IEC SRD 63520

Edition 1.0 2024-10

SYSTEMS REFERENCE DELIVERABLE

Smart cities – Application of IEC SRD 63235 – Concept system building for energy challenge

IEC SRD 63520:2024-10(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC SRD 63520

Edition 1.0 2024-10

SYSTEMS REFERENCE DELIVERABLE

Smart cities – Application of IEC SRD 63235 – Concept system building for energy challenge

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 01.040.01; 13.020.20

ISBN 978-2-8322-9782-7

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

SMART CITIES – APPLICATION OF IEC SRD 63235 – CONCEPT SYSTEM BUILDING FOR ENERGY CHALLENGE

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

IEC SRD 63520 has been prepared by IEC systems committee Smart Cities: Electrotechnical aspects of Smart Cities. It is a Systems Reference Deliverable.

The text of this Systems Reference Deliverable is based on the following documents:

Draft	Report on voting
SyCSmartCities/346/DTS	SyCSmartCities/352/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Systems Reference Deliverable is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

As global climate change and energy scarcity become increasingly prominent, it is important that cities and stakeholders proactively address energy challenges to achieve the Sustainable Development Goals. According to the IEC White Paper *Coping with the Energy Challenge – The IEC's role from 2010 to 2030*, cities are facing the following major energy challenges: stabilizing climate impact from fossil fuel use; meeting the energy demands of a growing urban population; bringing electricity to citizens without access; ensuring stable and secure energy access for all cities.

Cities are very complex "system of systems", including power grid (energy), industry, buildings, transport, water, waste and other domains, each of which plays an important role. Various domains play an important role in coping with urban energy challenges. On the one hand, not only is it important for the power grid domain to be transformed, but also for industry, buildings, transport and other domains to take proactive measures. Therefore, it is essential for stakeholders in different domains to reach a consensus on energy challenges (including but not limited to the intension, solutions, visions, etc.), which is conducive to improving the pertinency, systematization and effectiveness of the city's response to energy challenges. On the other hand, from the perspective of urban governance, it is not the most effective for each domain to cope with energy challenges independently, and the comprehensive governance capacity of cities to cope with energy challenges can be significantly improved through cross-domain collaboration, interoperability and integration.

Semantic interoperability is proposed by the IEC White Paper *Semantic Interoperability: challenges in the digital transformation age*. Research on semantic interoperability is being carried out or planned in the future in the domains of city, power grid (energy), industry, buildings, transport, etc. For example, in the domain of city, IEC SRD 63476-1 provides a gap analysis of smart city ontology; in the domain of power grid (energy), IEC SRD 63417:–[1] provides guidance and planning for the development of smart energy ontologies. Domain-based ontologies have been developed for semantic interoperability in a specific domain, but there is a lack of cross-domain semantic interoperability research. IEC SRD 63417:– includes the following recommendation: "Start a joint work with IEC SyC Smart Cities and IEC SyC Smart Energy on cross domain ontologies".

From the perspective of urban governance, focusing on cross-domain semantic interoperability and at the same time considering the diversity of technology application in rural and remote areas, this document builds a concept system for energy challenges in smart cities, covering core concepts such as intension, stakeholders, solutions and visions of energy challenges. As semantic interoperability research is being carried out or planned in power grid (energy), industry, buildings, transport and other domains, SyC Smart Cities will not be involved in semantic interoperability within these domains. The concept system of this document contains the core concepts of the city domain and the core concepts of cross-domain. The core concepts relevant to energy challenges in other domains, such as power grid (energy), industry, buildings, transport, etc., are developed for semantic interoperability within each domain and fall outside the scope of this document. The purpose of this document includes, but is not limited to:

– fostering the coordination of perspectives on energy challenges among stakeholders in different domains of city, and helping stakeholders identify the intension, solutions, visions, etc. of energy challenges;
– providing a basic framework for semantic coherence and standardization of energy challenges in different domains of city, and promoting cross-domain collaboration, interoperability and integration;
– helping relevant standards development organizations (SDOs) identify gaps in concepts and standards related to energy challenges in smart cities.

1 Under preparation. Stage at the time of publication: IEC SRD CD 63417:2023.

This document provides a basic framework for cities to adopt top-down, bottom up and federated planning and design, engineering construction, management and operation, standard setting and other measures to effectively respond to energy challenges. This document promotes the collaboration, integration and sustainable development of global smart cities.

SMART CITIES – APPLICATION OF IEC SRD 63235 – CONCEPT SYSTEM BUILDING FOR ENERGY CHALLENGE

1 Scope

This document, which is a Systems Reference Deliverable (SRD), provides the concept system of energy challenges in smart cities, using the methodology framework and development processes in IEC SRD 63235.

This document is applicable to development and improvement of the terms and concepts relevant to energy challenges in smart cities.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
associative relation
associative concept relation
pragmatic relation
non-hierarchical concept relation (3.5)

[SOURCE: ISO 1087:2019, 3.2.23, modified – The EXAMPLE has been deleted.]

3.2
characteristic
abstraction of a property

Note 1 to entry: Characteristics are used for describing concepts (3.3).

[SOURCE: ISO 1087:2019, 3.2.1, modified – The EXAMPLE has been deleted.]

3.3
concept
unit of knowledge created by a unique combination of characteristics (3.2)

Note 1 to entry: Concepts are not necessarily bound to particular natural languages. They are, however, influenced by the social or cultural background, which often leads to different categorizations.

Note 2 to entry: This is the concept "concept" as used and designated by the term "concept" in terminology work. It is a very different concept from that designated by other domains such as industrial automation or marketing.

[SOURCE: ISO 1087:2019, 3.2.7]

3.4
concept model
concept diagram formed by means of a formal language

[SOURCE: ISO 24156-1:2014, 3.2]

3.5
concept relation
relation between concepts (3.3)

[SOURCE: ISO 1087:2019, 3.2.11]

3.6
concept system
system of concepts
set of concepts (3.3) structured in one or more related domains (3.8) according to the concept relations among its concepts (3.3)

[SOURCE: ISO 1087:2019, 3.2.28]

3.7
core concept
concept (3.3) that has focus of interest in a group of related concepts

[SOURCE: ISO/TR 24156-1:2008, 3.4]

3.8
domain
subject field
field of special knowledge

Note 1 to entry: The borderlines and granularity of a domain are determined from a purpose-related point of view. If a domain is subdivided, the result is again a domain.

[SOURCE: ISO 1087:2019, 3.1.4]

3.9
extension
set of all of the objects to which a concept (3.3) corresponds

[SOURCE: ISO 1087:2019, 3.1.2]

3.10
generic relation
generic concept relation
genus-species relation
concept relation (3.5) between a generic concept and a specific concept where the intension of the specific concept includes the intension of the generic concept plus at least one additional delimiting characteristic (3.2)

Note 1 to entry: Outside the terminology community, "type-of relation" and "is-a relation" are also used instead of "generic relation".

Note 2 to entry: In a generic relation the subordinate concept is a specific concept and the superordinate concept is a generic concept.

[SOURCE: ISO 1087:2019, 3.2.13, modified – The EXAMPLE has been deleted.]

3.11
hierarchical relation
hierarchical concept relation
generic relation (3.9) or partitive relation (3.13)

[SOURCE: ISO 1087:2019, 3.2.12]

3.12
intension
set of characteristics (3.2) that make up a concept (3.3)

[SOURCE: ISO 1087:2019, 3.2.6]

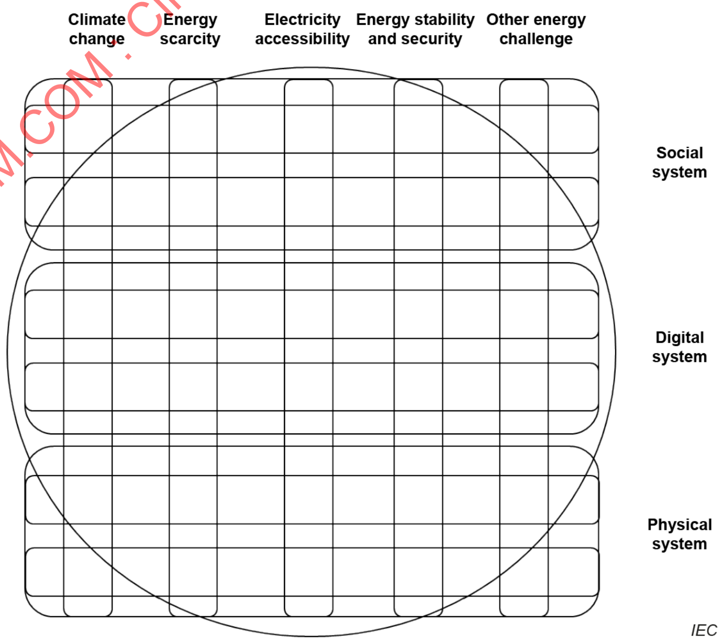
3.13
partitive relation
partitive concept relation
part-whole relation
part-of relation
concept relation (3.5) between a comprehensive concept and a partitive concept

[SOURCE: ISO 1087:2019, 3.2.14, modified – The EXAMPLE has been deleted.]

4 General

4.1 A system of systems view

There are different economic models and levels of development in different countries. Even within the same country, there are significant differences in the level of urbanization in different regions. In consequence, the content of energy challenge is not exactly the same. Although the specifics of energy challenges are not identical, it is important to identify common energy challenges and find solutions accordingly. This document analyses energy challenges in smart city from a system of systems view, as shown in Figure 1, which integrates social system, digital system and physical system of a city to cope with energy challenge.



