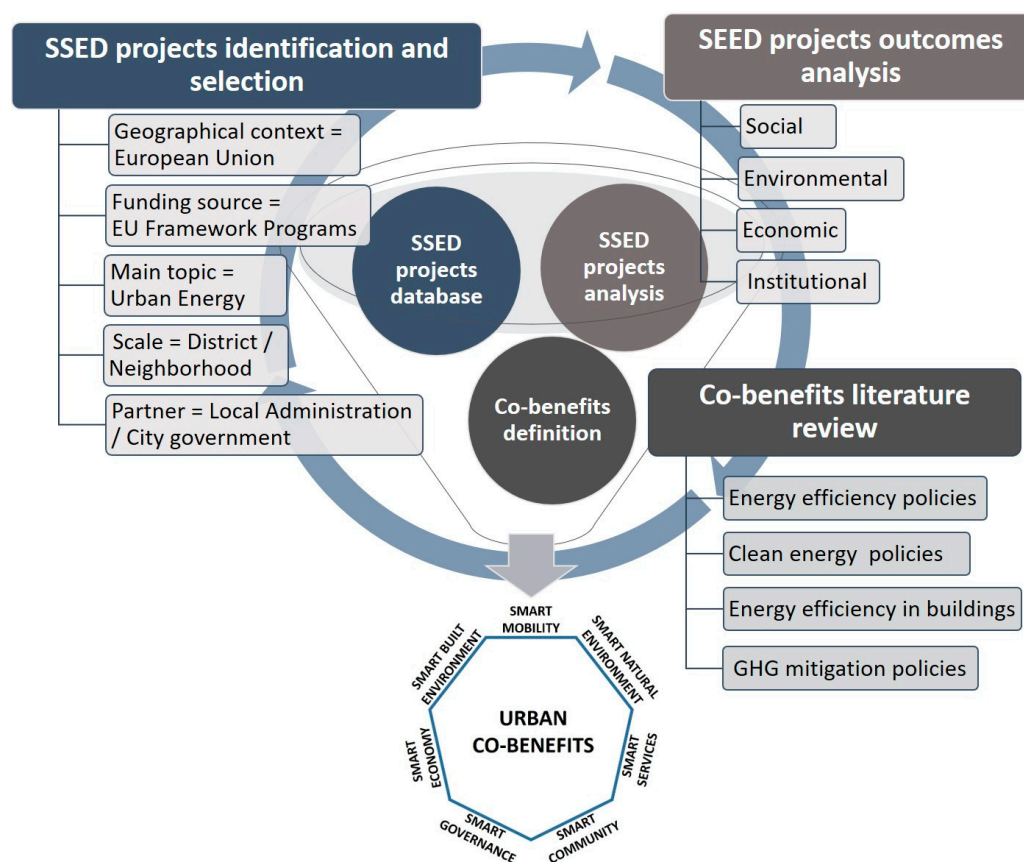


Figure 1. Conceptualization of the iterative refinement and selection process linking SSED projects, co-benefits, and literature/reports to elaborate a new taxonomy of urban co-benefits.

Table 1. Framework of 19 key urban co-benefits from SSED projects applied to the six smart city dimensions.

N.	Co-Benefit Description	Ref. Literature	Ref. EU Projects	Action (*)
Smart natural environment				
Local air quality improved.				
1	Shifting thermal energy and electricity production from fossil fuels to renewables and decreasing energy needs reduce local air pollutants (e.g., SO _x , NO _x , particulate matter), with positive effects on human health.	[9,22–26]	STEP-UP, SINFONIA	ER
Environmental resources management improved.				
2	Establishing a better way to manage environmental resources reduces the environmental footprint of construction activities, with positive effects on ecosystems.	[8,27–29]	Class1, R2CITIES, ECO-city, Energy in Minds!, ECOSTILLER, CITYFIELD	ER
Smart services				
Health and well-being of residents increased.				
3	Improving the indoor thermal comfort and spatial quality in buildings improves living and psychological conditions of occupants.	[9,22,25,30–34]	Class1, ECO-city, Energy in Minds!, Act2, STACCATO, SERVE, PLEEC, ZENN, STEP-UP, CITYFIELD, SINFONIA	ER
Smart community				
Fuel poverty tackled.				
4	Reducing energy expenses to an affordable level, especially for low-income people, can lower harmful health effects caused by indoor thermal shocks (in summer as in winter).	[25,35–37]	SORCER, STACCATO, SERVE, Eco-life, STEP-UP, TRANSFORM, Zenn, PLEEC	ER
Users' awareness of energy-related issues increased.				
5	Educational and communication activities change positively stakeholders' and tenants' energy behavior and acceptance of new technologies.	[38–47]	Act2, ECOSTILER, SORCER, Eco-life, SOLUTIONS, cRRescendo, ECO-city, Concerto AL Piano, TRANSFORM, POLiCITY, Green Solar cities, Class1	STK
Enhanced neighborhood identity.				
6	Creating new neighborhood relationships and a sense of place leads to the formulation of dense social networks and ultimately better economic and social outcomes.	[48,49]	ECO-city, Green Solar cities, SOLUTION, REMININ-LOWEX, Eco-life, RENAISSANCE	ER
Smart governance				
Innovation in processes and decision-making.				
7	The exchange of experiences introduces innovation while improving the quality and effectiveness of decision-making.	[38,50]	Energy in Minds!, RENAISSANCE, Green Solar cities, TetraEner, PLEEC, TRANSFORM, Eco-life, cRRescendo, TRANSFORM, READY	PM
Territorial attractiveness increased.				
8	An exemplary smart and sustainable district attracts visitors (e.g., institutions, public officials, researchers or green tourists) interested in innovative and green solutions	[14,51]	Act2, ECOSTILER, SEMS, Eco-life, SOLUTION, SESAC, STEEP, Green Solar Cities	ER
Institutional relationships and networks created.				
9	Creating and strengthening existing relationships between partners and cities leads to further joint activities, projects, and collaboration.	[38,52–54]	STEP-UP, SOLUTION, EU-GUGLE, R2CITIES, ZenN, CELSIUS CITYFiED, SINFONIA, READY, City-zen	PM

Table 1. Cont.

N.	Co-Benefit Description	Ref. Literature	Ref. EU Projects	Action (*)
Smart economy				
10	Positive change in local tax revenue. Creating new jobs and economic activities positively affects local public revenues.	[9,55]	SEMS, SERVE, STEP-UP	ER
11	Softer loan conditions. Large-scale interventions financially supported by the European Union can be attractive for banks and other investors, so project partners may, therefore, negotiate better financial conditions.	[14,29,36,56]	STACCATO, HOLISTIC, SORCER, R2CITIES, cRRescendo	ER
12	Local labor market stimulated. New direct or indirect jobs are created by the implementation of construction activities, project management, and other intervention measures.	[9,36,57–59]	TetraEner, SORCER, SEMS, SESAC, Class1, Concerto AL Piano, Green Solar Cities, Eco-life, SOLUTION, TRANSFORM, RENAISSANCE, ECOSTILER, SERVE CITYFiED	ER
13	Local energy-supply chain established. Developing a new energy supply chain using local renewable sources or by-products (e.g., waste-to-energy, bio-energy, wasted energy) generates additional revenues.	[14,27]	PITAGORAS, SINFONIA, Energy in Minds!, GEOCOM, SERVE	ER
14	Energy services developed. Developing innovative energy schemes enable partners to cover refurbishment intervention costs without additional expenses for tenants or owners.	[14,58]	RENAISSANCE, PIME'S, SESAC, Energy in Minds!, CITY FIELD	ER
15	Innovation in technology development and adoption. Companies involved in the project will be frontrunners in the adoption of innovative solutions and therefore have an advantage over their competitors on the market.	[56,60,61]	Eco-life, cRRescendo, ECOSTILER, TRANSFORM, EU-GUGLE, SESAC, SEMS, CITY-ZEN, TRANSFORM, READY	ER
16	Professional skills development. An increase in the knowledge and know-how of professionals and practitioners on innovative processes and energy technologies enhances productivity and competitiveness.	[14,36,56,62,63]	SOLUTIONS, TetraEner, Act2, ECOSTILER, RENAISSANCE, SESAC, Green Solar Cities, HOLISTIC, R2CITIES, CITYFiED	STK
Smart build environment				
17	Property value increased. Green (new and retrofitted) buildings with attractive features and high energy performance have a property-value premium exceeding the expected economic value of the energy saving.	[28,29,31,33,64–68]	ECO-city, RENAISSANCE, Class1	ER
18	Cost reductions of buildings' life cycle. Large-scale interventions introduce efficient technologies, lower the construction costs (allowing economy of scale), and reduce maintenance, repair, and operation costs.	[29,34,69,70]	STACCATO, Class1, cRRescendo	ER
19	Resilience of energy infrastructures increased. Better response to load peaks (the ability to prevent and react to them) and to adverse climatic events increases efficiency and safety in energy systems, reducing interruptions and blackouts.	[71]	Energy in Minds!, RENAISSANCE	ER

* ER = co-benefits related to energy retrofit at district scale; STK = co-benefits related to actions on stakeholders; PM = co-benefits related to project design and management processes. Source: adapted from [11].

