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Guidelines Positive Energy Districts (PEDs)

PED Pathways: From Vision to Reality

Dr. Juliana Zapata
Michelle Scacco
Dr. Silvia Ulli-Beer

(COST ACTION „PED-EU-NET“)

Institute of Sustainable Development, Zurich University of Applied Sciences (ZHAW)

Table of Content

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A Swiss Example of a PED- Related Project Output

WHAT ARE POSITIVE ENERGY DISTRICTS (PEDS)?

PEDs are defined as urban areas or districts that, on an annual balance, produce more energy from renewable sources than they consume.

(Wyckmans et al., 2023)

PEDS KEY CHARACTERISTICS

ENERGY EFFICIENCY : ADVANCED CONSTRUCTION, RETROFITTING, SMART ENERGY MANAGEMENT.

RENEWABLE ENERGY PRODUCTION: SOLAR, WIND, GEOTHERMAL ENERGY SOURCES.

SMART ENERGY SYSTEMS: INTEGRATION OF SMART GRIDS AND ENERGY STORAGE FOR EFFICIENT MANAGEMENT.

SUSTAINABILITY, LIVABILITY & QUALITY OF LIFE: SUSTAINABLE WATER MANAGEMENT, WASTE REDUCTION, GREEN SPACES, AND ENHANCED WELL-BEING THROUGH COMFORT AND SOCIAL CONNECTIVITY.

COMMUNITY ENGAGEMENT: INVOLVING RESIDENTS IN DECISION-MAKING.

(Gollner, 2020)

Purpose of this guide

- **Provide a practical framework**
  Equip project managers, policymakers, urban planners, developers, and stakeholders with actionable strategies and tools to design, implement, and sustain Positive Energy Districts (PEDs).

- **Facilitate collaborative action**
  Encourage cooperation among municipalities, private entities, communities, and technical experts to create energy-efficient, sustainable urban environments.

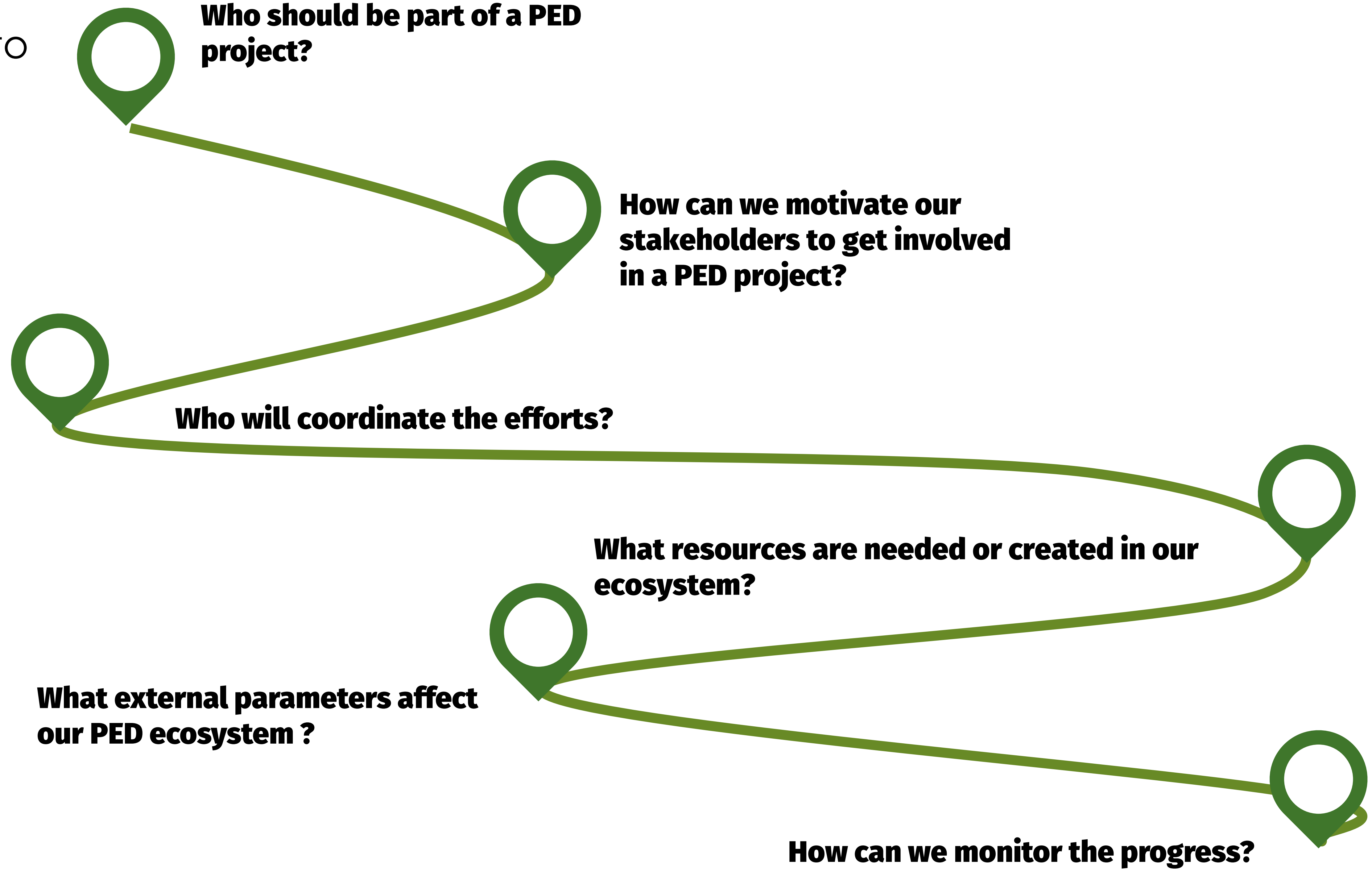
- **Showcase proven practices**
  Highlight successful PED projects, share lessons learned, and inspire new initiatives by showcasing innovation and creativity in energy-positive urban planning.

- **Drive the energy transition**
  Support cities and districts in their journey towards GHG neutrality, renewable energy adoption, and resilient energy systems aligned with global sustainability goals.

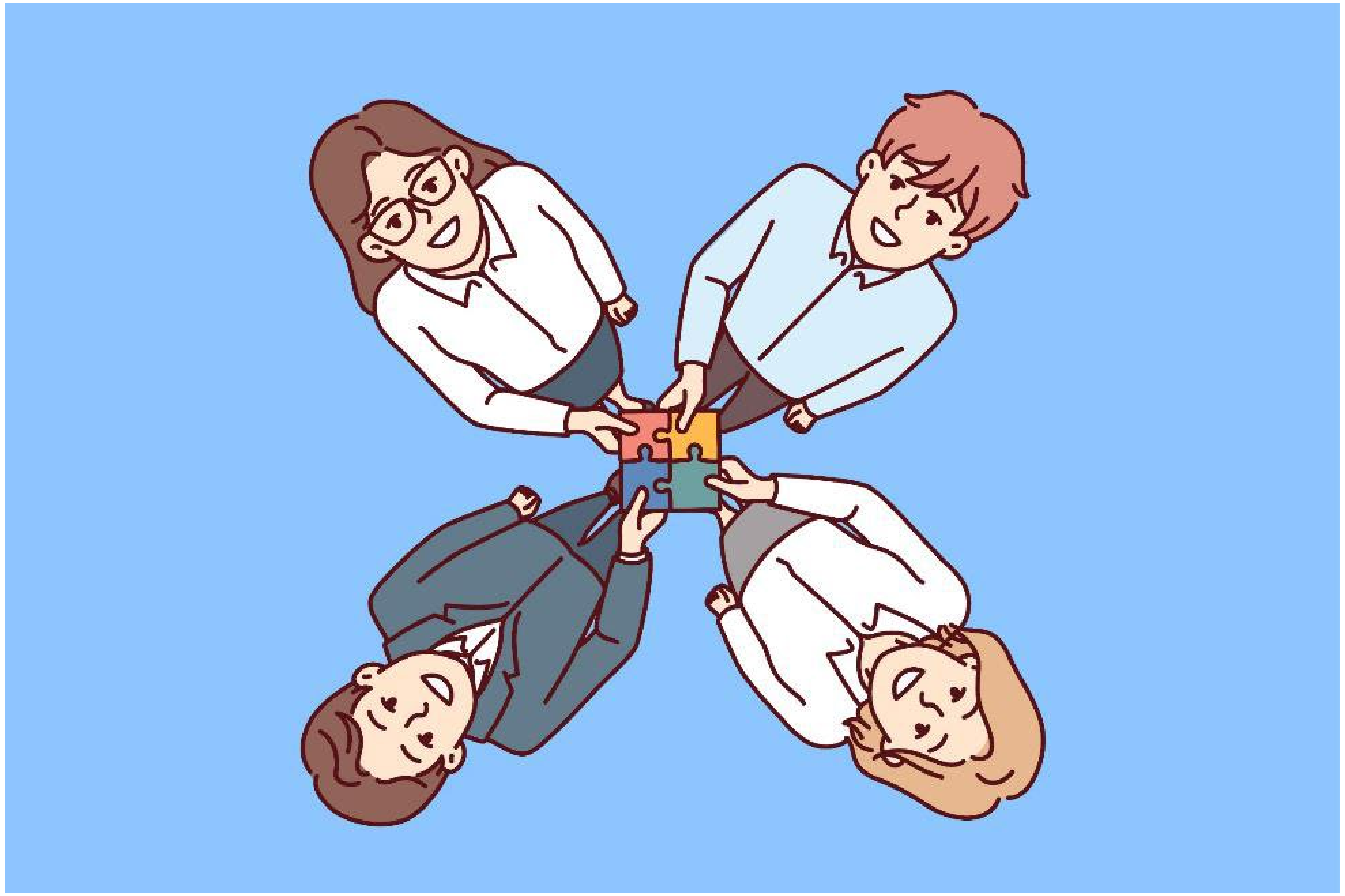
Implementation Framework for Positive Energy Districts and Related Concepts

The Road to PEDS

During the planning and development process, you should ask yourself these key questions as guidance. We will go through them together to ensure that every aspect is covered and the project is set up for success.



Who can be part of a PED project?



Identify Stakeholders

Identify your **stakeholders**, **understand their interest**, and **measure progress** to ensure lasting collaboration and success in creating PEDs.

(PED-ID, 2022)

Key questions to consider:

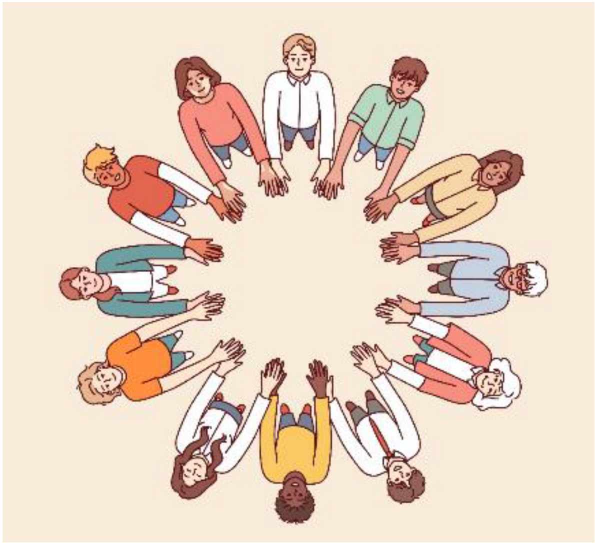
- Who are the critical actors in your PED?
- What role does each stakeholder play in your PED creation?

Municipalities

Products and Service providers

Financers

Citizens



Owners of the district and buildings

Stakeholder Analysis Matrix

Identify and map the stakeholders by name, assessing their potential impact and influence on the project (low, medium, high). Understand their key priorities, or driving forces, and evaluate their potential contributions or, in the worst case, risks that could hinder the project. Lastly, develop a strategy to effectively engage each stakeholder (PED-ID, 2022)

Name Stakeholder	**Impact:** How much does the project impact the stakeholder? (Low, medium, high)	**Influence:** How much influence does the stakeholder has? (Low, medium, high)	**Relevance:** What is important to the stakeholder?	**Involvement:** How could the stakeholder contribute to the project?	**Barriers:** How might the stakeholder potentially obstruct or delay the project? (Pains or concerns)	**Alignment:** Strategy to engage the stakeholder

Community engagement

Why engage the community?

