34th Annual INCOSE international symposium

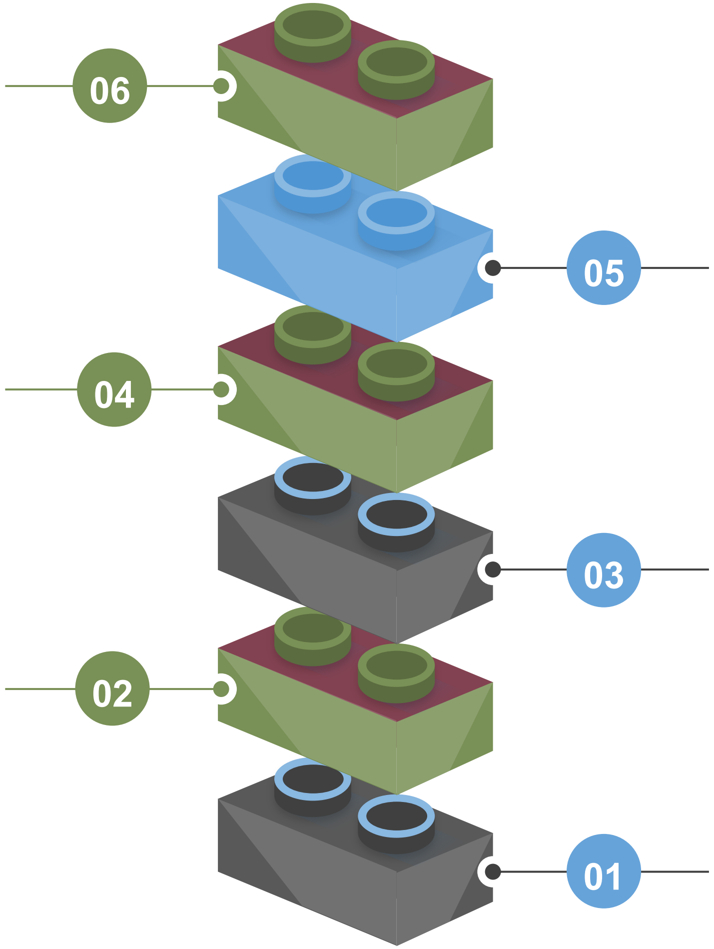
hybrid event

Dublin, Ireland
July 2 - 6, 2024

Smart Cities from Architecture to Application: A socialization of industry best practices

Our Panelists represent a global perspective

Christian Neureiter, PhD
Austria



Martin Serrano, PhD
Ireland

Ray Barton, PhD
Canada

Cecilia Haskins, PhD
Norway

Jawahar Bhalla, PhD Candidate
Australia

Jennifer Russell, EISE
USA

Cities are layered with interacting teams

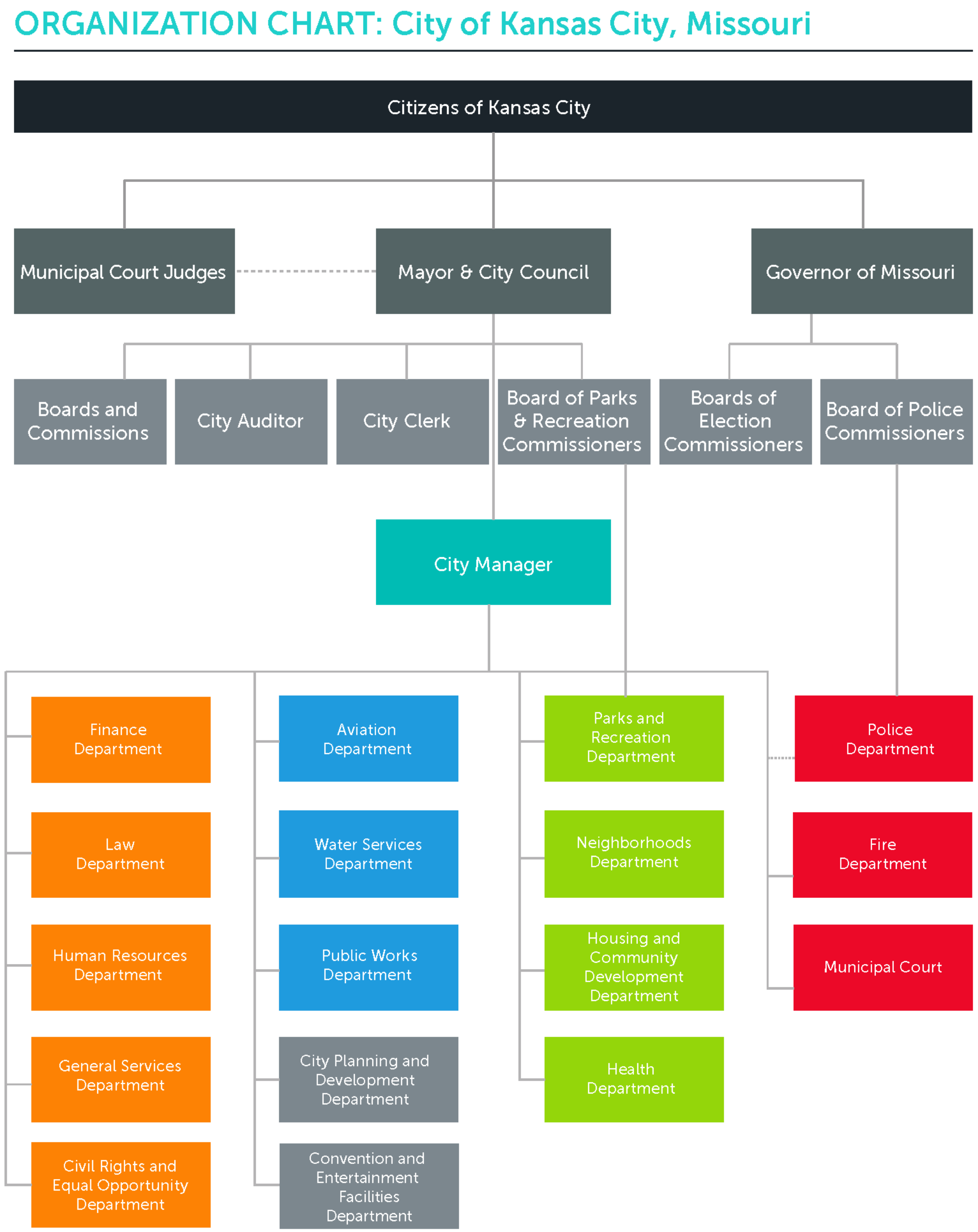
Elected officials

Specialized officials

The Glue?

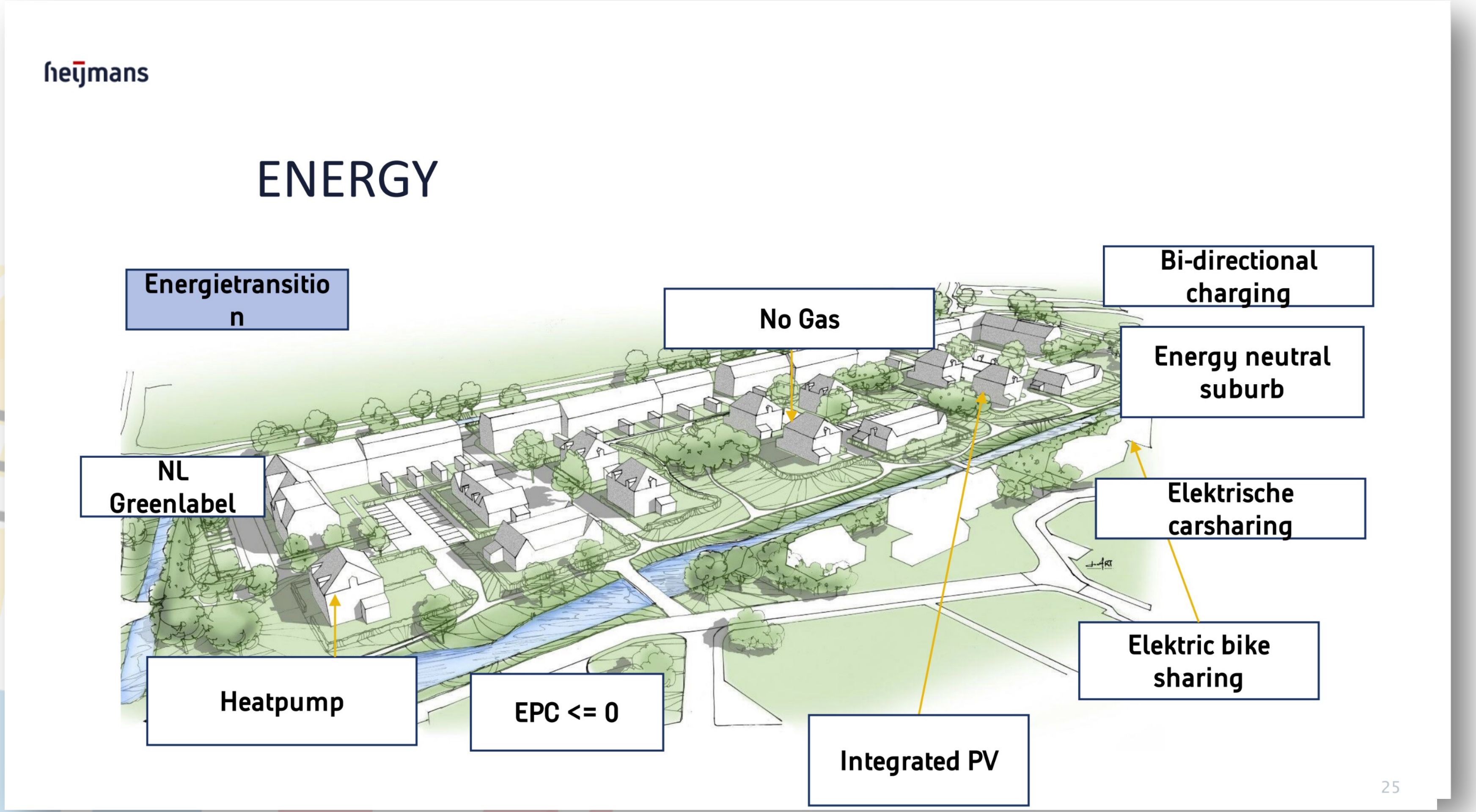
The Executors

4,022 employees in 17 Departments



https://stories.opengov.com/kansascitymo/published/jBjpAqzaW

Smart city applications are evolving as seen in Heijman's rural development in Maanwijk, Luesden, Netherlands

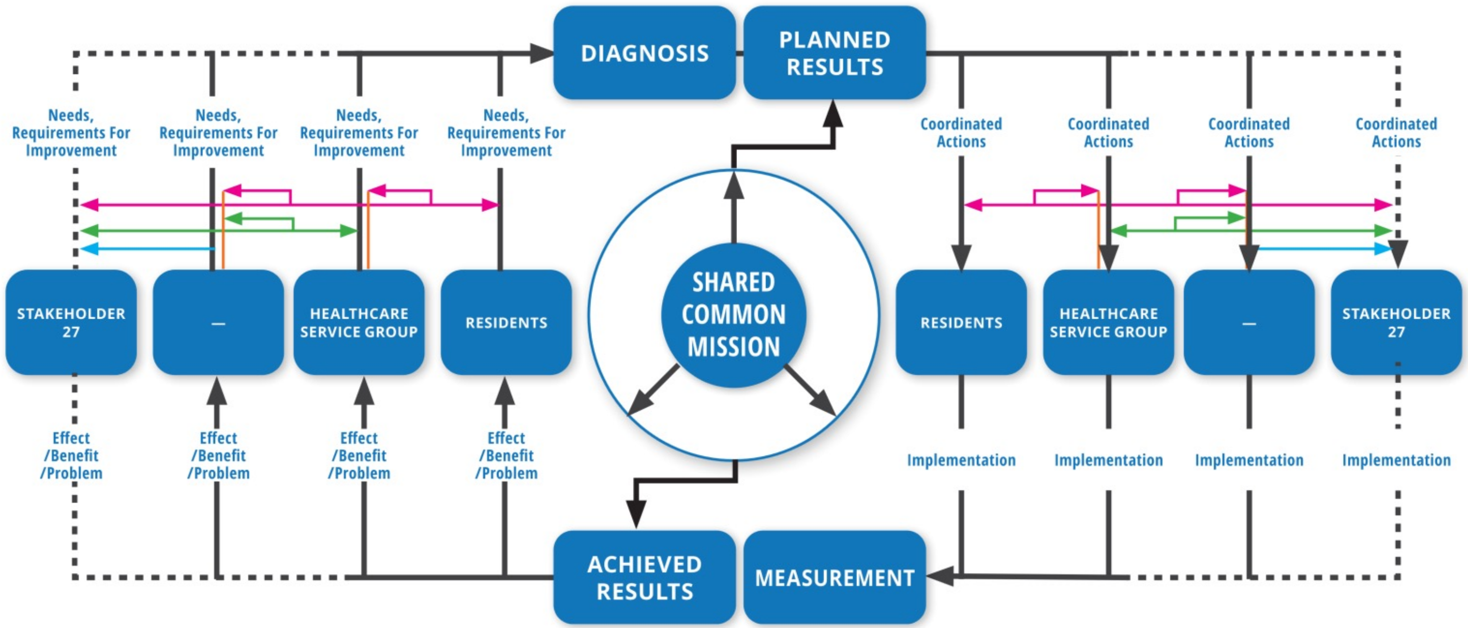


INCOSE Smart City Definition provides evaluation and comparison

- A smart city is capable of
- identifying its problems and
- mitigating root causes
- by generating and processing
- engineered quality data in a continuous and inclusive manner.

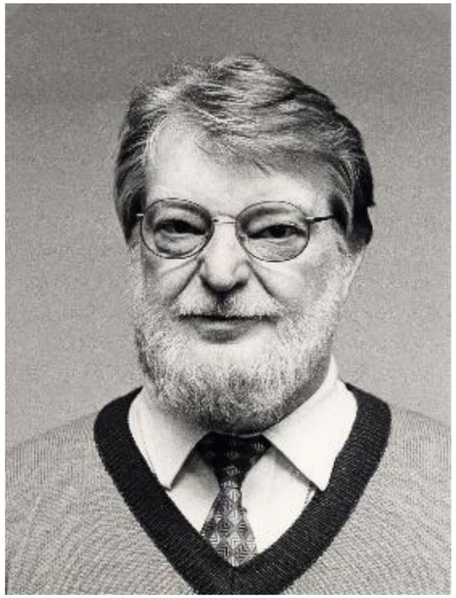
Smart Cities Initiative

The INCOSE-TUS Reference Model is a robust, tailorable, and systematic way to view and evaluate a smart city as an integrated complex social system



Smart Cities Initiative

Fundamental human needs are the basis for a Smart City's goal



Economist
Artur Manfred Max Neef /*1932-2019/*

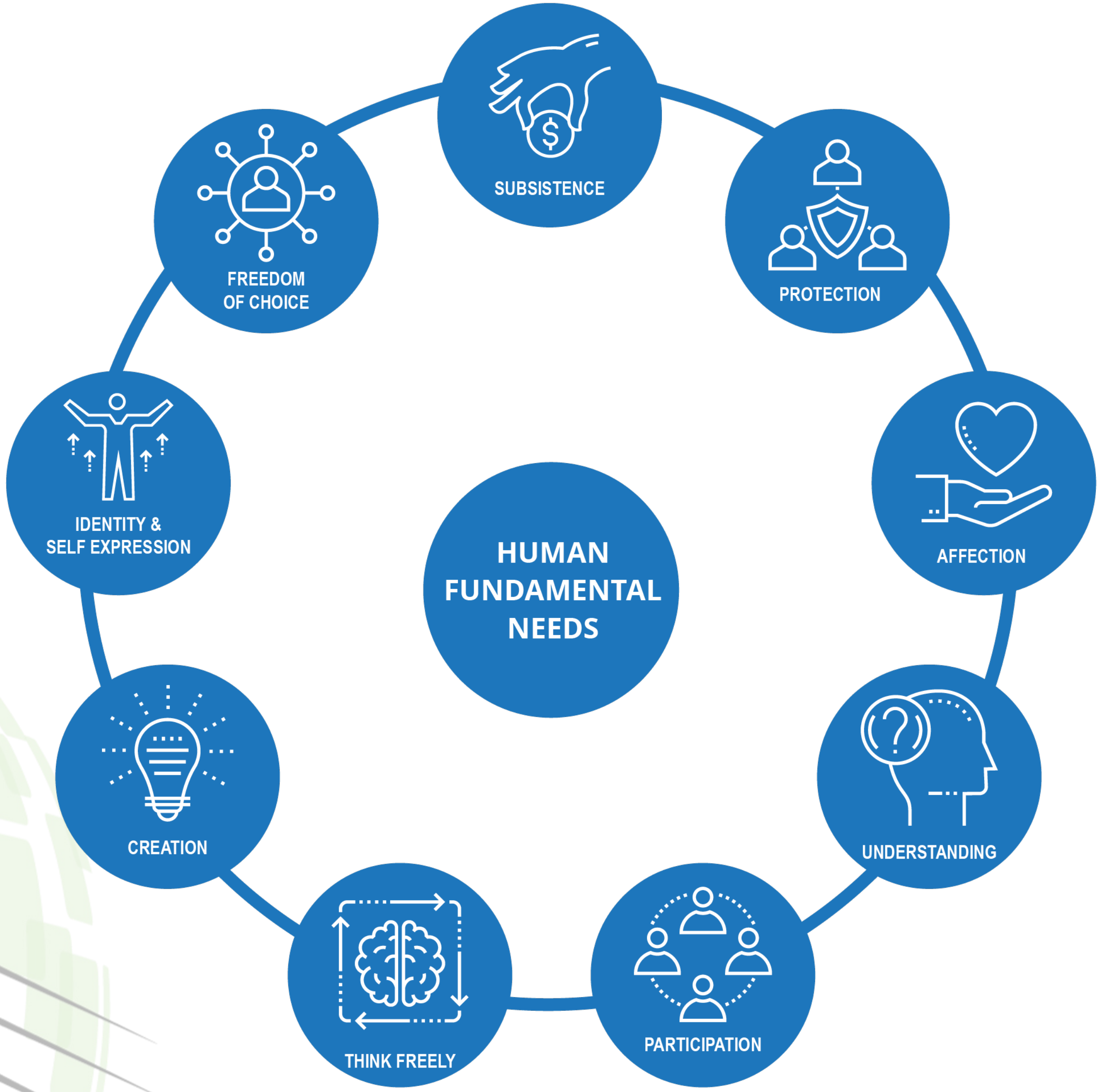


Figure 4: Based on Max Neef's Human Fundamental Needs

Smart Cities Initiative

Christian Neureiter, PhD

Application of Architecture

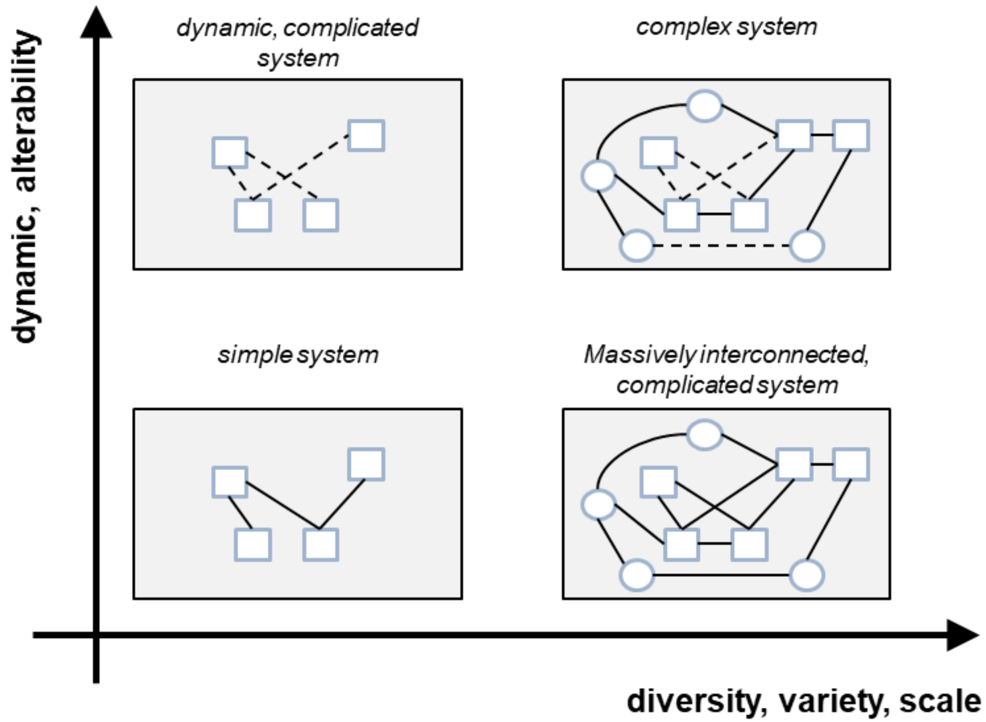
An Engineer‘s Perspective on Developing System-of-Systems

Developing Smart Cities

The Challenge: A System's Perspective

Smart City as Cyber-Physical System

- Integrations of computation with physical processes
- Embedded computers and networks monitor and control the physical processes (…) where physical processes affect computations and vice versa.