The list obtained from the desk research became the starting point of the discussion among project partners organized during the SINFONIA general assembly held in June 2016 in Seville. The 38 participants, who represent the project partner institutions (encompassing universities and research centers, municipalities, energy and technology providers, social housing agencies), were introduced to the co-benefits concept thanks to a dedicated half-hour lecture on this topic reporting the results of the previous research. Then, the same participants were invited to individually complete a questionnaire on co-benefits, requiring them to rank the most important five on the suggested list.

“Health and well-being of residents increased—(ER)” was mentioned as the most important by 20% of respondents and no other co-benefit was mentioned as the first by a larger share of respondents (see Figure 2). Similarly, “Innovation in processes and decision making—(PM)” was mentioned second by 20%, and “innovation in technology development and adoption—(ER)” ranked third according to 24%. The fourth and fifth positions were occupied by “professional skills development—(STK)” (16%) and “users’ awareness on energy-related issues increased—(STK)” (20%).

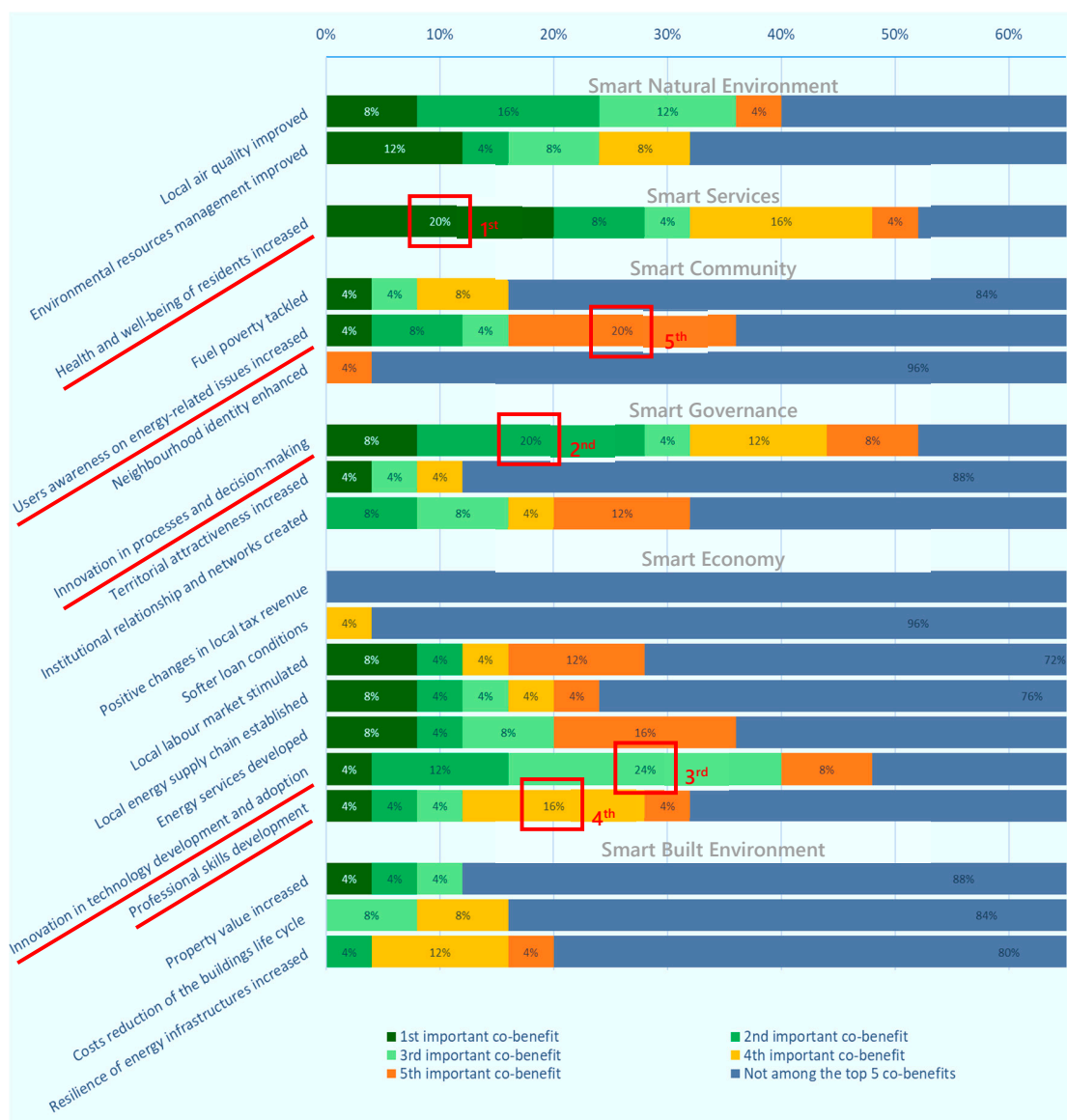


Figure 2. Co-benefits evaluation provided by project partners at halfway of the SINFONIA project. Top five co-benefits are underlined in red. The percentage in the bar refers to the share of respondents attributing the specific ranking position (from first to fifth).

It is useful to acknowledge that two out of the five mentioned co-benefits deal with the stakeholder-engagement activities (STK), and one to project management (PM), thus limiting the assessment of the outcomes only to energy-retrofit activities on the district scale (ER) will substantially diminish the overall value of SINFONIA and similar SSED projects.

2.2. Final Re-Evaluation

In January 2020, close to the end of the project (month 67 since the inception), and after the implementation of the majority of the activities, a re-evaluation of the co-benefits was proposed to the project partners. The initial idea was to have a sort of Delphi technique [72] by contacting the same persons involved in the previous exercise. The questionnaire, distributed via email by the coordinator, was designed to be as short and easy to complete as possible and to limit the time required to 10 min, with the goal of avoiding incomplete responses or sloppy and careless answers. It was accompanied by instructions and a visual representation of the co-benefits framework (see Figure 3), including the textual description found in Table 1.

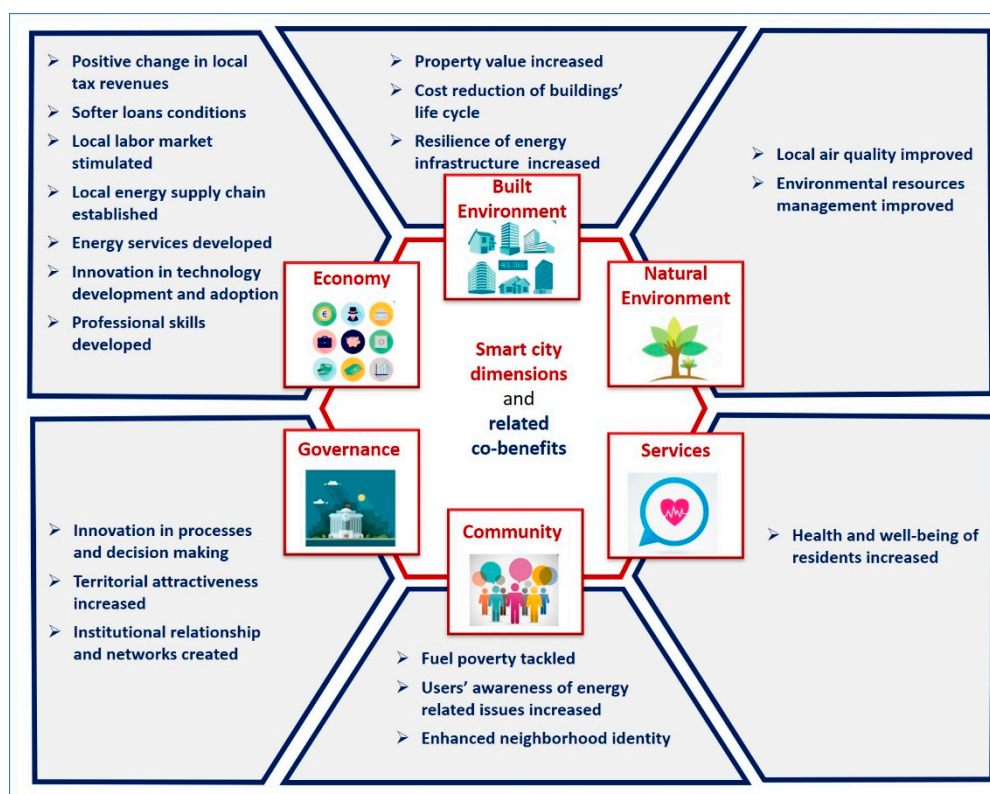


Figure 3. Co-benefits framework, as visually suggested to the SINFONIA partners during the final re-evaluation exercise performed in subtask 2.4.

Within a few weeks, 17 questionnaires were collected, but, despite that the involved institutions had not changed, in some cases, the respondents were not the same, due to modifications in teams, departing collaborators, etc.