- Builds trust and local support
- Encourages behavioral change for energy efficiency and self-sufficiency
- Ensures context–specific solutions meet community needs

Steps to effective community engagement:

1. **Creating participation channels:** Workshops, surveys, focus groups, and public forums.
2. **Educating and informing:** Using accessible language to explain goals and impacts.
3. **Empowering residents:** Offer ways for the community to actively contribute.

Example: Virtual Reality (VR) App to Educate and Raise Awareness
The VR App „ *A mystic journey towards PEDs*“ is an innovative tool to engage and educate communities about Positive Energy Districts (PEDs). Guided by a wise owl that serves as their trusted avatar, players venture through enchanting magical districts, each symbolizing a cornerstone of the energy transition: sustainable mobility, renewable energy, energy efficiency, and community engagement. This immersive experience helps residents understand and visualize the impacts of PEDs, fostering greater enthusiasm and motivating positive behavior changes.

Further information: https://www.zhaw.ch/de/engineering/institute-zentren/ine/nachhaltige-energiesysteme/virtual-reality

Citizen and Community Motivation, Needs & Preferences

Motivating citizens and communities to get involved in a PED project collectively requires a clear understanding of to what extent citizens understand **the rationale behind developing PED project** (i.e. what are they for?), which **roles** the citizens perceive of themselves as part of the PEDs and what their **preferences** are in terms of technologies, actors who governs these technologies as well as ownership of such technologies in a PED. This is where multiple **socio-technical analysis** with both quantitative and qualitative research methods becomes handy, as it helps map out the various forms of drivers, aspirations of the citizens with regards to PEDs as well as preoccupations and needs of the citizens. By identifying these factors, we gain insights into how each citizen can be engaged with the PED via **diverse governance and ownership structures**, what types of **communication chann**els are needed to engage them, as well as **co-developing solutions** that effectively responds to the needs, capacities, aspirations and preferences of the citizens.

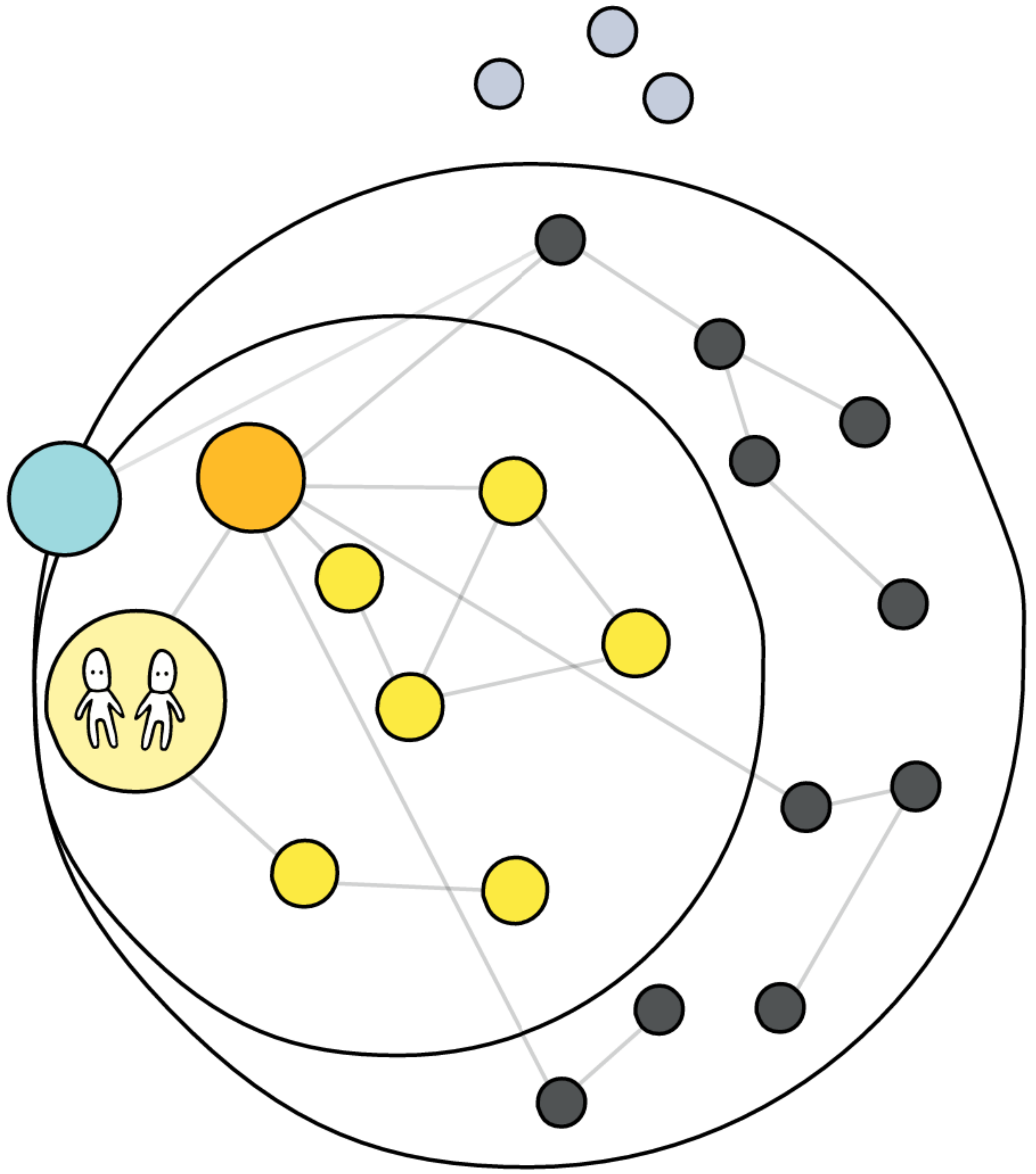
Citizen and Community engagement

To strengthen community and citizen engagement in PEDs, it is essential to move **beyond a passive consumer approach** and **foster active civic participation**. This requires creating accessible opportunities **for dialogue, co-design, and decision-making**, ensuring that citizens see themselves as key actors in shaping energy transitions. Providing clear and relatable role definitions, alongside practical tools and resources, will empower individuals to engage meaningfully. Additionally, **leveraging trusted institutions** namely local municipalities, local energy companies and other private enterprises to facilitate engagement while supporting citizen groups can help bridge gaps in participation. Ultimately, engagement strategies must be **inclusive, adaptive, and responsive** to diverse community needs to ensure long-term commitment and impact.

PEDs are Intrinsic Ecosystems

- PEDs are often a result of a partnership between different stakeholders who work together towards a common goal and, as a result, create environmental, ecological and economical value.
- An ecosystem perspective is a suitable analytical lense for the PED analysis since it takes into account:
- Interdependency of (business and policy) goals.
- Heterogeneous actors providing (both private and public) values.
- Governance as a key challenge.

(Zapata Riveros et al., 2024)

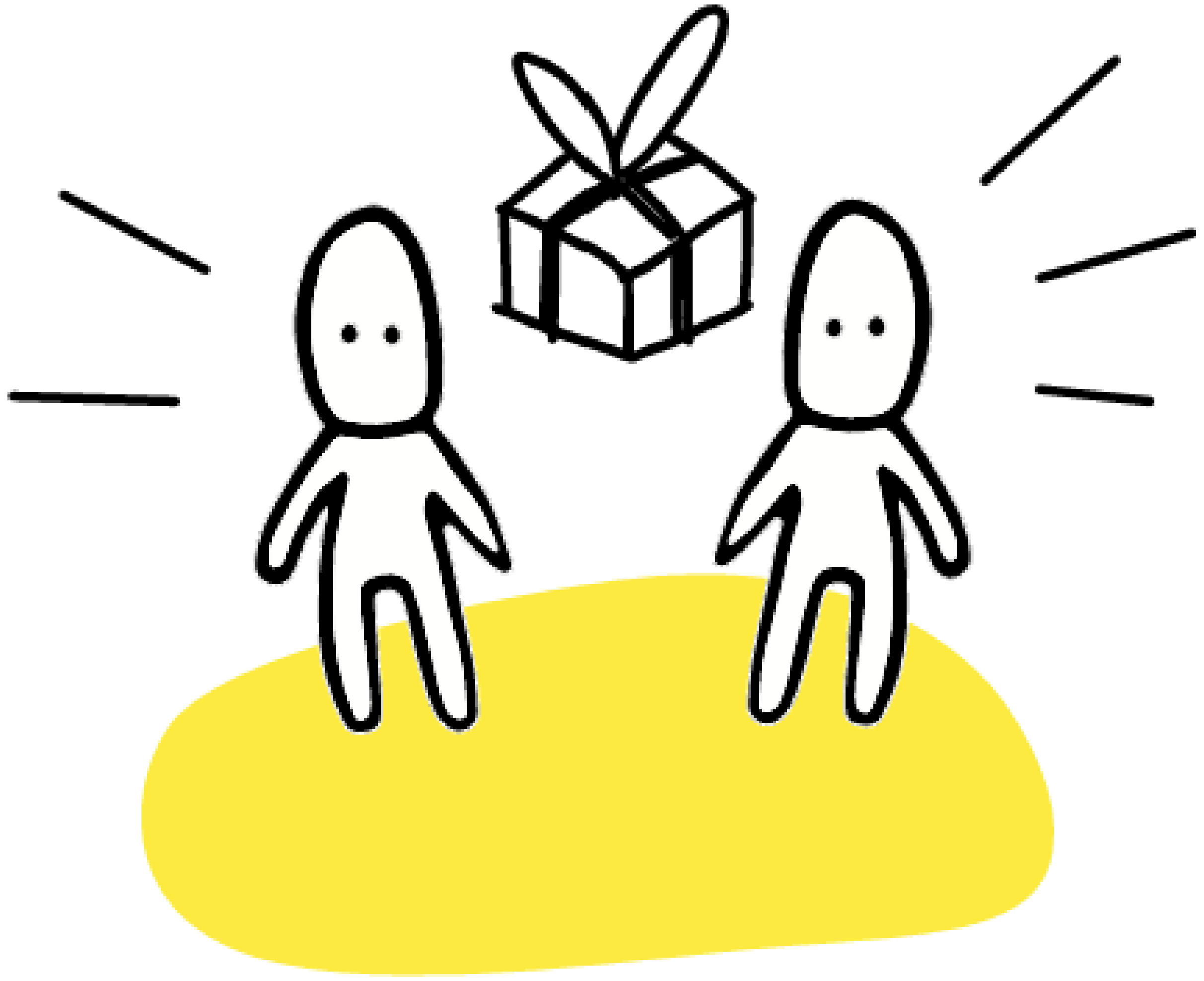


(Lewrick, 2021)

PEDs and Business Models perspective

- a Business Model focuses on value creation by a single organization
- But PEDs should address situations, where…
- Value creation depends on the interactions of several, independent organizations
- Value is created for end customers as well as for society
- Systemic innovations are required

(Zapata Riveros et al., 2024)



(Lewrick, 2021)

How can we motivate our stakeholders to get involved in a PED project?

Stakeholders Motivation & Value Exchange

Motivating stakeholders to get involved in a PED project requires a clear understanding of what **drives** each participant. This is where **value network analysis** comes in, as it helps map out the various forms of value exchanged within the ecosystem, not just financial but also knowledge, relationships, and intangible benefits. By identifying these **value streams**, we gain insights into how each stakeholder can benefit from the project.

Outlining these values creates a **shared understanding of the roles and responsibilities of each actor**, which in turn fosters a sense of ownership and alignment. When **stakeholders** see how their contributions, whether tangible or intangible, directly impact the success of the project, they are more likely to **feel motivated and engaged**.