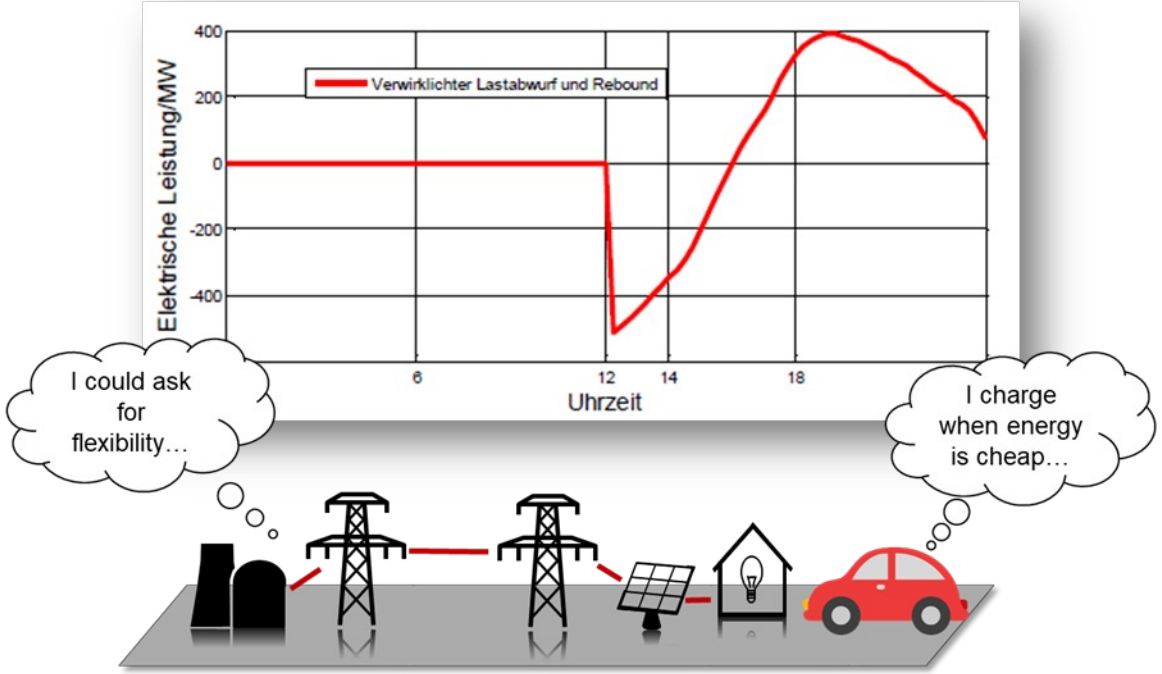
Challenges

- Need for dependability
- Increasing Complexity
- Interdisciplinary Collaboration

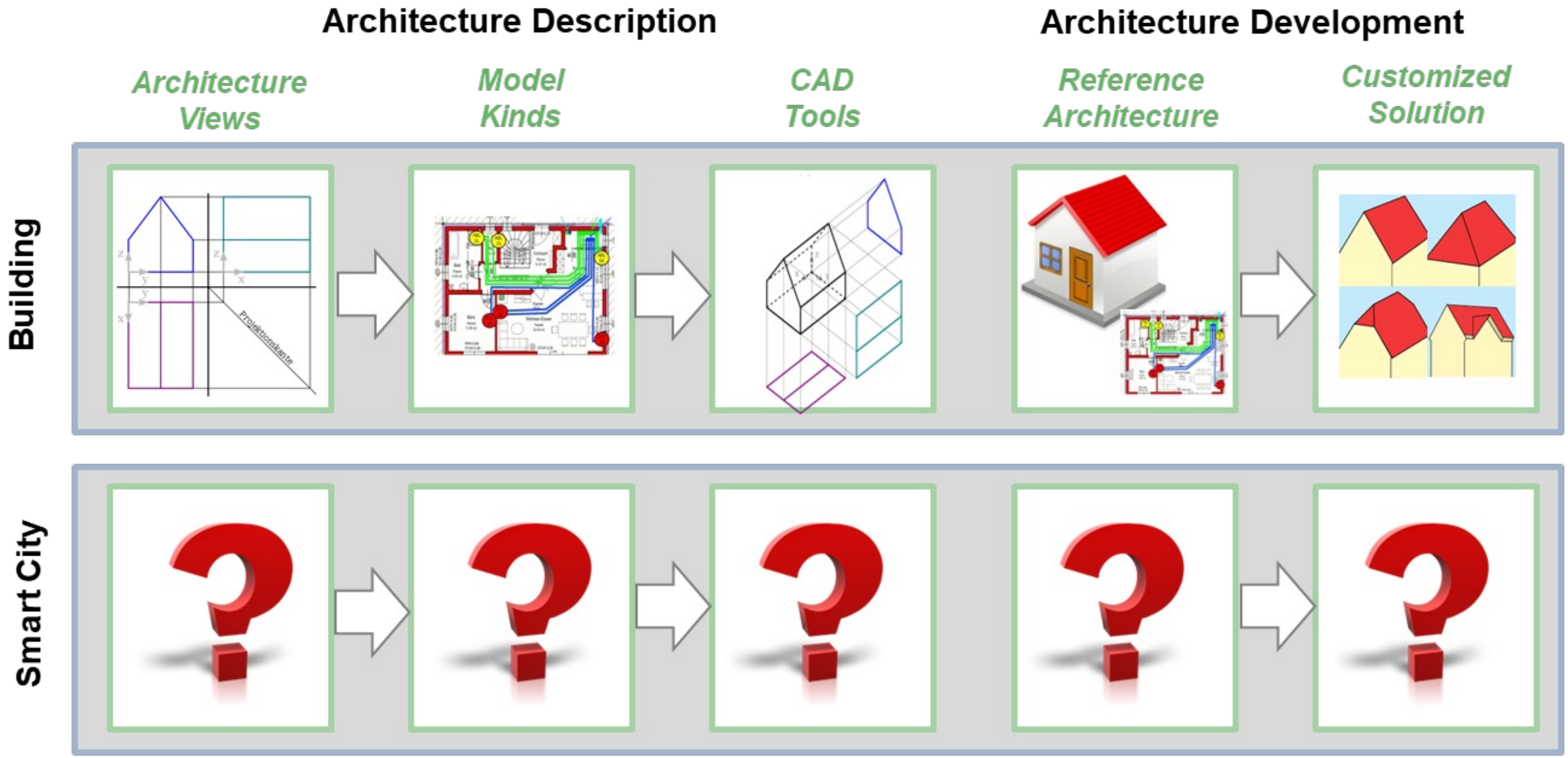
The Challenge: A System’s Perspective

Smart City as System-of-Systems

- Operational independence of elements
- Managerial independence of elements
- Evolutionary development
- Geographical distribution of elements
- Interdisciplinary study
- Heterogeneity of systems
- Networks of systems
- Emergent behavior



How to build a house?



Example: Generic Modeling Stack

Domain Model

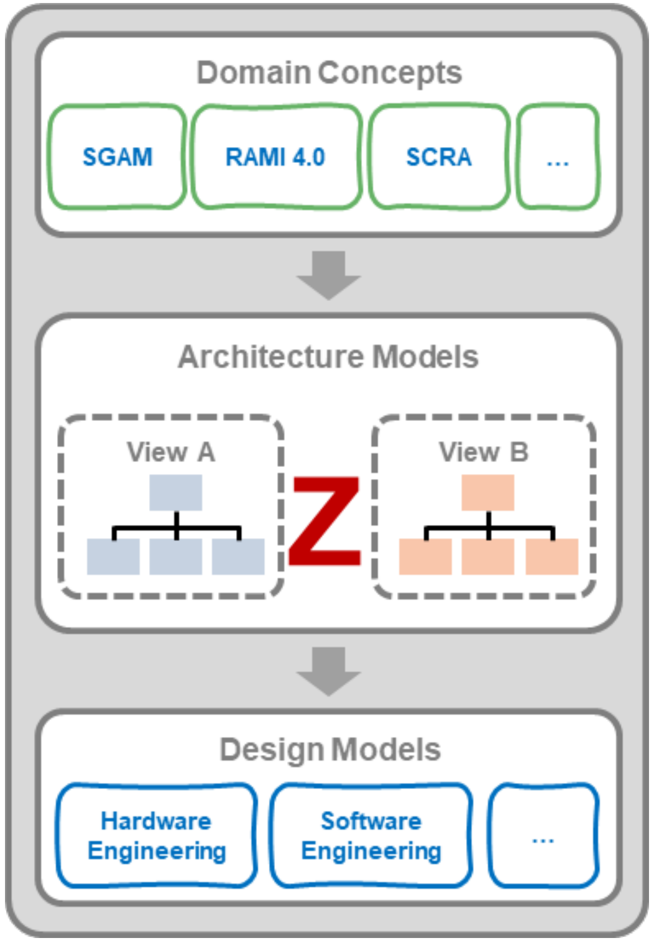
- Application Domain
- → Involve Stakeholders

Architecture Model

- System Architecture
- → Decompose Systems

Design Model

- Detailed Design
- → Develop Components



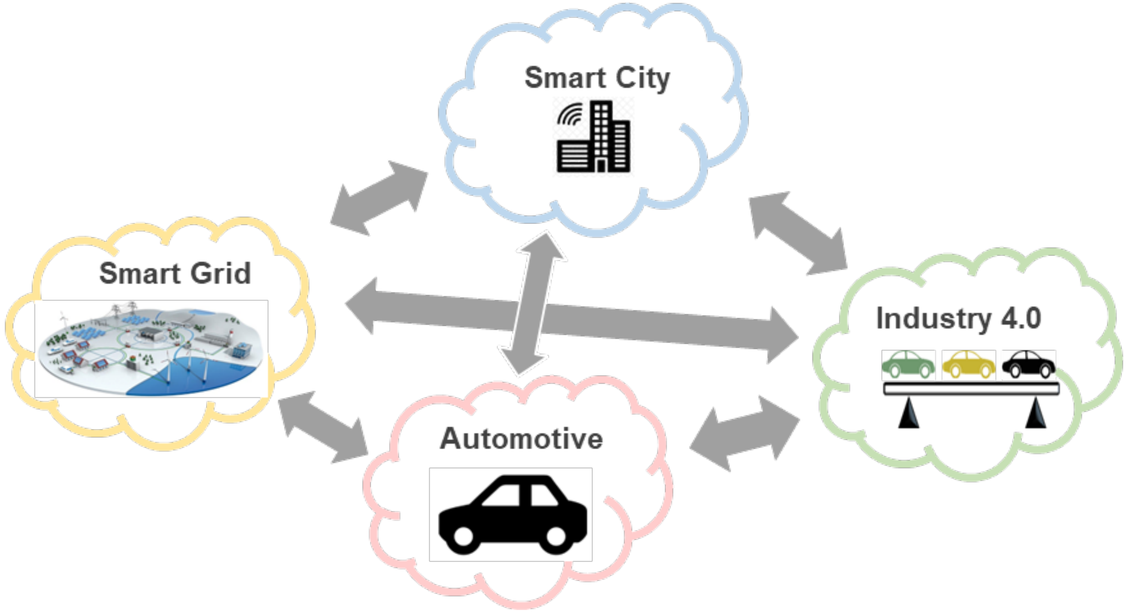
Smart City as "System-of-Systems"

Smart City as System-of-Systems

- Integration of different Systems
- Integration of different Domains
- Integration of different Models

Hypothèses:

« When Systems shall be interoperable,
Models need to be as well »

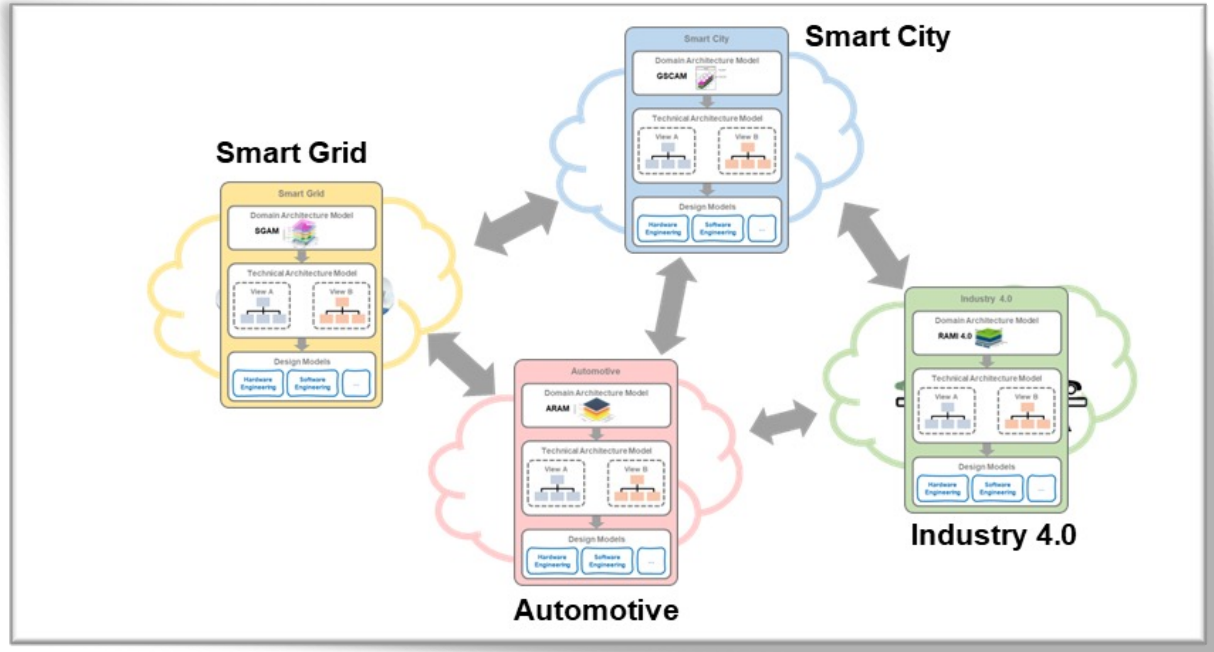


My Position

- Smart Cities represent System-of-Systems
- They are challenged by complexity, interdisciplinarity, dependability

"If we want to be able to develop dependable Smart Cities, we need to find :

(1) trans-disciplinary engineering approaches and
(2) trans-disciplinary modelling concepts



Martin Serrano, PhD

Application to Policy

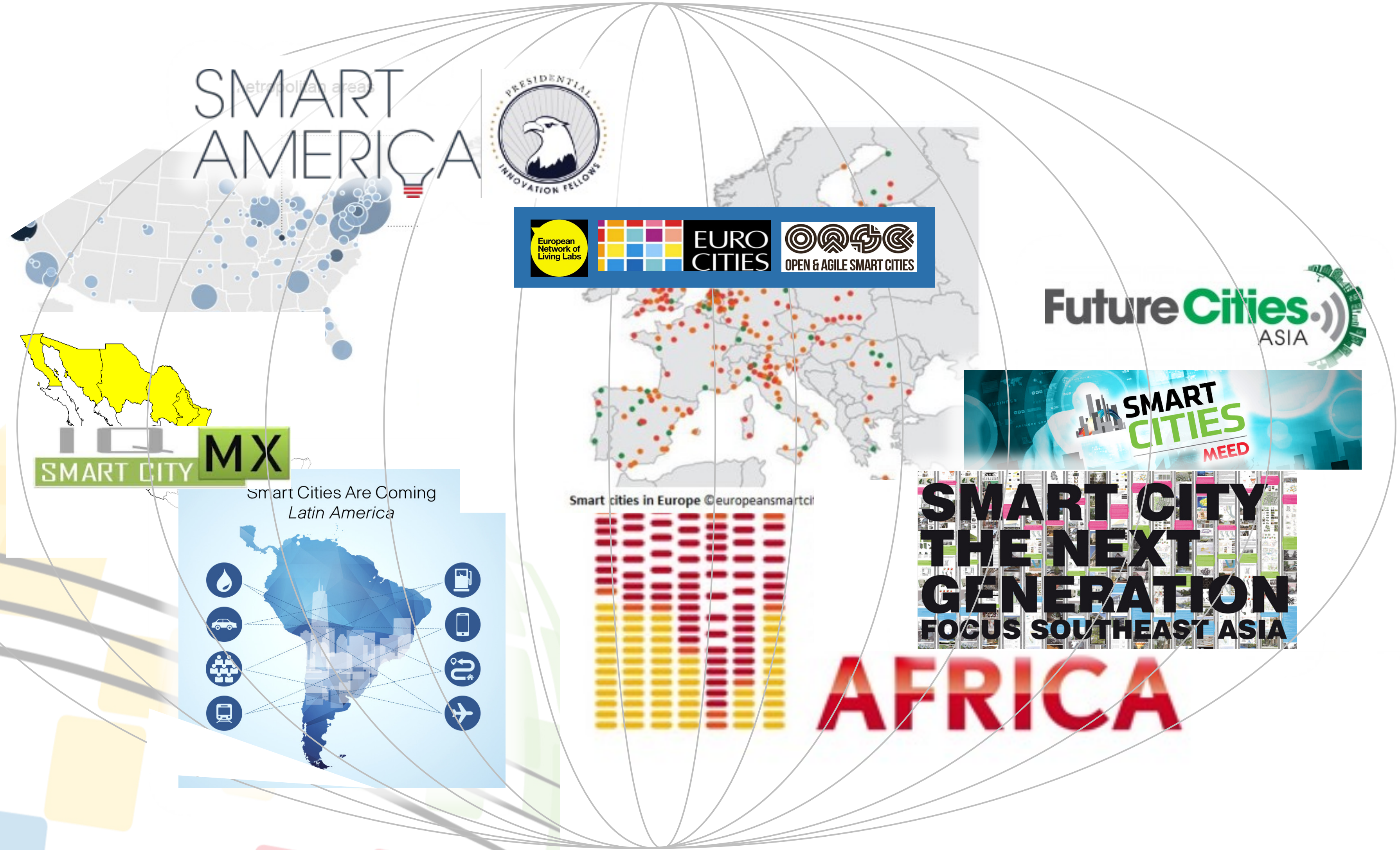
Smart City
A Data-Driven Society

Data is produced everywhere, everytime by Everyone …

Insight
SFI RESEARCH CENTRE FOR DATA ANALYTICS

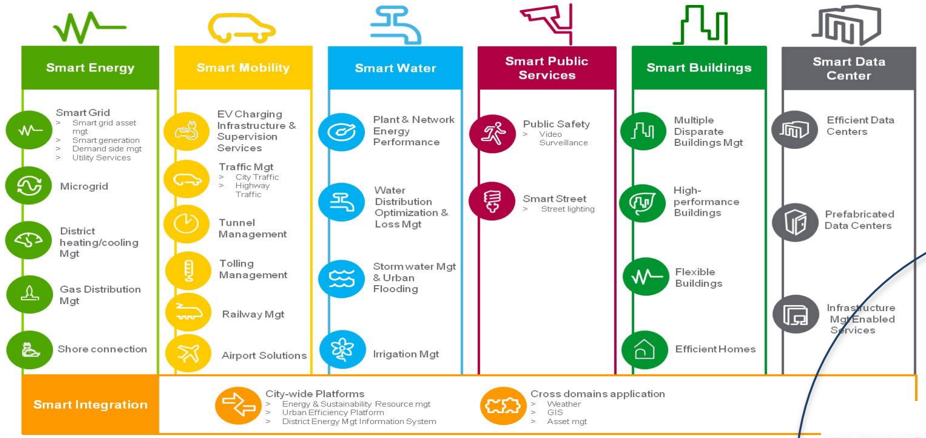
OLLSCOIL NA GAILLIMHE
UNIVERSITY OF GALWAY