Interestingly, despite such changes, looking at the specific result of the survey, the judgments about co-benefits' importance are quite stable: four of the top five remain there, although the rankings change, except for the first place that remains "health and well-being of residents increased" (see Table 2).

In particular, the co-benefits "users' awareness of energy-related issues increased" and "professional skills development" rose in ranking, while skepticism arose about the possibility to promote "innovation in technology development and adoption" among the project partners. It could be deduced that, looking beyond the pluriannual experience already acquired, the increase in human

capital [54] is considered more relevant than a mere technology transfer based on the innovative alterations of the business as usual [73]. Moreover, a related point is the presence in the top five of aspects connected to territorial attractiveness and neighborhood identity, which confirms the relevant role of this project—sometimes underestimated at the beginning of the process by the partners and the local authority, too—in substantially transforming the demonstration site, not only from a technological point of view but also from an architectural and social perspective [74].

Table 2. Variation in co-benefits’ ranking from halfway of SINFONIA to the end of the project.

Ranking Position	Questionnaire Evaluation Halfway through the Project (M24)	Questionnaire Evaluation at the End of the Project (M67)	Variation
1st	Health and well-being of residents increased (20%)	Health and well-being of residents increased (29%)	=
2nd	Innovation in processes and decision-making (20%)	Users’ awareness of energy-related issues increased (18%)	↑
3rd	Innovation in technology development and adoption (24%)	Professional skills development (24%)	↑
4th	Professional skills development (16%)	Territorial attractiveness increased (18%)/enhanced neighborhood identity (18%)	NEW
5th	Users’ awareness of energy-related issues increased (20%)	Innovation in technology development and adoption (18%)	↓

3. From Theory to Practice: Three Assessment Exercises

In between the activities summarized in Sections 2.1 and 2.2, three assessment exercises were carried out within the Subtask 2.4 of the SINFONIA project to start the empirical work on co-benefits’ assessment. Their aim was to answer as many questions, closely related to the implementation of activities already foreseen by the project, or to the extension of its approach at the urban level. The first question “what services increase the most the perceived benefits of an innovative smart urban infrastructure?” has been answered using a stated-preference method because market data are not available, welfare change is estimated by creating a hypothetical scenario and asking people their willingness to pay if that scenario was a reality. The second question “what will be the effect on the price of deep-energy retrofit interventions, similar to those tested on public buildings, on the local residential property market?” has been investigated adopting an indirect approach referring to the revealed preferences of consumers. The hedonic price method is applied to market data, breaking down the offer price and estimating the marginal value (price premium) of energy efficiency. The last question, “which co-benefits are expected by a homeowner who undertakes deep energy refurbishment of a property?”, is assessed looking at the decision-making process, instead of using monetization techniques. Thus, a multicriteria analysis is developed to understand the divergent priorities combined in a complex problem.

The following Sections 3.1–3.3 offer a major summary and answer these questions, while the full descriptions are available in dedicated research works, respectively [75–77].

3.1. Willingness to Pay for a Smart Urban Infrastructure

All around the world, cities seek to become smart by developing ICT-related solutions to meet urban challenges [78]. Any new public infrastructure should be carefully planned to avoid falling into the high-tech traps potentially hiding behind the alluring “smart city” label. Ideally, the local community should find the public assets to be places that stimulate new ways and forms of social and economic development [79], especially in the common situation of constraints on expenditures in the public budget.

Thus, the SINFONIA project is introducing in Bolzano an innovative urban infrastructure, providing services and information dedicated to citizens and tourists. The infrastructure is based on the Urban Service-Oriented Sensible Grid (USOS-grid) interfaced with the electrical grid, meteorological stations, and other sensors. It also provides a new physical interface to users, which consists of three smart service points called “totems” (see Figure 4). In view of its development, efforts were made to answer specific questions concerning the willingness to pay (WTP) for it and the selection of offered services that would increase the perceived benefits.

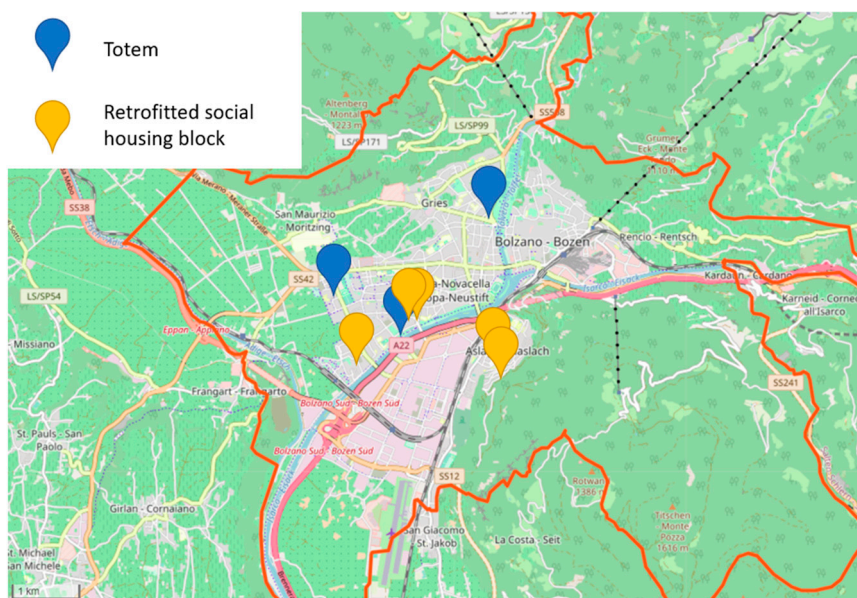


Figure 4. Main interventions of the SINFONIA project in the city of Bolzano (IT) concerning the installation of the totems (blue pins) and the deep energy retrofit of social housing blocks (yellow pins).

3.1.1. Methods and Materials

A Choice Experiment valuation method (CE) was applied to estimate the economic value of the innovative urban infrastructure, as a non-market good, by interviewing citizens and tourists.

Potential users are not directly asked about their WTP for one scenario, but they are asked to identify the best and worst options of the totem configuration [80] by choosing among multiple bundles of attributes at the various levels that may characterize the totem. Price, here intended as a theoretical monthly fee, is included as one of the attributes. This strategy makes the calculation of marginal WTP for each attribute possible [81]. The CE survey was designed following the specialized scientific literature [82,83].

The first section of the survey helps the interviewer to break the ice by establishing the framework of the research and to engage the respondent in a positive relationship. The second section investigates more in-depth the attitude of respondents toward the technology, the search for information, and their daily habits. The third section is the core of the survey: it introduces the concept of the totem and presents eight choice cards. Each card foreshadows two alternative configurations of the totem and the related monthly fee, plus the status-quo option (i.e., no totem/service and no usage charges). The final section aims to collect some socio-demographic data to ensure the statistical significance of the sample composition.

The choice card is built on a combination of seven attributes, as shown in Figure 5. Three attributes only have two levels, namely no (status quo, no service) or yes (having the attribute), while the other three have increasing levels of service, providing more features or additional info. The last attribute is the given by six monthly costs, increasing accordingly to the complexity of the totem and the zero cost for the status quo (EUR 0.50, EUR 1.00, EUR 1.50, EUR 2.00, EUR 2.50, EUR 3.00€, EUR 0.00). The dichotomy attributes are the availability of an emergency call service (SOS), Wi-Fi hot spots (WI-FI),

and drinking water (WATER). The attribute ELECTRICITY refers to a charging station providing electricity for tablets and smartphones (DEVICES) or additionally to e-bikes (BICYCLE) or even to e-vehicles (AUTO). INFO concerns the access to information about the city, going from the basic level of weather and environmental conditions (WEATHER), and then adding touristic and cultural news (TOURISTS) up to dedicated info for residents to interact with public offices (RESIDENTS). The same incremental scheme applies to MOBILITY, giving information about the availability of charging points for e-vehicles (CHARGE), traffic conditions, and public transport (TRAFFIC), and real time availability of free parking spaces (PARKING).

The effective rotation orthogonal design of the CE was obtained thanks to the function called “rotation.design” in the package “support.CEs” [84] of “R” software and a pre-test phase that reduced the overall number of the choice tasks [85]. Data has been analyzed using both a multinomial logit model (MNL) and a mixed-logit model (MXL) in the “willingness-to-pay space” [86]. The MNL model generates a point estimate for each parameter, so the marginal effect is assumed to be the same for all respondents, while the MXL provides distributions.










	SERVICES	OPTION 1	OPTION 2	OPTION 3
	SOS	NO	YES	NO
	WATER	YES	NO	NO
	WI-FI	YES	NO	NO
	ELECTRICITY	• TABLET or SMARTPHONES	• TABLET or SMARTPHONES • ELECTRIC BICYCLES	NO
	INFO	• WEATHER and ENVIRONM. CONDITIONS	• WEATHER and ENVIRONM. CONDITIONS • TOURISTIC and CULTURAL	NO
	MOBILITY	• FREE PARKING SPACES • FREE CHARGING POINTS	• FREE PARKING SPACES • FREE CHARGING POINTS • TRAFFIC CONDITIONS and PUBLIC TRANSPORTS	NO
	COST	2.00 €	2.50 €	0 €
	BEST OPTION			
	WORST OPTION			

Figure 5. Layout of the choice experiment card included in the interviewer’s supporting materials (translated from the Italian version). Options 1 and 2 are alternative configurations, while option 3 is the status quo, without the totem and any cost.