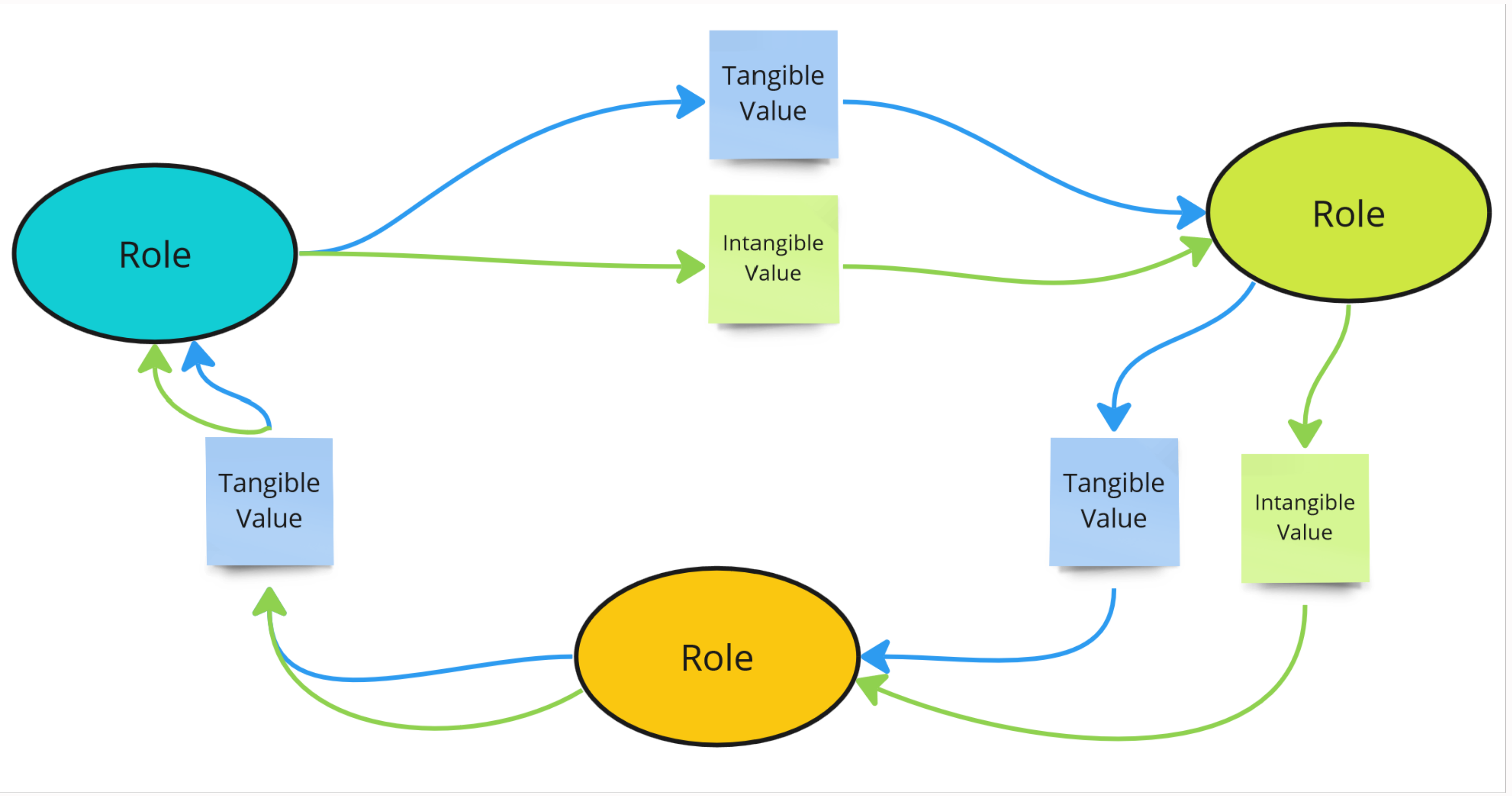
Thus, by understanding the value exchanges within the network, we can tailor our engagement strategies to highlight these benefits, ensuring **stakeholders are not only motivated to participate but also see the long-term value** they contribute to and gain from the PED project.

Value Network Analysis

The value network analysis to map the exchange of value among the ecosystem actors, considering not only the financial exchange but other kinds of values such as knowledge or intangible benefits.

Outlining these value streams improve the understanding of each other's roles and responsibilities, as well as the benefits that are being created between the ecosystem.

(Mihailova et al., 2022)



KPIs as a bridge in the Value Network

Key Performance Indicators (KPIs) are essential for assessing the impact of the **value network** in a PED. They provide measurable outcomes that help stakeholders understand the success of their contributions. However, KPIs do more than just track performance, they also serve as a **motivational tool**.

- **KPIs** measure the **effectiveness and efficiency** of stakeholder interactions.
- KPIs provide **tangible metrics** to assess:
  - How well stakeholders are fulfilling their roles
  - Whether the overall system is achieving its sustainability goals

Example KPIs in PEDs

To do`s for everyone

Comfort

- Indoor air temperature
- Indoor relative humidity
- Indoor air speed and distribution
- Indoor air renewal rate
- Thermal comfort
- Indoor air quality
- Heat island
- Noise pollution
- Indoor acustic comfort

Environmental and energy performance

- Increase in local renewable energy production
- Increase in storage capacity
- Charging capacity managed (no. and power of charging points for electric vehicles subjected to an energy demand management)
- Use of waste heat
- Percentage of district buildings with certified energy-efficient standards
- Energy savings
- Electrification

Climate change and pollution

- Total value and/or reduction in greenhouse (CO_2) gas emissions
- Air quality index
- Climate resilience strategy

Waste and water management

- Total value and/or reduction in greenhouse (CO_2) gas emissions
- Air quality index
- Climate resilience strategy

Sustainable mobility infrastructure

- No. of electric vehicles (EVs) and low-carbon emission vehicles deployed in the area
- No. of electric vehicles (EVs) per capita
- Availability rate of e-buses (percentage of days in which the e-buses are available to provide transportation service)
- Vehicle-To-Grid (V2G) parking places (car and bicycle)
- No. of electric vehicle (EV) charging stations

Environmental sustainability and citizenship

- Residents' energy awareness
- Economic incentives to promote sustainable actions
- Progress towards energy citizenship
- Active/pro-active behavior of citizens (e.g., willingness to invest in energy savings measures or pay more for RES or service)
- Well-being

(Marotta et al., 2021)

Example KPIs for different stakeholders

Municipalities

Responsible for creating policies and governance frameworks.

KPIs:

- Reduction in greenhouse (CO_2) gas emissions
- Air quality index
- Climate resilience strategy
- Increase in local renewable energy production
- Increase in installed RES storage capacity
- Increase in new RES system integration

Products and Service providers

Deliver technologies and services for energy efficiency, renewables, and electric mobility.

KPIs:

- Charging capacity managed (no. and power of charging points for EVs subjected to an energy demand management)
- No. of electric vehicle (EV) charging stations
- Vehicle-To-Grid (V2G) parking places (car and bicycle)

Example KPIs for different stakeholders

Financers

Provide funding for projects and incentivize sustainable investments.

KPIs:

- Investments in renewable energy systems and infrastructure
- Incentives for renewable energy adoption and electric vehicles

Citizens

Consume energy, adopt sustainable behaviors, and engage with energy systems.

KPIs:

- Indoor air quality
- Residents' energy awareness
- Willingness to pay more for renewable energy services or products

Owners of the district and buildings

Responsible for managing, maintaining, and upgrading buildings or districts to align with energy efficiency and sustainability goals.

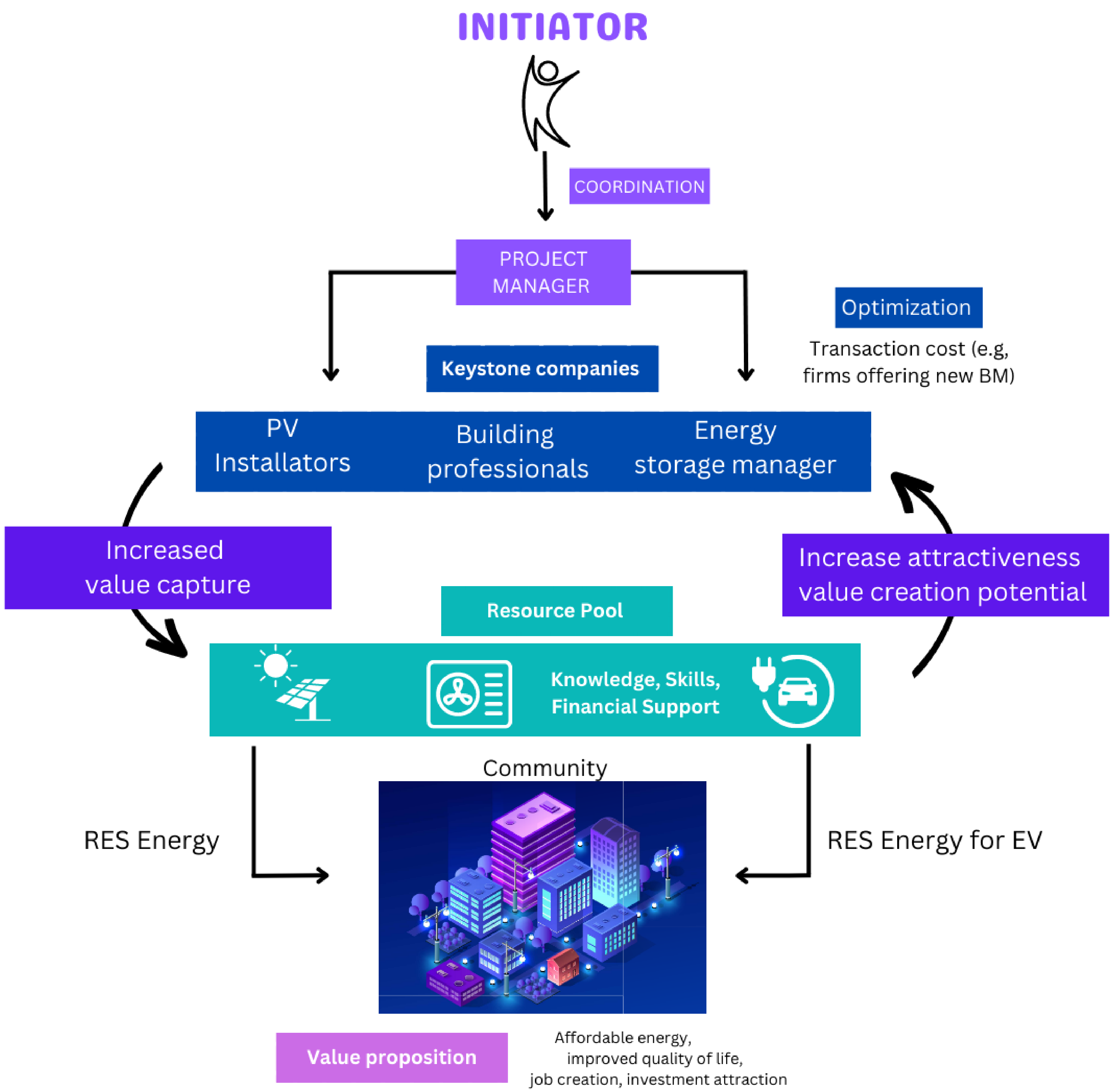
KPIs:

- Percentage of district buildings with certified energy-efficient standards.
- Increase in Installed Renewable Energy Storage Capacity

How can business models effectively address the multiple dimensions of PEDs?

Conceptual model of the PED business ecosystem

The graphic provides a high-level overview of the ecosystem activities. Multiple stakeholders, such as the project initiator, the orchestrator (or project manager) and the companies that belong to the business ecosystem (i.e., service and product providers), interact with each other and share the goal to develop a PED. Their activities enlarge the **resource pool** by expanding the knowledge and technology base, which might also attract new financial resources. Through this co-evolutionary process, **new value propositions for customers and the ecosystem actors emerge,** consequently enhancing the attractiveness of the ecosystem.



(Zapata Riveros et al., 2024)

Business Models in PED context

PEDs and other related concepts are becoming increasingly important to achieve the goal of zero GHG emissions, as it ideally considers not only the generation of local renewable electricity, but also the retrofitting of buildings to reduce energy demand, the electrification of heating and transport, the expansion of shared mobility, and the use of intelligent algorithms to increase efficiency and flexibility (Nguyen and Batel, 2021; Eicker, 2022).

Therefore, there is a need for supporting business models that address the different dimensions of PEDs: Renewable energy generation, energy efficiency, sustainable mobility, and building refurbishment (Bossi et al., 2020; Zhang, 2023).

Overview Business models in the Energy Sector

BUSINESS MODEL	DESCRIPTION	IMPLEMENTATION EXAMPLE IN SWITZERLAND
Energy Cooperatives	Energy cooperatives are a classic example of citizen-led initiatives where end-users collective finance their renewable energy system.	Energiegenossenschaft Schweiz Plans, support and operates solar energy cooperatives.
Community Prosumerism and Local Energy Markets	Prosumers trade energy with other community members, usually through a P2P transaction platform.	Quartierstrom
Community Collective Generation	Community Collective Generation relies on shared generation facilities (usually photovoltaic) located at on the roofs of multi-family dwellings, where the generated energy is distributed among several customers.	Quartiers Hohlen
Community Flexibility Aggregation	Pooling the available flexibility of the community's generation and demand and commercializing it in energy and flexibility markets.	Fleco power Aggregation and integration of decentralized renewable plants
Third-Party-Sponsored Communities	Energy communities that are partially or fully funded by external actors, such as utilities, which typically retain ownership of the assets and work closely with the communities.	Lugaggia Innovation community
Community Energy Service Companies	External companies, usually utilities, can partner with energy communities to jointly create and operate a community ESCO to deliver renewable energy.	https://www.groupe-e.ch/fr EKZ

Example Business Models in the Energy Sector:

Energy Cooperatives

- Energy cooperatives are a classic example of citizen-led initiatives where end-users collective finance their renewable energy system.
- There are about 300 energy cooperatives in Switzerland that produce heat and/or electricity.
- Cooperatives are usually non-profit organizations that aim to increase the share of local renewable energy.
- Local consumption of the energy produced is one of the most common sources of income.

