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Smart City Projects Implementation in Europe: Assessment of Barriers and Drivers

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Abstract

This investigation has the aim to provide advice and support on the implementation of smart city projects at European Union level. A quantitative feasibility study - strengths, weaknesses, opportunities and threats analysis - based on more than one hundred previous experiences of smart city projects in Europe, indicates a certain difficulty in carrying out the investigated efforts. Results show that the main obstacle is the environment external to the analysed activities (opportunities and threats), while issues internal (strengths and weaknesses) to the investigated projects appear to facilitate their execution. The following were identified as main barriers (weaknesses and threats): i.) subsidies, ii.) communication between project participants and the public, and iii.) expertise in designing new technologies and solutions. In contrast, the most effective drivers (strengths and opportunities) are i.) public participation, ii.) cooperation between different stakeholders, and iii.) political commitment over the long term. Public participation is not only the most powerful driver, but also the most utilized factor to overcome the detected barriers.

Keywords:	Smart cities; Projects; Implementation; Europe; Barriers and drivers

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1. Introduction

The European Union (EU) is facing unprecedented challenges related to climate, energy, social and economic aspects, with specific goals to be achieved by 2020, 2030 and 2050 [1-3].

Europe has both an ecological footprint twice as large as its area and a dependence on imported energy (primarily in the form of fossil fuels) coming mainly from Africa, Russia, and the Organization of Petroleum Exporting Countries (OPEC) - all of which have current conflicts causing them to be fragile markets [4]. Less than half of the gross energy consumption of Europe is domestically produced [5]. The International Energy Agency (IEA) has predicted that, specifically for fossil fuels, Europe's energy dependence will continue to increase, potentially reaching 90% in 2030 [6].

Transitioning to a low-carbon economy is currently a major European goal. Key aspects of a low-carbon economy include: support for smart energy management, reductions in emissions and higher levels of energy efficiency. A low-carbon economy will place much higher value compared to a modern day economy on energy efficient building materials, renewable energy sources (RES), hybrid and electric cars, low-carbon power generation, smart grid equipment, smart cities (SCs), and carbon capture & storage [3].

The primary energy utilization in Europe in 2010 was approximately 1,800 Mtoe [7]. Currently cities consume 40% of the energy and studies have predicted that the percentage will increase to 75% by 2030 [8-9]. Smart cities represent a method of creating urban areas, which are both sustainable and efficient. Currently, SC projects primarily focus on energy efficiency measures, adding RES, and offsetting emissions [10].

As noted in the literature, most renewable energy technologies are economically competitive compared to

traditional energy sources; however, due to a wide range of technical, market-related and institutional barriers, the implementation of such technologies has not reached yet its full potential [11-14]. Considering the limited evidence in the literature concerning the performance of SC projects at EU level, the main purpose of this study is to grant deep understanding on the development of previously-completed and current SC projects in Europe. Thus, a quantitative feasibility assessment framework consisting of four elements (strengths, weaknesses, opportunities, and threats - SWOT) has been applied to assess more than one hundred previous experiences in SC projects.

The paper is structured as follows: developed framework - section 2; results obtained from the survey on the main barriers and drivers for European SC projects - section 3; conclusions are drawn in the final section.

2. Methodology

This work consists primarily of a SWOT analysis supporting decision makers who are transforming European urban environments into SCs. Analysing experiences from previously-completed and current SC projects helps to provide a more effective implementation of future ones. The analysis includes understanding possible difficulties (weaknesses and threats) and the factors, which will lead to a successful project implementation (strengths and opportunities).

The highest number of ongoing and completed SC projects in Europe were identified using an extensive investigation. Available documentation on SC projects analysed in the present work was provided especially by:

- The European Commission (EC - financed within the Sixth and Seventh Framework Programme "CONCERTO initiative", the "Smart cities and communities initiative" - Seventh Framework Programme, and Horizon 2020 "Smart Cities & Communities" activities) [15-19];
- "Amsterdam smart city" [20]; and
- Individual EU member states programmes (e.g. Austria´s "Climate and Energy Fund") [21].

