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Review

i-ISSUES—Industrial-Interoperable Safe and Secure Urban Energy Systems

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Abstract: Urban planners are involved in designing future urban energy systems as a part of their path toward decarbonization or Net Zero targets before 2050. In this process, new energy and information flows between industrial and urban regions should be considered, as well as safety and security managerial aspects regarding the existing and new infrastructures. This research aims to help engineering professionals and public planners define new collaboration dynamics to make industrial energy systems safer, more secure, and interoperable, surpassing the existing knowledge. Firstly, several recent R&D aspects are analyzed, demonstrating the organizational gap and providing early integration or knowledge reuse opportunities from R&D projects. After that, the authors present a model called Industrial-Interoperable Safe and Secure Urban Energy Systems (i-ISSUES), a multi-disciplinary approach combining classic urban energy planning, information technology use, safety and security management, and systems engineering as the integrated disciplines. The model detects research trends, providing a first set of readings with some improvements.

Keywords: interoperability; urban energy planning; city resilience; systems engineering; i-ISSUES

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1. Introduction

The European Union (EU) has decided to reduce greenhouse emissions to at least 55% [1] compared to 1990's levels by 2030. This target shall stimulate green job creation, resilience, and a new economic model based on clean energy technologies. This is an essential challenge for the education system, industrial enterprises, and service providers. Industries and cities must progress in their decarbonization process, and engineering needs to materialize this. The Climate Emergency was declared by the European Union at the United Nations Climate Summit in Madrid on 28 November 2019 [2], whereby Parliament urged the Commission to fully assess the climate and the environmental impact of all relevant legislative and budgetary proposals and ensure that they are all fully aligned to limit global warming to below 1.5 °C and that they are not contributing to the loss of biodiversity. Risk management will involve considering environmental safety measures and security to protect new assets from external threats. At the same time, the EU Zero Emissions Industry Regulation [3] intends to help small and medium-sized companies (SMEs) benefit when implementing their decarbonization processes, ensuring they can participate in them. SMEs, which were quite affected by the pandemic, constitute over 99% of all businesses in the EU. The 2020 EU SME strategy has three axes: capacity building, support for the transition to sustainability, and digitalization [4]. In July 2023, McKinsey's Global Resilience Survey focused on the automotive and assembly, commercial aerospace, industrial and electronics, and semiconductors sectors. It concluded that only 31% of those in executive/leadership roles felt prepared for future disruptions, which denotes little resilience traction within advanced industries [5]. That figure can be extrapolated to their industrial polygons.

As advanced in [6], urban planners are involved in designing future urban energy systems as a part of their path toward decarbonization or Net Zero targets before 2050. The Making-city project and other current research works [7–9] provide carbon-free energy solutions for Positive Energy Districts (PEDs) and the potential to create sustainable and energy-positive communities. The project established a validated procedure to support the definition of the PED concept, including assessing the technical conditions, which would defined the first demand for engineering work that could be used to include industrial areas in future urban planning until these urban districts reached the condition of being PEDs, with an affordable energy cost and a lower carbon footprint at the same time. On their route towards zero-emission cities, cities rely on trend studies, which provide inventories of actions for achieving renewable energy and cogeneration [10]. Soon, it is foreseeable that these inventories will also include waste heat or solar energy surplus, as these authors state, "to increase the efficiency of energy systems and reduce the need for additional thermal energy production". Following this route, new energy and information flows should be considered, including the ones between industrial and urban areas, as well as safety and security managerial aspects regarding the existing and new infrastructures to manage new risks, which will also help to build resilience.

PESI, the Spanish Industrial Safety and Security Platform, promotes a framework for integrated safety, security, and resilience [11] that can be applied to any industrial polygon level and cities in general. PESI connects risks and technological solutions regularly. Imagine a city wants to use heat from its sanitation pipes (sewage). To make this heat available to the city, you need a certain reliability. The better the reliability, the less vulnerable events will be to cyberattacks (less secure), and fewer accidents will occur during repairing works (less safe). A better maintenance plan will help, as will designing systems to be more reliable. Zero-emission city planners are already concerned about risks affecting their plans. Still, risk management seems to be out of the scope of allocating safety and security measures [12]. The industrial sector is more familiar with risk management, safety/security management, lifecycle engineering, and digitalization than the public sector. Soon, new public information from industries will be accessible to the public [13], but forecasting the energy demand, space, and infrastructures for energy generation and/or distribution needs will also be challenging to achieve. In this sense, reliability, safety, and security planning at the polygon level could provide extra information channels to achieve quality in and provide value-added information for urban decarbonization plans, but to leap from the current situation towards proactive management or continuous improvement, at least two elements are required: training and digitalization. Training should be aimed at professionals who can assimilate it and put it into practice, and digitalization must have an economic return on investment for the industry. To this end, engineering professionals and public planners should define new collaboration dynamics, surpassing the existing knowledge to make the industrial energy, safety, and security systems interoperable, in line with the latest European Interoperability proposal [14] and the lifecycle Systems Engineering practices described in ISO 15288 and applied in the INCOSE Smart City Initiative [15], with the aim of supporting municipalities and public agencies in adopting innovative technologies. Such requirements must be reused, and knowledge management approaches and essential activities must be adopted [16,17].

As mentioned, cities or towns can receive solar heat and/or electricity surplus or other low-emission energy sources that industries can supply. Applying the New European Energy Efficiency Directive [18] will imply engineering new energy infrastructures and/or refurbishing them to extend their lifetime, which will help decarbonize both industry and cities. Semantic interoperability management is a must to promote the necessary collaboration between sectors, service providers, and public agents, and other collectives with public responsibilities are facing this successfully [19]. The challenge also requires managing technical interoperability and combining this technical, managerial process into a more comprehensive quality engineering managerial plan. Just think of demand management controls or safety and/or security measures allowing infrastructure life extension to save public and private money. The new Interoperable Europe Act delivers more efficient public services through improved cooperation between national administrations on data exchanges and IT solutions [20–22].