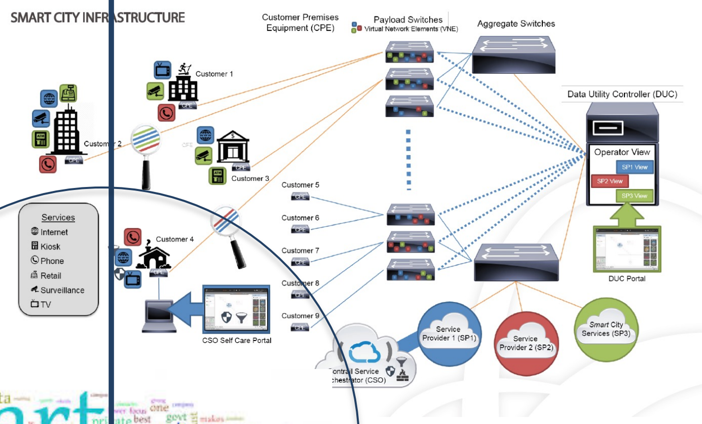
#SmartCityCulture in Place #Global



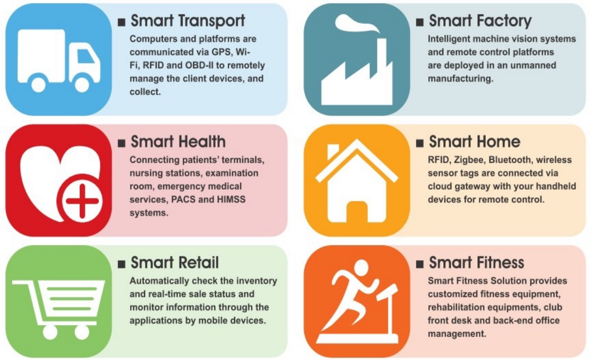
#SmartCity Multiple Views

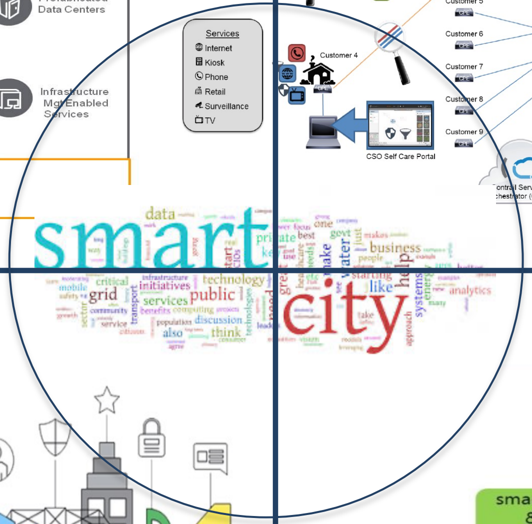
Services and Infrastructure



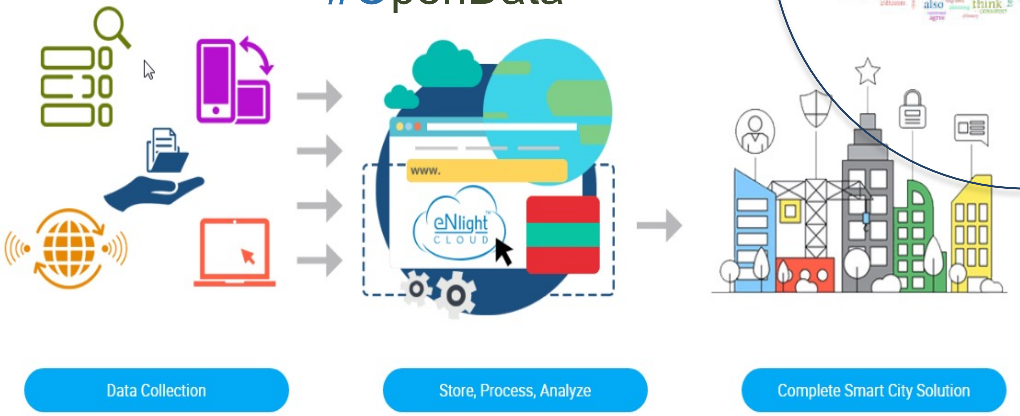


Citizens & Technology



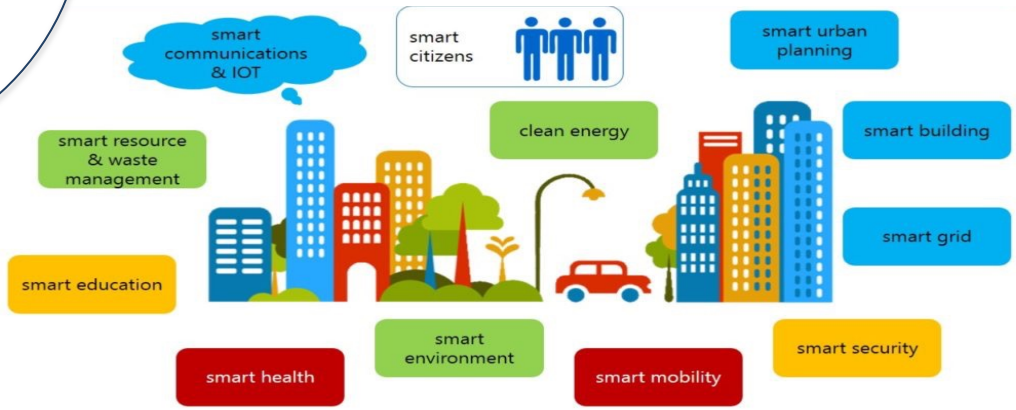


#OpenData



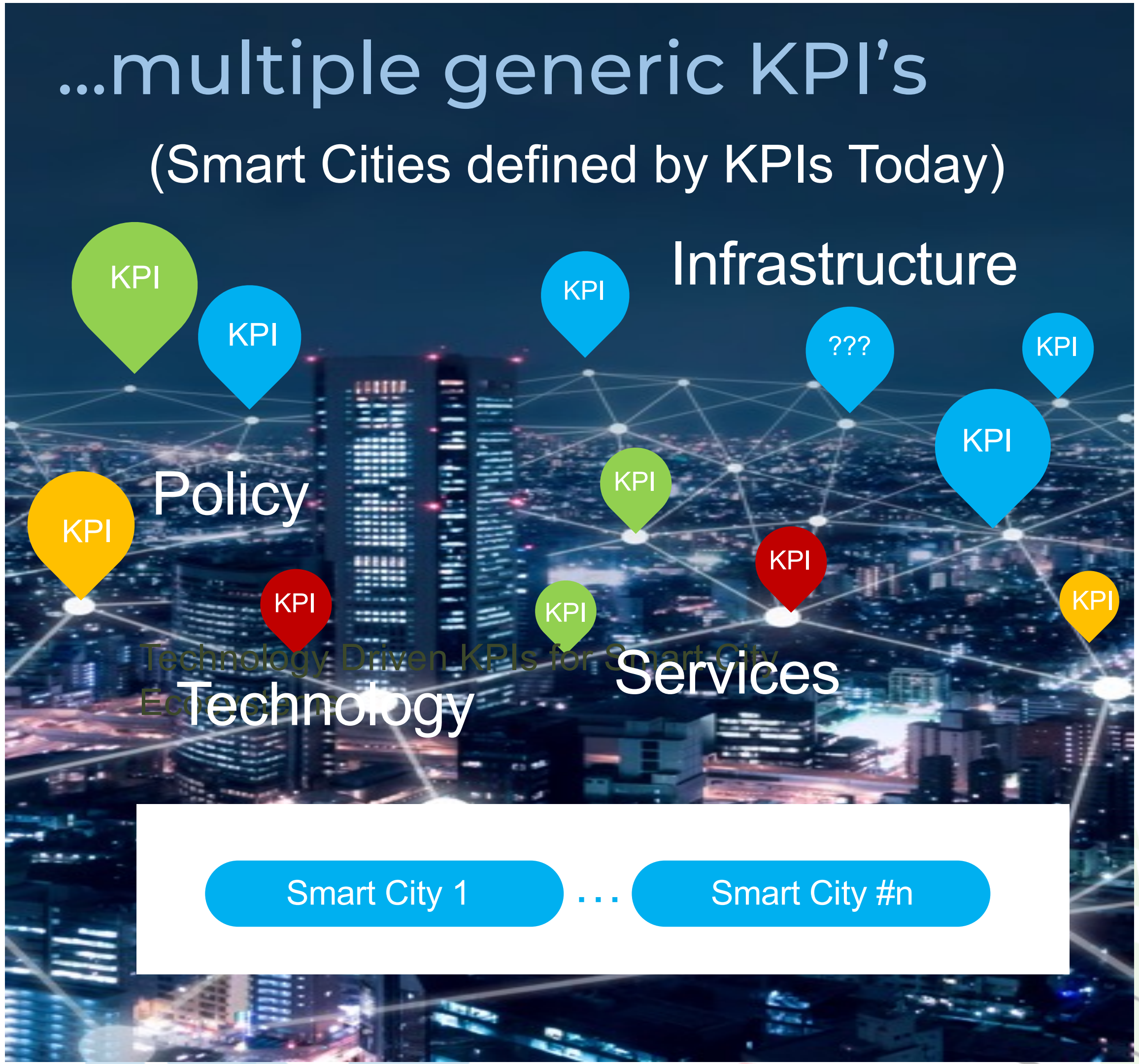
Data Openness & Interoperability

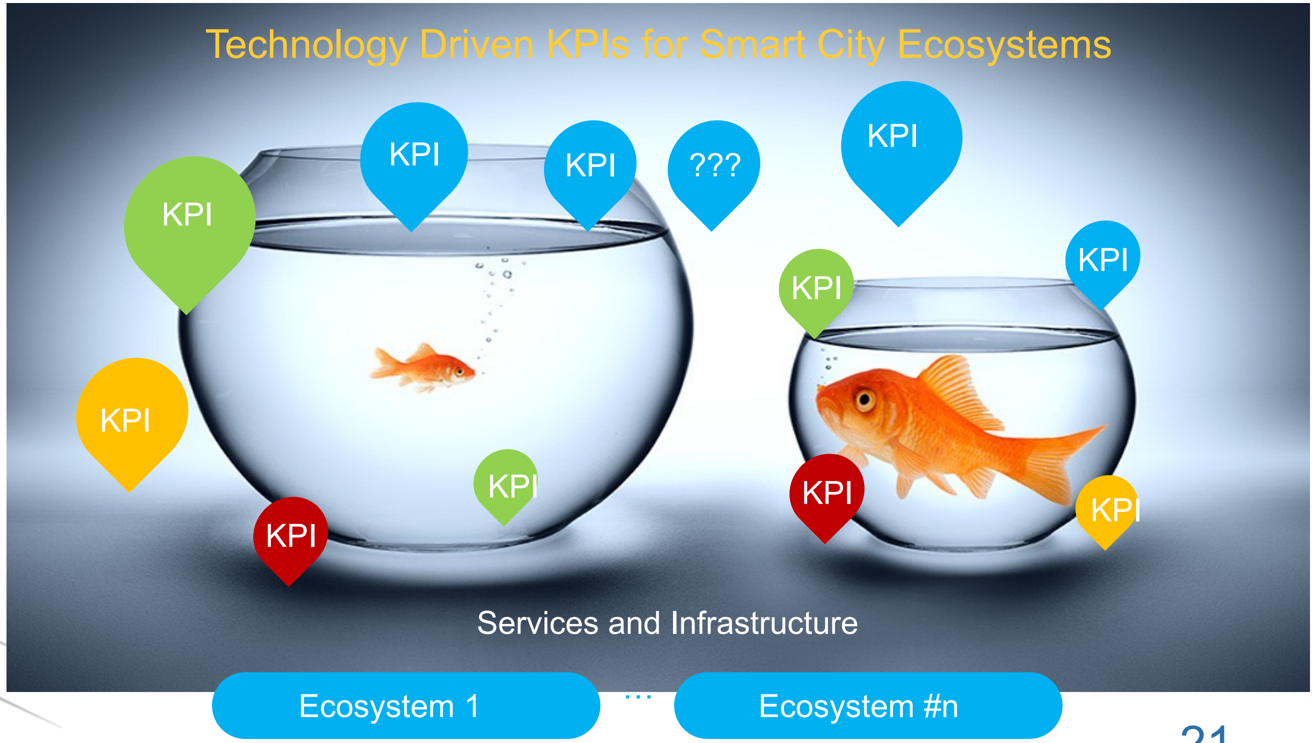
#e-Government



Policy & Good Government

#SmartCity Problems Today





Frameworks – Conceptual Structures for Collective Understanding

2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

Smart Grid

Cloud Computing

Cybersecurity

Community Disaster Resilience

Big Data

Global City Teams Challenge Blueprints

Cyber-Physical Systems

IoT Enabled Smart City Framework

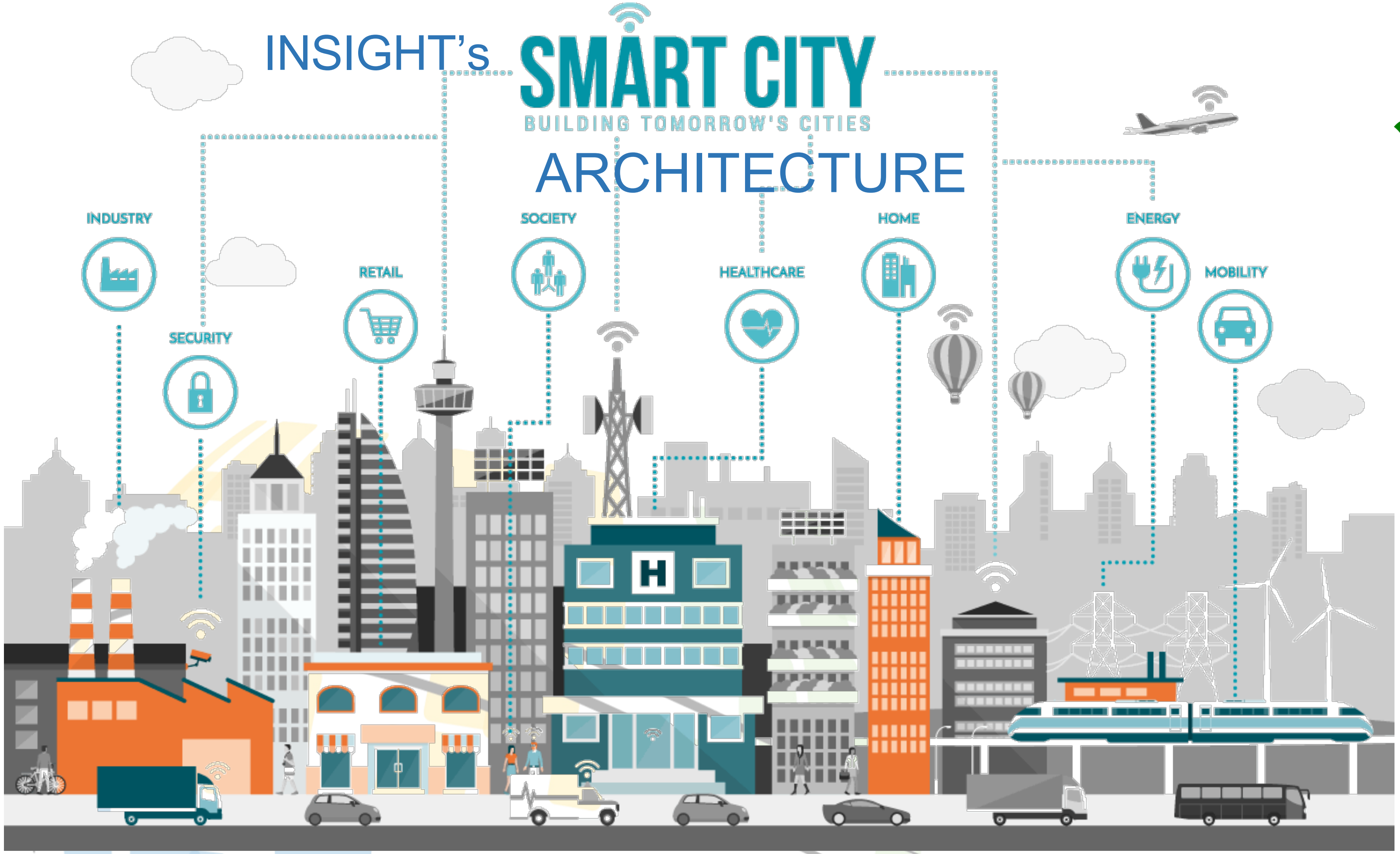
NIST Cybersecurity Framework v.1

Holistic KPIs for Smart Cities

- Frameworks are documented conceptual structures that organize and make clear collective wisdom (vision, principles, underlying structure, functions, requirements)
- Frameworks are created with technical expertise through a consensus-based process involving all relevant stakeholders
- Representing a range of perspectives, viewpoints, interests, communities of practice, processes, and policy objectives