The investigation revealed 124 SC projects and identified a list of barriers and drivers for those. The analysis was performed in two ways: studying the freely available documentation, and performing direct interviews with SC experts.

The expert interviews only considered empirical information. In the case of current projects, the interviews only covered barriers and drivers that had occurred previously in the project. The experts were specifically asked to provide only that information.

Throughout the analysis, it was assumed that strengths and weaknesses are "internal factors", or characteristics of a SC project itself. The opportunities and threats for a given project are considered to be "external factors", or factors describing the environment surrounding a SC project [22].

An exploratory study was used to identify the factors, both barriers and drivers, for each project. A literature review was used to identify those encountered during project implementation, and then the most common factors were selected from the list.

After the list was created, experts were asked to quantitatively describe the effectiveness of each factor for the SC project(s) they work(ed) on.

Out of 124 smart city projects, a new sample size (new ss) deriving from 94 questionnaire responses (randomly selected) was used to identify the quantified effectiveness for each factor. This value was calculated using equation (1), which identifies the required sample size to perform an accurate quantitative statistical elaboration [23]:

$$new\ ss = ss / \left[1 + (ss - 1 / population)\right] \quad (1)$$

where

$$ss = Z^2 * p * (1 - p) / c^2$$

Z (constant) = 1.96 for 95% confidence level

p (level of significance) = 50%

c (confidence interval) = 4.84%

The factors were rated on a Likert scale, with a possible range of -5 to 5, including 0 (see Table 2, Appendix). The values have the following significance:

- Negative values represent barriers, with -1 indicating a minor barrier and -5 a major barrier
- 0 indicates neutrality
- Positive values represent drivers, with +5 representing a very effective driver and +1 a less effective driver

The use of average absolute values of expert responses allowed to define the effectiveness of each factor by focusing the analysis on its relevance, while neglecting whether it was a driver or barrier [24].

To determine the uniformity of expert responses, a consistency analysis was performed. The level of agreement of the experts was quantified using the interquartile range (IQR) of the weights distribution [25-27]. A higher IQR indicates a low level of agreement [28].