2. Materials and Methods

The authors hypothesize that there is an operational knowledge gap in integrating urban planning with industry decarbonization, safety and security, and interoperability management.

The authors conduct a first search of European Research and Development (R&D) projects regarding decarbonization, safety and security, and interoperability management to detect the current trends in R&D works considering the topics related to hypothesis, using the public CORDIS database.

After verifying the projects relevant to the hypothesis, a new high-level operational model is defined, enabling early integration or knowledge reuse from R&D projects.

A detailed operational model consistent with the high-level model is defined based on the introduction and the authors' experience in detecting research trends, confirming the mentioned gap using specific questions. Recent scientific literature from the ScienceDirect database and its search portal are selected to search for specific textual alerts regarding the questions. The textual alerts are implemented using a natural language processing (NLP) method that looks for textual evidence. Acting as experts, the authors verify the degree of interest for each work in each question to confirm the gap. Finally, the most exciting works are analyzed to find potential improvements for the detailed model and validate the model's utility to save research time.

2.1. R&D Projects

The authors conducted a first search of European Research and Development (R&D) projects regarding decarbonization, safety and security, and interoperability management to detect the current trends in R&D works considering the hypothesis topics. The public CORDIS database was used to search for projects from the FP7, Horizon 2020, and Horizon Europe programs using the following search criteria:

- Urban Planning and Decarbonization
- Safety or Security and Polygons
- Interoperability and Public Services

The result of this search was stored in Excel tables in Supplementary Materials.

2.1.1. Urban Planning and Decarbonization R&D Projects

A first search of European R&D projects was conducted to detect trends in urban decarbonization planning using the CORDIS search portal. The result of this research is shown in Table 1, showing six projects:

Table 1. R&D projects related to urban planning and decarbonization.

ID	Project ID	Project Name and Link	End Date	Leading Country
1	689669	MAGIC Moving Towards Adaptive Governance in Complexity: Informing Nexus Security	2020	ES
2	691883	SmartEnCity Towards Smart Zero CO_2 Cities Across Europe	2022	ES
3	723757	PLANHEAT Integrated tool for empowering public authorities in the development of sustainable plans for low carbon heating and cooling	2020	IT
4	846463	sEEnergies Quantification of synergies between Energy Efficiency First principle and renewable energy systems	2022	DK
5	101096405	UP2030 Urban Planning and Design Ready for 2030	2025	DE

The search results can be grouped into three main categories. Table 2 classifies the projects (using the project IDs) into the chosen categories:

Table 2. Classification proof for the R&D projects related to urban planning and decarbonization.

Urban Decarbonization Strategies and Principles	Systemic and Socio-Ecological Systems Approach	Tools to Support Local Authorities
(846463) The EU-funded synergies project aims to comprehensively assess and quantify the impact of Energy Efficiency First principle policies. (101096405) The UP2030 project will enable a quantum leap from a "business as usual" project-by-project decarbonization approach to a vision-driven, strategy-based approach anchored on sound projects and renewed policy development.	(689669) The approach involved checking the feasibility, viability, security (openness), and desirability of the metabolic patterns of socio-ecological systems as the underlying theoretical concept and doing so across spatial scales, i.e., pan-EU, Member States, and selected regions. (691883) SmartEnCity's main objective is to develop a highly adaptable and replicable systemic approach to transforming urban environments in Europe into sustainable, smart, and resource-efficient ones through the integrated planning and implementation of measures.	(723757) PLANHEAT's main objective is to develop and demonstrate an integrated and easy-to-use tool that will support local authorities (cities and regions) in selecting, simulating, and comparing alternative low-carbon and economically sustainable scenarios for heating and cooling that will include the integration of alternative supply solutions (from a panel of advanced critical technologies for the new heating and cooling supply) that could balance the forecasted demand.

Notice that the classification is based on the CORDIS results section document called "Summary of the context and overall objectives of the project".

As can be seen, none of the categories were dominant, but the most recently selected projects were about strategies and principles for urban decarbonization. According to the authors' experience, all the categories are complementary.

2.1.2. Safety and Security in Polygons R&D Projects

A second search of European R&D projects was conducted to detect the safety and security management trends in industrial polygons using the CORDIS search portal. The result of this research is shown in Table 3, showing seven projects:

Table 3. R&D projects related to safety or security in polygons.

ID	Project ID	Project Name and Link	End Date	Leading Country
6	262371	PANGEO Enabling access to geological information in support of GMES	2014	HR
7	644128	AEROWORKS Collaborative Aerial Robotic Workers	2017	SE
8	700099	ANYWHERE EnhANcing emergency management and response to extreme WeatHER and climate Events	2019	ES
9	776115	PerceptiveSentinel Perceptive Sentinel—BIG DATA knowledge extraction and re-creation platform	2020	SK
10	850990	PSOTI Privacy-preserving Services On The Internet	2025	DE
11	870228	OpertusMundi: A Single Digital Market for Industrial Geospatial Data Assets	2022	EL
12	876019	ADACORSA Airborne data collection on resilient system architectures	2023	DE

The search results can be grouped into three main categories. Table 4 classifies the projects (using their project IDs) into the chosen categories:

Notice that the classification is based on the CORDIS results section document called "Summary of the context and overall objectives of the project".

The dominant category is new geospatial information for urban hazards and emergency management. Still, only one of the projects was explicitly focused on industries despite the fact that the other categories are complementary.

Table 4. Classification proof for the R&D projects related to safety or security in polygons.

UAV Drone Works	Urban Hazards Geoinformation and Early Warning for Emergencies	Data Protection
(644128) Collaborative aerial robotic workers will attend to ageing infrastructures and distributed installations. (876019) UAV drone with safe, reliable, and secure operations.	(262371) Urban geohazard open data/services. (700099) Decision support platforms and early warning products are needed to manage weather emergencies for institutions and citizens better. (776115) Free and open access to high-temporal-resolution, high-spatial-resolution, multi-temporal, and multi-spectral Copernicus satellite data. (870228) OpertusMundi will deliver a trusted, secure, and highly scalable pan-European industrial geospatial data market.	(850990) Provide additional protection to the General Data Protection Regulation (GDPR) by applying not only legal but also technical measures when processing sensitive user data

2.1.3. Interoperability and Public Services R&D Projects

A third search of European R&D projects was conducted using the CORDIS search portal to detect trends in interoperability for public services. The result of this research is shown in Table 5, showing four projects:

Table 5. R&D projects related to interoperability and public services.