SOURCE: Figure 1 of IEC SRD 63235:2021, modified by adding energy challenge concerns.

Figure 1 – A system of systems view of energy challenges in smart cities

The social system, digital system and physical system work together as a complementary whole in responding to the concerns and interests of different stakeholders. In vertical dimension, it is made up of many energy challenges in smart city referring to IEC White Paper "Coping with the Energy Challenge – The IEC's role from 2010 to 2030", such as climate change, energy scarcity, electricity accessibility, energy stability and security, and so on. Taking system of systems view enables the total capability of a city to be enhanced in a way that none of the constituent systems can accomplish on its own.

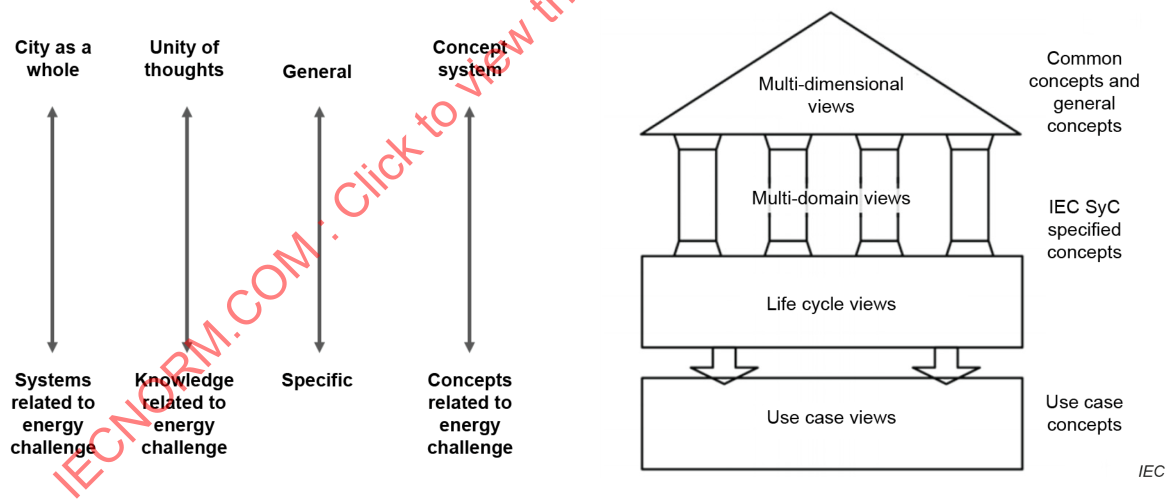
The physical system provides an application framework that promotes the energy connection of infrastructure in energy network, industry, building, transport and other domains in smart city, and supports the energy interconnection and interaction among these domains in physical layer.

The digital system provides an ICT framework that achieves integration of energy network, industry, building, transport and other domains in information and communication layer, and turns isolated domains into horizontal integration of services using data from different domains, which is key to achieving interoperability.

The social system provides a governance framework that coordinates arrangements of energy challenge relevant strategies, policies, decisions, accountabilities, management measures, etc. to reflect multiple stakeholders' concerns in social layer.

4.2 Methodology framework

The methodology framework for concept system building of energy challenges in smart cities is a specific application of IEC SRD 63235. The methodology framework refers to a system of systems way of thinking that supports multi-dimensional, multi-domain and multi-layer, life-cycle and use-case analysis approaches to be used together as a complementary whole, as shown in Figure 2.



SOURCE: Figure 2 of IEC SRD 63235:2021, modified by adding energy challenge concerns.

Figure 2 – Methodology framework for building concept system of energy challenge in smart city

5 Principles for concept system building

5.1 Concept system building steps

Concept system building involves a series of steps, as shown in Figure 3.

The concept system building steps include:

– selecting the concept field, which is "energy challenges in smart cities" (as shown in Clause 4);
– extracting characteristics according to the components of the concept "energy challenges in smart cities", and extracting concepts from these characteristics (as shown in 6.2);

NOTE Considering that the components which are given by IEC, ISO, ITU and other SDOs can be incomplete or not widely applicable, it is crucial to extract supplementary concepts through the extension of "energy challenges in smart cities".

– extracting concepts according to the extension of "energy challenges in smart cities" (as shown in 6.3);
– identifying core concepts by relevance assessment (as shown in Clause 7);
– determining the relations and positions of these core concepts within the concept system (as shown in Clause 8);
– visualizing the resulting concept system by means of a concept model (as shown in Clause 8).

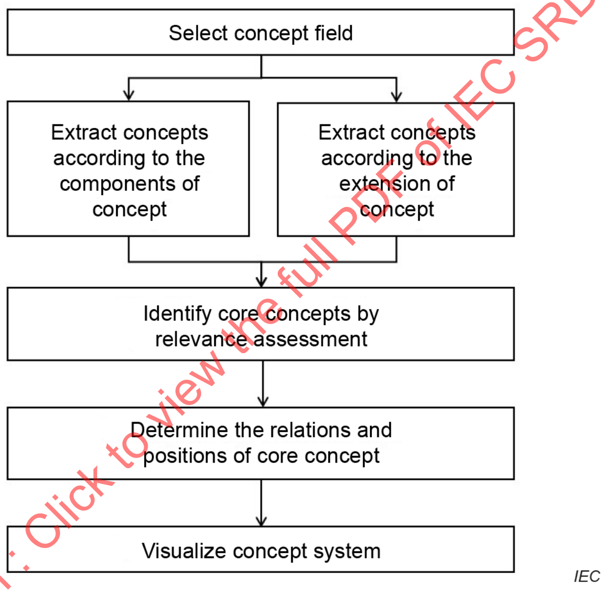


Figure 3 – Concept system building steps

5.2 Concept relation

Concept system describes concepts and their relations. Different concepts can be connected through different types of concept relations. The following relations are used to develop the concept system of energy challenges in smart cities:

a) hierarchical relation:
   1) generic relation;
   2) partitive relation;
b) associative relation.

   In this document, Unified Modelling Language (UML)-based concept models are drawn in accordance with ISO 24156-1. The UML-based concept model of generic relation, partitive relation, and associative relation is shown in Figure 4, Figure 5, and Figure 6.

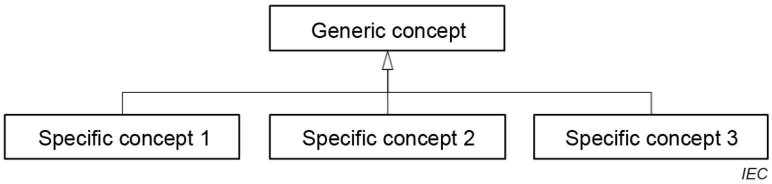


Figure 4 – UML-based concept model to represent generic relation

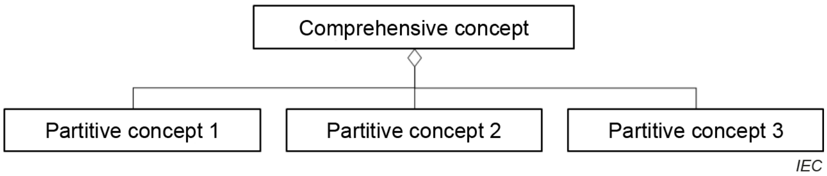


Figure 5 – UML-based concept model to represent partitive relation

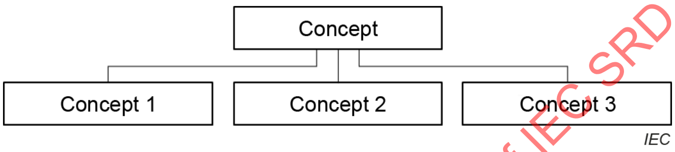


Figure 6 – UML-based concept model to represent associative relation

6 Extract concepts

6.1 General

Characteristics were extracted from the components of the concept "energy challenges in smart cities" by taking into account the smart city and the stakeholders. Then, from the city perspectives, concepts were extracted from these characteristics. Considering that the components of the concept energy challenges in smart cities, which is given by IEC, ISO, ITU and other SDOs, can be incomplete or not widely applicable, it is essential to extract supplementary concepts through the extension of "energy challenges in smart cities".

NOTE The characteristics that make up a concept can themselves be concepts.

6.2 Extracting concepts from the components

IEC and ISO offer different perspectives and understanding as shown in Table 1, though an agreed definition for the energy challenge in smart cities given by IEC, ISO, ITU and other SDOs remains to be agreed. The IEC's role from 2010 to 2030 outlines what are the energy challenges. ISO addresses how these energy challenges have occurred and can be resolved. The characteristics were extracted through the analysis of the components of the concepts, "energy challenge" and "smart city". Then the concepts related to "energy challenges in smart cities" were extracted through the analysis of these characteristics from the city perspectives.