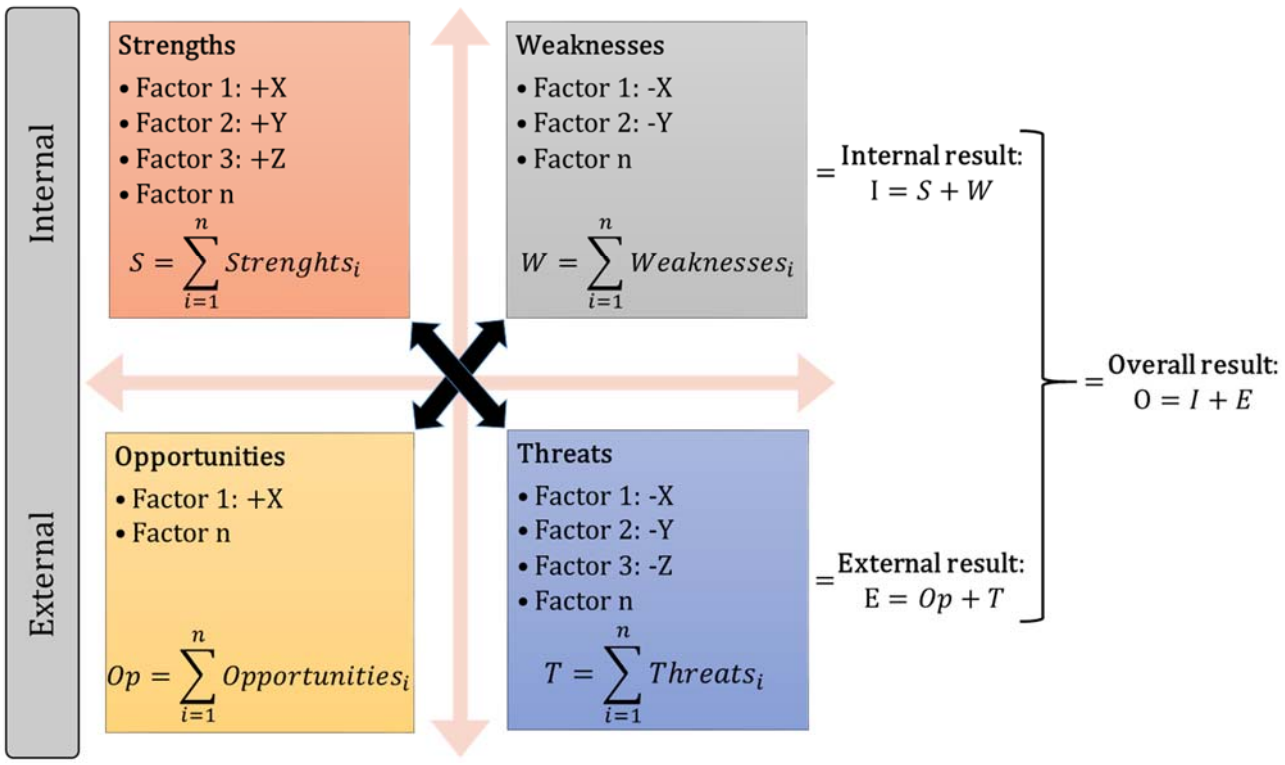

Figure 1. Quantitative approach of the utilized SWOT matrix

Each factor´s impact was defined as the product of the number of times it appeared and its effectiveness value (see Table 1).

Allocating a factor within the four aspects of the SWOT matrix is difficult if the limits of an item are floating. When the appropriate section was uncertain, the choice of where to allocate the factor was made by analysing how closely it fit one side compared to another one.

Next, the quantitative result was derived from the developed SWOT matrix. In order to achieve this, a more detailed evaluation methodology was developed in substitution of the traditional one.

After assigning the impact value for each factor in the SWOT matrix, the values are summed for each section and the total sum is identified for internal and external factors. The final result is the combined sum of internal and external factors.

The result is the final output of the SWOT matrix, which provides an estimate of how challenging the implementation of SC projects has historically been in Europe. The complete procedure is shown in Figure 1.

For the final step, the experts were surveyed to identify the best strengths and opportunities to use for overcoming the observed weaknesses and threats. This step is indicated in Figure 1 by the crossed arrows.

The reason for choosing an applied methodology in contrast to a fundamental research approach is that findings can be applied to related issues. The SWOT analysis provides stakeholders with a broader understanding of SC projects management and it helps them to enhance the implementation of energy efficiency and energy saving initiatives in cities.

3. Results

A survey was used to understand the most frequently encountered barriers and drivers in European SC projects. There were an extraordinarily high number of barriers (over 500) and drivers (nearly 400) covering administration, policy, technique, legislation, operativity, economy, and behaviour fields.

This section describes the significance of the most important factors and specifies their classification (strength, weakness, opportunity, or threat).

– Public participation (strengths)

This factor refers to cases in which all necessary attention is dedicated to the involvement of key players in SC projects during the whole life cycle of the project. This factor usually results in higher adoption rates for project decisions and both acceptance and support for project activities [29-31].

– Cooperation among stakeholders (strengths)

This strength drives effective coordination and increases trust between collaborators, which helps when

implementing steps toward reaching the goals of the project [32], [33-35].

– Marketing application for awareness and involvement (strengths)

This factor describes the communication of activities and values of each SC project. It mainly increases awareness and involvement of the public in SC activities using radio, television, internet communication strategies, and newspapers [3], [36-37].