ID	Project ID	Project Name and Link	End Date	Leading Country
13	830927	CONCORDIA Cyber security cOmpeteNCe fOr Research anD InnovAtion	2023	DE
14	870635	DE4A Digital Europe for All	2023	ES
15	870675	PolicyCLOUD Policy Management through technologies across the complete data lifecycle on cloud environments.	2022	ES
16	959157	ACROSS Towards user journeys for the delivery of cross-border services, ensuring data sovereignty	2024	EL

The search results can be grouped into three main categories. Table 6 classifies the projects (using their project IDs) into the chosen categories:

Table 6. Classification proof for the R&D projects related to interoperability in public services.

Cloud and Data-Centric Platform	Capability Building
(870635) Creating European interoperable platforms, such as a common framework for citizens' electronic identity management (eID), will enable a single digital market across the EU. (870675) An integrated cloud-based environment enables data-driven approaches to evidence-based policies using traditional policy-making data.	(830927) Interconnects all of Europe's cybersecurity capabilities into a network of expertise to help build a secure, trusted, resilient, and competitive ecosystem. (959157) A novel framework aiming to leverage the advanced capabilities of cloud services, privacy preservation, semantic interoperability, and mobile technologies to build a next-generation public services ecosystem while maintaining the highest privacy level.

None of the categories were dominant and, according to our experience, are complementary.

Notice that the classification is based on the CORDIS results section document called "Summary of the context and overall objectives of the project."

2.1.4. Recent R&D Projects Analysis

As seen in Section 2.1.1, Section 2.1.2, and Section 2.1.3, none of the 17 identified projects cover a combination of two or three of the interest topics (urban planning and decarbonization, safety or security in polygons, interoperability in public services), despite the fact it was possible to classify them into eight exciting categories:

- Urban decarbonization strategies and principles
- Systemic and socio-ecological systems approach
- Tools to support local authorities
- UAV drone works
- Urban hazard geoinformation and early warning for emergencies
- Data protection
- Cloud and data-centric platforms
- Capability building

To help address the knowledge, engineering, and organizational gaps, the authors present a conceptual model called Industrial-Interoperable Safe and Secure Urban Energy Systems (i-ISSUES). This model takes a multidisciplinary approach that covers urban energy planning, information technologies, safety and security management, and systems engineering disciplines.

2.2. The i-ISSUES Model

Figure 1 represents i-ISSUES's primary process with inputs, outputs, controls, and enablers. In advance, the design principles or process goals are shown inside the process itself.

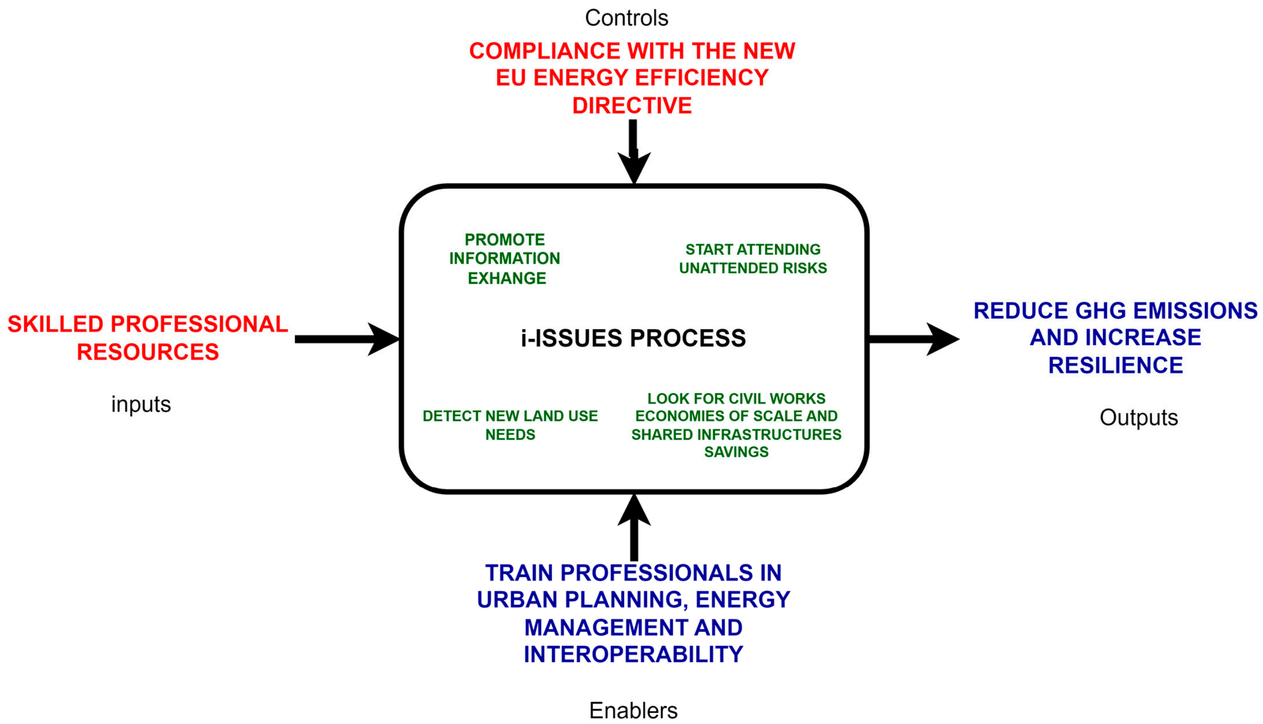

Figure 1. i-ISSUES model representation as a process and expected outputs.