3.1.2. Results and Implications

The data collection took place from July to October 2016 in locations used by a heterogeneous public in the city of Bolzano (the Isarco river promenade, Vittoria square, viale Druso), including 221 respondents who were engaged in face-to-face interviews.

This led to 3536 observations (eight choice cards per interview, each one presenting best and worst option) referring to a heterogeneous sample of potential users, either Italian- or German-speaking, encompassing gender and age distribution in adequate proportions.

The statistical analyses of respondents’ choices by using MNL and MXL produces positive and statistically significant coefficients, except I_WHEATER (positive but not significant) and COST. The coefficient of the cost is negative and statistically significant, which is fundamental to validating the model because it means that the perceived utility of the totem decreases with payments for its use (COST = −€0.42 MNL or −€1.01 MXL). The MXL model should be preferred according to the control indicators AIC and BIC. Moreover, the “Sd_” coefficients are significant, meaning that there is heterogeneity in preferences and thus a distribution should be preferable to the point estimate provided by MNL. Concerning the electricity-charging service, high coefficients are attached to e-vehicles (E_CARS = €1.82 MNL or €1.7 MXL) or personal devices, such as a tablet or a smartphone (E_DEVICES

= €1.27 MNL or €1.03 MXL), while valuable mobility services include the info on available parking spaces (M_PARKING = €1.58 MNL or €1.23 MXL) and traffic conditions (M_TRAFFIC = €1.51 MNL or €1.25 MXL). Having access to the data network, thanks to Wi-Fi, is also appreciated (WI-FI = €1.49 MNL or €1.23 MXL), while the information service with the highest WTP is that dedicated to interaction with public offices (I_RESIDENTS = €1.41 MNL or €1.07 MXL). The availability of having emergency call rounds €1/month (SOS = €0.98 MNL or €1.0 MXL), while other attributes are rated slightly lower. The only one rated considerably lower is the info on meteorological conditions, particularly low in MXL (I_WHEATER = €0.38 MNL or €0.13 MXL). The status quo situation is not statistically significant, meaning that respondents do not focus on this as an alternative, and thus they are in favor of the new infrastructure.

It is interesting to note how the highest WTP coefficients identify different services and therefore an integrated and multipurpose infrastructure should have been designed, according to the survey. In practice, the design and installation of totems in Bolzano encountered some delays and difficulties, due to the novelty of the topic and the need to combine in an adequate way the design concept developed by the University IUAV of Venice with the engineering and construction phases involving software and hardware development. However, the actual trend in infrastructure development confirms these interests [87]. In recent years, the availability of charging points for e-vehicles in the city of Bolzano has increased continuously, surpassing two dozen and become integrated at the provincial level to support the diffusion of these vehicles. This is the case even though not only the infrastructure needs to be built out but also cognitive biases must be removed informing people, to prevent their diffusion [88]. Similarly, to find Wi-Fi coverage or USB plugs to power devices in public spaces are becoming a conventional expectation in EU urban areas: see, for example, [89]. In parallel, many cities are developing solutions to digitally manage traffic flows and reduce waiting to find an available parking spot, providing real-time parking information to drivers, contributing to reductions of both air pollution and congestion [90].

Finally, three totems with different features and interactive displays were realized by the technology provider and installed in July 2020 in many key locations in the city (see Figure 6): Vittoria Square (designed for parking and including charging point for EVs), Maria Montessori Square (designed for urban areas, including an air pump to fill up bike tires), and along the Israco River (designed for green areas) [91]. The final costs of supply and installation for this infrastructure was EUR 107,179.04, while the cost of the concept design EUR 15,000 (VAT excluded). The WTP obtained by the MNL model for the offered services (excluding drinkable water, which has not been included in the totem) totals EUR 7.28/month; theoretically, even if only 2% of the local population pays for this service, that will have covered the developmental costs within the first year of operation.

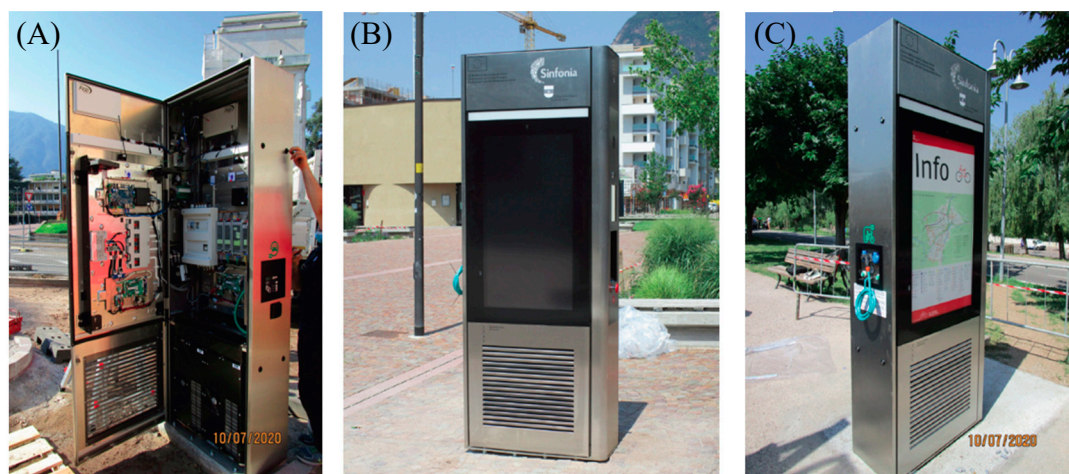


Figure 6. The three totems installed in Bolzano, specifically designed for parking areas (A), urban areas (B), and green areas (C). Photo credit: Brunella Franchini, Municipality of Bolzano.

3.2. The Marginal Implicit Value of Energy Efficiency in Buildings

For many years now, each building in Europe is required by law to have energy performance certificate (EPC) [92] when on the first- or second-hand market. The maximum consumption legally allowed differs across the Member States, but nevertheless, it has consistently been lowered compared to the benchmark of those built up in the second half of the 20th century, when the majority of European cities experienced major growth. Technically speaking, the feasibility of low energy or even net-zero residential buildings has been confirmed [92], as well as the specifications of intervention packages for those already build [93] and guidelines for the implementation of nearly zero-energy neighborhoods [94]. However, action plans for improving the existing building stock still deserve research because of the need to couple construction works and systems enhancement into the daily life of occupants—buildings are usually inhabited and not empty—and the existence of various economic perspectives [95], social habits or behaviors and decision-making capacities [96].

The SINFONIA project has tested and confirmed the possibility to reduce energy consumption by a factor of ten in inhabited social housing districts; for example, the annual energy consumption of a residential block of 5500 m² located in via Aslago (Bolzano), having 70 dwellings, was reduced from 263 kWh/m² to 26 kWh/m² (see Table 3) [97].

Table 3. Overview of the deep energy retrofit interventions in Bolzano.

Demo Site	Address (Bolzano)	Gross Surface (m ²)	Number of Dwellings	Energy Consumption Excluding RES Contribution	Energy Consumption Including RES Contribution
1	Via Brescia 1-3-5; via Cagliari 10-10/A	9403	106	221	49
2	Via Palermo 74-76-78-80	3996	38	204	46
3	Via Passeggiata dei Castani 33	5712	72	260	15 *
4	Via Similaun 10-12-14	4864	59	212	44
5	Via Aslago 25-27-29-31-33-35	5524	70	263	26 *
Total		29,498	345	232 **	36 **

* Energy consumption including renewable energy source (RES) contribution; ** Average value. Data source: <http://www.sinfonia-smartcities.eu/en/demo-city/bolzano>.

Even more significant results were achieved in Passeggiata dei Castani, which a size and pre-intervention energy performance that placed the building in the worst energy class “G”; it was finally certified in the EPC issued by CasaClima with a “A” rating (see Figure 7). The overall costs for the renovation of this site were: EUR 5,394,130.23 (EUR 167,463.16 for monitoring, EUR 6897.95 for the monitoring system, and EUR 153,211.51 for supervision of the construction work), of which EUR 1,486,480.00 was covered by the SINFONIA project (plus the contribution for monitoring of EUR 247,000.00, EUR 7795.00 for the monitoring system, and EUR 72,800.00 for supervision of construction work) and an additional EUR 3,301,650.00 provided by the Italian incentive scheme “Conto Termico”.

This feat of jumping from the bottom to the top of the EPC scale results for the occupants, in this case, tenants, great savings in energy consumption and related costs, as well as increased comfort. However, moving from the social-housing context of public rental apartments to the residential property market, an additional relevant point enters the debate that deserves in-depth research. In fact, the investigation into a positive relationship between EPC and sales price, which is of utmost relevance for the householders and business operators of the real estate market, is still inconclusive or partly contradictory, because of the wide variety of the many local markets [98–101], although some clear indication does emerges relevant to active markets and office locations (as in the case of Milan described by [102]).