– Communication between project participants and the public to increase awareness (weakness)

A lack of adequate information concerning SC projects on the side of utilizers and inhabitants can lead to aversion and resistance to the project. Two types of project information obstacles are unavailability, and asymmetric access [16], [38].

– Expertise in designing new technologies and solutions (weakness)

This factor quantifies the available experience in technologies used within a given SC project (e.g. solar thermal systems, photovoltaics, district heating systems etc.). Inadequate expertise can cause unsuccessful installations, delays, and/or operation problems [39-41].

– Inertia (weakness)

Inertia describes the challenges associated with changing behaviour, and also refers to resistance to technology and developing new habits. Inertia can occur in both organizations and individuals, and can cause delays in project implementation [34-35].

– Political commitment over the long term (opportunity)

This term describes the consistency of political support, mainly given by stability of the local government, which can lead to a significant support for a project, facilitating implementation [37], [39], [42-43].

– Environmental awareness (opportunity)

This factor is based on the understanding that a given project experiences higher public acceptance when it addresses publicly appreciable issues such as air pollution, climate change, and reductions in CO_2 emissions.

– Affordable and mature technologies suitable for local conditions (opportunity)

Smart city projects depend on the availability of economically affordable technologies, which are both sufficiently developed, and appropriate for the present local conditions (e.g. a wind turbine project requires an adequate local wind resource) [26], [41], [44].

– Subsidies (threat)

Subsidies provide financial support for SC activities [45]. Examples of different kinds of subsidies include: interest-free loans, tax breaks, cash grants etc. [46]. A lack of subsidies can cause barriers to implementation of and investment in SC projects [26], [42], [47].

– Requirements from the EC concerning reporting and accountancy (threat)

According to several of the interviewed experts, EC reporting and accountancy requests can be excessively strict and require a large time investment. This factor describes how this threat affects a given project.

Table 1: Effectiveness of factors (barriers and drivers)

FACTORS	Effectiveness	IQR	Appearances	Impact
• Public participation	2.07	2.3	52	107.64
• Cooperation among stakeholders	3.80	1.2	19	72.20
• Marketing application for awareness and involvement	3.71	1.7	14	51.94
• Communication between project participants and the public to increase awareness	3.79	2.2	20	75.80
• Expertise in designing new technologies and solutions	3.99	0.2	18	71.82
• Inertia	2.55	2.5	28	71.40
• Political commitment over the long term	4.12	2.2	17	70.04
• Environmental awareness	4.51	1.5	15	67.65
• Affordable and mature technologies suitable for local conditions	1.48	1.3	30	44.4
• Subsidies	2.31	2.3	33	76.23
• Requirements from the European Commission concerning reporting and accountancy	4.80	2.1	13	62.40
• Ownership structure of realities	4.60	2.4	13	59.80