To enable early integration and knowledge reuse opportunities from the R&D projects, the i-ISSUES model is related to the project categories defined in Section 2.1.4 in Table 7:

Table 7. R&D allocation for i-ISSUES.

R&D Categories	The Process Itself	Inputs	(Expected) Outputs	Controls	Enablers
Urban decarbonization strategies and principles				(846463, ID 4) Impact evaluation of Energy Efficiency First principle [23]	(101096405, ID 5) A vision-driven, strategy-based approach [24]
Systemic and socio-ecological systems approach	(691883, ID 2) Integrated planning form of managing the nexus for researchers and decision-makers [25]		(691883, ID 4) A highly adaptable and replicable systemic approach to urban transformation [23]		
Tools to support local authorities					(723757, ID 3) Easy-to-use tools [26]
UAV drone works		(876019, ID 12) UAV drone with safe, reliable, and secure operations [27]			(644128, ID 7) Collaborative aerial robotic workers [28]
Urban hazard geoinformation and early warning for emergencies		(262371, ID 6) Urban geohazards open data/services [29] (776115, ID 9) Free and open access to multi-temporal satellite data [30]		(700099, ID 8) Decision support platform and early warning products [31]	
Data protection				(850990, ID 10) The General Data Protection Regulation [32]	
Cloud and data-centric platforms	(870635, ID 11) European interoperable platforms for eID [33]			(870635, ID 13) European interoperable platforms to enable a single digital market across the EU [34]	
Capacity building					(959157, ID 16) Framework for cloud services, including privacy preservation and semantic interoperability [35]

2.2.1. Model's Purpose

The model detects research trends, providing a first set of readings for further integrating energy urban planning with local industrial refurbishment and city resilience. The following questions may help to find trends in the intelligent city knowledge domain:

Is there a specification for public organizations on interoperability, enabling urban energy planning?

- Answer by looking for the earliest training needs within the i-ISSUES workflow.

Is industrial private information being used for energy urban planning?

- Answer by looking for the earliest industrial information and needs within the i-ISSUES workflow.

Is urban energy planning being extended to industrial planning at the polygon level?

- Answer by detecting the potential benefits of starting the i-ISSUES workflow.

The questions must be converted into textual alerts in documents obtained from search portals. Textual alerts have been defined previously in [6] as represented in Figure 2. The main difference here is that the research topic is not an urban energy system (UES) but the potential to build resilience and reduce GHG (greenhouse gases) and other emissions:

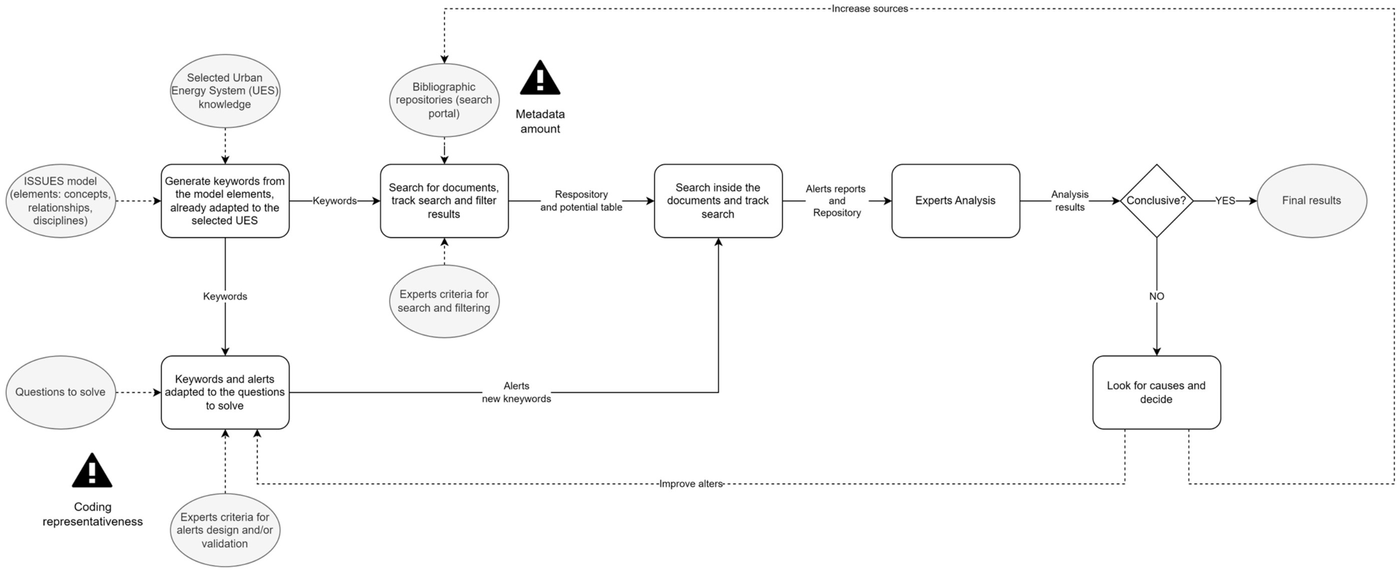

Figure 2. Search methodology representation [6].

2.2.2. Model Description

Figure 3 represents the i-ISSUES model as a process diagram or workflow. The arrows represent the information and/or precedence "relationships" between "concepts", while the dashed lines represent the relationships between subprocesses and the main process variables and/or the design principles.