(Rivas, 2018)

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Example Business models in the Energy Sector:

Peer to peer energy exchange

Quartierstrom

- Prosumers trade energy with other community members, usually through a P2P transaction platform.
- This was a pilot project that demonstrated the use of peer-to-peer in a community in Switzerland.
- The commercial application of this project in Switzerlandis currently not possible due to legal restrictions.
- The pilot project has been further developed in a **startup** that offers an energy billing and sharing platform in several European countries.

Overview Business models in the Mobility Sector

BUSINESS MODEL DESIGN OPTION	DESCRIPTION OF THE BM DESIGN	EXAMPLE COMPANIES
Asset ownership model	The service provider owns the assets (e.g., the vehicles) that are rented to customers for a fee.	Hertz, Enterprise Rent-A-Car
Peer-to-peer (P2P) model	Private persons rent out their personal vehicles to others via an online platform.	2EM, Sharoo
Subscription model	Customers can pay a monthly or annual fee for access to different transportation services.	Mobility
Pay-per-use model	Customers pay only for the transportation services they use.	Mobility, Lime, Carvelo
Bundled services model	Various transportation services (e.g., public transit, ride-hailing, bike-sharing) are combined into a single package for customers.	Mixmyride
Collaborative consumption	Individuals share their own assets (e.g., carpooling, bike sharing) with others through a community-based platform	HitchHike

(Boer et al., 2022); (Cohen & Kietzmann, 2014)

Example Business models in the energy sector:

Car Sharing

Mobility Carsharing Explained Briefly

1 / Reserve Conveniently reserve a vehicle near you online.
2 / Open Open the reserved car with the Mobility Card or SwissPass, start the engine, and go!
3 / Drive Refuel for free while on the go and extend or shorten the rental period.
4 / Close Return the vehicle to its original location and lock it with the Mobility Card. Pay by invoice or credit card.

- There are at least two different car-sharing models:
  - Traditional car-sharing: an operator owns a fleet of vehicles and distributes their use among its customers
  - P2P car-sharing: private car owners rent their vehicles through a platform for short time
- The most well know traditional carsharing operator in Switzerland is the cooperative Mobility, which offers subscription and pay per use models to its customers

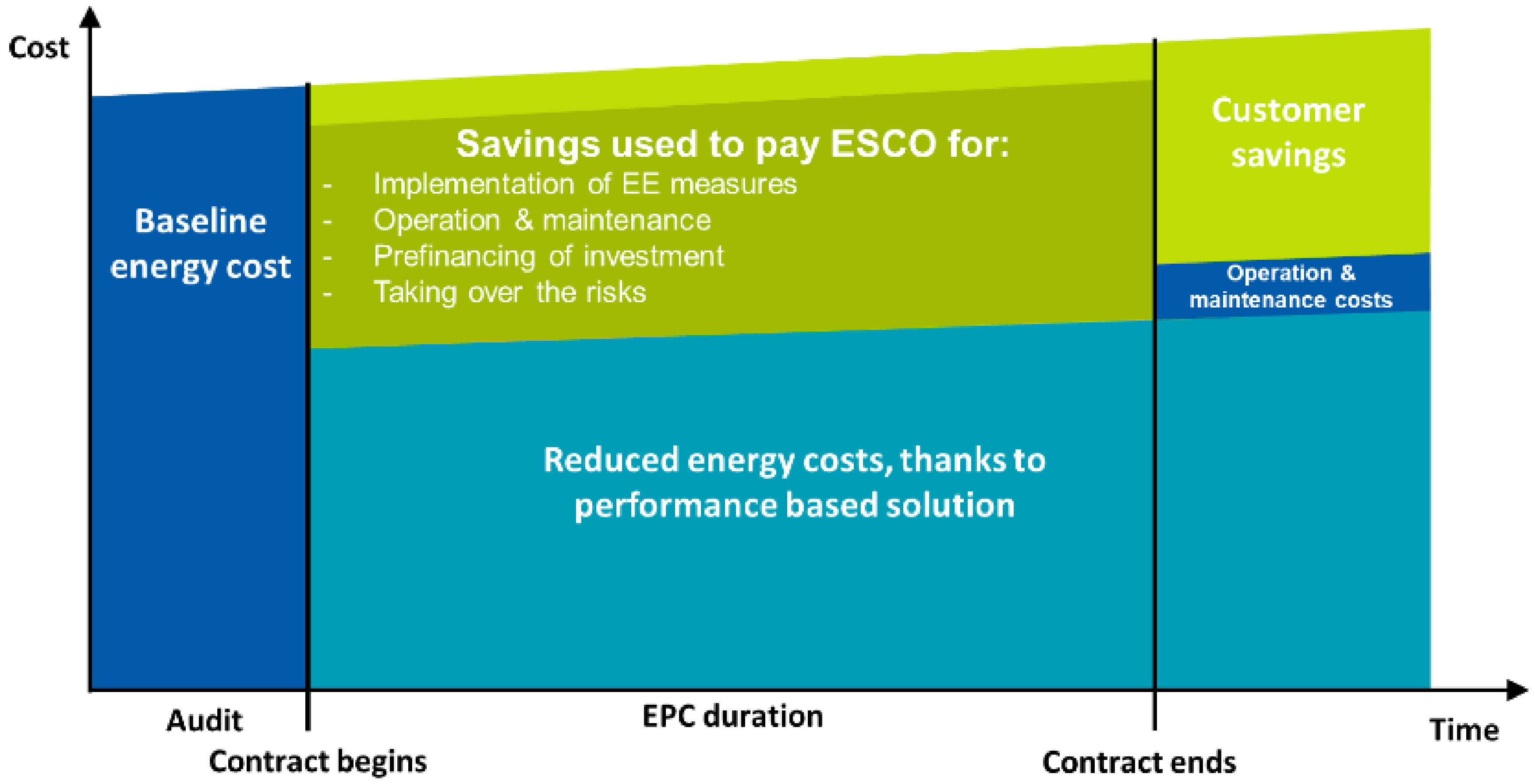
Overview Building retrofit Business Models

BUSINESS MODEL DESIGN OPTION	DESCRIPTION OF THE BM DESIGN
Traditional Model	Linear model: owners and tenants pay themselves for the buildings´ renovation.
Grants and Subsidies	Government and non-profit organizations provide financial incentives for energy-efficient renovations. These incentives can take the form of grants, rebates, tax credits, and low-interest loans.
Cooperative Refurbishment Model	A model where building tenants or owners form a cooperative to finance and implement building refurbishment and energy efficiency measures.
Energy Performance Contracting (EPC) Model	An EPC company funds and implements building renovation and energy efficiency measures, and receives payment based on the resulting energy savings.
Energy Efficiency as a Service (EEaaS)	Similar to EPC, but the ESCO retains ownership of the energy-efficient equipment and sells energy services to the building owner. The building owner pays for the energy savings achieved.
Public-Private Partnership (PPP) Model	Collaboration between public and private sectors to renovate public buildings, often using a long-term contract and performance-based payment system.
Crowdfunding	Financing model where multiple investors provide funds for energy-efficient renovations in exchange for a share of the energy savings.

Example Building retrofit Business Models:

Energy service company & Energy Performance Contractring

An EPC company funds and implements building renovation and energy efficiency measures, and receives payment based on the resulting energy savings.



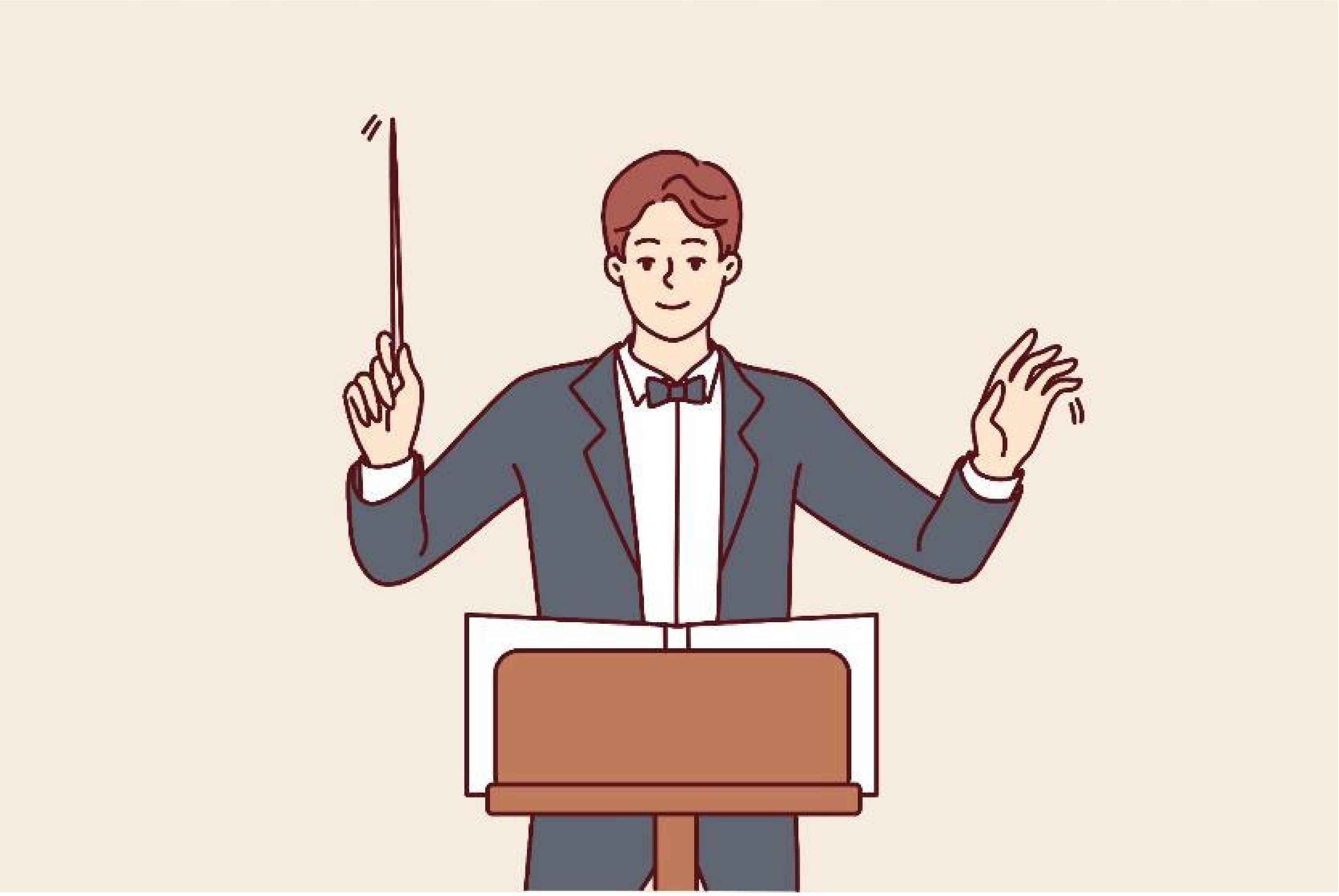
Planning and Implementation

Who will coordinate the efforts?