Smart Grid Stakeholder Conference 2009

#Smart Cities Cluster #Ireland



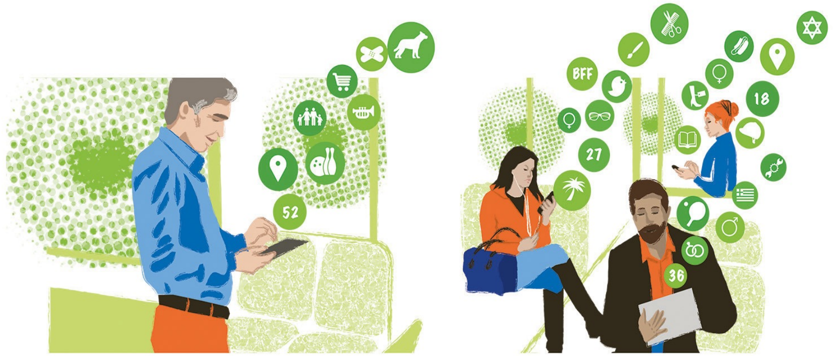
- ✓ Measurements
- ✓ View
- ✓ Vision
- ✓ Expertise
- ✓ Experience
- ✓ Technology
- ✓ Plan
- ✓ Roadmap

#Measuring Smart #Data Services

Smart Cities needs new Methodologies to Use Collected Data then Understand Real Needs and Produce Economy Benefits

Measuring ‘Smart’ in ’Smart City’

Smart = **Efficient use of digital technologies to provide prioritized services and benefits to the community.**

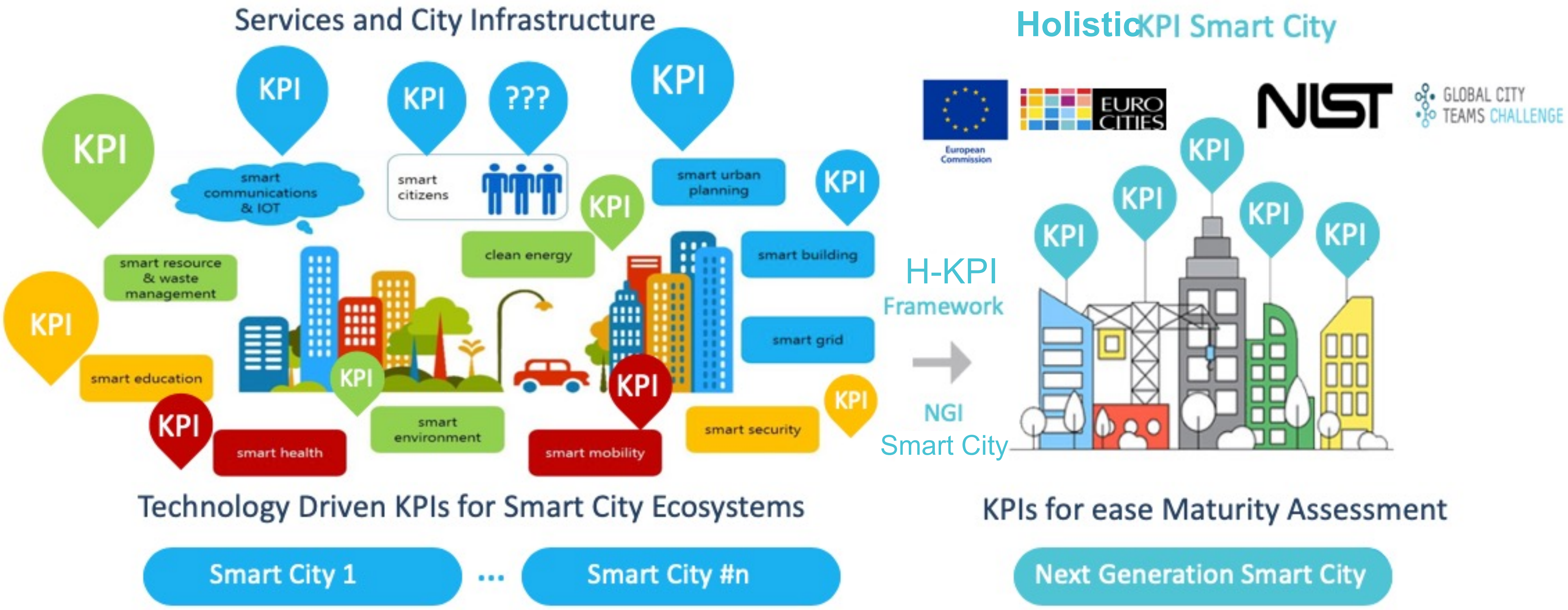


Data Producers

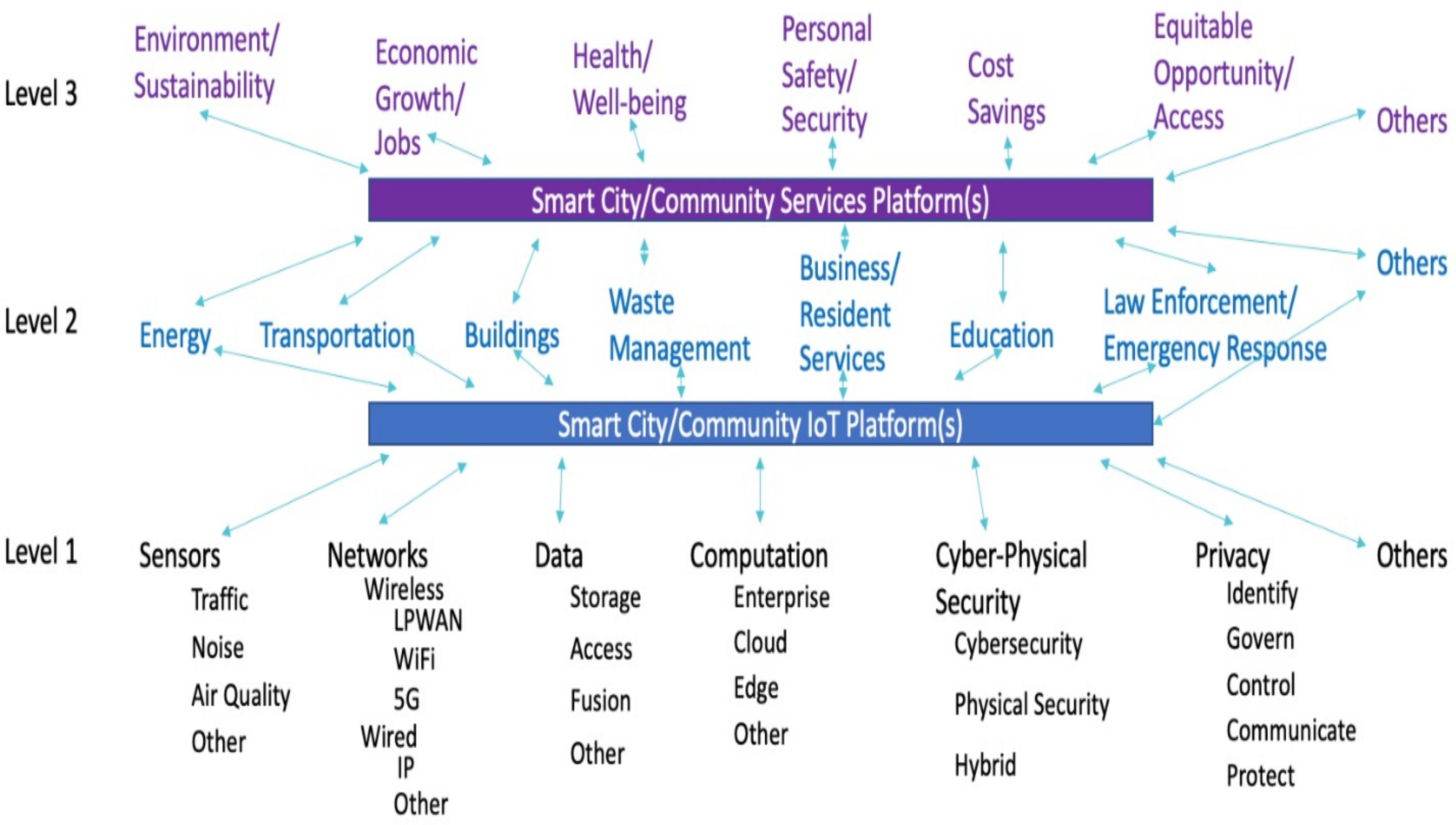
1. **Number of digital services & benefits**
2. **Efficiency in implementation, including dual use**
3. **Quality of services and benefits**
4. **Alignment with community priorities**

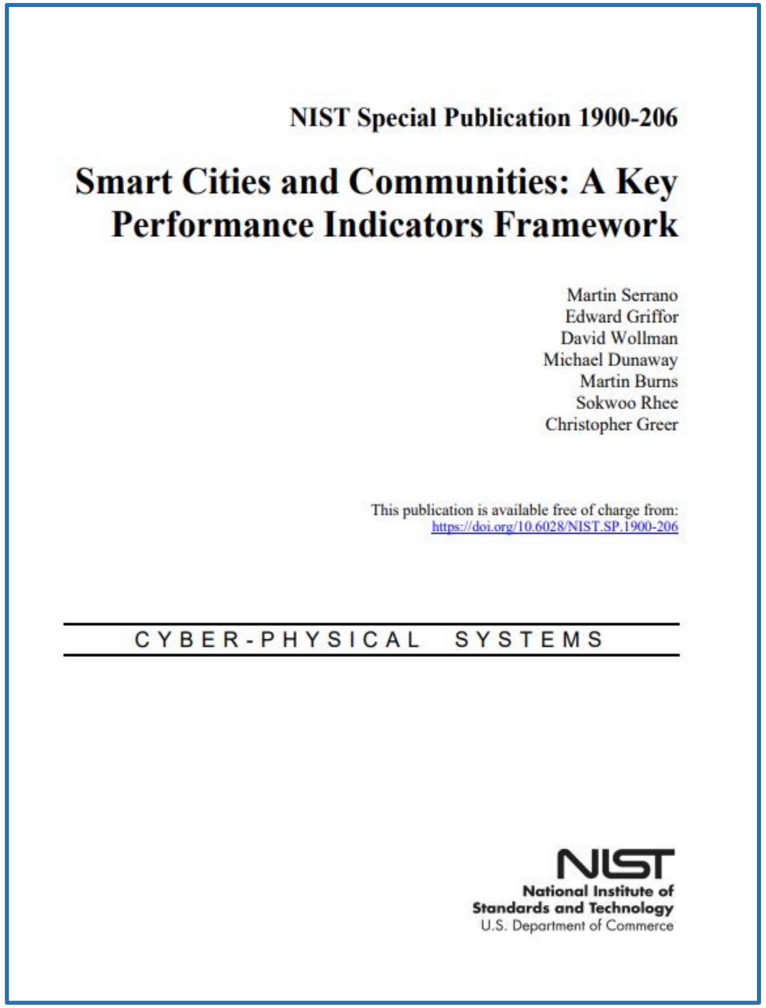
Data Consumers

Holistic KPI – Key Performance Indicators View



Holistic KPI – Key Performance Indicators Measurement





NIST Special Publication 1900-206

Smart Cities and Communities: A Key Performance Indicators Framework

Martin Serrano
Edward Griffor
David Wollman
Michael Dunaway
Martin Burns
Sokwoo Rhee
Christopher Greer

This publication is available free of charge from:
https://doi.org/10.6028/NIST.SP.1900-206

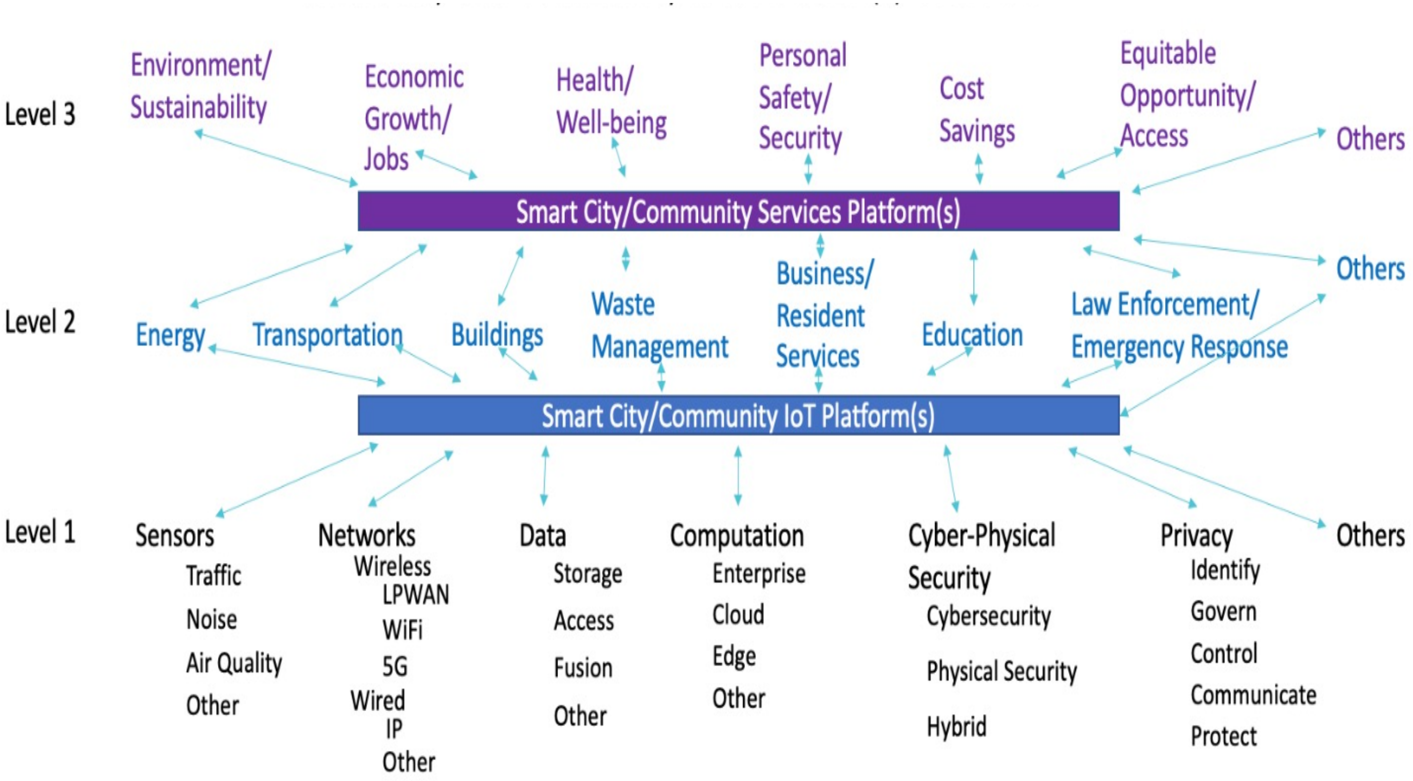
CYBER-PHYSICAL SYSTEMS

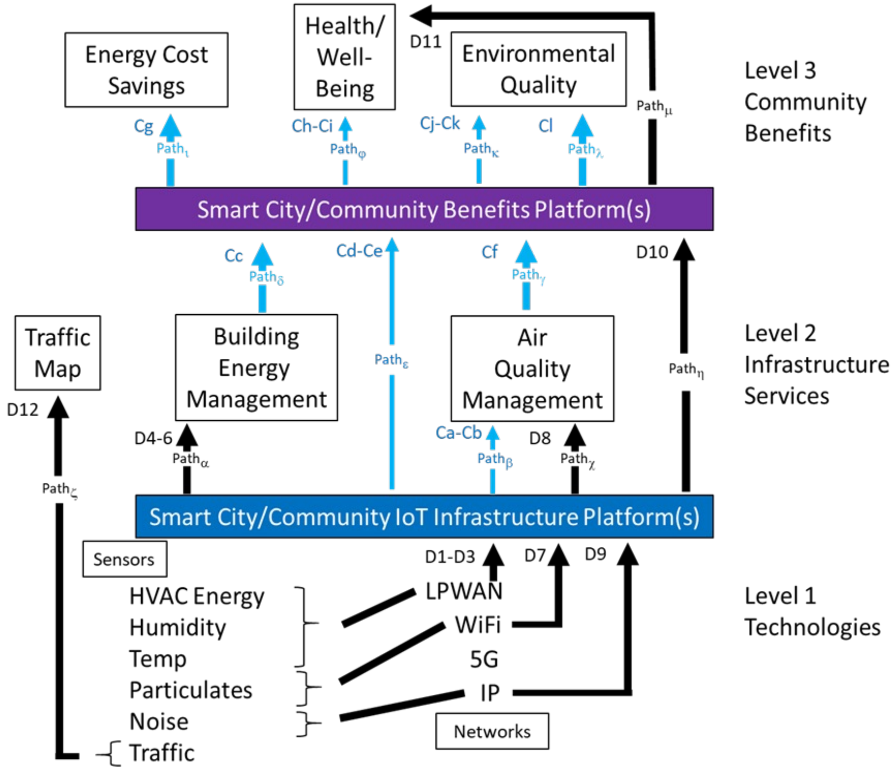
NIST
National Institute of Standards and Technology
U.S. Department of Commerce

[Smart Cities and Communities: A Key Performance Indicators Framework | NIST]

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE https://www.nist.gov/el/cyber-physical-systems/smart-americaglobal-cities

Use Case #1: Smart Connected Infrastructure (Smart Building)



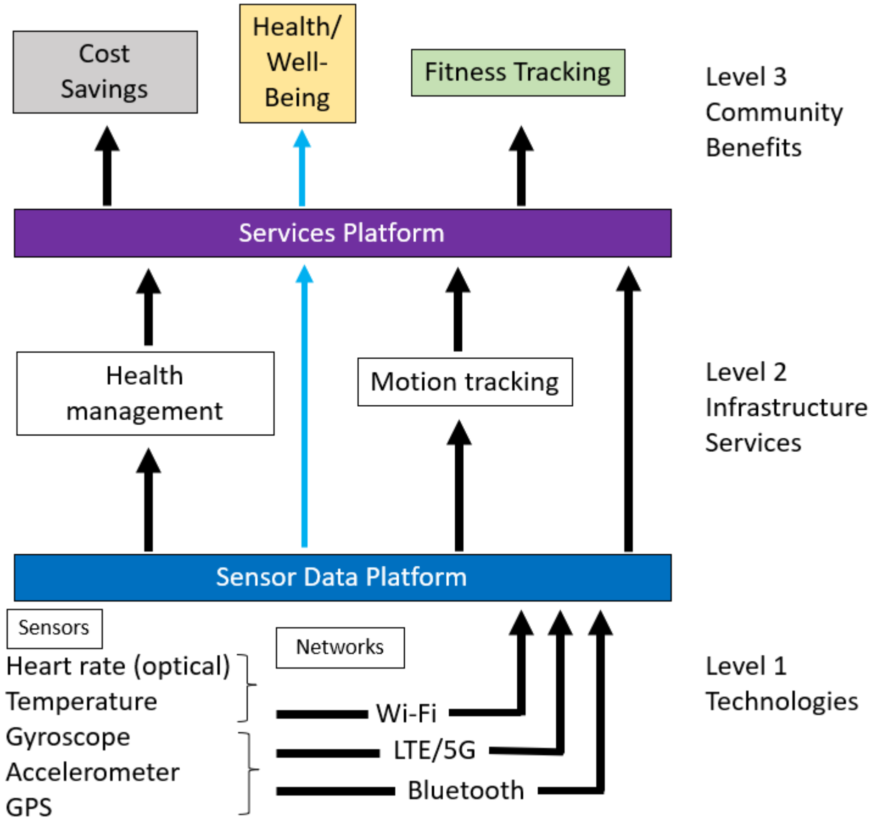


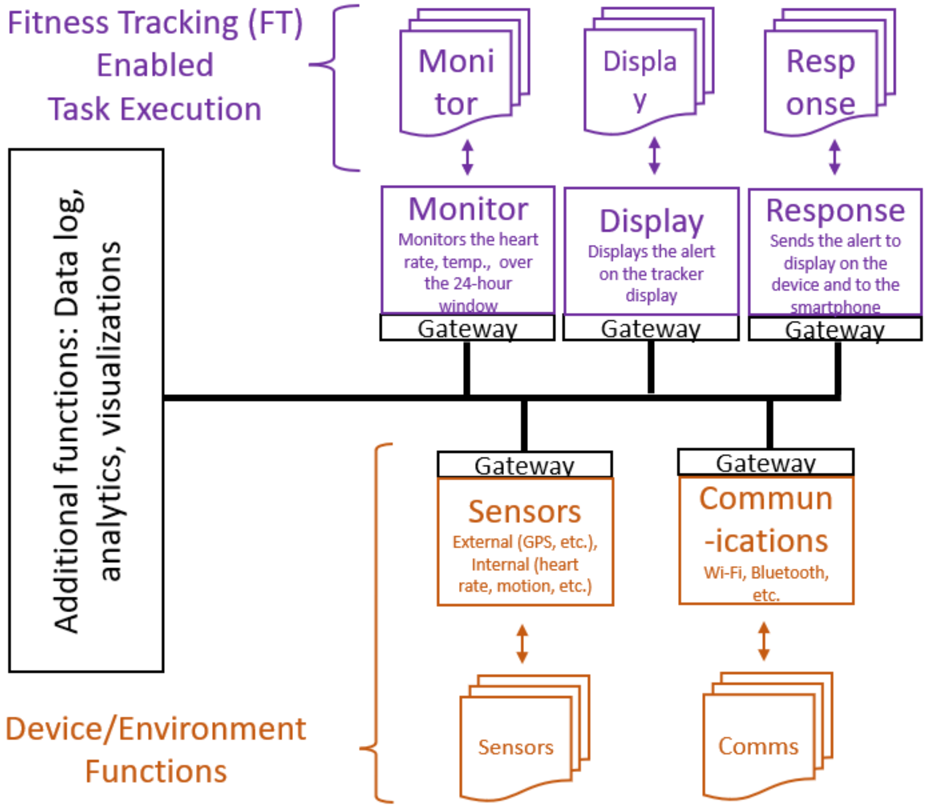
[Smart Cities and Communities: A Key Performance Indicators Framework | NIST]