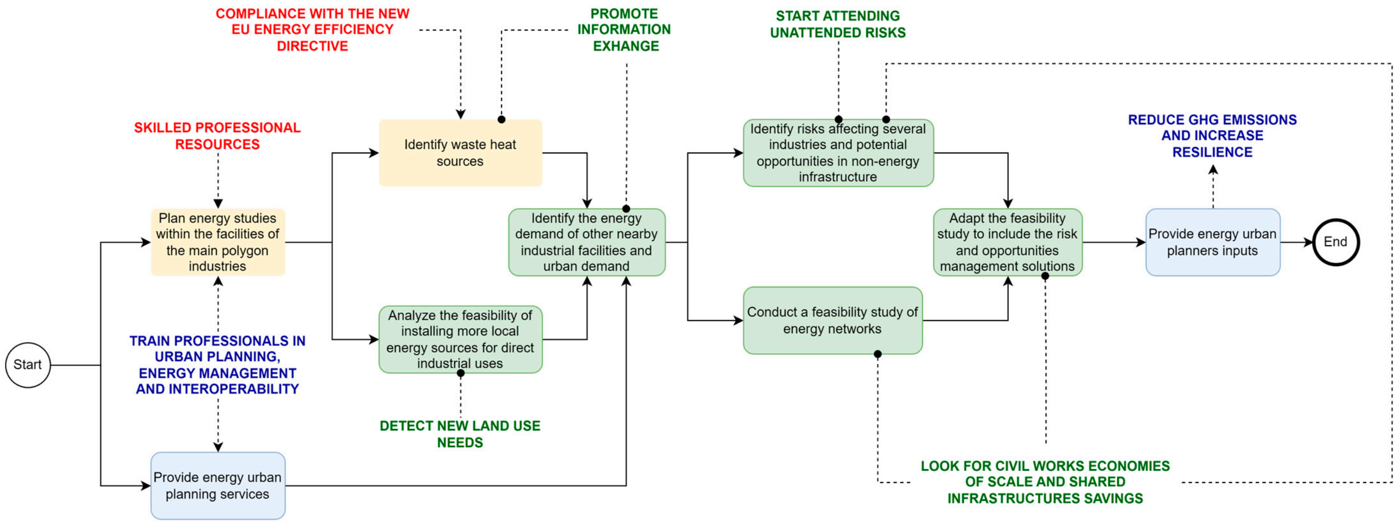

Figure 3. i-ISSUES model subprocesses.

The presented process is an engineering workflow divided into three stages: (1) planning energy studies parallel to regular collaboration in urban energy planning, (2) conducting studies for the industry within the polygon, and (3) providing risk and opportunity assessments, including for energy networks. The main result of the whole process is a set of inputs for urban energy planners about GHG reduction and increasing resilience, understanding that any opportunity or risk at any industry level should be managed at that level.

This workflow could not be started and performed without technical capability in handling energy planning (trained engineers), renewable energy design rules (potentially demanding extra land), data exchange procedures and tools (under an interoperability and respect for privacy framework), and updated knowledge about industrial risk (at the polygon level).

Table 8 summarizes the i-ISSUES model ontology:

Table 8. i-ISSUES model ontology elements.

Concept	Model Element	Type of Element	Metadata and Operators (for the Search Portal)	Keywords (for the Search Portal)	<Cluster> (for Alerts)
ENERGY INDUSTRIAL PLANNING	Plan energy studies within the main industry polygons	subprocess	smart city AND energy	Assessment, study	Assessment, study, polygon, industry, manufacturing, urban, city
ENERGY URBAN PLANNING	Provide energy urban planning services	subprocess		Hire, contract	Hire, contract, engineer, technician, consultant.
WASTE HEAT ID	Identify waste heat sources	subprocess		Waste heat exceeding	Waste heat, exceeding, identification, identify, asset. Energy
MORE LOCAL RES	Analyze the feasibility of installing more local energy sources for direct industrial uses	subprocess		Renewable, local	Renewable, local, solar, geothermal, hydrothermal, ATES, TES, storage, need, station, substation, request, field, land, space, area, around, permit, license/license
OTHER ENERGY DEMAND ID	Identify the energy demand of other nearby industrial facilities and urban demand	subprocess		Demand, industry	Demand, industry, energy, neighbour
TRAIN FOR INDUSTRIES	Train professionals in urban planning, energy management, and interoperability	enabler		Training, professional, engineer, technician	Training, professional, engineer, technician, energy management, industry, process, maintenance, assessment
TRAIN		enabler			Training, professional, engineer, technician, urban, assessment, infrastructure, interoperability, plan
ENGINEERS	Skilled professional resources	input		Hire, contract	Hire, contract, engineer, technician, firm, consultant.
COMPLIANCE EE	Compliance with the new EU Energy Efficiency Directive	control		Comply, energy efficiency, European.	Comply with energy efficiency, European Directive, regulations, and new directives.
INFO DEMAND	Promote information exchange	principle		Share, exchange	Share, exchange, information, data, consumption, audit, report
INFO WASTE HEAT		principle			Waste, exceeding heat
NEW LAND	Detect new land use needs	principle		Need, right	Need, correct, change, use, land.

Table 8. *Cont.*

Concept	Model Element	Type of Element	Metadata and Operators (for the Search Portal)	Keywords (for the Search Portal)	<Cluster> (for Alerts)
RISK AND OPPS ID	Identify risks affecting several industries and potential opportunities in non-energy infrastructure	subprocess	smart city AND (resilience OR GHG)	Risk, opportunity	Risk, opportunity, identification, impact, probability, likelihood, industry
ENERGY NETS FEES	Conduct a feasibility study of energy networks	subprocess		Network, district heating, smart grid, electric grid	Network, district heating, smart grid, electric grid, energy, feasibility, study, assessment
ADAPT FOR SOL	Adapt the feasibility study to include the risk and opportunity management solutions	subprocess		Risk management, opportunity management	Risk management, opportunity management, reduce, mitigate, transfer, manage, safety, security, recovery, emergency, cybersecurity, SIL.
INPUTS FOR ENERGY PLANS	Provide urban energy planner inputs	subprocess		Energy planning	Energy planning, urban, energy
UNATTENDED RISKS	Start attending to unattended risks	principle		Risk	Risk, unattended risk
SAVING RISKS	Look for civil economies of scale and shared infrastructure savings	principle		Saving, scale	Saving, scale, risk, SIL, infrastructure, effect
SAVING ENERGY		principle			Saving, scale, energy, network, OPEX
SAVING INFRAS		principle			Saving, scale, infrastructure, cost, CAPEX
SAVING GHG AND RESILIENCE	Reduce GHG emissions and increase resilience	output		Resilience, GHG, greenhouse	Resilience, GHG, greenhouse, reduction, compensation, increase, build

2.2.3. Model Alerts for Detecting Research Trends

At this point, the questions are converted into textual alerts using the previous ontology. The strategy followed is to use semantic clusters corresponding to the principles for triggering a textual alert and to close the alert detection with the more suitable processes' clusters and/or other principles, inputs, or outputs. The reverse composition is also possible. This is why the ontology does not need to be accurately populated for any model element, just the clusters in Table 9:

Table 9. Questions and alerts.