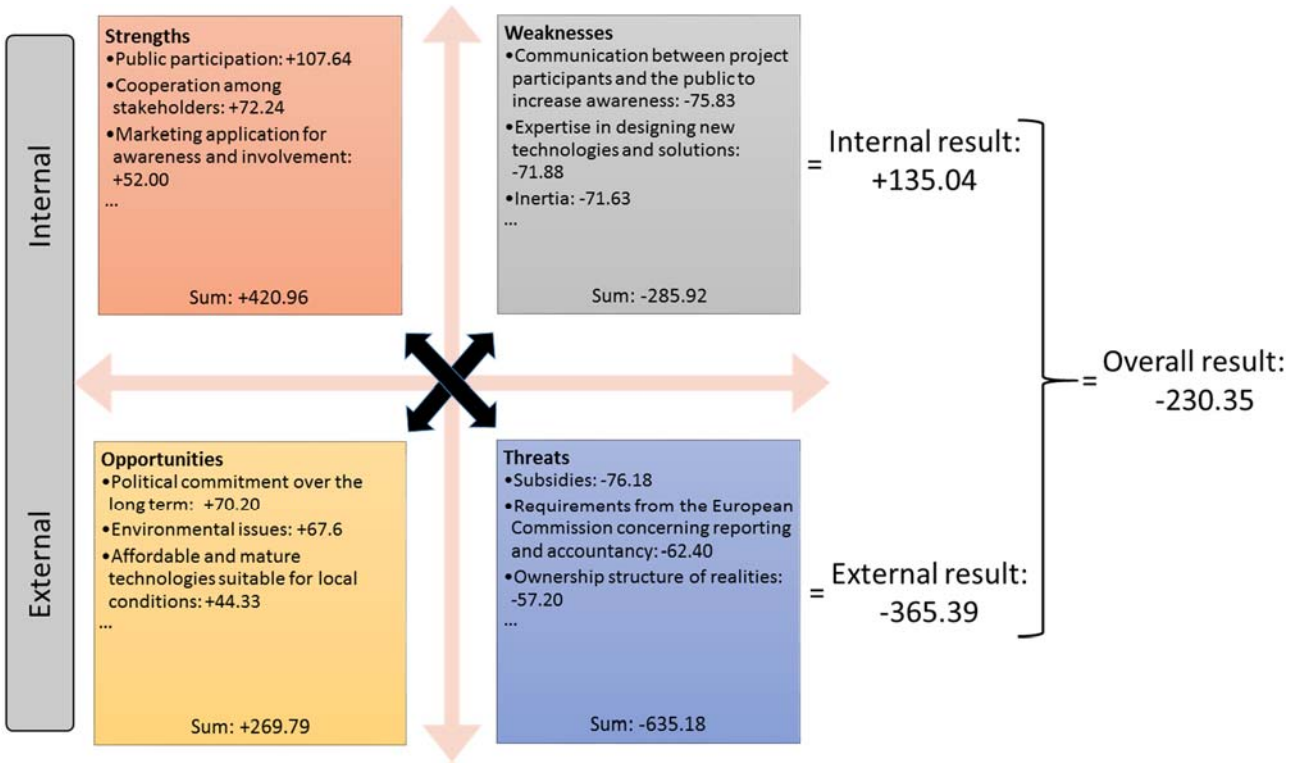

Figure 2. Main SWOT analysis results

– Ownership structure of realities (threat)

The ownership structure of real estate can have a significant impact on the success of a SC project. Target properties with fragmented ownership models (e.g. high-rise office buildings, or multi-family houses) might cause disagreement among property owners, and raise significant challenges for the project.

Table 1 provides the effectiveness value calculated for each factor, IQR calculations, and the impact numbers for each addressed issue.

To quantify the level of agreement among the experts, a consistency analysis was also implemented. The agreement was quantified using the IQR of the weights' distribution. The interquartile range does not exceed 2.5 for any single factor, indicating a high level of agreement among the experts.

As exhibited in Figure 2, the highest total impact sum (about -650) is given within the threats section of the SWOT matrix. Strengths, at around +400, have the second highest impact value. The third highest impact value of -300 corresponds to the weaknesses. Opportunities received the lowest total impact value, at +250.

Counterpositioning the impact values sum of the internal factors (strengths and weaknesses) a positive value of approximately +150 is obtained. The impact value for strengths exceeds that of the weaknesses by about one third. The opposite trend is observed for the external factors (opportunities and threats). The difference between these two values is nearly -400. The impact value of the threats category is nearly double that of the opportunities category.

The overall result of the SWOT matrix is approximately -250. This negative value implies that completing SC projects within Europe is highly difficult. This is largely a result of the external factors in the SWOT matrix. The internal factors from the SC projects analysed (amounting to about +150) facilitate project implementation. The external factors (about -350) in the SC projects investigated significantly hinder completion.

The driver used to overcome the barriers most frequently mentioned by experts is public participation. As shown in Table 1, this factor appeared 52 times. Since this factor is characterised also by the highest impact value (+107), it is safe to conclude that public participation is the key driver of the SWOT analysis.