Table 1 – Concepts relating to energy challenges in smart cities

No.	Concepts	Components	Characteristics	Concepts (From city perspectives)	Source
1	Energy challenge	The challenge is ensuring energy availability and preserving the environment. The key elements are the following: 1) stabilizing climate impact from fossil fuel use; 2) meeting the energy demand of a growing global population; 3) bringing electricity to the 1,6 billion people without access; 4) ensuring stable and secure energy access for all nations; 5) transporting electricity long distances from where it is generated to where it is used.	ensuring energy availability, preserving the environment, stabilizing climate impact from fossil fuel use, meeting the energy demand of a growing global population, bringing electricity to the people without access, ensuring stable and secure energy access for all nations, transporting electricity long distances	energy availability, protection of the environment, climate change, energy scarcity, citizen, electricity accessibility, energy stability and security, government	IEC White Paper: Coping with the Energy Challenge. The IEC's role from 2010 to 2030
2	Energy challenge	ISO standards help organizations reduce their energy consumption and adopt renewable energy technologies. They also ensure interoperability, which encourages the transition to renewable energy sources, opening up markets for innovations that address the global energy challenge.	organization, reduce energy consumption, adopt renewable energy technologies, interoperability, market, innovation, address the global energy challenge	nonprofit organization or enterprise, energy efficiency, energy conservation, renewable energy, interoperability, market, innovation	ISO and energy
3	Smart city	City (IEV 831-01-03) where improvements in quality of life, services (IEV 831-01-18), sustainability (IEV 831-01-20) and resilience are facilitated by the effective integration of many and various types of physical, digital and social systems (IEV 831-01-21) and the transformative use of data (IEV 831-02-02) and technology. Note 1 to entry: This is a general definition of a smart city. The IEC looks at these aspects from an electrotechnical perspective. Note 2 to entry: The effective integration of physical, digital and social systems can be facilitated by integration of digital twins of all these systems.	quality of life, service, sustainability, resilience, integration, physical, digital and social systems, transformative use of data and technology, electrotechnical perspective, digital twins	quality of life, service, sustainability, resilience, integration, physical system, digital system, social system, data, technology, electrotechnical, digital twin	IEC 60050-831 International Electrotechnical Vocabulary (IEV) – Part 831: Smart city systems

"Energy challenges in smart cities" can be categorized into five dimensions: smart city vision, stakeholder, solution, energy challenge and smart city system, as shown in Figure 7. This conceptual framework deepens understanding by extending the scope and grouping systems of systems to understand the complex relationships between them in balancing energy solutions with energy availability and environmental protection within a complex smart city ecosystem. Figure 7 has terms extracted from current relevant standards to analyse potential solutions to this complex issue and opportunities that can be applied to a concept system building framework (see 8.1 and 8.3).

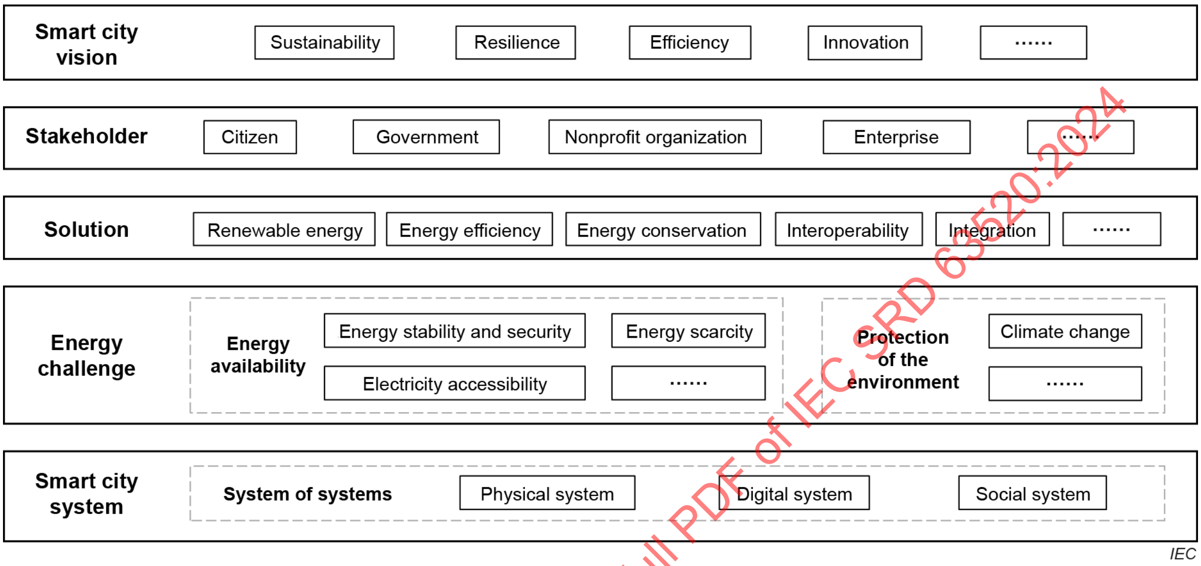


Figure 7 – Concepts category for energy challenges in smart cities based on the components

6.3 Extracting concepts from the extension

It is important that concepts extracted from the extension of "energy challenges in smart cities" satisfy the following principles:

– relevancy: highly relevant to smart city for addressing energy challenge;
– accuracy: it is important that concepts are accurate, clear and neutral;
– readability: the meaning is understandable without reference;
– usefulness: using and applying frequently in relevant deliverables;
– reliability: the concepts have authoritative sources or are recommended and agreed upon by experts from relevant domains.

This document extracted concepts from the extension of "energy challenges in smart cities", based on above principles and the category in Figure 7. The definitions of some relevant extension are presented in Annex A for reference. Since there are many concepts extracted from the extension, and the objects of these concepts are not at the same level, this document further clustered these concepts, as shown in Table 2.

Table 2 – Clustering concepts extracted from the extension

No.	Concepts extracted from the extension	Concepts after clustering
1	system, physical system, digital system, social system	System of systems
2	Smart Cities Reference Architecture (SCRA), Smart Grid Architecture Model (SGAM), business reference architecture, security architecture, Smart Cities Reference Architecture Methodology (SCRAM), SCRA view, SCRA model	Reference architecture
3	application programme life cycle, electrical power system life cycle, life cycle activities, life cycle approach, Life Cycle Assessment (LCA), Life Cycle Impact Assessment (LCIA), life-cycle management	Life cycle
4	distributed energy resource system, photovoltaic (PV), wind power plant, distributed energy resource unit, Electrical Connection Point (ECP), Distributed Energy Resource Management System (DERMS), biogas	Distributed energy resources (DER)
5	energy storage, battery, Battery Energy Storage System (BESS), Electric Energy Storage (EES), electric energy storage system, thermal storage system, electrical energy storage devices, electrical energy storage management, energy storage capacitor, Energy Storage Unit (ESU), flywheel energy storage system, Home Energy Storage System (HESS)	Energy storage
6	consumer, Demand Response (DR), energy efficiency, energy conservation, Electrical Connection Point (ECP), virtual resource, dispatchable load, building attached PV (BAPV), building integrated PV (BIPV), EV charging system	Prosumer
7	industrial heat supply, electric arc furnace, electric motor, Carbon Capture and Storage (CCS), Carbon Capture, Utilization and Storage (CCUS), refrigeration, air-conditioning system, industrial fan, gas cleaning system, electrical energy management system (EEMS), Customer Energy Manager (CEM), flexibility aggregator	Industry
8	pump, pumped-storage power plant, water feed by pump, ground-water heat pump, heat exchange water heater, electric instantaneous water heater, hydraulic instantaneous water heater, supplementary water heater, potable water heaters, energy use for domestic hot water	Water
9	Home, building, built environment, household appliances, home electronic device, smart appliance, Consumer Electronics (CE), domestic photovoltaic system, off-grid domestic photovoltaic system, building-attached photovoltaics (BAPV), building-integrated photovoltaics (BIPV), building-integrated photovoltaic module, electrical installation of building, DC distribution network, indoor heat exchanger, small scale energy supply (SSES), Smart Grid Connection Point (SG CP)	Home and building
10	transportation infrastructure, transportation, battery-electric vehicle (BEV), hybrid-electric vehicle (HEV), electrically propelled vehicle (EV), electric vehicle (EV), electric road vehicle, fuel cell vehicle (FCV), fuel cell vehicle, fuel cell hybrid-electric vehicle (FCHEV), charging point, DC EV charging station, charging station, WPT system, automated vehicle	Transport
11	smart energy grid, decentralized energy network, decentralized energy network operator, distribution network, distribution system, electric power network, transmission network, microgrid, power line, power transformer	Energy network
12	Wind Power Station (WPS), wind power plant, photovoltaic plant, PV power plant, renewable energy power plant, rural mini-power plant, solar power tower plant, micropower plant, Nuclear Power Plant (NPP)	Power station
13	Air Insulated Substation (AIS), Gas Insulated Substation (GIS), HVDC substation, HVDC converter station, smart electrical power substation, substation automation system	Substation
14	wireless power transfer, transmission of electricity, two-terminal HVDC transmission system	Long transmission network
15	DC distribution network, distributed generation, Distribution System Operator (DSO), Distribution Network Operator (DNO), distribution system, feeder, Distribution Substation Unit (DSU), electric power network	Distribution network
16	HVDC back-to-back system, HVDC transmission system, HVDC substation HVDC/converter station, HVDC substation circuit breaker, VSC converter station	HVDC system
17	microgrid, microgrid energy management system, isolated microgrid, non-isolated microgrid, collective electrification system, interface switch, point of connection	Microgrid