Question	Filter Cluster	Context Cluster	[Pattern 1]	[Pattern 2]
(Q1) Is there a specification for public organizations on interoperability enabling urban energy planning?	<TRAIN>	Cluster 1: <ENERGY INDUSTRIAL PLANNING> Cluster 2: <ENERGY URBAN PLANNING>	<Filter>...<Context 1> OR <Context 2>	The reverse of pattern 1
(Q2) Is industrial private information being used for energy urban planning?	<INFO WASTE HEAT> OR <INFO DEMAND>	Cluster 1: <MORE LOCAL RES> Cluster 2: <NEW LAND>	<Filter>...<Context 1> OR <Context 2>	The reverse of pattern 1
(Q3) Is urban energy planning being extended to industrial planning at the polygon level?	<SAVING GHG & RESILIENCE>	Cluster 1: <ENERGY INDUSTRIAL PLANNING> Cluster 2: <SAVING INFRAS>	<Filter>...<Context 1> OR <Context 2>	The reverse of pattern 1

3. Results and Discussion

Using the ScienceDirect portal, 109 works were found. After eliminating inaccessible or out-of-scope readings, 31 works were selected for textual processing with alerts and further expert analysis by the authors as shown in Table 10. The results of the search were stored in Excel tables.

Table 10. Question and research utility validation by experts (R = relevant; I = interesting but not necessarily relevant; IR = irrelevant).

id	Bibliography Index (DOI) and Title	Expert's Utility Validation		
		Q1	Q2	Q3
1	https://doi.org/10.1016/j.asej.2022.102103 (accessed on 16 March 2024). Simulation of the Environmental Impact of Industries in Smart Cities.		I	IR
2	https://doi.org/10.1016/j.future.2021.06.017 (accessed on 16 March 2024). Technical research on realizing remote intelligent diagnosis of petroleum drilling loss circulation under smart city strategy.	IR	IR	
3	https://doi.org/10.1016/j.rser.2019.109263 (accessed on 16 March 2024). University campuses as small-scale models of cities: Quantitative assessment of a low carbon transition path.		I	IR
4	https://doi.org/10.1016/j.advengsoft.2019.102731 (accessed on 16 March 2024). The UDSA ontology: An ontology to support real time urban sustainability assessment.	R	R	I
5	https://doi.org/10.1016/j.apenergy.2016.07.097 (accessed on 16 March 2024). Technology assessment of the two most relevant aspects for improving urban energy efficiency identified in six mid-sized European cities from case studies in Sweden.		I	R
6	https://doi.org/10.1016/j.egypro.2018.08.167 (accessed on 16 March 2024). Assessment methodology for urban excess heat recovery solutions in energy-efficient District Heating Networks.		R	R
7	https://doi.org/10.1016/j.cities.2018.11.014 (accessed on 16 March 2024). Potential pitfalls in the development of smart cities and mitigation measures: An exploratory study.	I	I	IR
8	https://doi.org/10.1016/j.scs.2021.103492 (accessed on 16 March 2024). Urban energy efficiency assessment models from an AI and big data perspective: Tools for policy makers.	R	I	IR
9	https://doi.org/10.1016/j.scs.2019.101889 (accessed on 16 March 2024). The assessment of smart city projects using zSlice type-2 fuzzy sets based Interval Agreement Method.		I	IR