4. Conclusions

The quantitative results of the strengths, weaknesses, opportunities and threats analysis show that it is currently difficult to implement smart city projects in Europe. The challenge derives primarily from the external factors (opportunities and threats) in the studied smart city projects.

Contrarily, the internal factors in smart city projects support project success. As shown in the strengths, weaknesses, opportunities and threats matrix, the negative result of the external factors is nearly three times higher than the positive result of the internal factors. This means that the result of the matrix is a negative outcome. It should be noted that this result comes from the perception of experts who estimated the impact of various factors on projects they have/are working on.

The most impactful factors appear to be public participation, subsidies, and communication between project participants and the public to increase awareness. Thus, any measure that improves public participation or involvement in the project will likely facilitate project implementation.

The impact number comparing internal and external factors affecting the implementation of ongoing or previous projects indicates that the most impactful strengths are cooperation among stakeholders, public participation, and marketing applications for awareness and involvement. This information leads to conclude that information exchange is highly important to smart city projects.

In the analysed projects, the most impactful weaknesses were expertise in designing new technologies and solutions, inertia, and communication between project participants and the public. Thus, behavioural issues were more relevant than technical concerns in the studied projects.

Among the opportunities, the strongest impact was identified for environmental awareness, the presence of affordable and mature technologies suitable for local conditions and long-term political commitment. Similarly, to the weaknesses, technical issues are surpassed by other factors – this time environmental and political issues.

Finally, the biggest threats are ownership structure of realities, requirements from the European Commission concerning reporting and accountancy, and subsidies. All of these threats are based on legislation.

The final threats matrix includes a factor, requirements from the European Commission concerning reporting and accountancy, which has not been discussed in previous studies. This barrier makes it very important to track and document the activities of collaborators throughout the entirety of smart city projects.

Public participation is the driver most commonly utilized to overcome barriers. As this factor also has the highest impact value of all elements in the strengths, weaknesses, opportunities and threats matrix, it is the most important driver of the analysis.

This investigation provided an understanding of the most relevant drivers, external barriers, and internal barriers of smart city projects in Europe. It can assist in future smart city projects by indicating possible risks and opportunities that may arise in any given project. These barriers and drivers refer also to a number of important considerations for decision makers when initiating and evaluating smart city projects.

One possibility for future work includes the development of an open source strengths, weaknesses, opportunities and threats tool. The tool could include a web interface, and make use of the knowledge discussed in this investigation. It might further facilitate the decision making process, and assist in future smart city projects.

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List of abbreviations, acronyms and symbols

CO_2	Carbon dioxide
c	Confidence interval
EC	European Comission
EU	European Union
IEA	International Energy Agengy
IQR	Interquartile range
O	Overall
Op	Opportunities
OPEC	Organization of Petroleum Exporting Countries
p	Level of significance
RES	Renewable energy sources
S	Strenghts
SCs	Smart cities
SWOT	Strengths, Weaknesses, Opportunities, Threats
ss	Sample size
T	Threats
W	Weaknesses
Z	Constant

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Appendix

Table 2: Barriers and drivers of smart city projects, respective weighing possibilities and assessed effectiveness [10]