No.	Concepts extracted from the extension	Concepts after clustering
18	cable type current sensor, Current Sensor (CS), DC sensor, (electric) sensor, electronic sensor, hall effect sensor, intelligent Wireless Sensor Network (iWSN), line sensor unit, locating current sensor, primary current sensor, primary voltage sensor, residual current sensor	Sensor
19	isolation switch, circuit breaker, air circuit-breaker, circuit-breaker incorporating residual current protection (CBR), current-limiting circuit-breaker, DC circuit-breaker, gas circuit-breaker, moulded-case circuit-breaker, fuses	Actuator
20	Information and Communication Technology (ICT), Information and Communication Technology network (ICT network), communication terminal, server, network, information model, protocol, client, communication network, Internet of Things (IoT), communication, data, network interface	ICT equipment
21	data model, critical data, non-critical data, data integrity, user data, abstract data and objects, abstract data model for communication, big data, data access, data acquisition, data acquisition system (DAS), data availability, data backup	Data
22	Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS), application control service element, Application Control Service Element (ACSE), application service element, cloud service, data service, IIoT service platform, service catalogue, service development	Service
23	Information, concept, ontology, knowledge entirety, knowledge base, reference body of knowledge, knowledge model, knowledge network, knowledge acquisition, knowledge management, body of knowledge	Knowledge
24	Platform as a Service (PaaS), IIoT service platform, IoT Data Exchange Platform (IoT DEP), platform User Interface Services platform (UI Services), Energy Management System (EMS), Market Management System (MMS)	Platform
25	application control service element, application service element, application component, application domain, application function, application instance, application layer, application layer interoperability, application layer protocol, application level gateway, application programme application software	Application
26	governance organization, governance behaviour, governance framework, human governance, policy, organizational governance framework, corporate governance, organizational governance	Governance
27	policy, strategy, decision, policy-setter, environmental policy, security policy, sustainability policy, policy interoperability, policy subject, organizational policy	Energy policy
28	Ancillary Service Market (ASM), balancing market, day-ahead market, future market, intraday market, Market Management System (MMS), PV power system market, load management, spot market, Demand Side Management (DSM), Demand Response (DR)	Market
29	health, safety and environment, protected environment, decarbonization, urban environment, waste, environmental aspect, environmental impact, carbon tax, carbon metric, carbon neutrality, carbon capture and storage, carbon credit, carbon intensity, carbon footprint	Environment
30	carbon tax, carbon metric, carbon neutrality, carbon capture and storage, carbon credit, carbon intensity, carbon footprint	Decarbonization
31	waste management system, energy-from-waste, waste management, waste recovery, zero waste, waste heat recovery unit, solid waste, waste to energy, waste generator, waste processing	Waste treatment
32	consensus mechanism, consensus value, expert consensus	Consensus
33	Energy Efficiency Management System (EEMS), Energy management agent, Energy Management Team (EnMT), Energy Management Group (EnMG), Home Energy Management System (HEMS), Energy Management Committee (EnMC)	Energy management
34	common energy management system scope, common energy management system (common EnMS), energy management system scope (EnMS scope), Plan-Do-Check-Act (PDCA)	Energy Management System (EnMS)
35	stimulated emission, operation <of a mechanical switching device>, superconducting hot electron bolometric mixer, transition edge sensor detector	Energy transition
36	New energy resources, renewable energy resources, naturally replenished energy resources	Emerging energy resources
37	hydrogen content, hydrogen storage, EES system using hydrogen, hydrogen conversion system, portable hydrogen generator	Hydrogen

No.	Concepts extracted from the extension	Concepts after clustering
38	nuclear energy generation facilities, Nuclear Instrumentation System, nuclear level transmitter, Nuclear Power Plant site	Nuclear generation
39	renewable energy resource, variable renewable energy, renewable energy generation, renewable energy power plant, variable renewable energy generation	Renewable energy (RE)
40	photovoltaic (PV), photovoltaic power (PV), photovoltaic solar energy, photovoltaic system, photovoltaic generator	Solar photovoltaic (PV)
41	battery system, battery-electric vehicle (BEV), battery energy storage system BESS, battery management system (BMS), battery management unit (BMU)	Battery
42	climate change, climate change adaptation, climate change risk	Greenhouse gas (GHG) emission impact
43	energy transfer period, linear energy transfer, energy transfer type, transferred energy, energy transfer method, energy transfer scenario, energy transfer session, energy transfer stage	Cross border energy transfer
44	aerobic biological treatment, anoxic biological treatment, anaerobic biological treatment, aerobic biological treatment	Biological treatment
45	landfill gas, waste treatments, waste treatment facility, landfill compactor	Landfill treatment

7 Identify core concepts

7.1 Concept relevance assessment

Core concepts were identified by domain and stakeholder matrix relevance assessment, see Table 3. Domain relevance assessment aims to promote the integration, interoperability and effectiveness in addressing energy challenges in smart cities, including the following elements:

– domain criterion 1 (DC1): fundamental dimensions;
– domain criterion 2 (DC2): physical system;
– domain criterion 3 (DC3): digital system;
– domain criterion 4 (DC4): social system;
– domain criterion 5 (DC5): properties relevant to energy challenge, including solutions to carbon neutral;
– domain criterion 6 (DC6): properties relevant to smart city.

Stakeholder relevance assessment aims to evaluate the value for different stakeholders related to energy challenges in smart cities, including the following elements:

- stakeholders criterion 1 (SC1): value for citizen, including indigenous peoples;
- stakeholders criterion 2 (SC2): value for government;
- stakeholders criterion 3 (SC3): value for community groups and non-profit organizations;
- stakeholders criterion 4 (SC4): value for enterprises and private individuals.

The relevant assessment can be identified according to the relationships between concepts and domains, concepts and stakeholders. See Table 3.

Table 3 – Domain and stakeholder matrix relevance assessment

No.	Concepts	Fundamental dimension (DC1)	Physical system (DC2)	Digital system (DC3)	Social system (DC4)	Energy challenge (DC5)	Smart city (DC6)	Citizen (SC1)	Government (SC2)	Nonprofit organization (SC3)	Enterprise (SC4)
1	Energy challenge	√	√	√	√	√	√	√	√	√	√
2	Smart city	√	√	√	√	√	√	√	√	√	√
3	Energy availability					√	√	√	√	√	√
4	Protection of the environment					√	√	√	√	√	√
5	Climate change	√				√	√	√	√	√	√
6	Energy scarcity	√				√	√	√	√	√	√
7	Citizen	√				√	√	√			
8	Electricity accessibility	√				√	√	√	√	√	√
9	Energy stability and security	√				√	√	√	√	√	√
10	Government	√				√	√		√		
11	Nonprofit organization	√				√	√			√	
12	Enterprise	√				√	√				√
13	Energy efficiency	√	√			√	√	√	√	√	√
14	Energy conservation	√	√			√	√	√	√	√	√
15	Renewable energy		√			√	√	√	√	√	√
16	Interoperability	√	√	√	√	√	√	√	√	√	√
17	Market				√	√	√	√	√	√	√
18	Innovation	√					√	√	√	√	√
19	Quality of life				√		√	√	√	√	√
20	Service			√			√	√	√	√	√
21	Sustainability	√				√	√	√	√	√	√
22	Resilience	√				√	√	√	√	√	√
23	Integration	√	√	√	√	√	√	√	√	√	√

No.	Concepts	Fundamental dimension (DC1)	Physical system (DC2)	Digital system (DC3)	Social system (DC4)	Energy challenge (DC5)	Smart city (DC6)	Citizen (SC1)	Government (SC2)	Nonprofit organization (SC3)	Enterprise (SC4)
24	Physical system		√			√	√	√	√	√	√
25	Digital system			√		√	√	√	√	√	√
26	Social system				√	√	√	√	√	√	√
27	Data			√			√	√	√	√	√
28	Electrotechnical					√	√	√	√	√	√
29	Digital twin			√			√	√	√	√	√
30	System of systems	√				√	√				
31	Reference architecture	√				√	√				
32	Life cycle	√				√	√				
33	DER		√			√	√	√	√	√	√
34	Energy storage		√			√	√	√	√	√	√
35	Prosumer		√			√	√	√	√	√	√
36	Industry		√			√	√	√	√	√	√
37	Water		√				√	√	√	√	√
38	Home and building		√			√	√	√	√	√	√
39	Transport		√			√	√	√	√	√	√
40	Energy network		√			√	√	√	√	√	√
41	Power station		√			√			√		
42	Substation		√			√			√		
43	Long transmission network		√			√	√	√	√	√	√
44	Distribution network		√			√	√	√	√	√	√
45	HVDC system		√			√			√		
46	Microgrid		√			√	√	√	√	√	√
47	Sensor		√	√		√	√	√	√	√	√
48	Actuator		√	√		√	√	√	√	√	√

No.	Concepts	Fundamental dimension (DC1)	Physical system (DC2)	Digital system (DC3)	Social system (DC4)	Energy challenge (DC5)	Smart city (DC6)	Citizen (SC1)	Government (SC2)	Nonprofit organization (SC3)	Enterprise (SC4)
49	ICT equipment		√	√		√	√	√	√	√	√
50	Knowledge			√		√	√	√	√	√	√
51	Platform			√		√	√	√	√	√	√
52	Application			√	√	√	√	√	√	√	√
53	Governance				√	√	√	√	√	√	√
54	Energy policy				√	√	√	√	√	√	√
55	Environment				√	√	√	√	√	√	√
56	Decarbonization				√	√	√	√	√	√	√
57	Waste treatment				√	√	√	√	√	√	√
58	Consensus				√	√	√	√	√	√	√
59	Energy management				√	√	√		√	√	√
60	Energy Management System (EnMS)				√	√	√		√	√	√
61	Energy transition	√	√			√	√	√	√	√	√
62	Emerging energy resources		√			√	√	√	√	√	√
63	Hydrogen		√			√	√	√	√	√	√
64	Nuclear generation		√			√	√	√	√	√	√
65	Renewable energy (RE)		√			√	√	√	√	√	√
66	Solar photovoltaic (PV)		√			√	√	√	√	√	√
67	Battery		√			√	√	√	√	√	√
68	Greenhouse gas (GHG) emission impact				√	√	√	√	√	√	√
69	Cross border energy transfer				√	√	√	√	√	√	√
70	Biological treatment				√	√	√	√	√	√	√
71	Landfill treatment				√	√	√	√	√	√	√