However, in the urban context, the critical action remains to leverage such project results to stimulate the local market while following the decarbonization path. Therefore, research efforts have been made to analyze the local market to reveal the possible marginal implicit value of energy efficiency

in residential buildings and to detect the spillover effect of energy-efficient buildings on the prices of surrounding properties.

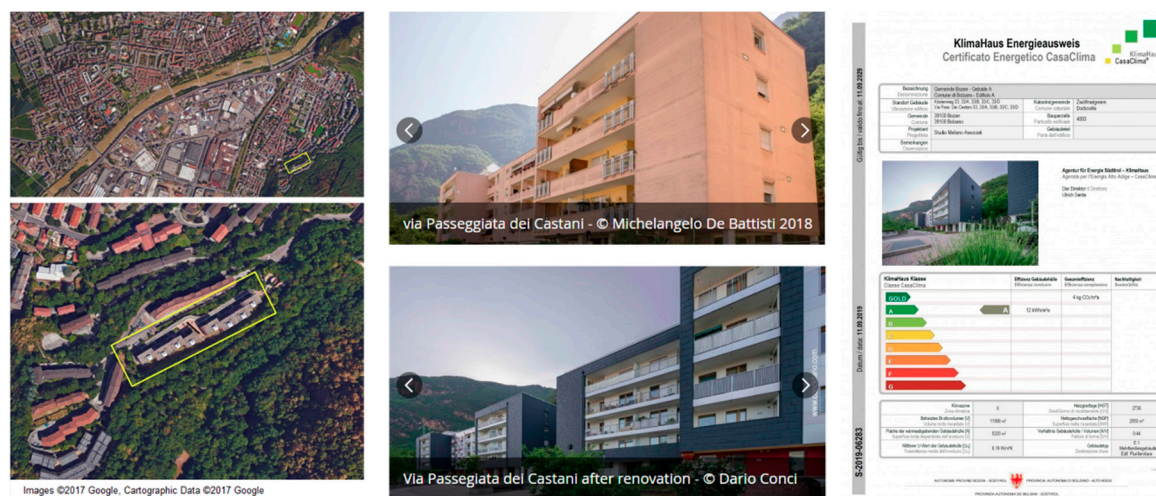


Figure 7. Demo site of Passeggiata dei Castani. Aerial overview, comparison pre- and post-intervention, and final EPC issued by the certification body CasaClima. Source: <http://www.sinfonia-smartcities.eu/en/demo-site/housing-complex->.

3.2.1. Methods and Materials

To detect the marginal implicit value of energy efficiency, we applied the well-known hedonic price model (HPM) [103] often used to estimate the monetary value of properties and nonmarket goods [104]. Indeed, HPM assumes that the price of a marketed good, such as a residential property in this case, is given by the sum of its characteristics, although they cannot be traded separately on the market. Such characteristics or attributes relate to the property itself (e.g., typology, maintenance level, quality, construction age), while others are locational characteristics, given by location (e.g., proximity to relevant services, accessibility, the reputation of the neighborhood). By applying the HPM, an estimate of the contribution of each nonmarketable characteristic to the price of the real estate asset is made explicit, using a multiple regression technique, usually solved by applying the Ordinary Least Squares (OLS) method. The criterion of the goodness of fit is usually applied for the identification of the most appropriate functional form, which often turns out to be the log of the price [105]. However, the presence of spatial dependence in a local real estate market is quite obvious because near things are more related than distant things [106], which leads to the violation of the OLS assumption of uncorrelated error terms. Consequently, according to [107], the omission of spatial effects can result in biased estimators and should be avoided.

The presence of spatial autocorrelation should be investigated by applying the global Moran test with the different specifications of a spatially weighted matrix (W) with non-zero elements in those row-column combinations corresponding to entities that are assumed to interact. The proximity relationship is defined by the analyst, following contiguity or distance rules (e.g., the k -nearest elements, the elements within a defined search radius, etc.) and should be tested against different specifications.

Having detected spatial autocorrelation in the basic OLS model, there are two spatial specifications that are often adopted in real-estate market studies: the Spatial Lag Model (SLM) and the Spatial Error Model (SEM) [107]. The first, SLM, assumes the presence the spillover effect (i.e., the price of each propriety is indirectly affected by the prices of nearby properties) and thus includes the spatial dependence parameter ρ and W in the HPM equation as a multiplier of the vector P of nearby properties (1).

$$P = \rho WP + \beta Z + \varepsilon \quad (1)$$

On the other side, the SEM postulates the presence of one or more hidden and spatially related variables in the error term of the HPM equation. Therefore, in the usual HPM equation, the error term ε is combined with the coefficient expressing the strength of spatial autocorrelation λ and again W .

$$\begin{cases} P = \beta Z + \eta \\ \eta = \lambda W \eta + \varepsilon \end{cases} \quad (2)$$

The results of multiple Lagrange Multiplier (LM) test statistics should be used to identify the most appropriate spatial specification to solve the model [108]. The general rule says:

- If LM-Lag test $\rightarrow H_0: \rho = 0$, then the SER should be tested;
- If LM-Error test $\rightarrow H_0: \lambda = 0$, then the SLM should be tested;
- If neither LM-Lag test or LM-Error test are significant, the OLS is the appropriate model;
- If both LM tests are significant, then the analysis path is determined by looking at the higher level of significance of Robust LM (RLM) tests result.

To conduct our investigation, an original dataset of 1058 residential properties in Bolzano was automatically extracted from a specialized website in March 2018 [109].

Advertisements, in almost all the cases inserted by specialized real-estate professionals, contain the selling price, the main technical characteristics, including the ECP class, the geographical coordinates, pictures and a brief description of the property and main amenities in the surroundings. The database was carefully revised to detect errors, misspecifications, and duplicate properties. Outliers (given by extreme numbers referring to the size or the selling price of the apartments) were removed, as well as single houses or properties outside the municipal borders. Finally, a refined sample of 849 apartments was obtained, and the logarithm of the advertised price was identified as the dependent variable to be analyzed against the following variables:

- The district, considering six alternative locations corresponding to the main neighborhoods of the city, namely Centro, Gries, Europa, Don Bosco, Piani, and Oltreisarco (dummy variable);
- The EPC class of the apartment, distinguishing among A, B, C, D, E, F, and G (dummy variable);
- The surface of the apartment (cardinal variable);
- The number of bedrooms (cardinal variable);
- The number of bathrooms (cardinal variable);
- The level to which the property is in the building (cardinal variable);
- The presence of the lift in the building (dichotomic variable);
- The presence of a parking space (dichotomic variable);
- The presence of a balcony (dichotomic variable);
- The presence of a private garden (dichotomic variable);
- The presence of other amenities, such as a cellar or a pool (dichotomic variable);
- Whether in a new development (first-hand property or deeply renovated) or already inhabited (second hand) (dichotomic variable);
- The state of repair, designated as poor, good, or excellent (ordinal variable).

3.2.2. Results and Implications

By analyzing the sample, we found that the technical characteristics in Bolzano do not diverge too greatly from the national building stock, having 95 m² of surface, two bedrooms and 1.3 bathrooms on average. The state of repair rated as excellent is 18%, which is in line with the expectation of a wealthy and good standing city. The sample reflects the well-known situation in Bolzano, characterized by a lack of garage or private parking spaces (only 26% has such), but a large presence of cellars (84%). The spatial distribution of the available data in the various districts is good, ranging from 7% in Piani to 27% in Gries. Looking at the declared EPC, 5% of the sample has A, B or C class, while 80% has

G. The availability on the market of high energy-performance apartments in the districts may vary by a factor of ten: the Piani district has the highest share (for either A or B, it is close to 33%) and the Europa district has only 3%. The average price by m² is EUR 3.643, ranging from EUR 1.700 to EUR 7.900; this means that a standard apartment costs close to EUR 350,000, more than twice the national reference market.