Orchestrator

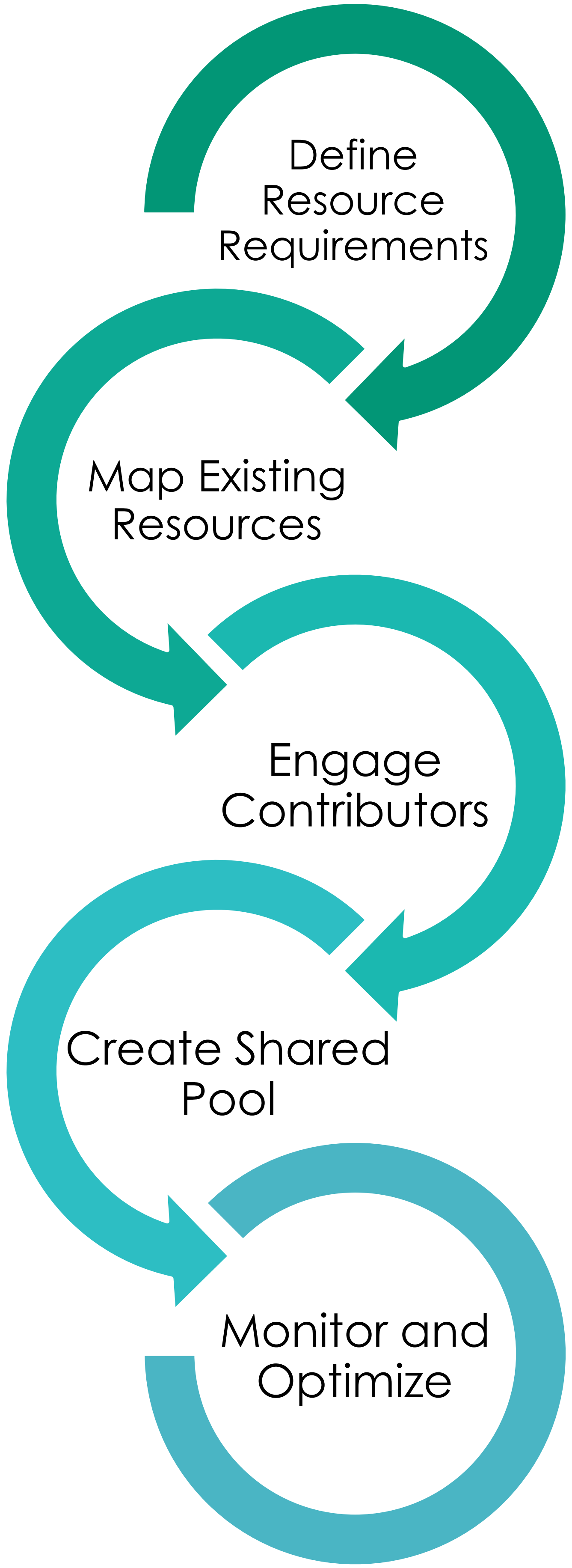
The role of an orchestrator is to coordinate the activities among the keystone actors i.e., the actors in the value network and the business environment.

The role of the orchestrator of a PED is usually played by the municipality, private companies or cooperatives that can involve private and public actors.



What resources are needed or created in our ecosystem?

How to apply Resource Pooling in PEDs



Understand the physical resources, financial resources, data infromation and digital assets , human resources and know how, social capital and intangible resources needed for your PED project.

Conduct an inventory of current resources and identify underutilized ones.

Bring municipalities, private companies, and communities on board.

Combine resources into a unified, managed pool.

Track progress, measure impact, and refine resource allocation.

Resource Pool

To understand what resources are needed or created within our ecosystem, it is essential to organize them into a structured resource pool. This pool is divided into various categories, each representing a specific type of resource or aspect of our ecosystem.

Physical Resources

- Energy infrastructure
- Renewable energy
- Energy conversion and storage devices

Financial Resources

- Investment capital
- Government incentives
- Subsidies

Data Information and digital assets

- Smart grid systems
- Data analytics
- Energy management software

Human Resources and know-how

- Technical skills
- Problem solving abilities
- Expertise in specific areas

Social Capital

- Engagement of citizens

Intangible Resources

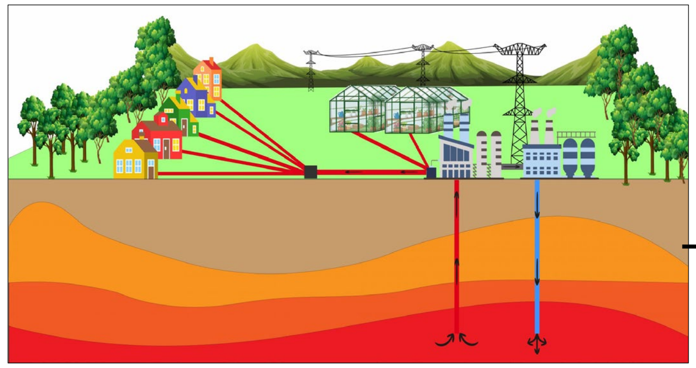
- Abstract assets important for the success of the project (e.g., information exchange)

Technological approach

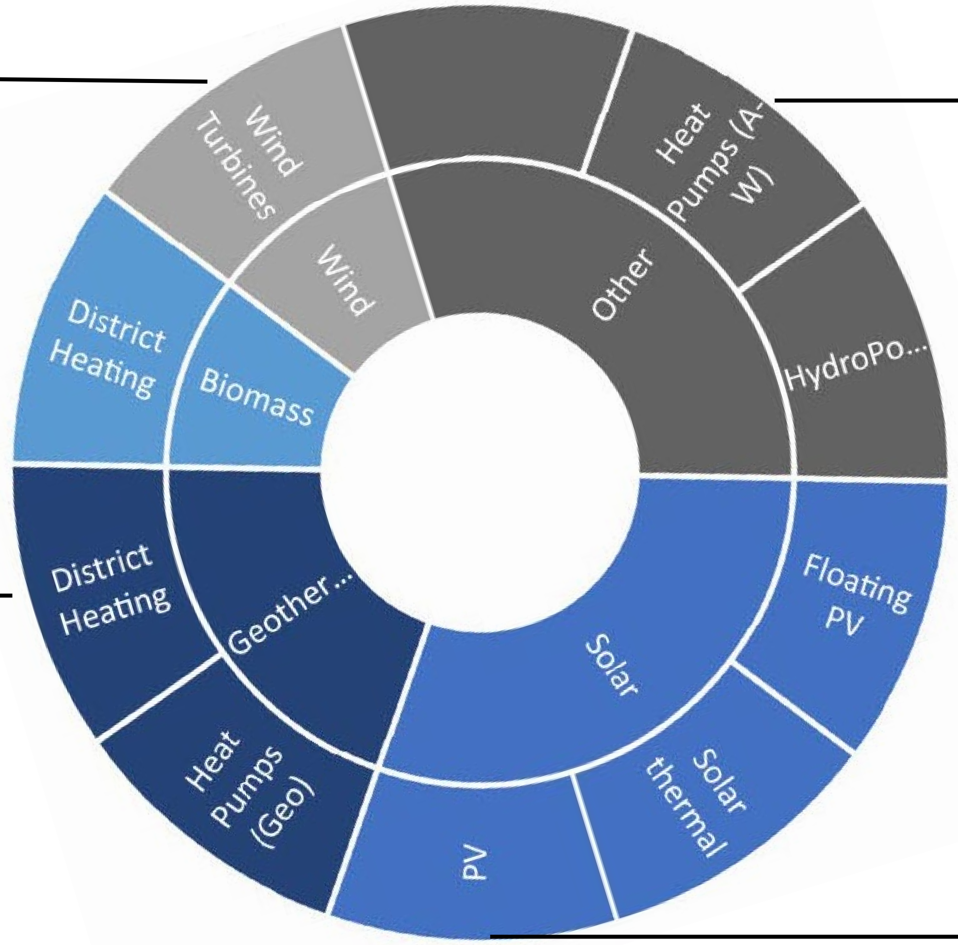
To select **an optimal energy mix** for the successful deployment of a PED, it is important to match energy technologies with energy requirements and locally available energy resources. The wheel diagram highlights the **most widely used technologies** in Swiss energy production.

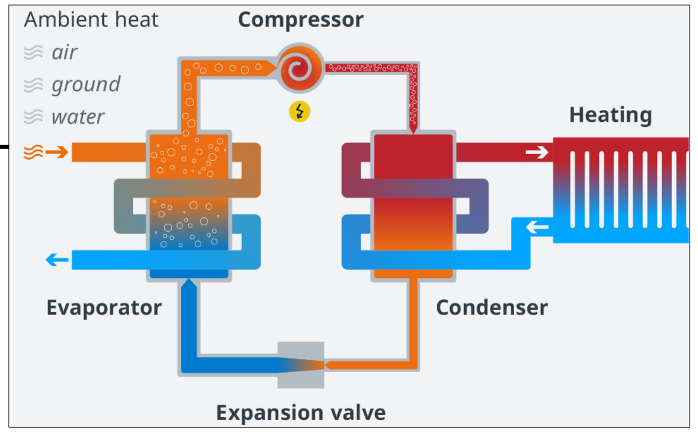
(Morais et al., 2025)

Wind Turbines - mechlesson.com

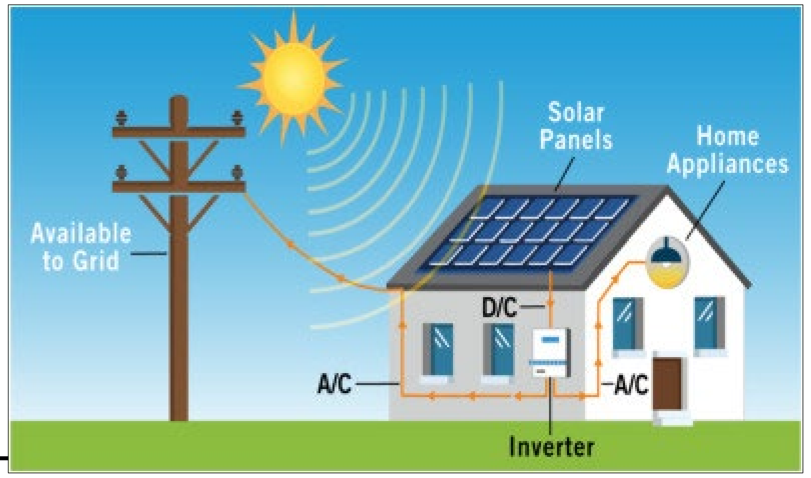


Geothermal District Heating - epigroup.com





Heat Pump - dw.com



Solar PV – Kumar et al. (2021)

Identify energy requirements

Energy requirements **are not equal** across all districts, neither in quantity nor in typology. The successful deployment of a PED depends on their analysis.
The analysis involves the specification of the different energy requirements, i.e. types and quantity.

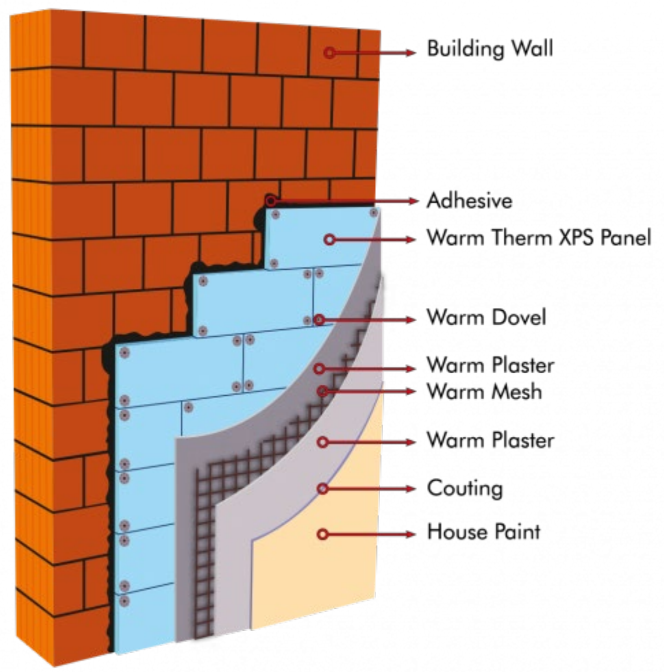
(Morais , 2023)

pedeu.net

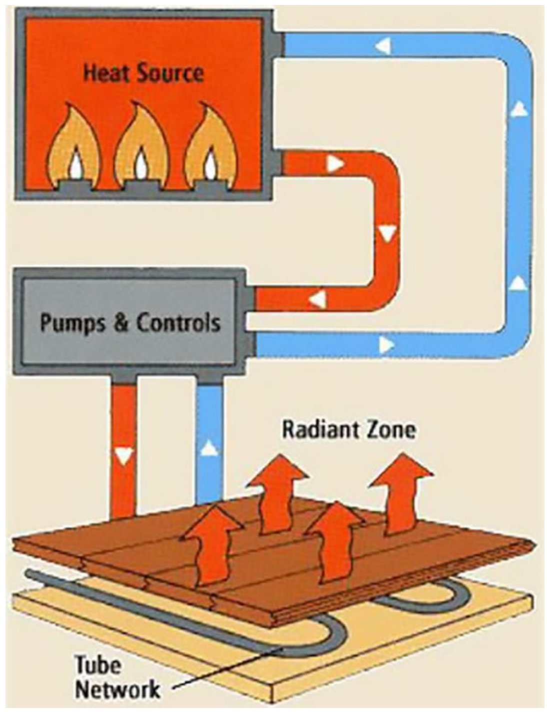
What are the energy requirements ?