Table 10. *Cont.*

id	Bibliography Index (DOI) and Title	Expert's Utility Validation		
		Q1	Q2	Q3
10	https://doi.org/10.1016/j.proeng.2017.04.309 (accessed on 16 March 2024). Assessment of Urban Energy Performance through Integration of BIM and GIS for Smart City Planning.		R	R
11	https://doi.org/10.1016/j.egypro.2016.06.006 (accessed on 16 March 2024). Technology Capacity Assessment Tool for Developing City Action Plans to Increase Efficiency in Mid-sized Cities in Europe.		I	IR
12	https://doi.org/10.1016/j.seta.2021.101801 (accessed on 16 March 2024). Thermodynamic assessment of cities applying exergetic efficiency as evaluation index.		I	I
13	https://doi.org/10.1016/j.egypro.2017.03.242 (accessed on 16 March 2024). A Decision Support Framework for Smart Cities Energy Assessment and Optimization.		R	I
14	https://doi.org/10.1016/j.scs.2023.104985 (accessed on 16 March 2024). Greening smart cities: An investigation of the integration of urban natural resources and smart city technologies for promoting environmental sustainability.	R	I	IR
15	https://doi.org/10.1016/j.rser.2023.113444 (accessed on 16 March 2024). Let's hear it from the cities: On the role of renewable energy in reaching climate neutrality in urban Europe.	IR	I	I
16	https://doi.org/10.1016/j.jclepro.2019.119932 (accessed on 16 March 2024). A digital tool for integrating renewable energy devices within landscape elements: Energy-scape online application.		R	I
17	https://doi.org/10.1016/j.scs.2022.104276 (accessed on 16 March 2024). A coordinated cyberattack targeting load centres and renewable distributed energy resources for undervoltage/overvoltage in the most vulnerable regions of a modern distribution system.		R	
18	https://doi.org/10.1016/j.rser.2020.109922 (accessed on 16 March 2024). Smart energy cities in a 100% renewable energy context.	I	R	R
19	https://doi.org/10.1016/j.wds.2022.100016 (accessed on 16 March 2024). Integration of renewable energies in the urban environment of the city of Soria (Spain).		I	IR
20	https://doi.org/10.1016/j.enrev.2022.100001 (accessed on 16 March 2024). Low-carbon transition in smart city with sustainable airport energy ecosystems and hydrogen-based renewable-grid-storage-flexibility.		I	I
21	https://doi.org/10.1016/j.jclepro.2023.139011 (accessed on 16 March 2024). Low-carbon transition in smart city with sustainable airport energy ecosystems and hydrogen-based renewable-grid-storage-flexibility.	R	R	I
22	https://doi.org/10.1016/j.sbspro.2015.08.103 (accessed on 16 March 2024). The 'Profession/Occupation Field Model' as an Activity Theoretical Framework for the Development of Engineers in the Context of the Smart City Approach.	I	I	I
23	https://doi.org/10.1016/j.scs.2018.02.013 (accessed on 16 March 2024). Privacy-enhancing aggregation of Internet of Things data via sensor grouping.		R	I
24	https://doi.org/10.1016/j.enpol.2021.112554 (accessed on 16 March 2024). Techno-economic optimisation of long-term energy supply strategy of Vienna city.		R	R
25	https://doi.org/10.1016/j.patter.2020.100003 (accessed on 16 March 2024). Interdependent Networks: A Data Science Perspective.	I	R	I
26	https://doi.org/10.1016/j.scs.2023.104713 (accessed on 16 March 2024). On the positioning of emergencies detection units based on geospatial data of urban response centres.		I	I
27	https://doi.org/10.1016/j.autcon.2018.02.008 (accessed on 16 March 2024). Water quality monitoring in smart city: A pilot project.	o	o	o
28	https://doi.org/10.1016/j.scs.2019.101636 (accessed on 16 March 2024). Is smart city resilient? Evidence from China.		IR	I
29	https://doi.org/10.1016/j.comcom.2022.06.007 (accessed on 16 March 2024). Resiliency-aware analysis of complex IoT process chains.		I	IR
30	https://doi.org/10.1016/j.jum.2022.09.003 (accessed on 16 March 2024). Smart communities in Japan: Requirements and simulation for determining index values.		I	I
31	https://doi.org/10.1016/j.cities.2023.104293 (accessed on 16 March 2024). Measuring sustainability, resilience and livability performance of European smart cities: A novel fuzzy expert-based multi-criteria decision support model.	I	I	I

As a first result after the expert analysis, the proportion of relevant (R) or attractive (I) works found was 82%, 93%, and 68% for Q1, Q2, and Q3, respectively, of the total works found (X). This result validates the effectiveness of the search method used. Only one reference could not be processed, but the experts included it.

The statistics for relevant works (R) were 36%, 37%, and 18%, respectively, validating that the given questions can be solved using recent research.

At this point, the experts conducted further analysis for the relevant (R) works regarding interoperability, safety and security, and low-carbon energy management improvement sources to the i-ISSUES model, along with the corresponding model element combinations. The result is summarized in Tables 11–13:

Table 11. Model improvements regarding interoperability management (Q1-Rs).

id	Model Improvements Regarding Interoperability Management
4	Consider the Urban District Sustainability ontology. It describes everyone involved within a community and tools for supporting decision-making. It can also raise awareness of sustainability in general. The UDSA semantic data model solves problems in smart cities: data heterogeneity, interoperability, and exchange [36].
8	Provides advice about the need for use cases for AI, data source selection, and decision-making processes [37].
14	This paper describes the green space data analysis initiative and the importance of public outreach and engagement to ensure stakeholders' support for such initiatives [38].
21	It provides context for complex human workers and a need for flexibility, where it is crucial to accurately assess and investigate cognitive ergonomic methods [39].

Table 12. Model improvements regarding low-carbon energy management (Q2-Rs).

id	Model Improvements Regarding Low-Carbon Energy Management
4	Introduces the importance of developing tools to track changes and adapt to continuous changes in the built (and natural) environment and interoperability for decision support, as it standardizes the information flows between different actors to ensure data quality in cloud-based services. It also mentions the innovative water ontology developed in the WISDOM [36].
6	Remarks on the large number of low-temperature urban excess heat sources available in the ReUseHeat project, which defines four advanced urban heat recovery solutions for district heating and cooling networks that are key to a more secure, renewable, and affordable energy supply and decarbonization [40].
10	Explains that complex issues in Japan, like an ageing society, disaster management, and external energy dependency, justify new methodologies for optimal urban energy planning, integrating all the information from different sectors in the way a smart city does. Analyzes "GIS-BIM"-based urban energy planning and readjustment of the city's infrastructure [41].
13	Introduces i-SCOPE (Interoperable Smart City services through an Open Platform for Urban Ecosystems), an open platform supporting "smart city" services development based on specific 3D urban information models. It also introduced the ENRIMA initiative (Energy Efficiency and Risk Management in Public Buildings), a decision support system (DSS) engine for integrated management of energy-efficient sites, and the need to use semantic technologies to assist city authorities in producing short-term energy plans transparently and comprehensively [42].
16	It provides some context about transitioning to a low-carbon future with the related renewable energy and ecosystem services. It mentions the software development life cycle (SDLC), covering analysis, design, and implementation [43].
17	Introduces a cyberattack framework to result in simultaneous undervoltage and overvoltage in a smart distribution with electric renewables [44].
18	It shows a case for district heating in which waste heat is the first source, followed by heat from electric heat pumps, combined heat and power plants, and boilers. It also explains that a" local community should exchange with surrounding regions to such a level that the exchange is the best for the overall system and invest in flexibility to deal with the rest of the imbalances" [45].
21	Analyzes studies highlighting that employees need soft, analytical, digital, and software/hardware skills for increasingly automated environments due to Industry 4.0 technologies and new employment opportunities, conditioning the future of training [39].
23	Explains problems with data privacy and the consequences of the cost of different data management approaches [46].
24	Introduces the model MAED-City (Model for evaluation of energy demand of City), which disaggregates the current urban energy demand by consumption sector and the factors affecting the future market [47].
25	Considers interdependent information exchange among multi-layer networks to identify probable problems while coupling several layers. It also explains the increasing number of devices in energy networks to ensure reliable energy delivery and how this will affect other networks or essential services [48].