After several attempts and testing of different combinations of variables, the application of the HPM returned a good fit for the model, close to 57%. The removal of the “state of repair” and “new development” variable solved the multicollinearity bias with the EPC class while omitting “level” and intermediate EPC classes (namely “D”, “E”, and “F”) ensured the high statistical significance of all selected variables (at <1% or <5%). The final Equation (3) explains the log of the unitary price (LogUP) against the default values of the variables, which are “Centro” for the location (expected as the most appreciated, thus bringing negative coefficients to the alternative options) and “G” for the EPC class (expected as the less appreciated, thus bringing positive coefficients to the alternative options).

$$\begin{aligned} \text{LogUP} = 3.63 & -0.1808 \cdot \text{OltreIsarco} - 0.1504 \cdot \text{Piani} - 0.1458 \cdot \text{DonBosco} \\ & -0.1184 \cdot \text{Europa} - 0.0639 \cdot \text{Gries} + 0.0073 \cdot \text{Rooms} + 0.0363 \\ & \cdot \text{Bathrooms} + 0.0305 \cdot \text{Lift} - 0.0012 \cdot \text{Area} + 0.0255 \cdot \text{ParkingSpace} \\ & +0.0542 \cdot \text{PrivateGarden} + 0.044 \cdot \text{Balcony} + 0.0142 \cdot \text{Others} \\ & +0.0635 \cdot \text{EPC_A} + 0.0544 \cdot \text{EPC_B} + 0.0292 \cdot \text{EPC_C} + \varepsilon \end{aligned} \quad (3)$$

The model is consistent with the expected sign (positive or negative) and magnitude of coefficients: (i) All the districts other than Centro have a negative correlation to the m² price, and this is particularly relevant in the peripheral areas, such as Oltreisarco; (ii) the greater the size of the apartment, the lower the price per m²; (iii) better the EPC, the higher the price per m². It is interesting to note that the coefficient of EPC “A” is closer to “B” than “B” to “C”, but “A” is more than double “C”. This means that the price premium on the market is quite similar for the best and second best EPC class, while achieving only the “C” class in a refurbished apartment means leaving on the table a significant part of the possible increase in its value, ceteris paribus (i.e., having all other characteristics unchanged). By comparison, the unitary value of moving from “G” to “A” or “B” class is comparable to including a private parking space to the value of the property (which is much desired in Bolzano).

The HPM in this form provides acceptable results, even though the Breusch–Pagan and Koenker–Bassett tests confirm the expected presence of heteroscedasticity, thus calling for a spatial specification of the model. The multiple LM test was conducted using two different spatial specifications of W (named W700 and W1000, respectively, having the bandwidth at 700 and 1000 m). According to the decision rules specified by [108] and choosing the one having the lower the Schwartz criterion, the SLM_W1000 was selected (4). This model recognizes the existence of a spatial dependence parameter ρ (0.693559 at a statistical significance < 1%), and thus a spillover effect among nearby properties. By comparing HPM to SLM_W1000, the coefficients of EPC “A”, “B”, and “C” are coherent in magnitude and arithmetic sign, while the best class “A” is even slightly higher.

$$\begin{aligned} \text{LogUP} = 1.13717 & +0.6936 \cdot \text{W700LogUP} - 0.1108 \cdot \text{OltreIsarco} - 0.1373 \cdot \text{Piani} \\ & -0.1049 \cdot \text{DonBosco} - 0.0848 \cdot \text{Europa} - 0.0567 \cdot \text{Gries} + 0.0088 \\ & \cdot \text{Rooms} + 0.0305 \cdot \text{Bathrooms} + 0.0299 \cdot \text{Lift} - 0.0012 \cdot \text{Area} \\ & +0.0259 \cdot \text{ParkingSpace} + 0.0528 \cdot \text{PrivateGarden} + 0.0432 \\ & \cdot \text{Balcony} + 0.0141 \cdot \text{Others} + 0.0654 \cdot \text{EPC_A} + 0.0527 \cdot \text{EPC_B} \\ & +0.0285 \cdot \text{EPC_C} + \varepsilon \end{aligned} \quad (4)$$

Both equations confirm that increasing the EPC of the apartment from the lowest class to one of the top three positively affects its value. Removing from the model the variable concerning “new development” may have led to the overestimation of the marginal contribution of the EPC in determining the advertised price, but the final results are aligned to [110–113]. Even though the

Municipality of Bolzano and the local social housing agency (IPES—Istituto per l’Edilizia Sociale dell’Alto Adige), the owners of the properties, cannot substantially modify the rent for the apartment or change the value of the refurbished assets in their economic balances, even considering a cautious 5% price premium, due to the increased energy performance, they theoretically gained EUR 15,000 at the apartment, and overall more than EUR 0.5 M. Moreover, in some demonstration sites, because of the outstanding energy performance achieved and the robustness of the building structure, there was the opportunity to exploit the local incentive scheme called “cubage bonus”, by increasing the volume of the building up to 20%, and thus adding another floor on the top, to become new rental apartments. Finally, one must consider the leverage effect of a public expenditure: because the result of (4) contributes the relevant information that increasing the prices of some residential units will lead to an increase of the prices of those nearby, one may argue that the large-scale urban-transformation process accomplished by the SINFONIA project will in some way positively affect the advertised prices of many other properties.

Concerning the methodology applied, a further step could be to compare results obtained by implementing different appraisal methods, for example, those referring to automated models for value prediction, based on machine learning or neural networks [114].

3.3. *Householder Priorities in the Decision-Making Process*

In the previous section, we described the outstanding increase of the energy performance achieved by the retrofitted buildings within the SINFONIA project. In these cases, however, the decision to participate in the project was made by the owner of the building (either the Municipality or IPES), who allocated the funds, decided on the intervention priorities, and defined the business plan—in some way, overcoming the well-known problem of the split incentive [96]. In fact, the main beneficiaries of the intervention are the tenants, those who, after enduring the hassle of the construction works, will benefit from the renovated apartment through reduced energy expenditures and increased comfort. However, since 75% of Italian families are living in their own property [115], the decision-making process is more often in the hands of the householder, and the correct evaluation of individual preferences and motivations is crucial [116]. A better understanding is also crucial for the professionals in the construction sectors to determine why energy-efficient buildings are attractive for their customers and to define adequate strategies to propose the intervention. Recent studies in this field suggest the relevance, besides monetary savings, of expected co-benefits dealing with the health and well-being of the occupants [117], the pleasure of enjoying higher spatial quality [118] and daylight [119], feeling part of a positive collective action for the environment, and thus considering motivations that may triumph over the economic calculation [120].

A better understanding of such a decision-making process is necessary to avoid project failures or underperformance in promoting this kind of intervention in the urban context. The SINFONIA project has therefore suggested analyzing the local context, in view of future replication or scale-up of the interventions, by adopting a multi-criteria decision analysis (MCDA) approach. MCDA deals with complex problems that may be solved by adopting multiple solutions (called alternatives) to be evaluated considering multidimensional elements (criteria) and is currently used to select alternatives in energy-related urban projects [121,122].

3.3.1. *Methods and Materials*

While MCDA methods enable the finding of compromise solutions following a rational path, in this case, the aim is to assign relative values for the expected utilities from deep energy-retrofitting interventions. Among the possible MCDA methods, we adopted the Analytic Hierarchy Process (AHP) because of its extensive use [123], especially in energy planning [124] or indoor comfort assessment [125].

In this way, it is possible to determine the relative percentage of contribution of each co-benefit (e.g., lowering the energy bill, reducing noise nuisances from outside, having better spatial quality) in

the decision-making process that supports the decision to refurbish a residential property (house or apartment).

Figure 8 represents the decision tree decomposing the problem, which in this case is articulated into five criteria and 15 sub-criteria derived from the literature [77]: three in “design and spatial quality benefits”, “economic benefits” and “acoustic comfort benefits”, four in “thermal comfort benefits” and two in “environmental benefits”. The AHP works through the involvement of a pool of respondents, asked to perform a pairwise comparison of each criterion against others, and the same for the sub-criteria, following a predefined the semantic scale. This semantic scale is composed by a verbal scale associated to numerical values (1 = equal importance, 3 = moderate importance, 5 = strong importance, 7 = very strong importance and 9 = extreme importance of one over other) and compromises (2, 4, 6, 8) between such values. Respondents are usually engaged in a face to face or phone interview, but because the procedure used to express preferences provide information only about the relative importance of the two criteria involved in the pairwise comparison, there may be some violations of transitivity in expressed judgments (e.g., sub-criterion A has strong importance over sub-criterion B, B has very strong importance over sub-criterion C, but C is equally important as A). To avoid inconsistencies, a check for each matrix of judgments is required during the process, keeping them below the threshold and inviting the respondent to reconsider some answers. To help the analyst, the “Super Decisions” software, specifically developed to support the data collection and the validation of results may be used, as in this case.