7.2 Core concepts relating to energy challenges in smart cities

Through domain and stakeholder matrix relevance assessment, highly relevant core concepts were identified. The following concepts, which can be classified into four dimensions, are identified as the core concepts relating to energy challenges in smart cities.

a) Fundamental concepts:
   1) citizen;
   2) climate change;
   3) decarbonization;
   4) efficiency;
   5) electricity accessibility;
   6) energy challenge;
   7) energy conservation;
   8) energy efficiency;
   9) energy scarcity;
   10) energy stability and security;
   11) energy transition;
   12) enterprise;
   13) government;
   14) innovation;
   15) integration;
   16) interoperability;
   17) life cycle;
   18) nonprofit organization;
   19) reference architecture;
   20) resilience;
   21) smart city;
   22) solution;
   23) stakeholder;
   24) sustainability;
   25) system of systems;
   26) vision.

b) Physical system concepts:
   1) actuator (the intersection of physical system and digital system);
   2) battery;
   3) distribution network;
   4) emerging energy resources;
   5) energy network;
   6) energy storage;
   7) home and building;
   8) hydrogen;
   9) ICT equipment (the intersection of physical system and digital system);
   10) industry;

11) long transmission network;
12) microgrid;
13) nuclear generation;
14) prosumer;
15) renewable energy (re);
16) sensor (the intersection of physical system and digital system);
17) solar photovoltaic (pv);
18) transport.

c) Digital system concepts:
   1) actuator (the intersection of physical system and digital system);
   2) application (the intersection of social system and digital system);
   3) data;
   4) ICT equipment (the intersection of physical system and digital system);
   5) knowledge;
   6) platform;
   7) sensor (the intersection of physical system and digital system);
   8) service.
d) Social system concepts:
   1) application (the intersection of social system and digital system);
   2) biological treatment;
   3) consensus;
   4) cross border energy transfer;
   5) Energy Management System (EnMS);
   6) energy management;
   7) energy policy;
   8) environment;
   9) governance;
   10) greenhouse gas (GHG) emission impact;
   11) landfill treatment;
   12) market;
   13) waste treatment.

8 Visualize concept system

8.1 Overview

Concepts do not exist as isolated units of knowledge, but always in relation to each other. Human mental processes constantly create and refine relations between concepts, whether these relations are formally acknowledged or not. When organizing concepts into a concept system, it is important to bear in mind the domain or subject that gave rise to the concept and to consider the expectations and objectives of the target audience. The domain or subject shall be used as the framework within which the concept system is established.

To develop a concept system, the core concepts and their relations shall be analysed and compared. A core concept can be connected to other core concepts by different concept relations, as shown in 5.2. This document analyses energy challenges in smart city from a system of systems view, which integrates social system, digital system and physical system of a city to cope with energy challenge. The effective integration of social system, physical system and digital system can help smart city better cope with energy challenges.

In this Clause 8, the concept system of energy challenges in smart city is divided into four categories: physical system concepts, digital system concepts, social system concepts and fundamental concepts. Fundamental concepts include the contents, solutions, stakeholders, visions, etc. of energy challenges in smart cities. The concept system of smart city energy challenge is shown in Figure 8.

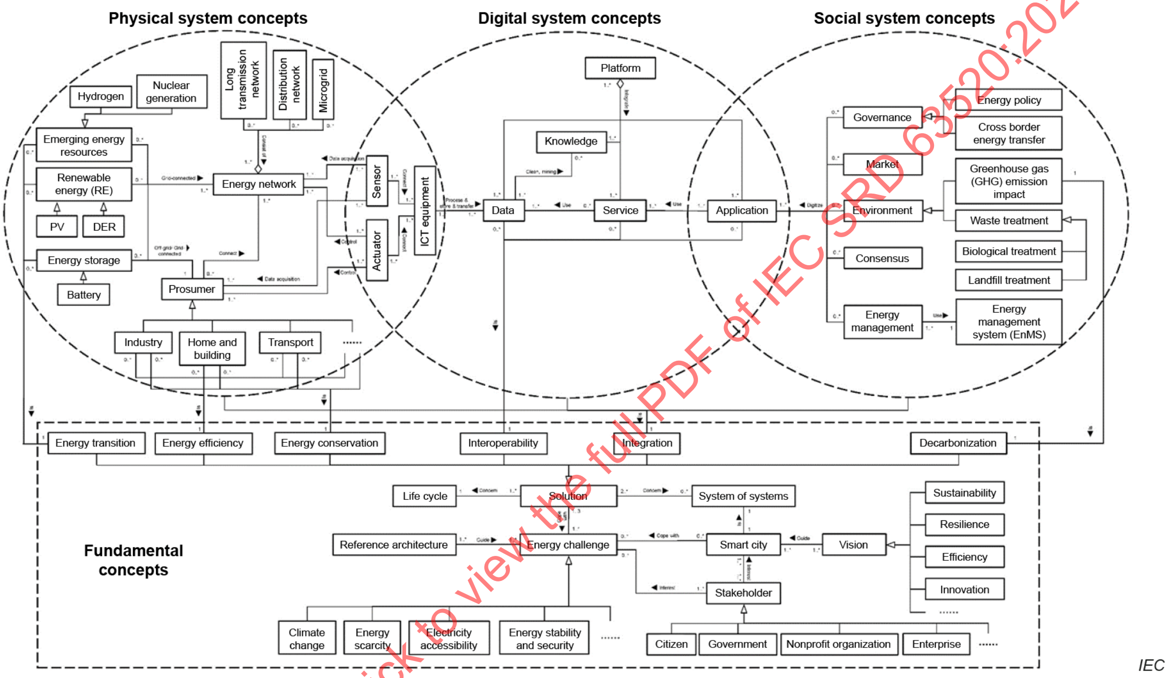


Figure 8 – Concept system for energy challenges in smart cities

8.2 Fundamental concepts

According to the concept category in 6.2, the energy challenges in smart cities can be divided into five dimensions:

– the content of energy challenges in smart cities, including climate change, energy scarcity, electricity accessibility as well as energy stability and security;

– the solutions to energy challenges in smart cities, including renewable energy, energy efficiency, energy conservation, interoperability and integration;

– the stakeholders of energy challenges in smart cities, including citizen, government, nonprofit organization, enterprise;

– the vision of addressing energy challenges in smart cities, including sustainability, resilience, efficiency and innovation;

– the basic requirements for addressing energy challenges in smart cities: building reference frameworks, adopting a life cycle and system of systems perspective.

The concept system for fundamental concepts of energy challenges in smart cities is shown in Figure 9.

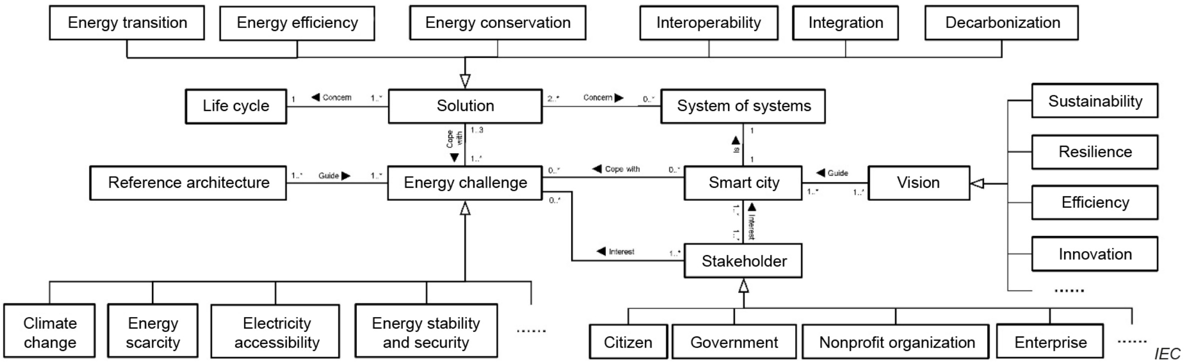


Figure 9 – Concept system for fundamental concepts of energy challenge in smart city

8.3 Physical system concepts

The physical system provides an application framework that promotes the energy connection of infrastructure in energy network, industry, building, transport and other domains in smart city, and supports the energy interconnection and interaction among these domains in physical space. The concept system for physical system of energy challenges in smart cities is shown in Figure 10.

Within the city limits, fossil fuels such as coal and petroleum, as well as renewable energy sources such as solar, wind and geothermal, are generally converted into secondary energy sources such as electricity and heat for energy distribution and consumption. On the one hand, fossil fuels are non-renewable and unsustainable. In the process of using fossil fuels, CO_2, SO_2 and other gases will be produced, causing environmental damage such as greenhouse effect and acid rain. On the other hand, with the rapid growth of city population and economy, the scale of energy consumption increases sharply, and the importance of energy efficiency and energy conservation becomes increasingly prominent. In smart city physical systems, measures to address energy challenges include:

– renewable energy;

– energy efficiency and energy conservation;

– "physical-digital-social" interoperability and integration.