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE

https://www.nist.gov/el/cyber-physical-systems/smart-americaglobal-cities

Use Case #2: Smart Connected Human (Fitness Tracking)





Smart Cities and Communities: A Key Performance Indicators Framework | NIST

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE https://www.nist.gov/el/cyber-physical-systems/smart-americaglobal-cities

Evolution of the concept and dimensions of the Smart City

2014 → **2023**

NIST National Institute of Standards and Technology, U.S. Department of Commerce https://www.nist.gov/el/cyber-physical-systems/smart-americaglobal-cities

NIST National Institute of Standards and Technology U.S. Department of Commerce

CTL Communications Technology Laboratory

NIST GCTC Guiding Principles

1. Open Source / Open Standards / Open Access
2. Cities and communities as complex adaptive systems
3. Holistic understanding of the “Smart” city/community
4. Focus on measurement of outcomes and success
5. Cities as both testbed and end-user of NIST R&D

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE https://www.nist.gov/el/cyber-physical-systems/smart-americaglobal-cities

National Institute of Standards and Technology
U.S. Department of Commerce

Communications Technology Laboratory

GCTC Priorities for 2024-2026

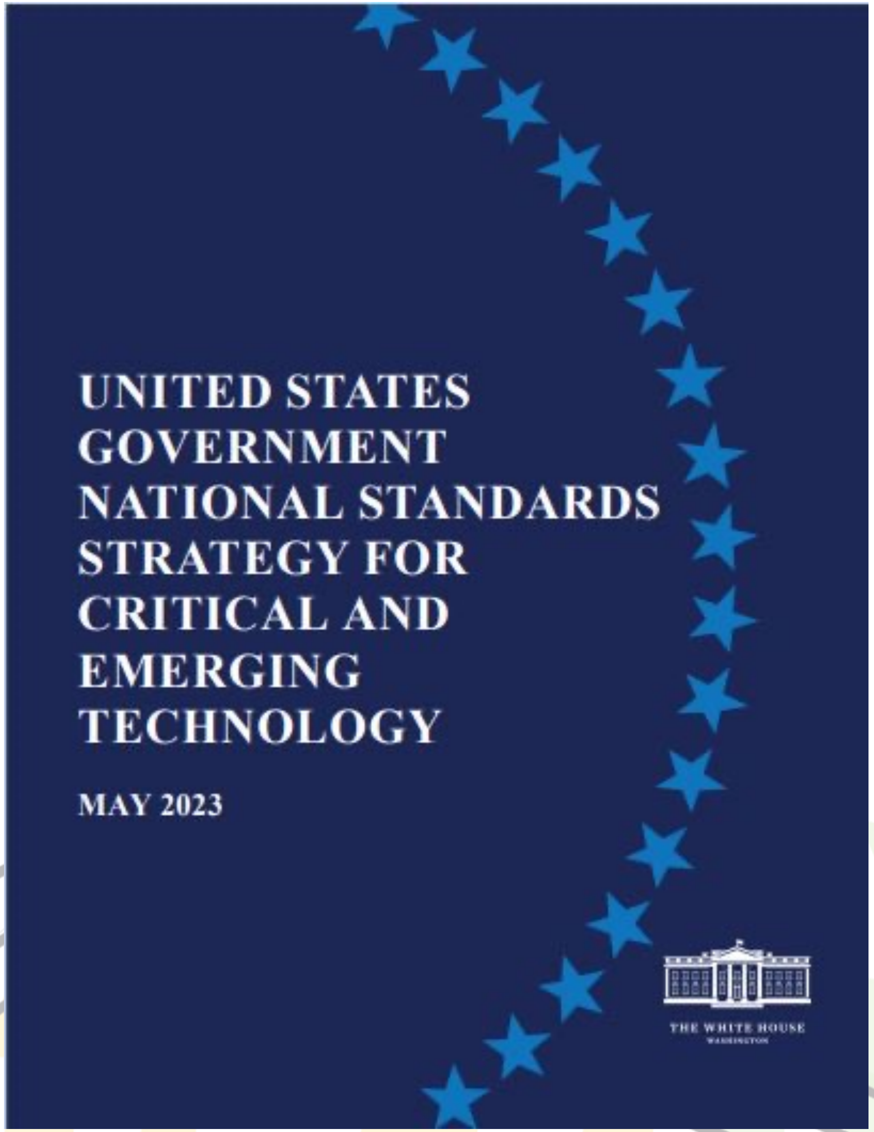
Goal 1: Establish a research-based, scientific foundation for GCTC and the NIST Smart Cities Infrastructure program, with emphasis on public safety/health, resilience and sustainability.

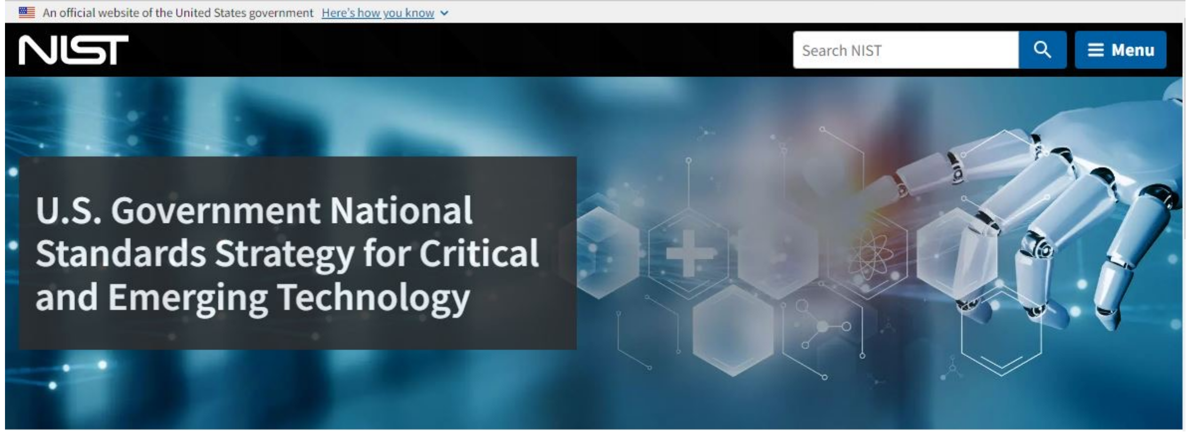
Goal 2: Broaden the definition and agenda for Smart Cities to address cross-cutting challenges and achieve a more equitable distribution of outcomes to communities and residents.

Goal 3: Develop the GCTC as the federal agency partner in a national public-private partnership dedicated to integration of advanced technologies for cities and communities.

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

https://www.nist.gov/el/cyber-physical-systems/smart-americaglobal-cities





U.S. Government National Standards Strategy | NIST
https://www.nist.gov/standardsgov/usg-nss

"Specific applications of CET that departments and agencies have determined will impact our global economy and national security. The United States will focus standards development activities and outreach on these applications, which include:

- **Automated and Connected Infrastructure, such as smart communities, Internet of Things, and other novel applications**
- **Automated, Connected, and Electrified Transportation, including automated and connected surface vehicles of many types and unmanned aircraft systems, electric vehicles (EVs), along with the safe and efficient integration into smart communities and the transportation system as a whole … "**

NSSCET p. 6

Smart Cities and Communities Resource Documents

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

NIST Special Publication 1900-206

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CYBER-PHYSICAL SYSTEMS

National Institute of Standards and Technology
U.S. Department of Commerce

NIST Special Publication 1500-201

**Framework for Cyber-Physical Systems:
Volume 1, Overview**

Version 1.0

Cyber-Physical Systems Public Working Group
Smart Grid and Cyber-Physical Systems Program Office
Engineering Laboratory

This publication is available free of charge from:
https://doi.org/10.6028/NIST.SP.1500-201

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International Technical Working Group on IoT-Enabled Smart City Framework

Two barriers currently exist to effective and powerful smart city solutions. First, many current smart city ICT deployments are based on custom systems that are not interoperable, portable across cities, extensible, or cost-effective. Second, a number of architectural design efforts are currently underway (e.g. ISO/IEC JTC1, IEC, IEEE, ITU and consortia) but have not yet converged, creating uncertainty among stakeholders. To reduce these barriers, NIST and its partners convened an international public working group to compare and distil from these architectural efforts and city stakeholders a consensus framework of common architectural features to enable smart city solutions that meet the needs of modern communities.

Developing a consensus Framework for Smart City Architectures

GLOBAL CITY TEAMS CHALLENGE

SMART AND SECURE CITIES AND COMMUNITIES CHALLENGE (SC3)

A Risk Management Approach to Smart City Cybersecurity and Privacy

A Guidebook from the
Cybersecurity and Privacy Advisory Committee
(CPAC) Public Working Group

July 2019

GLOBAL CITY TEAMS CHALLENGE

Blueprint for Smart Public Safety in Connected Communities

An Initiative of the Global City Teams Challenge

July 10, 2019

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

https://www.nist.gov/el/cyber-physical-systems/smart-americaglobal-cities

NIST National Institute of Standards and Technology U.S. Department of Commerce

Michael Dunaway, PhD

Smart Connected Systems Division
Communications Technology Laboratory
National Institute of Standards and Technology

Insight
Centre for
Data Analytics

Martin Serrano, PhD
IoT & Stream Processing Unit Head
Chair IEEE ComSoC IoT Experientation
NIST International Associate, USA

OLLSCOIL NA GAILLIMHE UNIVERSITY OF GALWAY
QS WORLD UNIVERSITY RANKINGS
TOP 1%
OF UNIVERSITIES
WORLDWIDE
THE TIMES HIGHER EDUCATION WORLD UNIVERSITY RANKINGS

NIST International Associate
Washington DC Area, USA

2020

Advisor/Contributor
Scientific Research & Innovation
Agenda for Europe

SMART 50 AWARDS

50 Best Smart City Award
NIST GCTC Smart Cities

2018

IEEE ComSoc
Emerging Technologies Chapter
Sub-Committee Internet of Things IoT Experimentation

Technical Coordinator, USA

siliconrepublic

25 key people influencing the internet of things

by John Kennedy

6 OCT 2015 · 936 SHARES

Irish and Ireland-based leaders, scientists and technologists are putting the country on the global map in terms of the internet of things (IoT) revolution.

University Guest Lecturer,
Silicon Valley, USA

2015

R+D+I Advisor, Dew Mobility, Fremont, CA USA

Research Excellence
President's Award
Nominee SFI, Ireland

Irish Software Association · Ibec
SHORTLISTED
ISA Software Industry Awards 2014

2014
Industry

IoT Scientific Director, Galway, Ireland
NUIG-National University of Ireland
Irish Software Association
Software Industry Awards outstanding
Academic Achievement Nominee, Ireland
Industry

MIT-IoT Hackaton
IoT Best Industry Solution
IoT Media Lab, Cambridge, Ma. USA

BLACKDUCK
OPEN SOURCE ROOKIES OF THE YEAR
OPENIoT

2013

NATIONAL Panasonic
Kumamoto, Japan

WIT-Waterford Institute of Technology
Cloud Computing & Semantics
Researcher, Ireland

Ray Barton, PhD

Application of Standards

Outline

- Introduction to IEEE Smart City Standards
- Overview of System Adaptability
- Adaptable City Planning in IEEE Standard

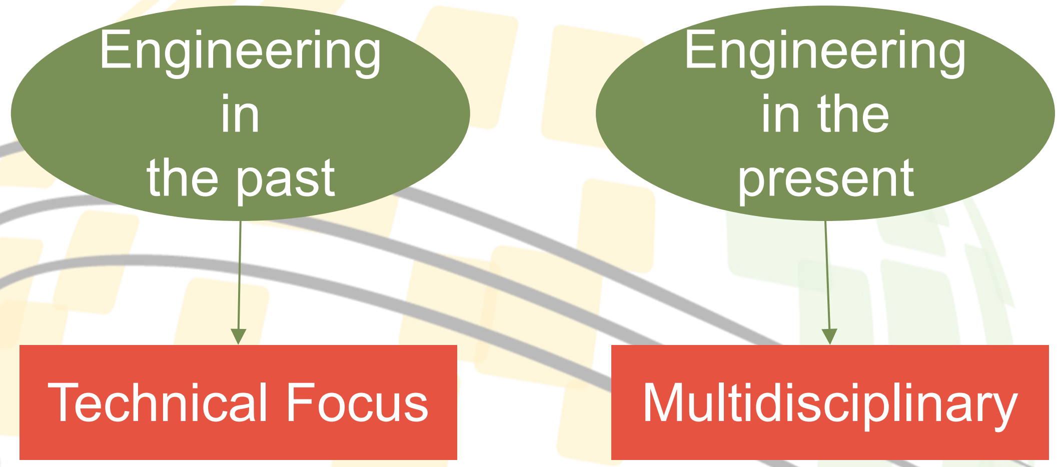
Section 1

Introduction to IEEE Smart City Standards

IEEE Smart City Planning Standard P2784

The IEEE Guide proposes a citizen-centric framework that aims to help city authorities to make decisions with human needs in mind.

Changing Engineering Environment



Additional related standards:

IEEE P1950.1 Standard for Communications Architectural Functional Framework for Smart Cities

IEEE P1951.1 Standard for Smart City Component Systems Discovery and Semantic Exchange of Objectives

IEEE P2413.1 Standard for a Reference Architecture for Smart City (RASC)

IEEE P2784 Guide for the Technology and Process Framework for Planning a Smart City

IEEE P2850 Standard for an Architectural Framework for Intelligent Cities Operation System

IEEE P2872 Standard for Interoperable and Secure Wireless Local Area Network (WLAN) Infrastructure and Architecture

IEEE P7803 Guide for the Technology and Process Framework for Planning a Smart City

Current Thinking	New Thinking
A smart city is a city with all problems solved	A smart city is a city capable of promptly identifying its problems and the root causes and mitigating the root causes
Humans are beneficiaries of a smart city	Humans are designers, inventors, developers, and beneficiaries by generating knowledge for Smart cities
Technologies make Smart cities	Humans develop technologies that support human activities aimed at building smart cities
Big data is critically important for all decision making for Smart cities	Big data is important, but it is not enough. To make fast and accurate decisions, the city needs engineered quality data
A city has its own Mission	A city has a Mission reflecting the common needs of the humans in the city and the mission is evolving over time. This is what adaptable city planning must consider.
The city government guarantees rights of city residents	The rights of city residents are guaranteed by services provided (or actions performed) by the stakeholders within the city government
The City must satisfy the needs of its residents	A city must create an environment enabling its residents to satisfy their own needs

Section 2

Overview of System Adaptability

System Adaptability Definition

- To *adapt* means "to make fit (as for a new use) often by modification" (Merriam-Webster,.)

- The term is traditionally used in natural ecosystems as the "modification of an an organism or its parts that makes it more fit for existence under the conditions of its environment" where the conditions can be either positive or negative.

- "System Adaptability" is a system's ability to satisfy mission and requirement changes, with or without modifications.

Note: Resilience is ability to stand up for now against negative events. Adaptability is ability to flex in future for both negative and positive events.

Three Fundamental Factors

Comparing adaptability among different systems relies on three fundamental factors:

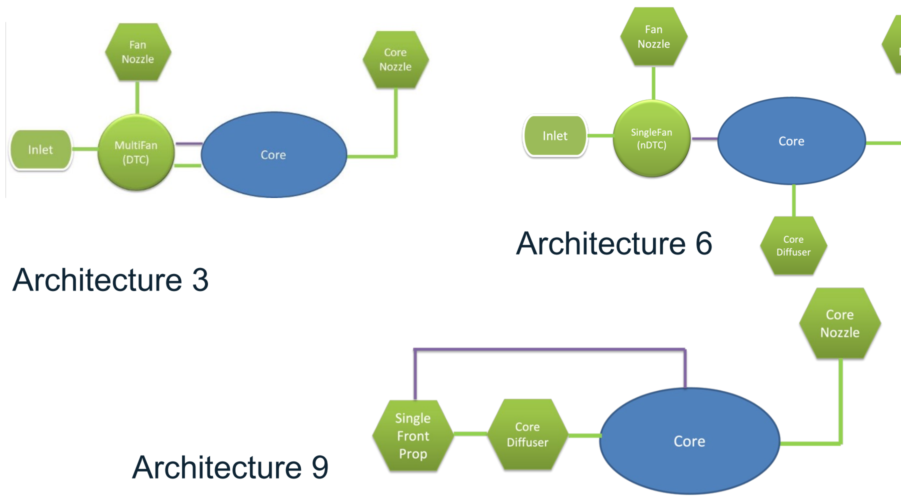
- **Mission and Requirement Evaluation Space (MRES)**
  - Common development practice assumes each requirement is for current needs and is often subject to budget constraint perceptions. MRES differs in that it uses systems thinking (see Systems Thinking) to project into the future and identifies requirements with high risk of change. They are potential needs that can optionally be considered.
  - MRES is a collection of current needs (i.e. requirements and missions) and optional potential needs. These projections into the future offer valuable information when designing for adaptability.
- **Design Space**
  - A collection of different possible system designs is called the *design space* or *trade space* in which tradeoff studies or trade studies are performed to pick the one that will be implemented.
- **Switching Cost**
  - If adapting the system requires modifying it, the ease of modification indicates the degree of adaptability. The cost incurred of switching from one system design/state to another design/state is called the *switching cost* which is a good indicator of how difficult it is to adapt.