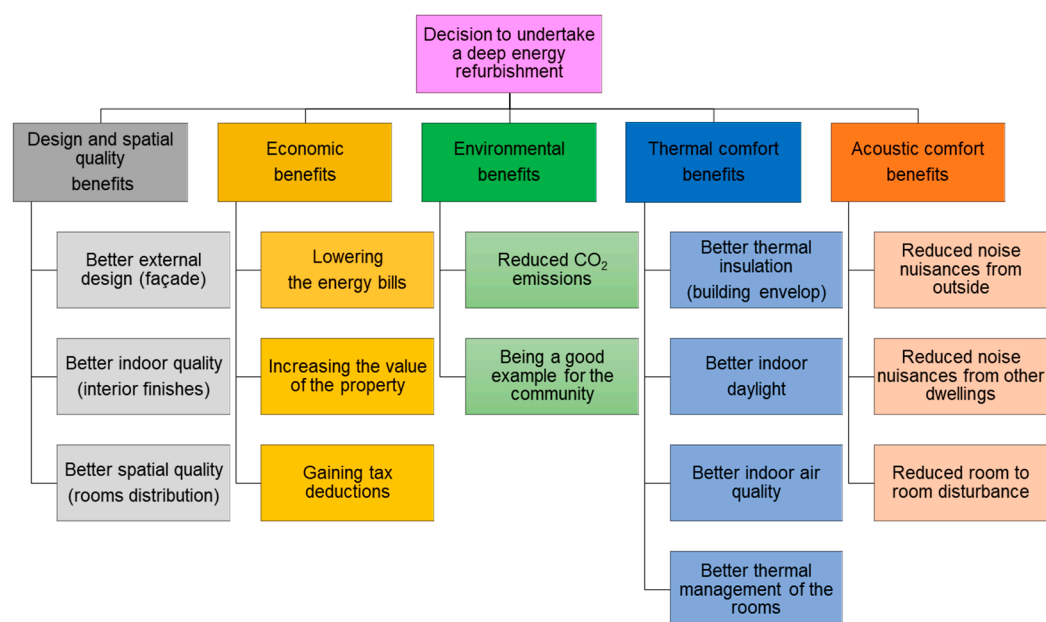


Figure 8. Structure of the decision tree decomposing the problem. The first level represents the in five criteria (in as many colors), the second the related sub-criteria (light colors).

Since energy behaviors and expectations may be very context-dependent, it is necessary to interview a pool of local experts/stakeholders. Thus, we asked the SINFONIA project partner “CasaClima—KlimaHaus” (responsible in the autonomous province of South Tyrol for the energy audit and certification of buildings) to contribute to the investigation, by inviting its associates to join the research. As a result, during June and July 2016, we conducted ten phone interviews, collecting information from local engineers, architects, and experts in the building sector. We invited respondents to answer the question “what are the most relevant benefits?”, considering their personal and professional experiences with local customers who seek deep energy refurbishment of their residential property.

3.3.2. Results and Implications

The contacted experts (four architects, two engineers, and two experts coming from the construction sectors) stated their availability to participate in the experiments and provided useful insights. The arithmetic mean of the judgments (see Table 4) assigns the first place to economic benefits (37%) and, remarkably, equal importance both to thermal comfort benefits (22%) and design and spatial quality benefits (22%). Smaller percentages give lower rankings to environmental benefits (10%) and acoustic comfort benefits (9%). Thermal comfort benefits and design and spatial quality benefits possess the largest standard deviation, while the criteria acoustic comfort benefits has the smallest.

Table 4. Decision criteria: descriptive statistics of the collected responses.

Criteria	Min	Mean	Max	Standard Deviation
Thermal comfort benefits	7%	22%	41%	11.6%
Acoustic comfort benefits	6%	9%	14%	2.2%
Design and spatial quality benefits	5%	22%	44%	12.0%
Economic benefits	22%	37%	56%	9.7%
Environmental benefits	3%	10%	21%	5.8%

Figure 9 offers an overview of the decision-making profile defined by the respondents, and their associated mean values. Respondents 1, 5 and 7 have similar profiles, with economic and thermal benefits clearly towering over the others, while 6, 8 and 10 focus on design and spatial quality benefits. Interestingly, both triples represent all the categories of involved experts, showing that practical experiences with clients go beyond the specific professional background of the respondent.

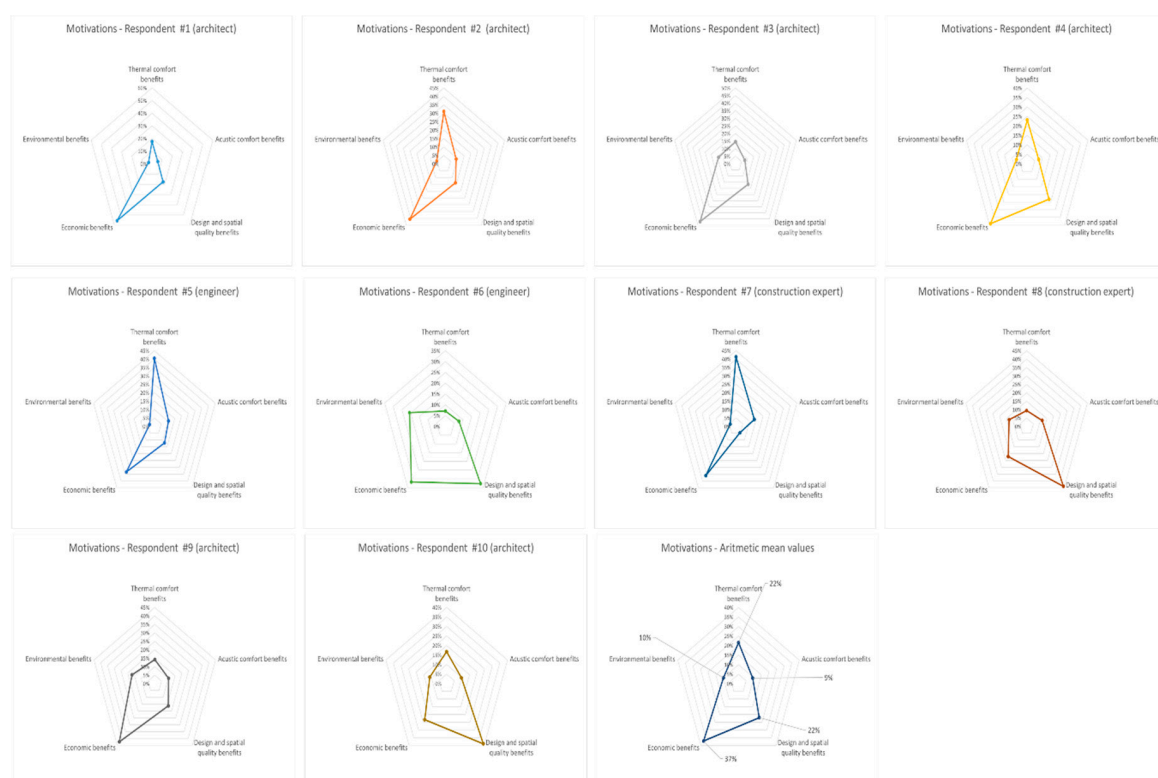


Figure 9. Importance of various benefits/motivations in the decision-making process resulting from AHP analysis. Individual answers and arithmetic mean.

By decomposing the decision to undertake a “deep energy refurbishment” of the residential property into microelements (the sub-criteria), the research confirms how the fiscal incentives in place in Italy at the time of the experiment played a prominent role in the decision-making process with 23%, more than double of any other sub-criterion (see Figure 7).

In fact, the financial legislation makes it possible for homeowners to recover, in ten years, a large share of the refurbishment investment (ranging from 50% to 65%) up to the threshold of EUR 96,000 spent per each property (This consisted originally of a tax credit, corresponding to 36% of the expenses incurred for the property refurbishment up to EUR 48,000, to be calculated by computing personal income tax (IRPEF). Thanks to the annual finance law, from 2012 onwards, this has been extended to higher tax credits (50% for refurbishment works, 65% for works contributing to relevant energy improvements), and the maximum limit has been revised upwards to EUR 96,000. The tax credit must be taken in ten equal annual installments). It would be interesting to compare the results to a nearby country not having such an incentive scheme in place, so as to see how the other sub-criteria will change, or again in Italy at the current time of August 2020, when the incentives become even more generous. the last evolution of this mechanism is the so-called “superbonus” defined in the national law 77/2020. Under strict circumstances (in particular the achievement of a two-level jump upwards in the EPC certification), some specific expenses for energy efficiency interventions (e.g., the insulation of the building envelope or changing of the heat generator), allow homeowners to be rewarded by a tax credit of 110% within five years. This credit may be also transferred to a financial institution in exchange for cash or to the construction company doing the refurbishment works, by receiving a discount of 100% of the full cost [126].

Concerning relevant sub-criteria, it is interesting to note how spatial and architectural quality closely follow thermal insulation, confirming the relevance of promoting technical intervention into the energy components (either active or passive solutions) as an opportunity to rearrange the living spaces and aesthetically renovate the property, following an integrated design process addressing the whole building [127]. On the other hand, despite the fact that research on building acoustics report a general inadequacy to provide satisfactory acoustic environments to their occupants, and the emerging of the “soundscape” as a trending topic, the practice suggests that little attention has been paid so far to acoustic comfort improvement [128]. Similarly, the environmental motivations—either CO₂ reduction or providing a good example to neighbors—and the conviction of doing the right thing seems to play a secondary role. This can be seen as aligning with survey studies from the latter part of the 2000s and early 2010s, which reported the proliferation of public doubts and skepticism about climate change and called for the creation of widespread awareness [129].

A final remark concerning the AHP experiment just described concerns the relevance in the decision-making process played by the sub-criteria affecting the health and well-being of occupants, which number 8 out of 15 (see Figure 10). Since they comprise a prominent part of the list and sum up to a significant percentage of the decision factors, the professionals and technicians should be justified to stress this topic in interactions with the stakeholders and in the ensuing discussion phase to define an effective strategy that leads to the roll-out of the intervention [130].