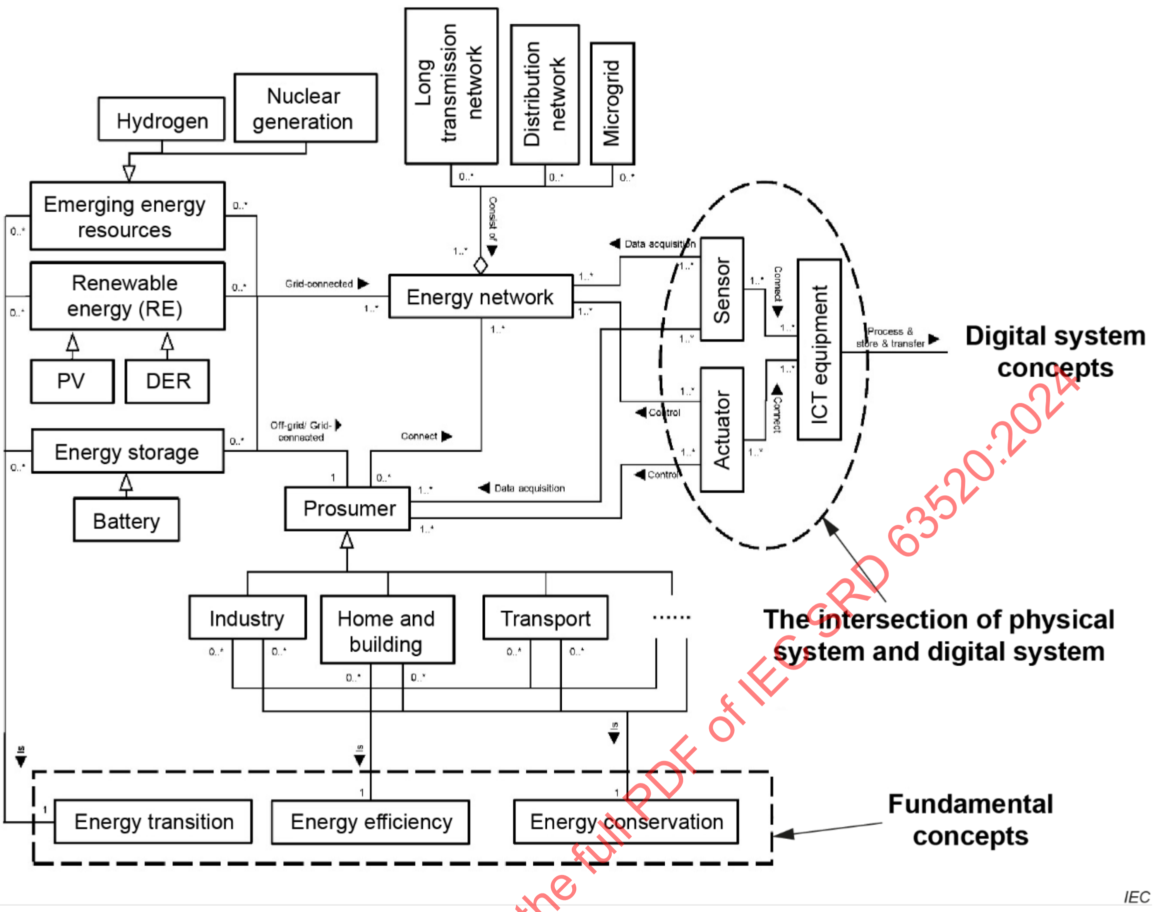


Figure 10 – Concept system for physical system of energy challenges in smart cities

1) In cities, the main form of renewable energy is DER, including solar energy, wind energy, water energy, biomass energy, wave energy, tidal energy, geothermal energy and other types. With the application of a large number of DER, traditional energy consumers are gradually transformed into prosumers. The application of renewable energy brings two aspects of impact: on the one hand, renewable energy is renewable and sustainable, hardly causing environmental pollution and climate change; on the other hand, DER, represented by solar energy and wind energy, has obvious volatility and randomness, which exacerbates challenges such as energy stability and security. Energy storage, microgrids, demand response and other technologies have facilitated the development of renewable energy:

– energy storage provides a means to solve the volatility and randomness of DER;
– microgrids can improve DER access while maintaining energy supply during city disasters;
– demand response realizes the orderly interaction between the power grid and consumers or prosumers and improves the security and stability of the power grid.

2) Within the city limits, reducing the loss of energy networks and improving energy efficiency and energy conservation are key to address the energy challenge. There are different ways to improve energy efficiency and save energy in different sectors:
   - in the industry sector, energy efficient motors, Combined Heat and Powers (CHP), energy management systems (EMS) and Carbon Capture, Utilization and Storage (CCUS), etc. are used to reduce greenhouse gas emissions while improving energy efficiency and saving energy;
   - in the home and building sector, energy-efficient appliances, Low Voltage Direct Current (LVDC), energy management systems (EMS), etc. are used to improve energy efficiency and save energy;
   - in the transport sector, electric vehicles (EVs), fuel cell vehicles and other new energy vehicles reduce the emission of greenhouse gases and pollutants. In addition, the interaction between EVs and the power grid through Vehicle-to-Grid (V2G) technology can improve the security and stability of the power grid.
3) The interoperability and integration of physical, digital and social systems through ICT infrastructure can significantly improve cities' ability to address energy challenges. In addition, ICT infrastructure, such as data centres and communication network, consumes a lot of energy, so it is important to improve energy efficiency and save energy.
4) Considering the government's energy billing regulations, it is feasible to collect energy usage data from different users through smart sensors and set varying electricity rates based on their energy efficiency or areas of energy use. It can motivate users to enhance their energy efficiency and ultimately reduce operating costs.
5) The carbon monitoring system is a crucial component of the physical system of smart cities and represents a significant technological avenue for advancing decarbonization goals. The carbon monitoring system can analyse the impact of energy on carbon emissions throughout the entire life cycle, including product creation, emissions, and waste disposal. This promotes effective decarbonization in smart cities to address energy challenges.

8.4 Digital system concepts

The digital system provides an ICT framework that achieves integration of energy network, industry, building, transport and other domains in information and communication layer, and turns isolated domains into horizontal integration of services using data from different domains, which is key to achieving interoperability. The concept system for digital system of energy challenges in smart cities is shown in Figure 11.

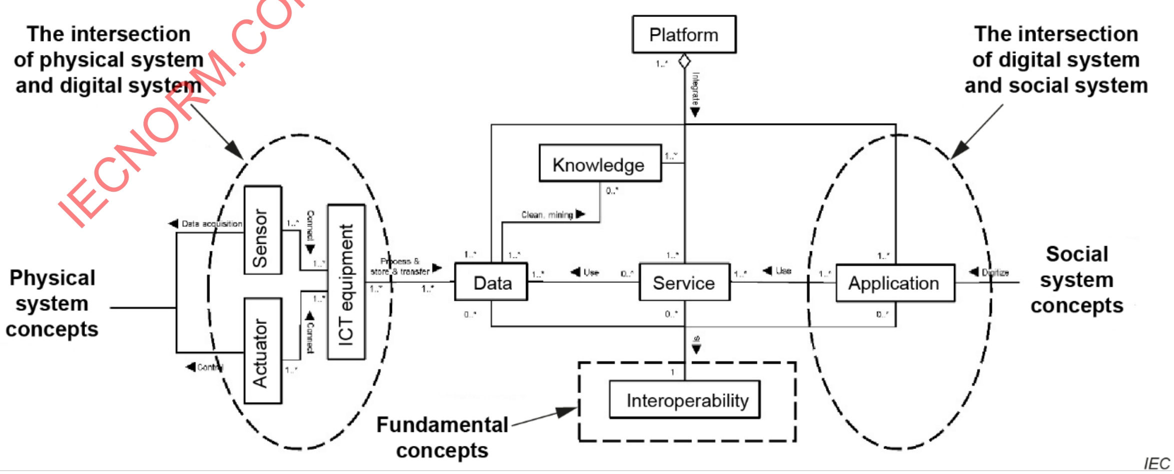


Figure 11 – Concept system for digital system of energy challenges in smart cities

Smart city requires an organic combination of top-down service construction and data-centred approach. Digital system integration includes vertical integration (from sensors, actuator to low-cost communications, real-time analysis and control) and horizontal integration (integration of systems isolated from each other). Horizontal integration of infrastructures through ICTs is critical to enhancing potential and critical efficiencies. When vertical integration and horizontal integration are combined, a unified system of multiple systems can be constructed.

Interoperability is the key to the management of a unified system covering several different kinds of systems. With a common standard, components from different suppliers and technologies can interact seamlessly. Interoperability can enable the integration of diverse data sources, services, applications and systems, enabling real-time data sharing, analysis and decision-making across the energy infrastructure.

8.5 Social system concepts

The social system provides a governance framework that coordinates arrangements of energy challenge relevant strategies, policies, decisions, accountabilities, management measures, etc., to reflect multiple stakeholders' concerns in social layer. The concept system for social system of energy challenges in smart cities is shown in Figure 12. The social system can be divided into five aspects: governance, market, environment, consensus and energy management.