An Aircraft Engine Example

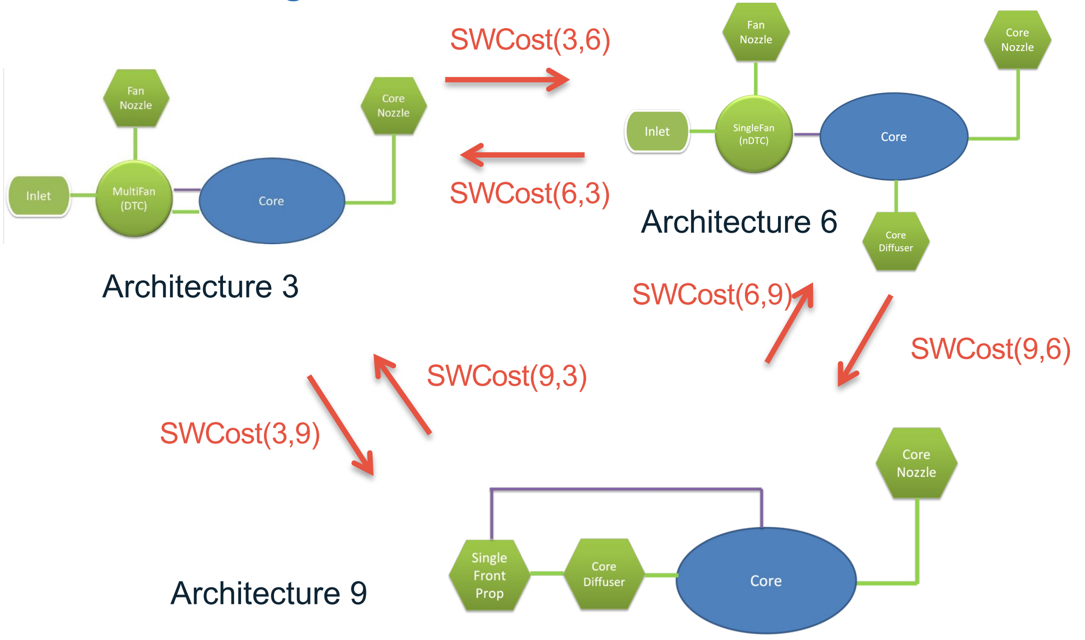
Missions/Requirements

Missions	1	2	3	4	5	6
Takeoff Gradient	low	low	low	high	high	high
Climb Rate	low	low	low	low	low	low
Cruise Range	long-range	mid-range	short-range	long-range	mid-range	short-range
Preference	optional	required	required	optional	optional	optional

Design Space: Engine Architectures



Switching Costs



Assume Architecture 3 and 6 both only meet the current needs, but Architecture 9 is capable of supporting the future needs too.

If Architecture 3 and 6 are both acceptable in cost, but the switching cost from Architecture 6 to Architecture 9 is much higher than the switching from Architecture 3 to Architecture 9, one might want to choose Architecture 3, from cost perspective.

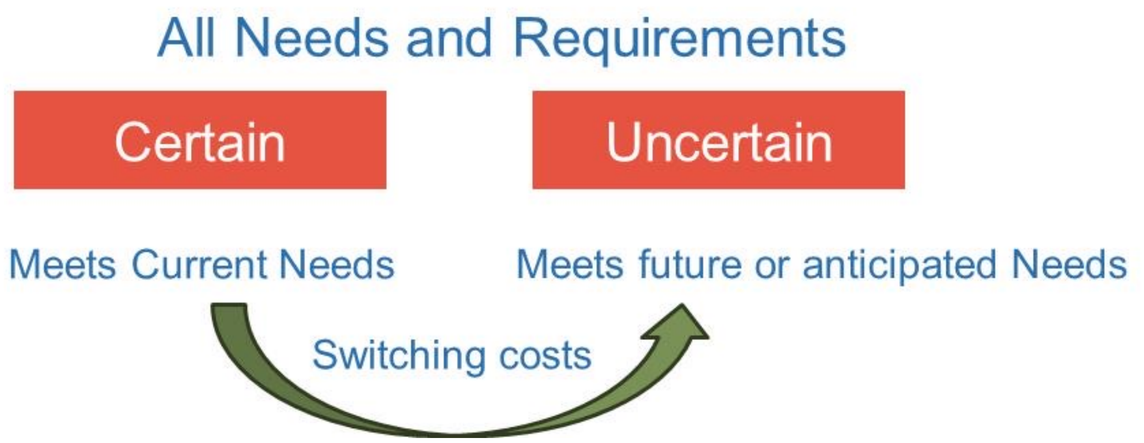
Section 3

Adaptable City Planning in IEEE Standard

Adaptable City Planning (ACP)

- Viewing a city as a system, adopt holistic system thinking and system adaptability methods to plan a city, to make it capable of meeting current needs with reasonable margins, but also ensure low cost for future changes.

Step 1 -- City planners need to systematically capture in writing the city's goal, mission and all its needs or requirements, which include both current and future ones.



Step 2 -- Generate all different candidate plans.
After different proposed plans are available, the city planners must estimate the switching costs between each pair of the candidate plans.

Step 3 – (final) is to select a candidate plan
Based on multiple weighting factors one of which is cost.
Using system adaptability methodology allows the city easier to be changed and adapt to future needs, without overly designing the city upfront, and thus is more sustainable.

Conclusion

- System Adaptability is important for city planning
  - It is also one of the backbones of INCOSE SE Vision 2035
  - It is useful for many system designs
    - Example: Boeing uses it for sustainable development https://www.linkedin.com/feed/update/urn:li:activity:7159262285008437249/

- Reference:
  - SEBoK System Adaptability Chapter: https://sebokwiki.org/wiki/System_Adaptability
  - INCOSE System Adaptability WG: https://www.incose.org/communities/working-groups-initiatives/systems-adaptability

Cecilia Haskins, ESEP, PhD

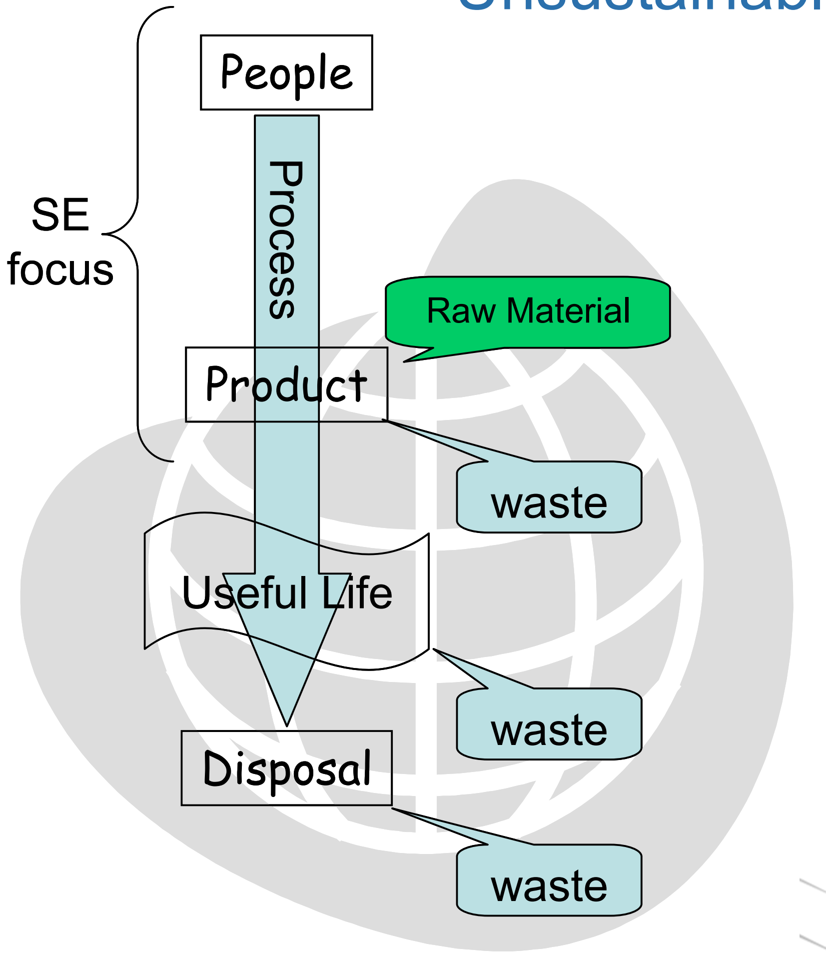
Application of Industry

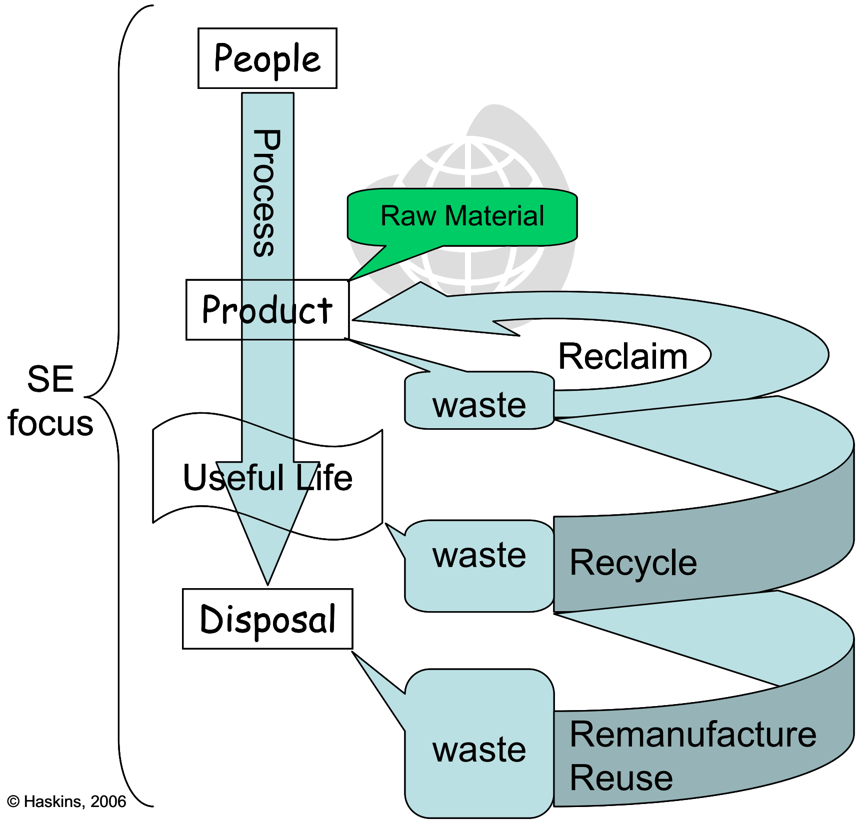
Cecilia Haskins, ESEP, PhD

- Associate professor of systems engineering, emerita
- INCOSE since 1993
- SEP since 2004
- PhD, NTNU, 2008: *Application of Systems Engineering to Eco-industrial park development*

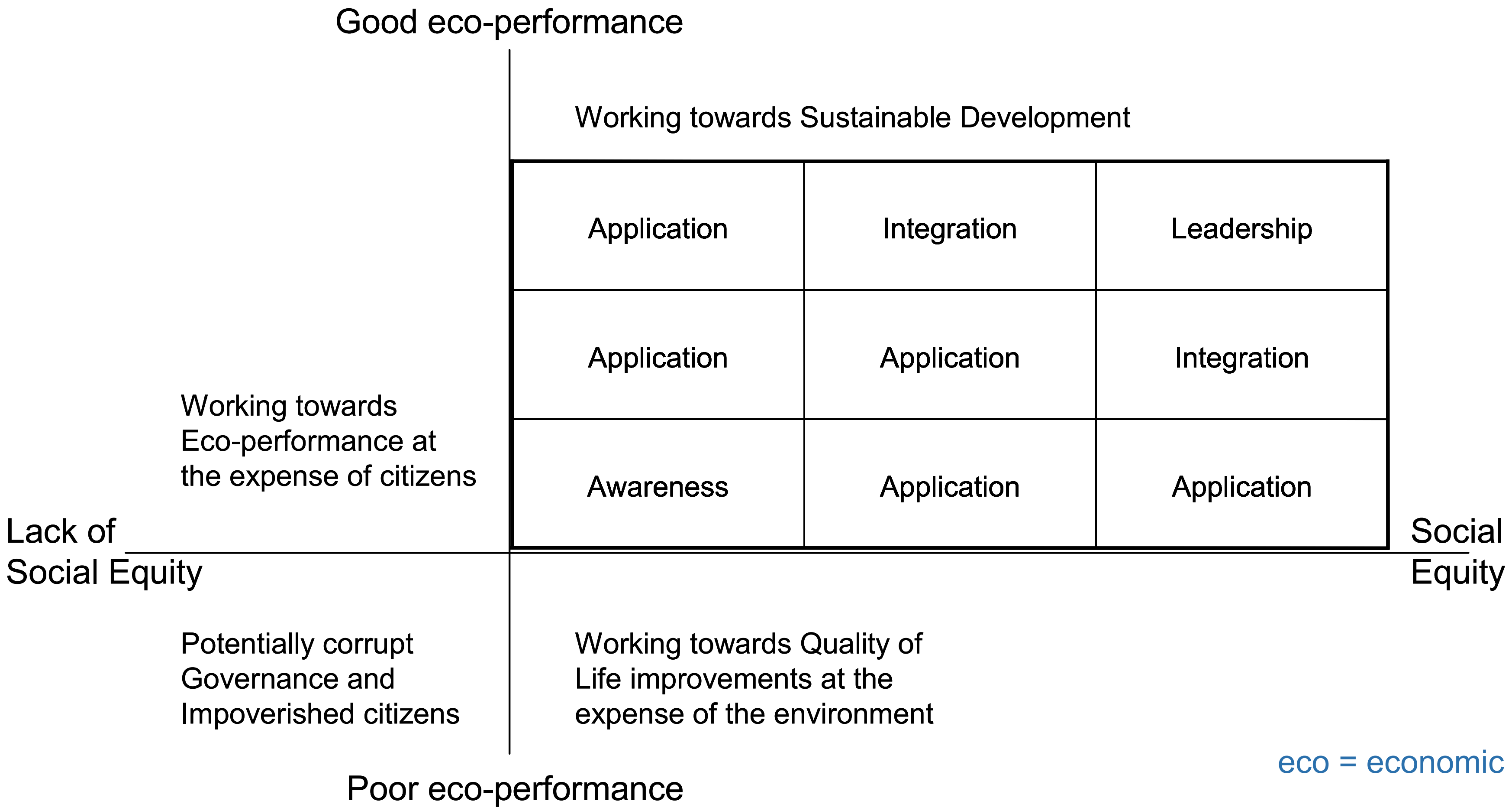
Technology challenge

Unsustainable versus sustainable development





Matrix of progress toward sustainable development – 3 E's
Equity, economic, environmental

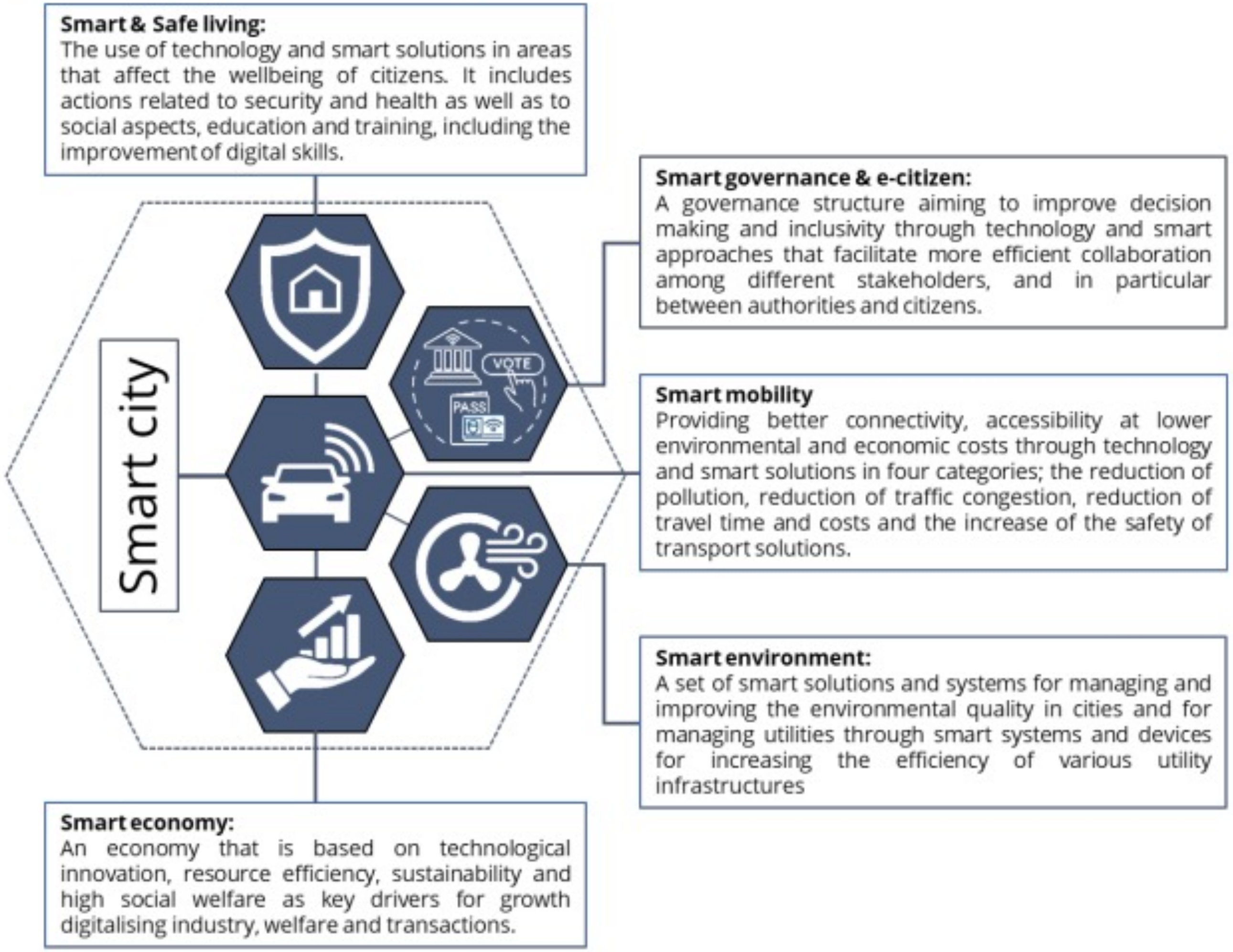


eco = economic and environmental

well under our component of Smart & safe living (Smart Living in the European Parliament study), which encompasses education, health and security.

Figure 2.3 provides an overview of our proposed five components and their definitions.