- Heating
- Domestic hot water
- Electricity
- Mobility

There are different types of energy requirements, for example heating is required to heat spaces. This heat can be provided at different temperature levels depending on the heating technology (e.g. low temperature level for floor heating). Different quantities of heat depending on the space use or construction specification (e.g. highly insulated construction will require less heating energy).



Wall insulation – warm-international.com



Floor heating – *hardwoodinfo.com*

Identify energy resources

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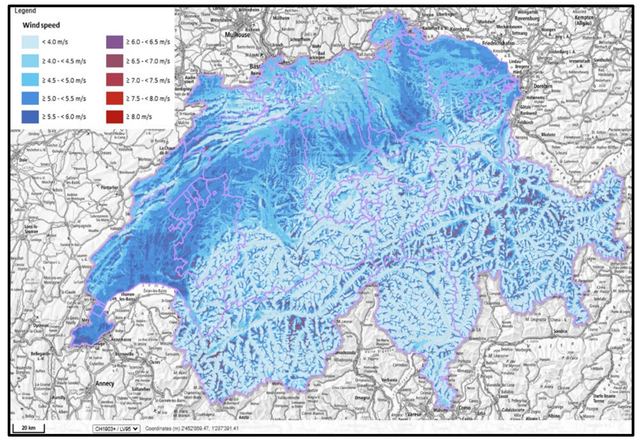
Energy resources and climate conditions **are not equal** across Switzerland. The successful deployment of a PED depends on their analysis.
The **suggested strategy** to tackle *"What energy resources are available in the deployment region?"* is illustrated in the diagram.

(Morais , 2023)

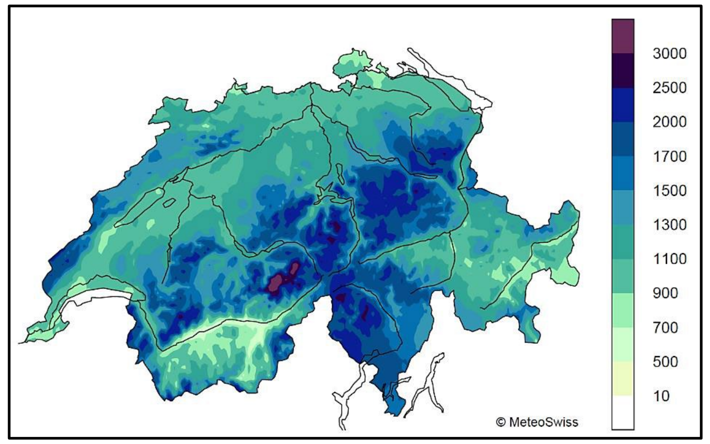
What energy resources can I use ?

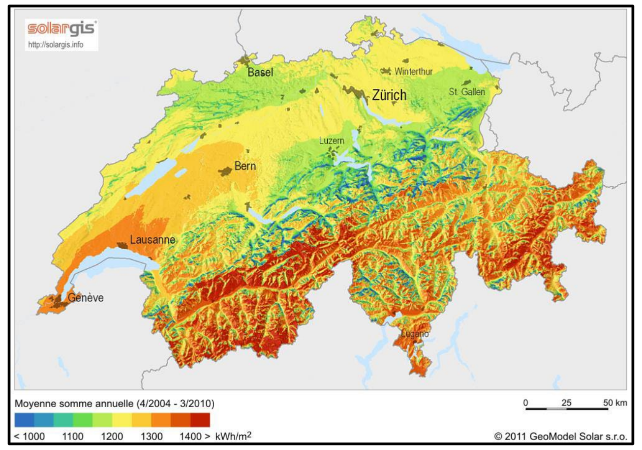
- Solar ?
- Biomass ?
- Geothermal sources?
- District heating ?

Windspeed - windatlas.ch

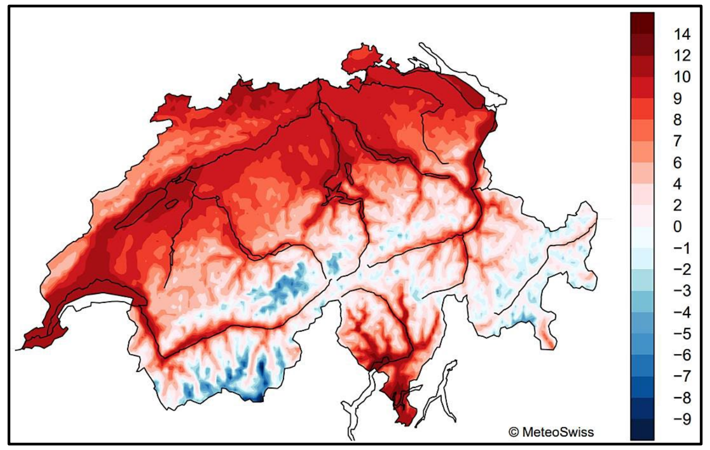


Precipitations - MeteoSwiss





Horizontal solar radiation - solargis.com



Temperature - MeteoSwiss

There are different types of energy resources. Each resource can be transformed to satisfy different energy requirements (e.g. solar energy can be transformed to heat or electricity). During the design of the PED, it is necessary to consider the climatic parameters of the region in the selection process of the technologies. As an example, a preliminary study of the available solar radiation is required to design and characterise a photovoltaic installation.

Several online tools already available can be helpfull, e.g. :

- Windatlas.ch
- MeteoSwiss
- map.geo.admin.ch
- Solar roof (bfe.admin.ch)
- Local GIS public system (e.g. sitg.ge.ch)
- …

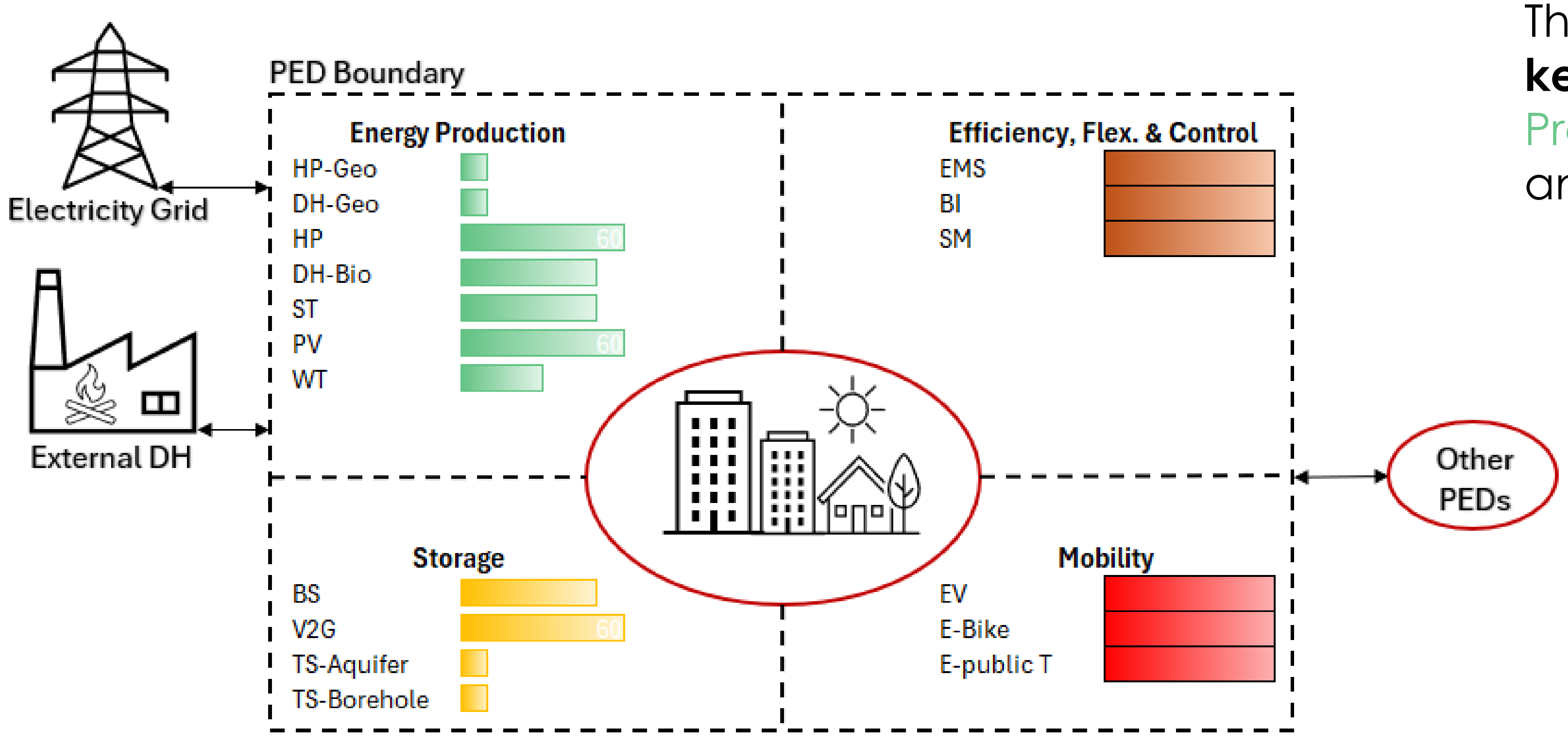
Example - PED deployment

Based on the energy requirements and resources, **a mix of technologies** can be defined for each case, e.g. 80% of heating production is satisfied by Heat Pump (HP).

The technologies sizing will be made to take advantage of the mostly available resources such that **production exceeds local requirements** and contributes to satisfy nearby districts needs.

The technologies deployed will have to meet the **4 key technical components** of a PED : Energy Production, Efficiency, Flexibility & Control, Storage and Mobility.

(Smart Cities Marketplace, 2020)



Example of an energy technologies mix

HP-Geo : Heat Pump – Geothermal
DH-Geo : District Heating – Geothermal
HP : Heat Pump
DH-Bio : District Heating – Biomass
ST : Solar Thermal
PV : Photovoltaic
WT : Wind Turbine
BS : Battery Storage
V2G : Vehicle To Grid
TS-Aquifer : Thermal Storage – Aquifer
TS-Borehole : Thermal Storage – Borehole
EMS : Energy Management System
BI : Building Insulation
SM : Smart Meters
EV : Electric Vehicle
E-Bike : Electric Bicycle
E-public T : Electric Public Transport

What external parameters affect our PED ecosystem ?

PESTLE

PESTLE stands for Political, Economic, Social, Technological, Legal and Environmental factors. This tool helps decision makers identify external influences that affect an ecosystem (Lewrick, 2022).

PESTLE Analysis for PEDS

Below, we provide you with some questions that you can consider when conducting the PESTLE analysis of your PED:

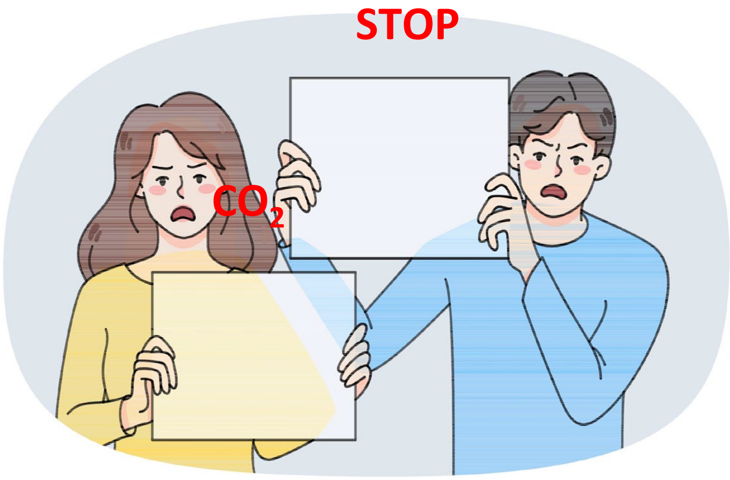
Political

What government policies could be beneficial or unfavorable to the success of the PED ecosystem? (e.g., environmental commitments)

Economic

Which economic factors will affect the development of the PED? (e.g., Gas and electricity cost)

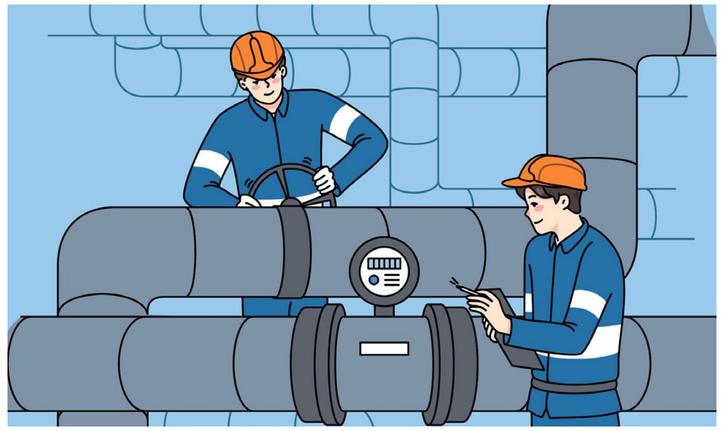
Social



How do human behavior or cultural trends play a role in the business ecosystem? (e.g., Health Well-being, work styles, environmental awareness etc.)