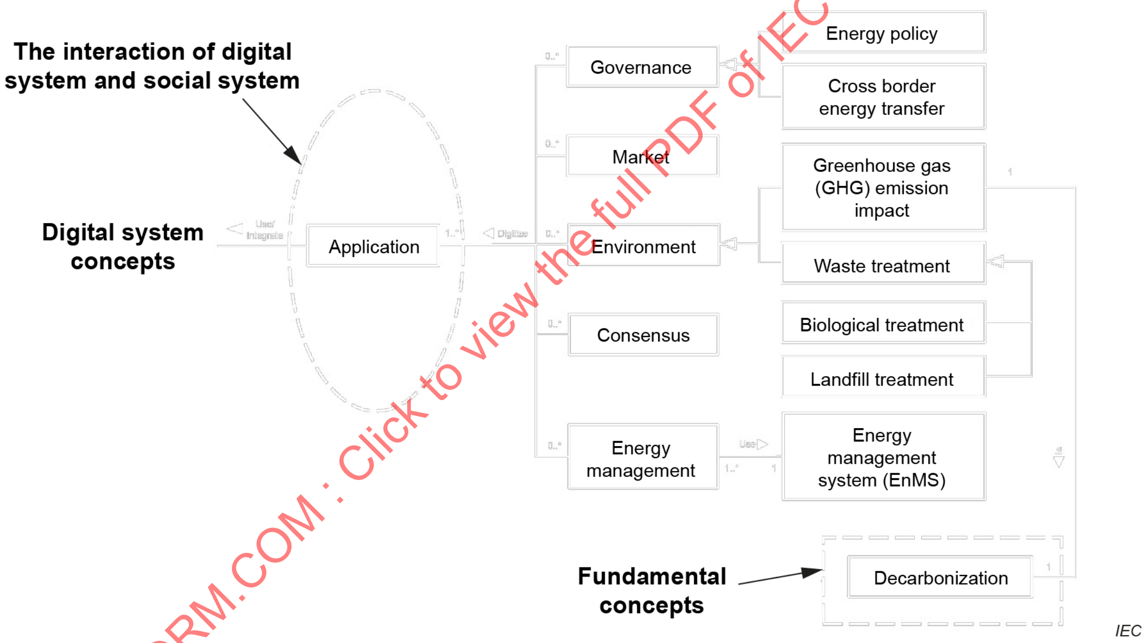


Figure 12 – Concept system for social system of energy challenges in smart cities

– City governance promotes sustainable development of economy, society, ecology and other aspects by integrating various resource elements. Countries or regions formulated a series of policies around energy production, supply and consumption, involving energy development and investment, energy prices, energy security and other aspects. For example, interconnection of DER systems is regulated by country, state, regional, or other regulatory body. The conditions under which renewable energy generation is traded in the electricity market also vary with different regulatory and legal frameworks.

– The market is divided into energy market and carbon market. From an economic perspective, energy (including electricity, heat and gas) is a commodity that can be bought, sold and traded. An energy market is a system for buying and selling energy, in which supply and demand determine prices. Carbon trading is the trading of greenhouse gas emission rights (emission reduction) established by the *Kyoto Protocol* in order to promote global reduction of greenhouse gas emissions, based on the *United Nations Framework Convention on Climate Change*.

– The environment is related to carbon and waste. In order to deal with climate change, it is essential to promote decarbonization by means of carbon footprint, carbon tax, carbon emission rights, etc. In the process of converting primary energy such as coal and oil into secondary energy such as electricity and heat, certain wastes will be generated. Environmental damage can be reduced by recycling wastes.

– An enormous effect can be anticipated from behavioural changes on the part of individuals and society. This can run from the choice of environmentally neutral means of transport, to totally changing the population's leisure pursuits, and will involve among other triggers spontaneous individual action out of concern for nature, emulation and changes in fashion, non-compulsory (e.g. financial) incentives and compulsory regulations.

– The Energy Management System (EnMS) provides an accepted framework for organizations to follow a "Plan-Do-Check-Act (PDCA)" process that drives effective energy management to achieve continuous improvement.

– Decarbonization is the process of reducing or eliminating carbon dioxide emissions. This process usually involves reducing the use of fossil fuels, increasing the use of renewable energy sources and improving energy efficiency. It requires not only the joint efforts of governments, enterprises and individuals, but also appropriate policies and measures to encourage and facilitate the implementation of decarbonization.

– Waste treatment is an important part of environmental protection and resource reuse, with biological treatment, landfill treatment and other measures. Some valuable energy combustion wastes, such as coal coke, can be recycled. Microorganisms can also be utilized to decompose the organic matter in energy combustion wastes into harmless substances to avoid pollution of the environment.

Annex A
(informative)

Concepts related to energy challenges in smart cities from different SDOs

Table A.1 shows the concepts that have been used in existing definitions from different SDOs, which are fundamental concepts of energy challenges in smart cities.

Table A.1 – Concepts related to energy challenges in smart cities from different SDOs (fundamental)

No.	Concept	Definition	Source
1	carbon footprint	net amount of greenhouse gas emissions removals, expressed as CO_2 equivalents	ISO 22067-1:2022, 3.17
2	citizen	inhabitant of a city	ISO/IEC TS 27570:2021, 3.4
3	climate change	change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer	ISO 6707-3:2022, 3.9.1
4	efficiency	ratio of output power to input power of a device	IEC 60050-151:2001, 151-15-25
5	energy challenges in smart cities	energy issues and concerns that affect the proper functioning of smart cities and their stakeholders	–
6	energy conservation	measures applied to reduce building energy use without seriously influencing the global environment and to provide the environment that achieves the design criteria	ISO 16813:2006, 3.16
7	energy efficiency	ratio of the electric energy provided from a secondary battery during discharge to the electric energy supplied to the battery during the preceding charge	IEC 60050-482:2004, 482-05-53
8	enterprise	public or private organization providing services	ISO/TS 24283-3:2022, 3.1
9	innovation	search for and the discovery, experimentation, development, implementation and adoption of new products and services	ISO 22886:2020, 3.6.9
10	integration	process of planning for and aggregating a progressively more complete set of physical, logical, or both, system elements and activating their interfaces to synthesize a system or part of a system whose properties can be verified and possibly validated	ISO/IEC/IEEE 24748-6: 2023, 3.1.4
11	interoperability	property permitting diverse systems or components to work together for a specified purpose	IEC 60050-871:2018, 871-05-06
12	life cycle	series of identifiable stages through which an item goes, from its conception to disposal	IEC 60050-192:2015, 192-01-09
13	reference architecture	authoritative source of information about a specific subject area that guides and constrains the instantiations of multiple architectures and solutions	ISO/IEC 20547-3:2020, 3.2
14	resilience	ability to anticipate and adapt to, resist or quickly recover from a potentially disruptive event, whether natural or man-made	ISO 6707-3:2022, 3.10.30

No.	Concept	Definition	Source
15	smart city	city that increases the pace at which it provides social, economic and environmental sustainability outcomes and responds to challenges such as climate change, rapid population growth, and political and economic instability by fundamentally improving how it engages society, applies collaborative leadership methods, works across disciplines and city systems, and uses data information and modern technologies to deliver better services and quality of life to those in the city (residents, businesses, visitors), now and for the foreseeable future, without unfair disadvantage of others or degradation of the natural environment	ISO/IEC TS 5147:2023, 3.1.11
16	solution	set of entities such that an equation becomes a true equality if the symbols for unknown entities refer to them	IEC 60050-102:2008, 102-01-26
17	stakeholder	person or organization that can affect, be affected by, or perceive themselves to be affected by a decision or activity	IEC 62960:2020, 3.1.13
18	sustainability	state of the global system (IEV 831-01-21) including the environmental, social, economic aspects, in which the needs of present are met without compromising the ability of future generations to meet their own needs	IEC 60050-831:–, 831-01-20
19	system of systems	set of operationally and managerially independent systems that are operated together for a period of time to achieve one or more stated purposes	IEC 60050-871:2018, 871-05-03
20	vision	aspiration of what an organization would like to become as expressed by top management	ISO 22886:2020, 3.5.10

Table A.2 shows the concepts that have been used in existing definitions from IEC and ISO, which are concepts relating to physical system of energy challenges in smart cities.

Table A.2 – Concepts related to energy challenges in smart cities from different SDOs (physical system)

No.	Concept	Definition	Source
1	actuator (the intersection of physical system and digital system)	IoT device that changes one or more properties of a physical entity in response to a valid input	IEC 60050-741:2020, 741-02-02
2	ADS-equipped vehicle automated vehicle (AV)	vehicle integrated with an ADS	ISO/TS 14812:2022, 3.7.3.15
3	advanced metering infrastructure	communications hardware and software and associated system and data management software that creates a network between advanced meters and utility business systems which allows collection and distribution of information to customers and other parties such as competitive retail suppliers, in addition to the utility itself [DRAM 2008]	IEC TS 61968-2:2011, 2.19
4	air-conditioning system	system which lowers the effective temperature of the air within the operator enclosure.	ISO 14269-2:1997
5	arc furnace	electric furnace with a chamber, in which a charge is heated mainly by electric arc	IEC 60050-841:2004, 841-26-05
6	automated urban guided transport (AUGT)	system featuring driverless or unattended train operation (as defined below) with self-propelled, guided vehicles, operating on an exclusive guide way	IEC 62267:2009, 3.1.1
7	automated vehicle	mobile device that includes a control system allowing it to operate either autonomously or under remote control	IEC TS 62443-1-1:2009, 3.2.15