Figure 2.3 - Components of a smart city



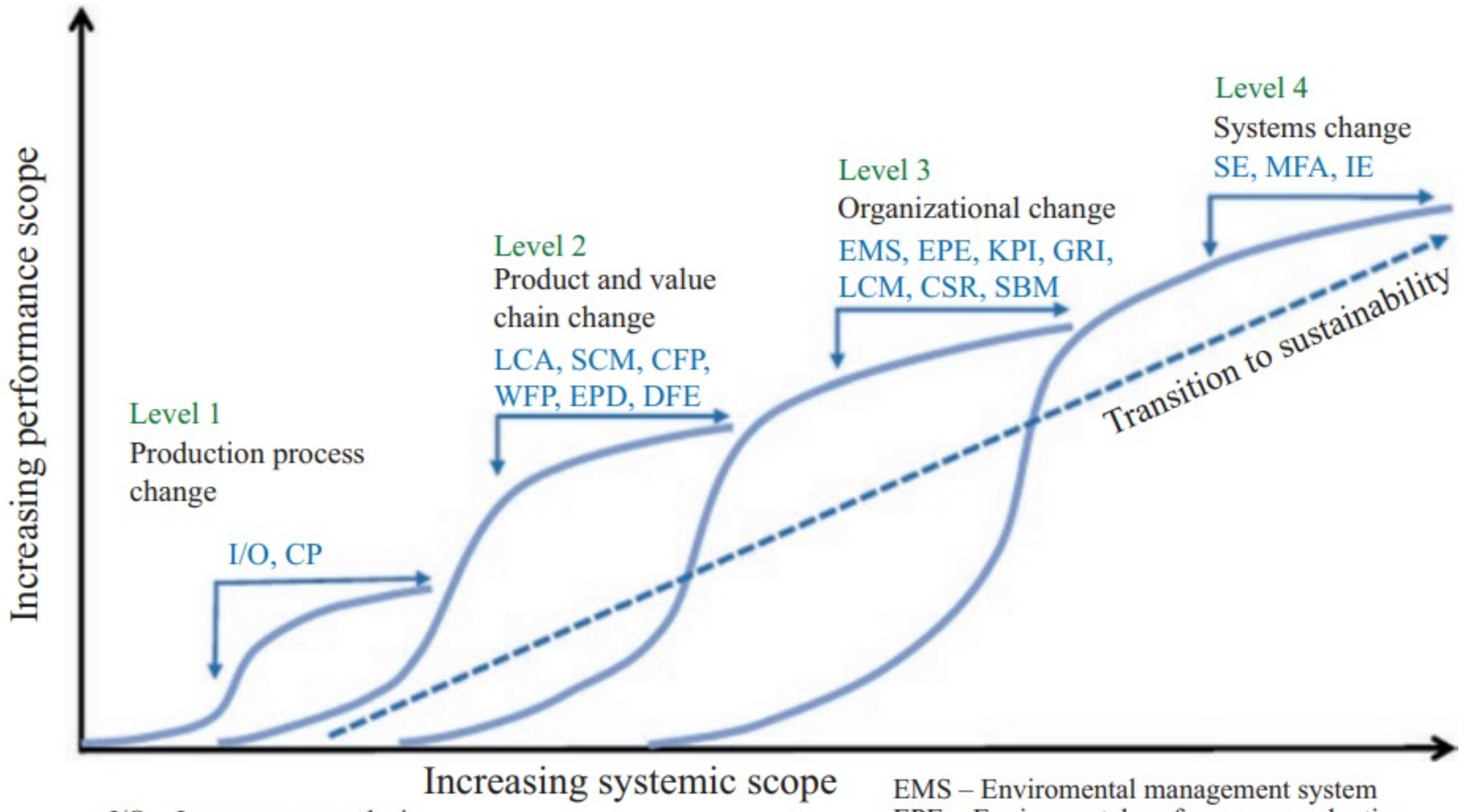
The five smart city components are described in more detail in Annex I.

The CapSEM model

- Organizations feel pressure to improve their sustainability performance but may not have either the knowledge or the resources to begin.
- A systematized collection of assessment and management tools for sustainability and environmental management is known as the *Capacity building in Sustainability and Environmental Management* model (the CapSEM Model).
- To streamline their application for the business sector and industry, the methods and tools are positioned in relation to four levels of development:
  - (1) **production** processes,
  - (2) **products** and value chains,
  - (3) **organization** and management and
  - (4) **meta-systems**, for example, industrial sectors or societies

Fet, A.M.(ed) 2023. Business Transitions: A Path to Sustainability: The CapSEM Model (p. 13)
See also https://bh4s.no/toolbox/

The CapSEM model

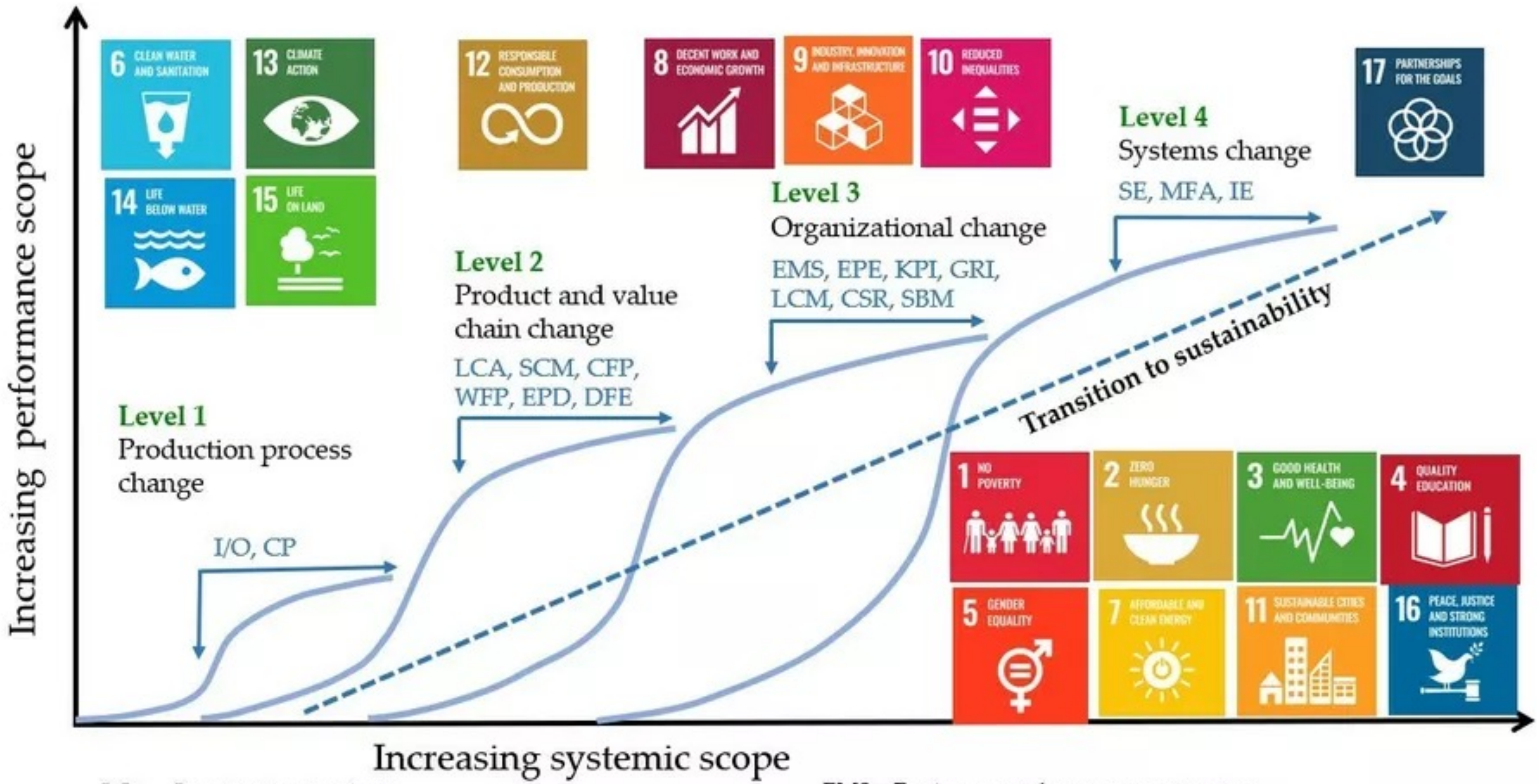


I/O – Input-output analysis
CP – Cleaner production
LCA – Life cycle assessment
SCM – Supply chain management
CFP – Carbon footprint
WFP – Water footprint
EPD – Environmental product delcaration
DFE – Design for environment

EMS – Enviromental management system
EPE – Enviromental performance evaluation
KPI – Key performance indicator
GRI – Global Reporting Initiative
LCM – Life cycle management
CSR – Corporate social responsibility
SBM – Sustainable business model
SE – Systems engineering
MFA – Material flow analysis
IE – Industrial ecology principles

Capacity building in Sustainability and Environmental Management (CapSEM) Model: a systemic approach towards sustainability. (Modified from (Fet and Knudson 2021)

CapSEM mapped to SDG



I/O – Input-output analysis
CP – Cleaner production
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SE enables the CapSEM tools

Systems engineering (SE)	Cleaner production (CP)	Life cycle assessment (LCA)	Design for environment (DfE)	Environmental management systems (EMS)	Environmental performance evaluation (EPE)
1. Identify needs	1. Planning and organising	1. Goal and scope definition	1. Needs analysis	1. Environmental policy	1. Commitment
2. Define requirements			2. Requirements	2. Initial planning	2. Planning
3. Specify performance	2. Assessment and preparation	2. Inventory analysis		3. Planning 4. Implementation and operation 5. Checking and corrective action	3. Applying
4. Analyse and optimise	3. Assessment step 4. Feasibility analysis step	3. Impact assessment 4. Interpretation	3. Life cycle strategies and evaluation		
5. Design, solve and improve	5. Reporting 6. Implementation	Application of LCA results	4. Design		4. Reviewing 5. Improving
6. Verify and report			5. Implement	6. Management review 7. Documentation 8. Registration	

Fig. 12.2 Mapping of systems engineering processes to CapSEM Model methods and tools (Fet 2002)

Jawahar (JB) Bhalla

Application of Systems Engineering

34th Annual INCOSE
international symposium

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Dublin, Ireland
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Environmental Management Systems (EMS)

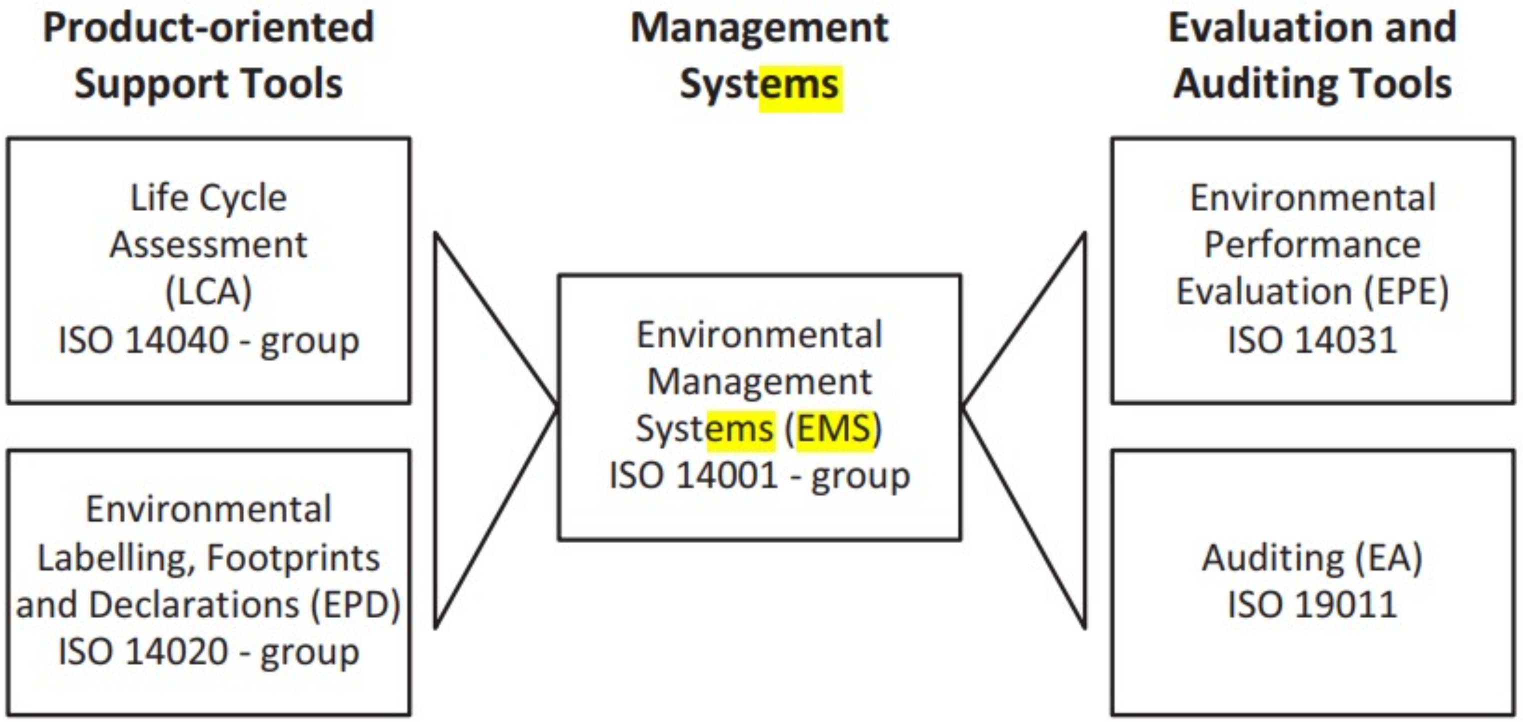


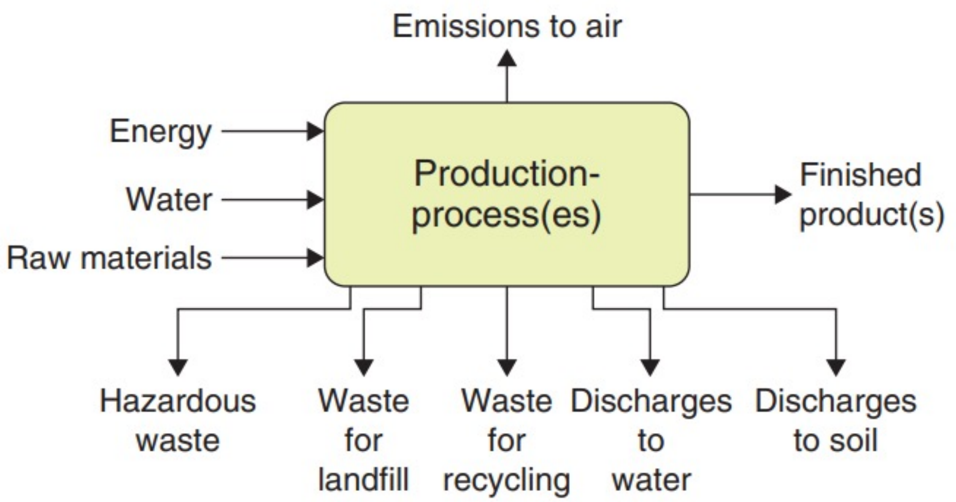
Fig. 7.1 Product-related standards and audit and evaluation standards underpinning environmental management. (Illustrated by examples from the ISO 14000-family)

Environmental Performance Evaluation (EPE)

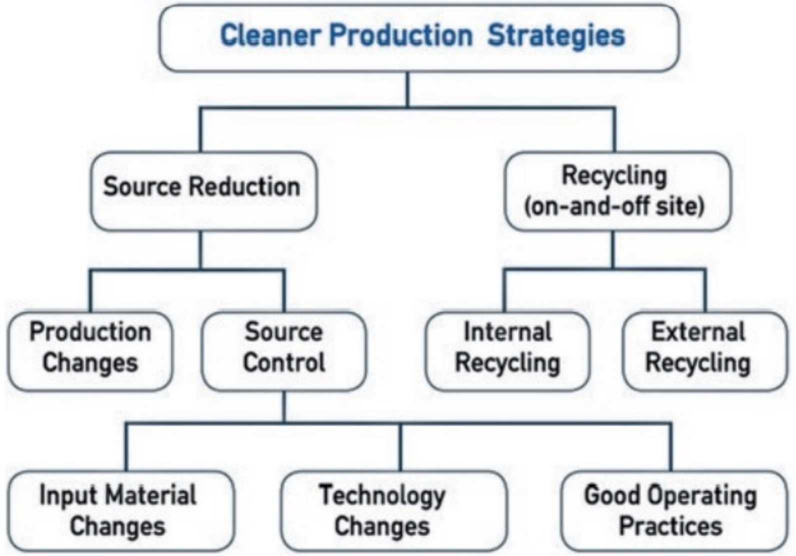
Table 8.1 Examples of EPIs expressed by OPIs and MPIs

Example of operation performance indicators (OPI).	Example of management performance indicators (MPI).
Category – materials	**Conformance – degree of compliance with regulations**
Quantity of materials used per unit of product	Costs (operational and capital) that are associated with a product's or process' environmental aspects
Quantity of processed, recycled or reused materials used	Return on investment for environmental improvement projects
Category – energy	**Category - financial performance**
Quantity of energy used per year or per unit of product	Costs (operational and capital) that are associated with a product's or process' environmental aspects
Quantity of energy used per service or customer	Return on investment for environmental improvement projects
Category – emissions	**Category - implementation of policies and programmes**
Quantity of specific emissions per year	Number of achieved objectives and targets
Quantity of specific emissions per unit of product	Number of organizational units achieving environmental objectives and targets
Category – wastes	**Category - community relations**
Quantity of waste per year or per unit of product	Number of inquiries or comments about environmentally related matters
Quantity of hazardous, recyclable or reusable waste produced per year	Number of press reports on the organization's environmental performance

Cleaner Production
«Waste is a failure of sustainability»



Material flow scheme with inputs & outputs for single/series of production process(es)



Principles for CP Strategies from USEPA

Life cycle assessment (LCA)

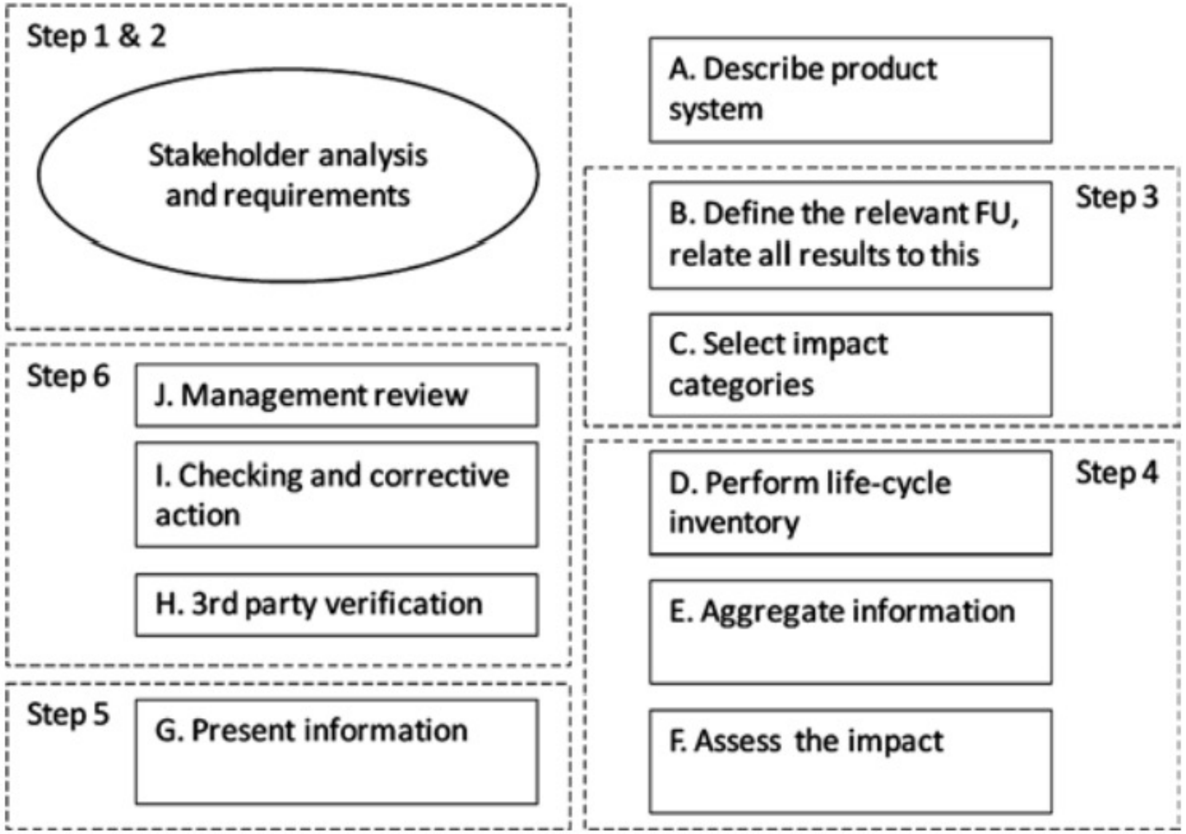


Fig. 14.1 Framework for management and communication of environmental aspects of products. (Skaar 2013)