PESTLE Analysis for PEDS

Technological



What innovations and technological advances are available or will be available in the future? (e.g., advanced Photovoltaic or heat networks, self driving cars)

Legal

Which regulations and laws apply to the envisaged PED? - Do they help or hinder the project?
(e.g., Ban on gas and oil heating systems)

Environmental

How does the environment affect the PED and, conversely, what effect does the PED have on the environment. (e.g., Total CO_2 emissions, primary energy use etc.)

Understanding PEDs Through Energy Modelling

Energy Modeling for PEDs: Analyzing Building Archetypes

Zurich University of Applied Sciences
zh aw School of Engineering
INE Institute of Sustainable Development

To analyze how different buildings can contribute to a Positive Energy District, a modelling approach was used. This involved studying 11,200 archetypes representing various factors, including:

- Different building types and sizes
- Varying levels of electrification (e.g., heating and transport)
- Presence or absence of photovoltaic (PV) systems

What is "Positive Energy Ratio" (PER)?

PER is a metric that indicates whether a building produces more energy than it consumes.

- **PER > 1** → The building is a net energy producer.
- **PER < 1** → The building is a net energy consumer.

Why is this important?

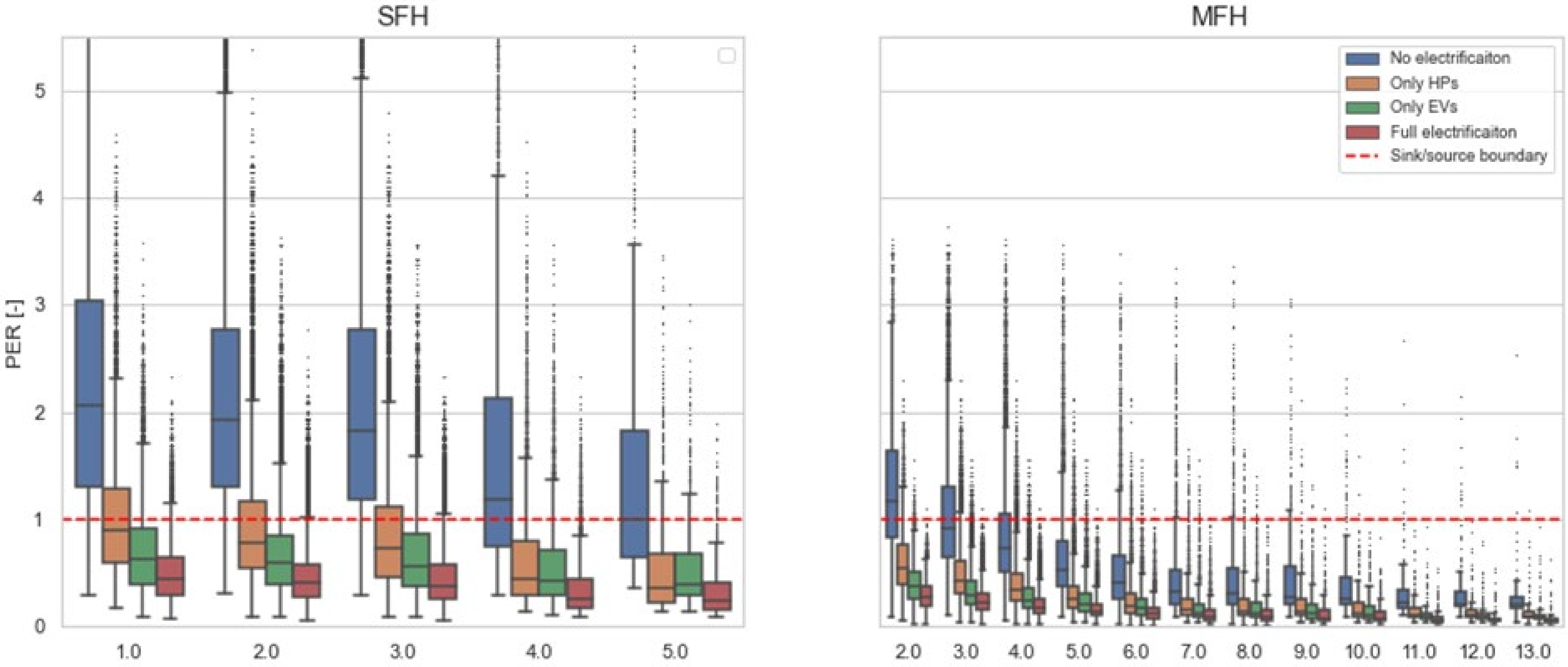
For sustainable urban development and climate protection, it is crucial to design buildings or entire districts that generate more energy than they consume

What does electrification mean?

- Replacing fossil fuels with **heat pumps (HPs)** and **electric vehicles (EVs)** increases electricity consumption.
- At the same time, **photovoltaic (PV) systems** on rooftops and facades enable self-sufficient energy production.

Positive Energy Ratio (PER): Measuring Energy Balance

A comparison of PER values for different building types (SFH vs. MFH).
PER (Positive Energy Ratio): >1 for net producers, <1 for net consumers



Manuscript submitted to a journal by UNIGE in January 2025

Understanding benefits and tradeoffs

What does the chart show?

- **Single-family houses (SFHs)** can be **net producers**, i.e. they can produce more electricity than they consume if electrification of heating systems and mobility is avoided
- **Multi-family houses (MFHs)** are typically **net consumers**, i.e. they mostly consume more electricity than they produce even without electrification. **PV area is insufficient**
- Electrification increases the level of **self-consumption** of autoproduced PV electricity, which improves the economic viability of PV systems
- Electrification reduces the level of **self-sufficiency** because the demand for electricity rises while the amount of autoproduced PV electricity is fixed (determined by the available roof area)
- Electrification is anyway considered essential for decarbonisation.

Recommendations

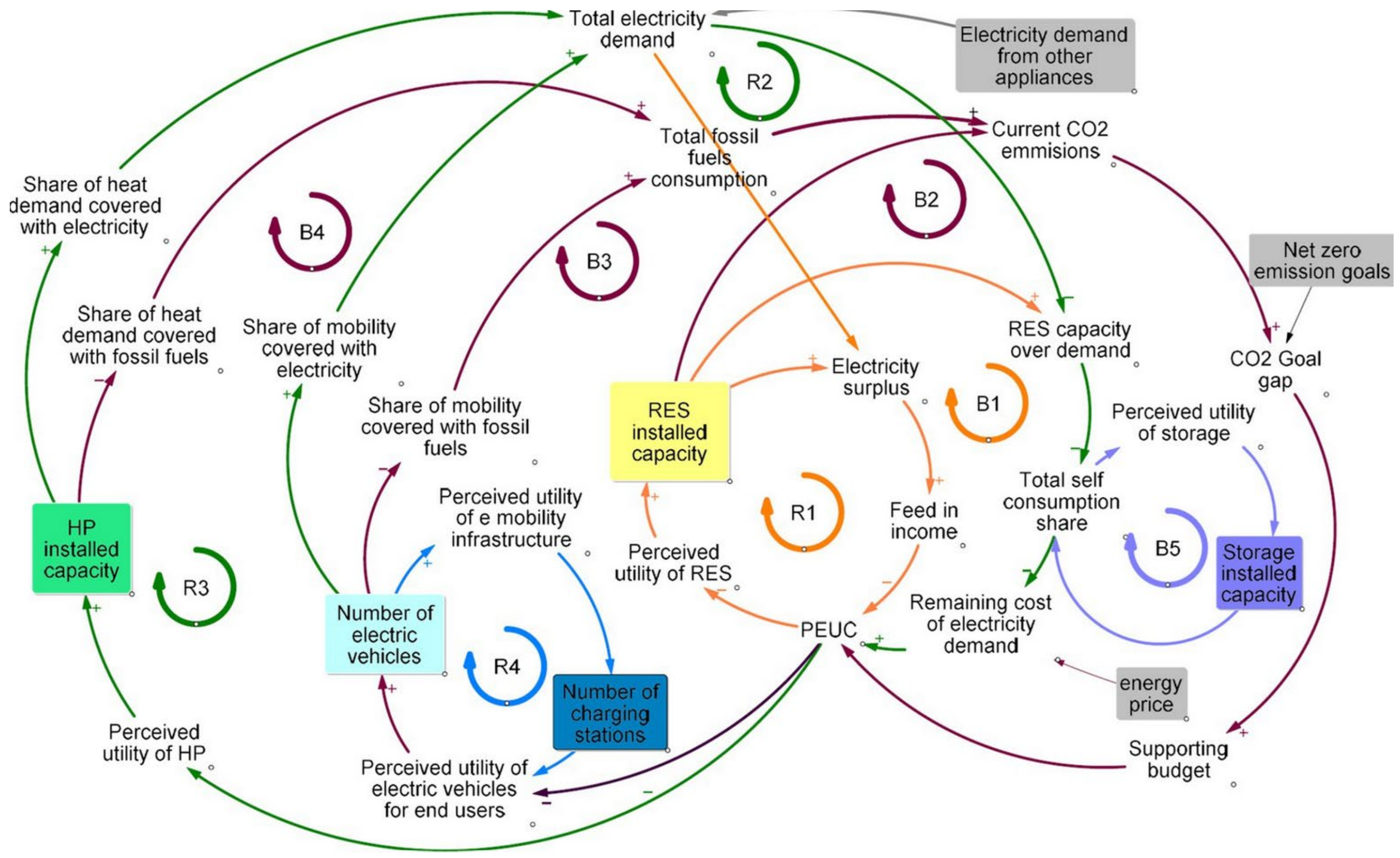
To realize more Positive Energy Districts,

- the autoproduction of **PV electricity should be maximised** by fully exploiting the roof area and increasingly implementing PV on facades
- the **electricity consumption should be reduced** while proceeding with elecrification. This can be achieved by energy efficiiency measures (e.g., lighting or insulation) and/or by sufficiency measures

System Dynamics: Insights for PEDs

System Dynamics (SD) Models: Insights for PED Implementation

Understanding the dynamics of Positive Energy Districts (PEDs) requires an analysis of how different technologies, business models, and stakeholder interactions influence the transition toward net-zero energy districts. System Dynamics (SD) models provide a framework for simulating these complex interactions, helping decision-makers anticipate potential challenges and opportunities.



Key Insights from the SD Models

The SD models tested different scenarios related to technology adoption, investment decisions, and CO_2 reduction strategies.

The most critical insights include:

- Factors Influencing PED Adoption and Success
- Impact of Business Models on Technology Diffusion
- Return on Investment (ROI) and Financial Considerations
- CO_2 Emission Reduction and Environmental Impact

Most important KPIs for the different stakeholders

		
Investor	**Public Authority**	**Residents**
Return on Investment	CO2 emission reduction Installed Capacity PV Installed Capaciy HP	Monthly rent increase Monthly Energy cost (savings)

HOW TO ESTIMATE THE ROI?

A real estate investor is interested in energy retrofitting a building if the return on investment is positive.
The return on investment is estimated to be:

$$\text{ROI} = \frac{\text{NET PROFIT}}{\text{COST OF INVESTMENT}} \times 100$$

Where the Net Profit is:

$$\text{NET PROFIT} = \text{Rent increase} + \text{Property value increase}$$

The allowable net increase is the portion of the investment cost that can be passed on to tenants.
It is assumed that the market value of the property will increase by 1-4% with an energetic renovation.

(Wüest Partner, 2020)

CO2 EMISSIONS REDUCTION

Replacing a fossil fuel boiler with district heating and heat pumps brings a significant reduction in CO2 emissions in the area.