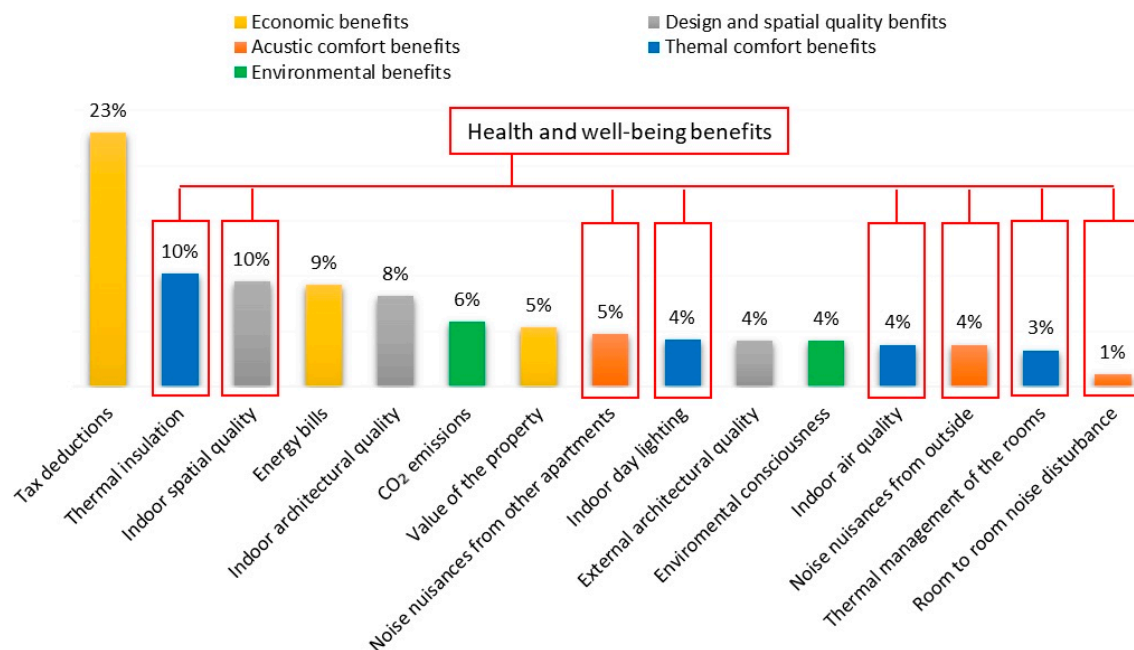


Figure 10. Relevance of single sub-criteria in the decision-making process resulting from AHP analysis.

4. Discussion and Concluding Remarks

This paper argues for an explicit and strategic use of the multiple-benefits approach to the assessment of smart and sustainable energy district projects. This implies that the co-benefits emerging alongside the kWh of energy savings or tons of CO₂ avoided must be clearly identified, discussed, described, measured and estimated, so as to accurately explain holistic contribution of the project to the city and involved actors. Through the work done by the SINFONIA project, we have offered practical guidelines for mobilizing the interest-focused co-benefits, stressing the pivotal role played by a trusted actor, often related to the execution of an European SSED project [131], working as a “mediator” among stakeholders (local administrators, public or private investors, technicians) involved in the urban redevelopment strategy. In particular, applying the multiple benefits approach may help in tackling well-known problems, as those recognized by [73]: “there is significant sustainability potential in cross-sectoral integration, but there are unresolved challenges of accountability for and measurability of these gains. [...] When a smart city project aims to integrate solutions, processes and actors and counter inefficiencies associated with silo-oriented organization, it becomes nearly impossible to measure energy sustainability as a discrete target”.

Section 2 demonstrated how discussion and awareness-creation activities around the co-benefits are needed to set a shared framework, and how the expectations and focusses may change along the project lifetime, calling for an iterative assessment and adjustment in the leading to further opportunities.

In particular, as suggested by [132], one must pass “from impact assessment to impact design: understanding co-benefit assessments as strategic planning instruments for progressive climate and renewable energy policies [or projects] to pro-actively seize the social and economic opportunities”, and “fostering the science-based but interest-focused co-benefits narrative, by structuring the discourse along (policy) performance categories [or in our case the smart city dimensions] rather than analytic research categories”. Establishing a “guiding framework and common understanding among policy makers and bureaucrats [or stakeholders, more in general]” effectively helps in overcoming a usual bottleneck: “even if co-benefits are incorporated in policy [or project] design, they often face implementation challenges due to a lack of awareness” [133].

Moreover, an effective method to stimulate awareness and to engage partners in the co-benefits discourse is the World Café Method (WCM). WCM rules are devised to facilitate an open debate about the topic, letting the participants becoming familiar with the new topic and to freely express

their opinions and expectations [134]. In this case, the final ranking results from a participatory decision-making process and may lead to a different classification. This is due to the exchange of viewpoints and debates developed in the WCM: in each discussion table, the participants had the opportunity to share their ideas and compare them with each other. Group dynamics may lead to the development of new agreements or the emergence of different priorities. [12]. Nevertheless, in the case of the SINFONIA project, both the WCM and the analysis of the individual answers halfway through the project, the same as in the final valuation, identified “health and well-being of residents increased” as the most important co-benefit.

Section 3 has thus translated the co-benefits theory into practice, reporting on three assessment exercises done in the lighthouse city of Bolzano. They are just an example of possible indicators and techniques that may be selected on the basis of larger sets, as those suggested by [5,7] or [132,135], that reveal the complexity of the topic and the need of a multidisciplinary approach and mixed methods.

The work done in the first assessment exercise on the WTP for smart service points, or totems, aligns with the diffusion and integration of information and communication technologies in the urban environment as a pillar of the current smart-city development approach. In the design and construction of an innovative urban information infrastructure, enabling the user’s interaction and communication, this plays a prominent role in understanding how and if the project meets users’ expectations. New public infrastructure aims to increase the quality of life of residents, meeting their needs and satisfying their expectations. In a context of scarcity of public budgets, investments should be done carefully, without following the “smart-city” fascination uncritically, but looking to sustainable infrastructure supporting “inclusive growth, enhance access to basic services that can reduce poverty and accelerate development, and promote environmental sustainability” [136]. Merging innovation and traditional solutions, well designed for the specific context by applying scientifically sound methods for assessment, makes the best result more likely to be achieved. Moreover, urban interventions promoting cycling stimulate to healthy lifestyles and therefore important positive co-benefits on the population health [137].

In the second assessment exercise, the analysis of the relationship between energy efficiency and residential building prices has confirmed relevant implications, not only for the identification of a price-premium coefficient recognized on the advertised properties (as discussed for example by [110–113]), but also in relation to future large-scale interventions, where “modernizing the building industry seems decisive in increasing productivity and therein making retrofitting costs more accessible” [138]. A project similar to SINFONIA, both in size and the extent of financial investment, means a very innovative large-scale approach for a city like Bolzano, having a magnitude close to one-third of the local residential market (more than 300 refurbished apartments of about 900 sales advertisements available on-line). Said in another way, in view of the 3% renovation-rate target posed by the EU, SINFONIA has constituted 0.65% by itself because the overall residential building stock of Bolzano corresponds to 52,781 residential properties (according to the official statistics in 2018). Proceeding at a constant annual 3% rate means theoretically the possibility to achieve the deep-energy refurbishment from “G” to “A” of 50% of the residential stock in less than 25 years, investing some EUR 2.5 billion (referring to the cost of the SINFONIA construction works) and, on the other hand, to increase the market value by roughly EUR 460 million, corresponding to 18% of the total investment (considering even a 5% price premium). A mass appraisal study, shedding light on possible implications deriving from large-scale refurbishment interventions, has not been developed in SINFONIA, and it deserves further research [139]. Finding the right way to apply a similar concept, supported by adequate business schemes and technical skills, would help in the next decades to radically transform Bolzano into a smart city by fostering the innovation of the local construction sector and by evolving the real estate market and property-management activities (thanks to the consistent monitoring activities) towards a proptech dimension.

The third and final assessment exercise has touched the issue of individuals’ motivations to undertake building refurbishment, which is a crucial point relevant to energy efficiency or

sustainable-energy actions [138]. This has been done by using an AHP method, which is often used in studies on the “attractiveness” of real-estate investments [140], combined with the WTP [116] approach. The result points out on one hand the existence on the Italian market of a main driver consisting in the fiscal incentive scheme, although its power is diminished by the “intricacy of administrative procedures” [141], and, on the other hand, the role in the decision played by the health and well-being sub-criteria. These co-benefits are in some way perceived by the homeowners, but they should be promoted in a more organic way by the professionals and the public authorities, considering the critical role they play in impacting monetary values [9,31].

The next research step could be the discussion and investigation of the multiple benefits related to positive energy district (PED) projects coupled with the creation of energy communities, which may enable the local energy sharing chiefly to generate environmental, economic or social community benefits rather than financial profits [142,143].

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