POLICY												**Effectiveness**
National roadmaps, strategies, and policies for energy goals	-5	-4	-3	-2	-1	0	1	2	3	4	5	2.67
Political commitment over the long term	-5	-4	-3	-2	-1	0	1	2	3	4	5	4.12
ADMINISTRATION												
Cooperation among stakeholders	-5	-4	-3	-2	-1	0	1	2	3	4	5	2.90
Communication between project participants and the public to increase awareness	-5	-4	-3	-2	-1	0	1	2	3	4	5	3.79
Existence of multi-actor/multi-sectorial planning tools	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.57
Share of valuable data between different departments	-5	-4	-3	-2	-1	0	1	2	3	4	5	2.27
Existence of public-private engagement models	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.80
Existence of financing models suitable for the innovation to address stakeholder involvement	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.27
Public procurement	-5	-4	-3	-2	-1	0	1	2	3	4	5	2.30
Coordination of a large number of tenants	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.30
Marketing application for awareness and involvement	-5	-4	-3	-2	-1	0	1	2	3	4	5	3.71
Set up of institutions to support the projects	-5	-4	-3	-2	-1	0	1	2	3	4	5	0.67
Obligations given to project participants	-5	-4	-3	-2	-1	0	1	2	3	4	5	0.53
Public participation	-5	-4	-3	-2	-1	0	1	2	3	4	5	2.07
LEGISLATION												
Transparency of legislation	-5	-4	-3	-2	-1	0	1	2	3	4	5	2.13
Consistency of implementation and interpretation of law	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.20
Existence of regulatory stability	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.37
Procedures for authorization of technologies	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.60
Existence of data security and privacy	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.13
Tax pressure	-5	-4	-3	-2	-1	0	1	2	3	4	5	0.73
Transparency of taxation system	-5	-4	-3	-2	-1	0	1	2	3	4	5	0.83
Subsidies	-5	-4	-3	-2	-1	0	1	2	3	4	5	2.31
Existence of regulatory incentives for implementation of smart city projects	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.42
Tariffs regulations	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.33
TECHNIQUE												
Affordable and mature technologies suitable for local conditions	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.48
Expertise in designing new technologies and solutions	-5	-4	-3	-2	-1	0	1	2	3	4	5	3.99
Existence of training material	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.63
Monitoring	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.59

ECONOMY												
Adverse selection	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.57
Principal-agent relationship	-5	-4	-3	-2	-1	0	1	2	3	4	5	0.70
Split incentives	-5	-4	-3	-2	-1	0	1	2	3	4	5	0.80
FINANCE												
Hidden costs	-5	-4	-3	-2	-1	0	1	2	3	4	5	0.80
Accessibility to capital	-5	-4	-3	-2	-1	0	1	2	3	4	5	0.83
Risk and uncertainty	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.07
Up-front costs	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.03
Costs of material, construction, and installation	-5	-4	-3	-2	-1	0	1	2	3	4	5	2.37
Economic crisis	-5	-4	-3	-2	-1	0	1	2	3	4	5	2.40
Existence of financial schemes	-5	-4	-3	-2	-1	0	1	2	3	4	5	2.80
Combining of different financial schemes	-5	-4	-3	-2	-1	0	1	2	3	4	5	0.30
Stability of costs during project life cycle	-5	-4	-3	-2	-1	0	1	2	3	4	5	0.93
Payback time	-5	-4	-3	-2	-1	0	1	2	3	4	5	0.97
OPERATIVITY												
Existence of tried and tested solutions and proven on the ground examples	-5	-4	-3	-2	-1	0	1	2	3	4	5	2.03
Complexity of applying solutions with regard to local conditions	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.13
Interoperability between systems	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.37
Supporting hard infrastructure	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.70
Well-defined or documented in detail processes	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.93
Existence of performance indicators for technologies implementation	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.13
BEHAVIOUR												
Form of information	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.67
Credibility and trust	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.77
Values related to energy efficiency, which may inhibit measures from being undertaken	-5	-4	-3	-2	-1	0	1	2	3	4	5	0.67
Inertia	-5	-4	-3	-2	-1	0	1	2	3	4	5	2.55
Bounded rationality	-5	-4	-3	-2	-1	0	1	2	3	4	5	2.03
Public acceptance of technologies	-5	-4	-3	-2	-1	0	1	2	3	4	5	1.77
ADDITIONAL FACTORS												
Environmental awareness	-5	-4	-3	-2	-1	0	1	2	3	4	5	4.51
Requirements from the European Commission concerning reporting and accountancy	-5	-4	-3	-2	-1	0	1	2	3	4	5	4.80
Ownership structure of realities	-5	-4	-3	-2	-1	0	1	2	3	4	5	4.60