No.	Concept	Definition	Source
8	automation system	system for loading and/or unloading of workpieces by highly automatic means, reducing human process intervention to a minimum	ISO 14955-4:2019, 3.15
9	battery	one or more cells fitted with devices necessary for use, for example case, terminals, marking and protective devices	IEC 60050-482:2004, 482-01-04
10	battery-electric vehicle (BEV)	electric vehicle with only a traction battery as the power source for vehicle propulsion	ISO/TR 13062:2015, 2.1.1.4
11	battery energy storage system BESS	stationary system to store and convert back electrical energy, which contains components necessary for this function, especially the battery, the power conversion system and the energy management system.	IEC 62485-5:2020, 3.1.3
12	battery management system (BMS)/ battery management unit (BMU)	electronic system associated with a battery which has functions to cut off in case of overcharge, overcurrent, overdischarge, or overheating	IEC 63115-1:2020, 3.6
13	biogas	gas mixture generated during anaerobic digestion consisting mainly of methane and carbon dioxide	ISO 19388:2023, 3.1.5
14	building	permanent construction provided with main services (e.g. water, electricity, gas, etc.) designed to protect equipment against the action of environmental conditions. A building may or may not be provided with climatic control	IEC 62498-3:2010, 3.5
15	building attached PV (BAPV)	system in which the PV modules are mounted on a building envelope and do not fulfil the criteria for building integrated PV	IEC 61730-1:2023, 3.3.1
16	building control system	measures taken to ensure the system operates in accordance with the specified conditions	ISO 19455-1:2019, 3.2
17	building information modelling (BIM)	use of a shared digital representation of an asset to facilitate design, construction and operation processes to form a reliable basis for decisions	ISO 23386:2020, 3.6
18	building information system (BIS)	systems, processes and sources of data about a building or its pattern of use	ISO/TS 50008:2018, 3.1
19	building integrated PV (BIPV)	system in which the PV modules form a building component providing additional functions as defined in 5.5 b)	IEC 61730-1:2023, 3.3.2
20	building management	persons or organization responsible for ensuring the day-to-day safe efficient running of the building and for ensuring the building is safely evacuated in line with the evacuation strategy	ISO/TS 18870:2014, 3.4
21	building-attached photovoltaics (BAPV)	photovoltaic materials that are simply attached to the building	ISO/TS 18178: 2018, 3.6
22	building-integrated photovoltaic module	photovoltaic module that provides one or more of the functions of the building envelope	IEC 63092-1:2020, 3.2
23	built environment	building or other structure	IEC 60695-1-12: 2015, 3.4
24	carbon capture and storage	long-term removal, capture or reduction of carbon dioxide from the atmosphere to slow or reverse CO_2e saturation and to mitigate or reverse global warming	ISO 6707-3:2022, 3.9.25
25	consumer electronics (CE)	class of devices used in the home, such as DVDs, DVRs, PVRs, PDAs, TVs, set-top boxes, cellular phones	IEC 62481-1-1:2017, 3.1.19
26	charging point	unit in a charging station at which an electric vehicle can be supplied with power	ISO/TS 21219-25: 2017, 3.4
27	charging station	physical equipment consisting of one or more CSCs and one or more EVSEs managing the energy transfer to and from EVs	IEC 63110-1:2022, 3.1.10

No.	Concept	Definition	Source
28	combined heat and power (CHP)	energy efficient technology that generates electricity and captures the heat that would otherwise be wasted to provide useful thermal energy – such as steam or hot water – that can be used for space heating, cooling, domestic hot water and industrial processes	IEC TR 63388:2021,
29	internal combustion engine	engine, which generates motive power by the burning of a fuel-air mixture by means of a crank mechanism	ISO 24195:2022, 3.17
30	customer energy manager (CEM)	central managing function used by the customer to manage the flow of information between the grid and connected smart devices at the customer premises	IEC TS 62746-3: 2015, 3.1.4
31	DC distribution network	local DC electricity supply network in the infrastructure of a certain site or building intended for connection of any type of equipment	IEC 61326-3-2: 2017,3.1.11
32	demand response (DR)	action resulting from management of the electricity demand in response to supply conditions	IEC 60050-617:2011, 617-04-16
33	demand response	ability of an organization consuming energy to respond to a trigger by lowering or raising their power consumption temporarily	ISO/PAS 50010:2023, 3.2.7
34	digital twin building	digital representation of a physical facility that receives sensor information from the facility and sends actuation information to the facility	ISO 6707-4:2021, 3.5.4
35	distributed energy resource system	collection of DER Units. This collection may also be called a DER plant or a DER facility	IEC 61850-7-420: 2021, 3.1.14
36	distributed energy resource (DER)	energy resource, often of a small size, operated by the utility to augment the local supply of energy	IEC 62872-2:2022, 3.3.6
37	distribution automation	actions to carry out automation of the distribution networks to enable automatic or remote operation	IEC TS 61968-2:2011, 2.87
38	distribution line	overhead line which is used for the distribution of electricity	IEC 60050-466:1990, 466-01-14
39	distribution management system (DMS)	computer system comprising a software platform providing basic support services and a set of applications providing the functionality needed for the effective operation of electrical distribution facilities so as to assure adequate security of energy supply at minimum cost	IEC 61968-11:2013, 3.2
40	distribution network	a collection of equipment and infrastructures that delivers information flows from the Access node to the Network termination elements of the Access network.	ISO/IEC 16500-4:1999, 3.13
41	domestic photovoltaic system	PV system that electrifies household loads	IEC TS 61836:2016, 3.3.65.4
42	dual-mode vehicle driving automation dual-mode vehicle	<driving automation> ADS-equipped vehicle designed for both driverless operation and operation by a conventional driver for complete trips	ISO/TS 14812:2022, 3.7.3.16
43	electric arc furnace	furnace that melts and refines iron-bearing material into steel	ISO 14404-4:2020, 3.10.5
44	electric motor	electric machine intended to transform electric energy into mechanical energy	IEC 61800-2:2021, 3.36
45	electric vehicle (EV) electric road vehicle	any vehicle propelled by an electric motor drawing current from an RESS intended primarily for use on public roads	IEC 62196-1:2022, 3.13
46	electric vehicle electrically propelled vehicle (EV)	vehicle with one or more electric drive(s) for vehicle propulsion	ISO/TR 13062: 2015, 2.1.1.3
47	electrical energy management system (EEMS)	system comprising different equipment and devices in the installation for the purpose of energy management	IEC 60364-8-2:2018, 3.9

No.	Concept	Definition	Source
48	electrical energy storage management	collection of methods used to manage EES with software, hardware, and services associated with the intelligent monitoring, management, and control of EES, for the specific purposes such as the enhancement of a system's efficiency, cost reduction or optimization of energy utilization to meet EES users' needs	IEC SRD 62913-2-3:2019, 3.1.12
49	electrical installation of building	assembly of associated electric equipment located in a building and having coordinated characteristics to fulfil specific purposes	IEC TS 62257-5:2015, B.1.5
50	electricity	set of the phenomena associated with electric charges and electric currents	IEC 60050-121:1998, 121-11-76
51	energy management system (EMS)	computer system comprising a software platform providing basic support services and a set of applications providing the functionality needed for the effective operation of electrical generation and transmission facilities so as to assure adequate security of energy supply at minimum cost	IEC 61970-301:2020, 3.1
52	energy storage	capture of energy produced at one time for use at a later time	IEC 61850-7-420:2021, 3.1.22
53	energy storage capacity	measure of the amount of energy a storage device can store and deliver, within established design limits and maintenance interval conditions	IEC TS 62600-1:2011, 2.23
54	energy storage capacitor	a power capacitor intended to store energy and to release it within a very short time	IEC 60050-436:1990, 436-02-08
55	energy storage system (ESS)	energy resource capable of storing energy for later use	IEC 62872-2:2022, 3.3.22
56	EV charging station	stationary part of EV supply equipment connected to the supply network	IEC 61851-1:2017, 3.1.5
57	flexibility aggregator	entity that buys and aggregates the flexibility of consumption (demand response) and distributed generation in order to value them on the market and through the transportation products (adjustment mechanism, capacity market)	IEC SRD 62913-2-2:2019, 3.1.5
58	flywheel storage system	mechanical energy storage system wherein stored kinetic energy can be converted to DC power during stored energy mode of operation	IEC 62040-3:2011, 3.1.10
59	fuel cell hybrid-electric vehicle (FCHEV)	electrically propelled vehicle with an RESS and a fuel cell system as power source for vehicle propulsion	ISO/TR 13062:2015, 2.1.1.7
60	fuel cell vehicle (FCV)	vehicle which stores hydrogen on-board and uses a fuel cell system to generate electricity for propulsion	ISO 19880-8:2019, 3.7
61	fuel cell	cell that can change chemical energy from continuously supplied reactants to electric energy by an electrochemical process	IEC 60050-482:2004, 482-01-05
62	gas	materials which are present completely in gaseous form at a temperature of 20 °C under the absolute pressure of 0,101 3 MPa. Note 1 to entry: The materials here include single mediums and mixtures.	ISO 19230:2020, 3.1
63	gas cleaning system	equipment for the collection and processing of created off-gas	ISO 13578:2017, 3.14
64	gas detection control unit	equipment intended to provide display indication, alarm functions, output contacts or alarm signal outputs or any combination when operated with remote sensor(s)	IEC 62990-1:2019, 3.2.10
65	gas pipeline	system of pipework for transportation of gas with all associated equipment and stations up to the point of delivery.	ISO 20675:2018, 3.27
66	heat	form of energy that is transferred by virtue of a temperature difference or a change in state of a material	ISO 16818:2008, 3.117