Table 13. Model improvements regarding safety and security (Q3-Rs).

id	Model Improvements Regarding Safety and Security
5	According to the authors' research, the liberalization of the energy markets and information technology has reduced energy costs and can guarantee efficient and reliable operation [49].
6	It explains that the heat recovery project's primary goal is to reduce the greenhouse gas emissions (GHG) from heating and cooling demands. It also describes the positive impacts on excess heat owners and heat recovery facility operators. It also considers that social impact evaluation is secondary, except for with heat recovery from sewage water [40].
10	Explains that Building Information Modeling (BIM) and Geographical Information Systems (GIS) are the base of an urban energy planning tool for smart cities, considering urban development and infrastructure regeneration at different scales [41].
18	The Smart Energy Aalborg case is described in Denmark, where heat demand savings and increased heat demand are covered by district heating [45].
24	Explains that a city's transformation towards an efficient, sustainable, and low-carbon future is predominantly driven by the decarbonization of urban energy systems due to the concentrated socio-economic activities in urban setting, along with the expected effectiveness of energy policy measures at this level in the context of underused synergy potentials but also dependent on importing resources, limited land, and land use competition. It also considers that cities' infrastructures must become more productive, efficient, and resilient in a sustainable urban transformation [47].

After detecting 17 R&D projects related to urban planning and decarbonization, safety or security in polygons, and interoperability in public services, it was possible to classify them into eight categories. Nevertheless, none simultaneously pointed to two or three of the topics the i-ISSUES model covers. Nevertheless, the i-ISSUES model provides solutions for early integration and knowledge reuse for the main model elements:

- (The Process itself) ID 2 and ID 11 R&D Projects
- (Inputs) ID 6, ID 9, and ID 12 R&D Projects
- (Expected Outputs) ID 2 R&D Project
- (Controls) ID 4, ID 8, ID 10, and ID 13 R&D Projects
- (Enablers) ID 3, ID 5, ID 7, and ID 16 R&D Projects

According to the authors, after analyzing 109 works, 31 potentially provided feedback, and 20 (65% of the relevant works) were pertinent to suggesting improvements to the i-ISSUES model, so 18% of the improvements were found in 109 works.

The potential improvements can be summarized as three main groups:

- (Ontology use) The existence of ontologies for smart cities (USDA, WISDOM) and the interoperability experience from smart city services (i-SCOPE) complements the first i-ISSUES ontology by starting further interoperability management works.
- (Digitalization practices) The convenience of promoting interoperability between BIM and GIS work products under the Industry 4.0 framework, which can be faced using specific systems engineering tools and authoritative sources of truth (ASoT). Both the tools and the related methodologies need to be considered in training programs.
- (Risks) Consider the risk of increasing the number of sensors and data privacy early on without compromising essential urban services.

4. Conclusions

After analyzing several recent R&D projects, it was clear that the i-ISSUES model is more industrial-focused than the original model. Nevertheless, the model allows for knowledge reuse and collaboration with other R&D projects, as described in Table 7. After gathering an extensive bibliography, the model's originality was also confirmed. Another general conclusion is that the i-ISSUES model has demonstrated utility in providing relevant information to the experts, with 30% effectiveness in helping to answer three questions (no less than 18% per question). It is ready to enroll more interested experts and stakeholders in continuous model construction, utility validation, and application to real projects. After analyzing potential improvements to the i-ISSUES model, some possible improvements have been considered.

The first specific conclusion is that the accessible research in the literature solves none of the research questions. That means there is an opportunity for further research and technology development; nevertheless, urban energy modeling, data exchange, and privacy trends are beneficial for improving the i-ISSUES model, as described in Tables 11–13. To cope with the model's understanding and acceptance barriers, it would be necessary to use the model in an industrial polygon of several cities at the same time and to compare the inputs (such as training) and the results (mostly given within feasibility studies), considering also the possibility of using any knowledge, tool, or technology from the R&D projects and, of course, the found improvements given in this research, defined in Tables 7 and 11–13, respectively, and adapting the participation processes, models, and tools as inspired by other parallel research [50,51].

The second specific conclusion of this work is that, according to the accessible literature, there is little evidence that urban energy planning is being extended to industrial planning at the polygon level towards smarter urban energy planning. This operational knowledge gap could underestimate the potential for industrial polygons to contribute to urban decarbonizing at a lower cost or to increase resilience given the barriers of some renewable technologies demanding space and urban infrastructure, such as solar thermal heat generation facilities, as well as to reinforce the safety and security of city districts. Our first research results can be used to improve ongoing projects like NetZeroCities [52] and public and private agents' strategies (local authorities, professional colleges, etc.) and can provide benefits not only by integrating systematically polygons' contributions to city decarbonization but also through their collaboration with engineers for current urban planning to be more safe, secure, and resilient.

The i-ISSUES model design principle "Look for civil works economies of scale and shared infrastructures savings" assumes there could be infrastructures shared by industrial polygons and the rest of the city. We can imagine a specific case study focused on new or refurbished urban infrastructures and buildings at the same time by applying the "Energy Efficiency First" principle. To make this possible, a city would use the engineering capacity previously developed in industrial polygons (at least for infrastructures like water or electricity, but not limited to them). Multivariate analysis (for optimization) and i-ISSUES model loops would be necessary.

Our next suggested step is to activate collaborative vocabulary enrichment and control activities and to include quality assurance automation. After that, it would be possible to transfer the model to open ontology in RDFs SKOS or OWL formats. More literature from the Scopus database on interdisciplinary research for model construction should also be reviewed after this initializing stage, including R&D project publications not found in the used database and the contribution of potential improvements to the model ontology for integrating urban resilience building projects [53], which requires expanding the i-ISSSUES model and answering the generic research question: How can urban resilience plans be reinforced by increasing safety and security in industrial polygons? Analogous to this research work, the question can be split into more detailed ones regarding the specifications, information types, and urban planning trends for given polygons.

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