Design for Environment (DfE)

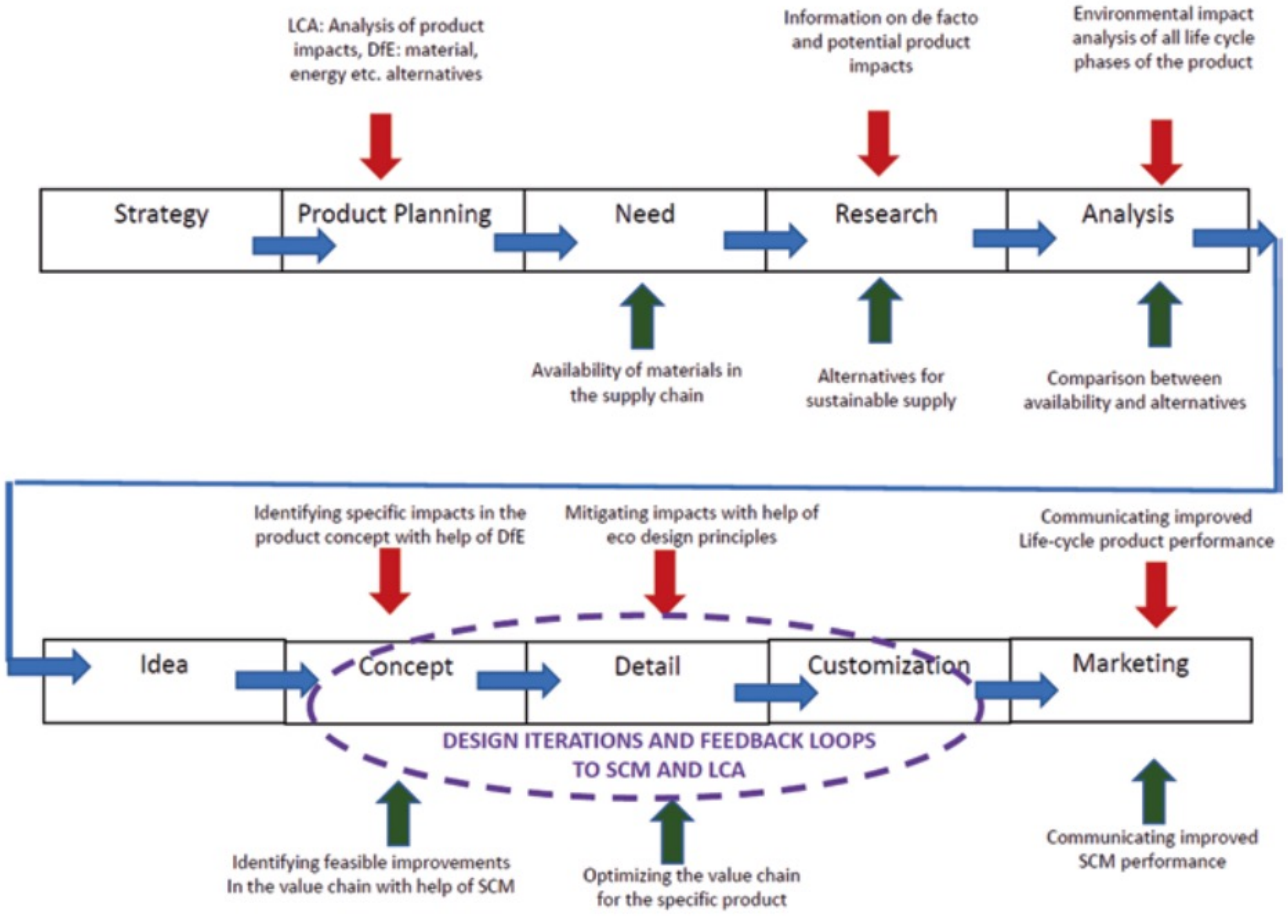


Fig. 5.1 Product development stages integrating aspects of LCA, DfE and SCM

References

- Ehrenfeld JR (1994) Industrial ecology: a strategic framework for product policy and other sustainable practices. In: Green goods: the second international conference and workshop on product-oriented policy, Stockholm, pp 1–40.
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- Fet AM (2002) Environmental management tools and their application – a review with references to case studies. In: Conceição P, Gibson DV, Heitor MV, Sirilli G, Veloso F (eds) Knowledge for inclusive development. Quorum Books, Westport, pp 451–464
- Fet, A. M., & Knudson, H. (2021). An Approach to Sustainability Management across Systemic Levels: The Capacity-Building in Sustainability and Environmental Management Model (CapSEM-Model). Sustainability, 13(9), 4910.
- Skaar C (2013) Accountability in the value chain: Product declarations as a tool for measuring, managing and communicating CSR performance. Dissertation, NTNU, Trondheim, Norway

Case study – construction sector

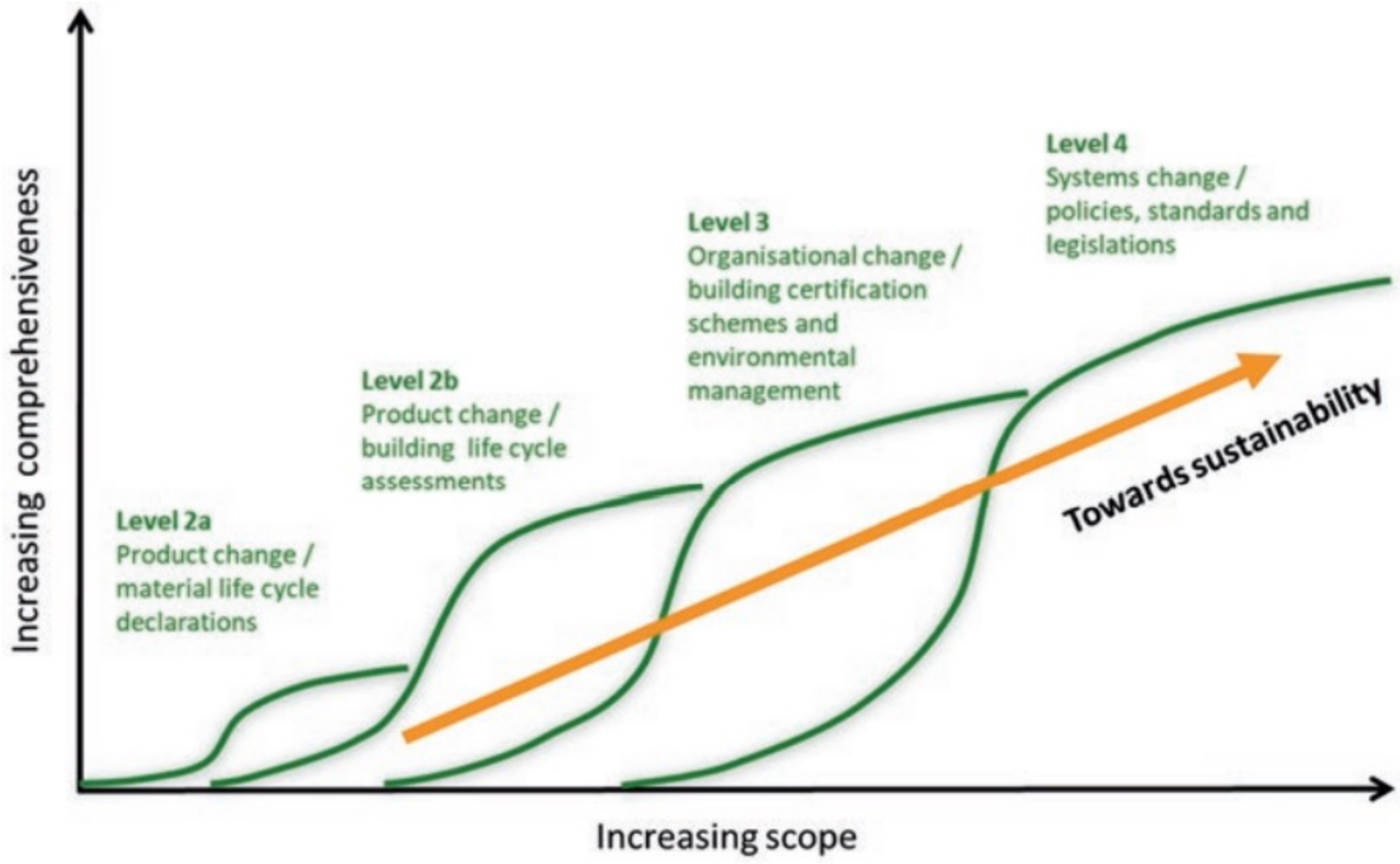
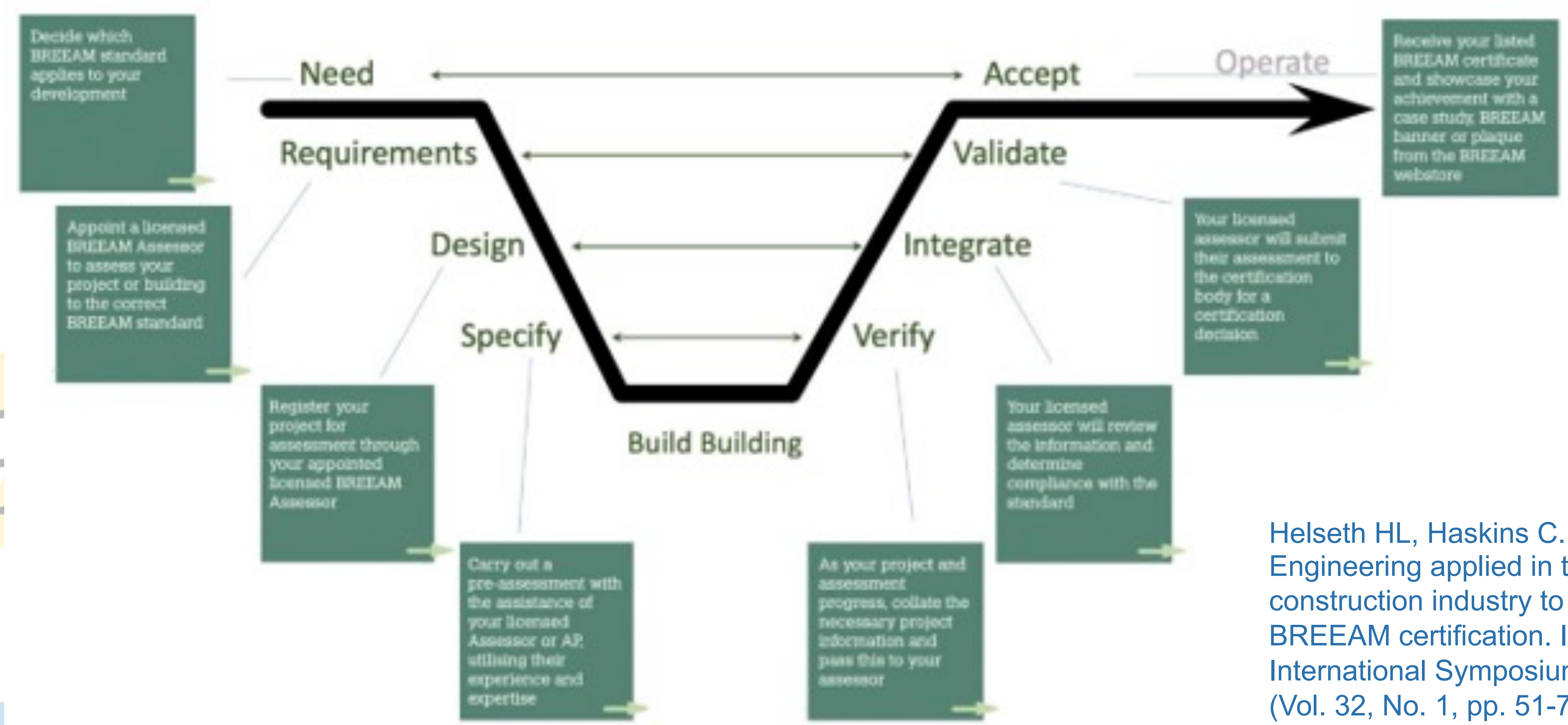


Fig. 16.2 Adapting the CAPSEM Model to the construction sector. (Sparrevik et al. 2021)

Sparrevik M, de Boer L, Michelsen O, Skaar C, Knudson H, Fet AM (2021) Circular economy in the construction sector: advancing environmental performance through systemic and holistic thinking. Environ Syst Decis 41:392–400

BREEAM certification and SE



Helseth HL, Haskins C. Systems Engineering applied in the construction industry to achieve a BREEAM certification. In INCOSE International Symposium 2022 Jul (Vol. 32, No. 1, pp. 51-74).

Case study –
maritime cleaner production, a longitudinal view

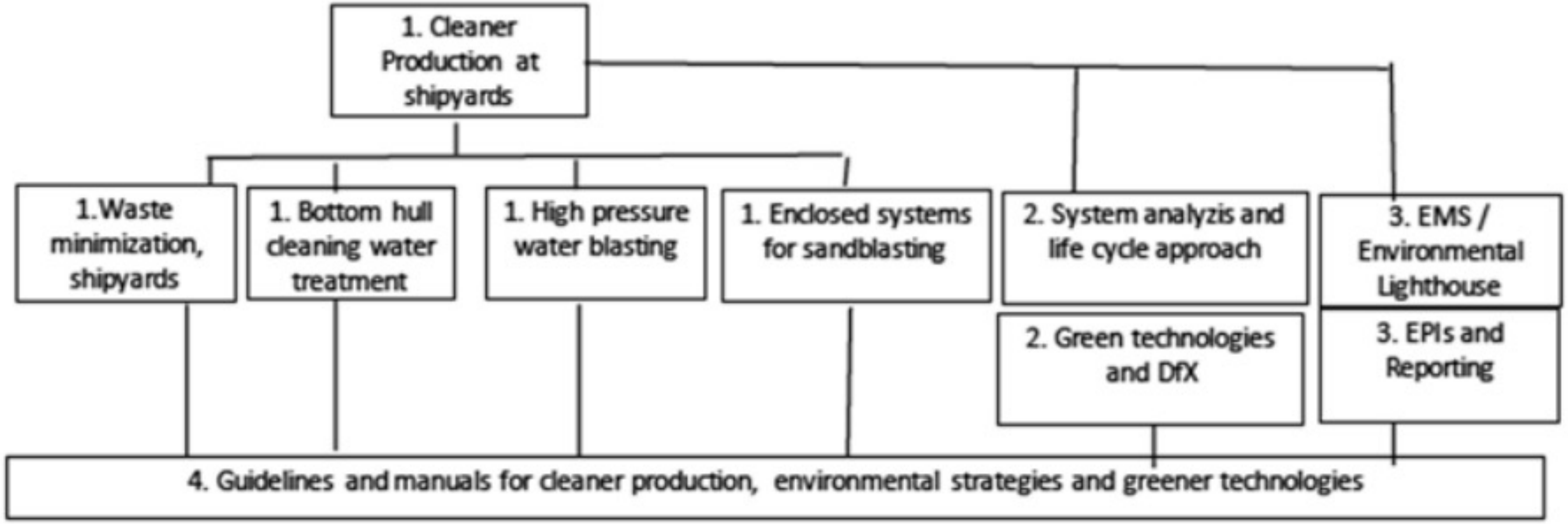
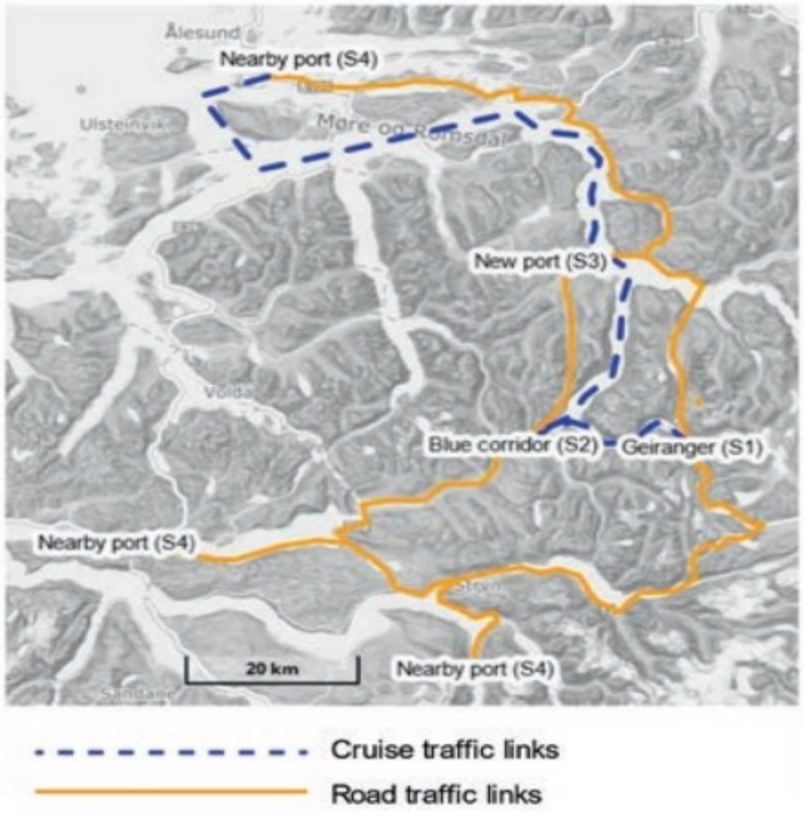


Fig. 18.1 Overview of activities resulting from the Cleaner Production project started in 1993. The numbers in the boxes reflect the Levels in the CapSEM model (modified from Fet 2002a, b)

Case study – using CapSEM to develop a DSS for transportation sector – structuring a MCDM analysis



S1	Strategy: Business as usual (BAU) Port: Geiranger
S2	Strategy: Blue Corridor Port: Hellesylt
S3	Strategy: New port Port: Stranda
S4	Strategy: Nearby ports Ports: Ålesund, Nordfjordeid, and Olden/Loen
S5	Strategy: No cruise Ports: Outside the study area

Fig. 19.2 Summary of boundaries and strategies defined in the problem structuring process. The map is created in the Norgeskart portal by ©Kartverket