Heating fuel	CO2 Equivalent (kg CO2eq per kWh)
Oil	0.3
Natural Gas	0.2
Electricity mix	0.11
District heating from industrial waste	0
District heating gas fired	0.2

RENT INCREASE AND ENERGY COST

As mentioned above, the investor is allowed to pass a portion of the investment cost on to tenants.

A decrease in utility costs due to a more efficient heating system and therefore **lower energy** costs partially offsets this rent increase.

INVESTORS DECISIONS AND FACTORS AFFECTING THE DECISIONS

Investors need to decide which technology to use to heat their property sustainably, either district heating, a heat pump or a combination of these with photovoltaic panels.

These decisions are based on the perceived utilities to investors, which is derived from:

- Financial utility for the investors
- Scarcity effect on PV (i.e., PV potential)
- Familiarity with the technologies
- Peer effects
- Availability of district heating

Simulation insights

		
Investor	**Public Authority**	**Residents**
The return on investment is fairly constant over time. It is highly dependent on the increase in the market value of the property.	▪ The assumed increase in property values accelerates uptake of RES and heat pumps. ▪ Contracting business models accelerates the adoption of DH ▪ In all simulated cases, there is a significant reduction in CO_2 emissions for heating. ▪ In the case of district heating, for example, this will be highly dependent on the type of fuel used and will therefore require further sensitivity analysis	▪ In all simulated scenarios, the gross rent tends to decrease, although the decrease is smaller over time as new tenants move into the building. ▪ The decrease is due to the decrease in heating costs, which depends on several factors such as district heating tariffs, electricity costs and needs to be subject to sensitivity

Implications for PED Implementation

To effectively integrate these insights into PED planning, key actions include:

- **Aligning Business Models with Technology Synergies**
  Policymakers should promote business models that enhance synergies between technologies, such as incentivizing PV and heat pump adoption together.

- **Minimizing Financial Barriers for Stakeholders**
  Financial incentives, subsidies, and contracting models should be used to lower upfront investment costs and encourage early adoption of renewable technologies.

- **Optimizing Stakeholder Engagement**
  Transparent communication of financial and environmental benefits can motivate investors and residents to support PED projects.

- **Monitoring Long-Term Impact**
  Using key performance indicators (KPIs) such as ROI, CO_2 reduction, and energy cost savings will help track progress and refine strategies over time.

Monitoring PEDs: Theory of Change

How can we monitor the progress?

Theory of Change

The **Theory of Change** is a valuable tool for analyzing and guiding value network transformations in PEDs. By linking resources to impact and addressing financial, environmental, and social dimensions, it ensures that PEDs deliver sustainable outcomes. ToC facilitates alignment among stakeholders, enhances accountability, and provides a robust framework for scaling these initiatives, making it a critical methodology for driving systemic change in urban energy systems.

ToC is widely applied in social initiatives to assess impact and ensure that interventions align with societal goals. It provides a structured way to measure progress and ensure accountability (Claus and Belcher, 2020).

Theory of Change

This framework can guide the development and analysis of Positive Energy Districts (PEDs).

Time

Start → Short term success → Mid term success → Long term success

Inputs	Activities	Outputs	Outcomes	Impact
Resources needed to complete the PED project.	Key activities to be conducted to complete the PED	The output comprises the services provided to the target groups. It is quantifiable and can be measured with numbers	The outcome is understood to be the intended effects of a service or intervention, which are triggered in the target groups.	Impact describes the effect at the societal level. It is the effect of services or interventions that go beyond the outcome.
Examples: Project cost, Employees, Salaries etc..	**Examples:** Infrastructure developed, community mobilization	**Examples:** # of people reached, # of sustainable living spaces. # Best practice guidelines	**Examples:** Citizens adopted sustainable mobility behavior, Increase sustainability assessment	**Examples:** Job creation, entrepreneurship, improve well being Increased attractiveness of the region

Best Practices: Case Study Hunziker Areal

Best Practice: Case Study Hunziker Areal

Hunziker Areal, Zurich: A Model for Cooperative Living

The Hunziker Areal in Zurich-Leutschenbach is the first project by the housing cooperative **mehr als wohnen**. Built on a 41,000 m² former industrial site, it transformed the area into a vibrant neighborhood, offering homes for 1,200 residents and 150 workplaces since 2014/2015.

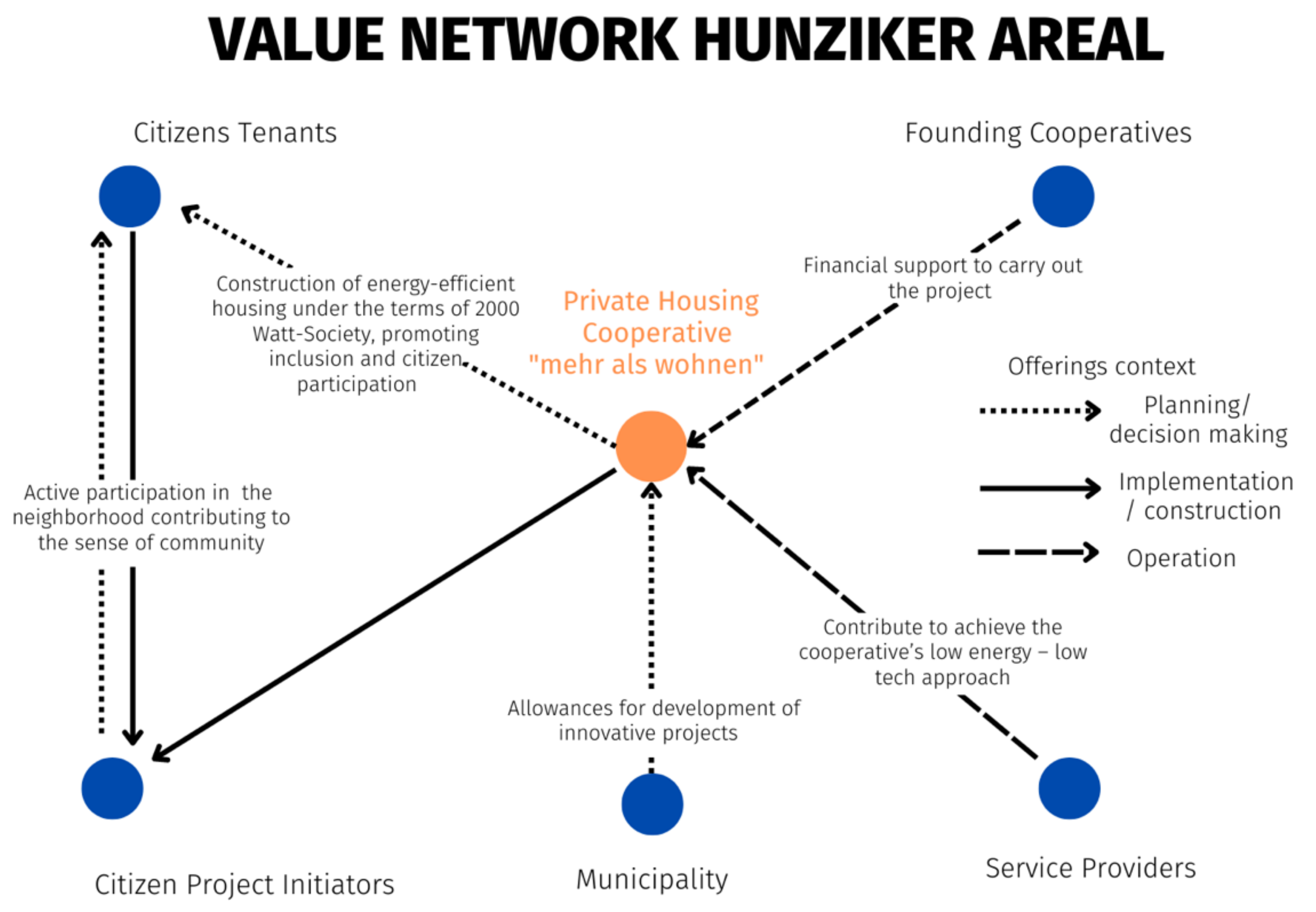
The project addresses evolving housing needs with innovative living models, shared spaces, and recreational infrastructure, while promoting sustainability through energy-efficient buildings, reduced car dependency, and a 2000-Watt Society vision.

With diverse residents, participatory processes, and democratic structures, Hunziker Areal fosters social and environmental sustainability, making it a pioneering example of modern urban living.

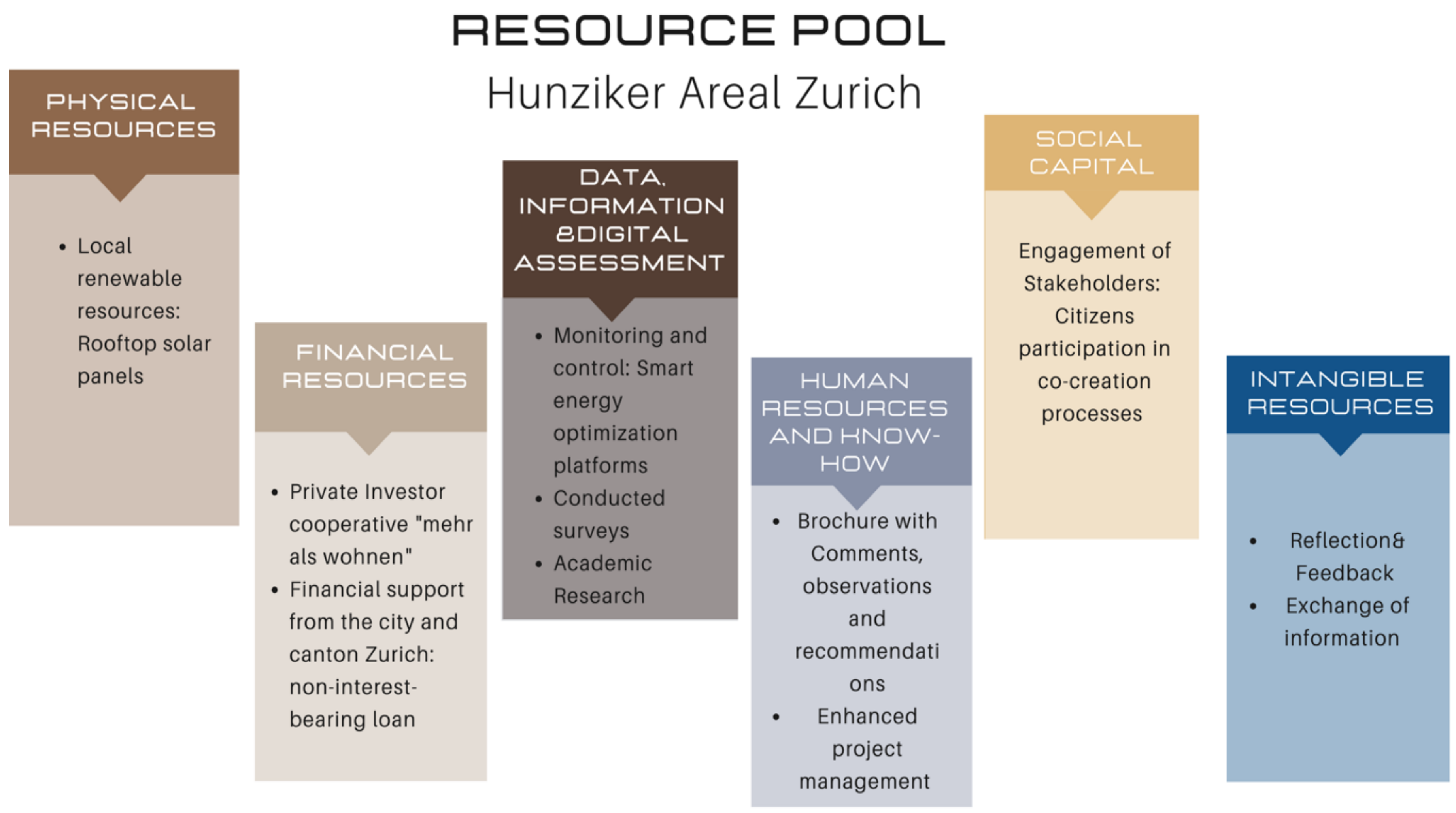
mehr als wohnen. (n.d.). *Das Hunziker Areal*.
Retrieved January 7, 2025, from https://www.mehralswohnen.ch/hunziker-areal/das-areal

HUNZIKER AREAL ZURICH

Best Practice: Case Study Hunziker Areal

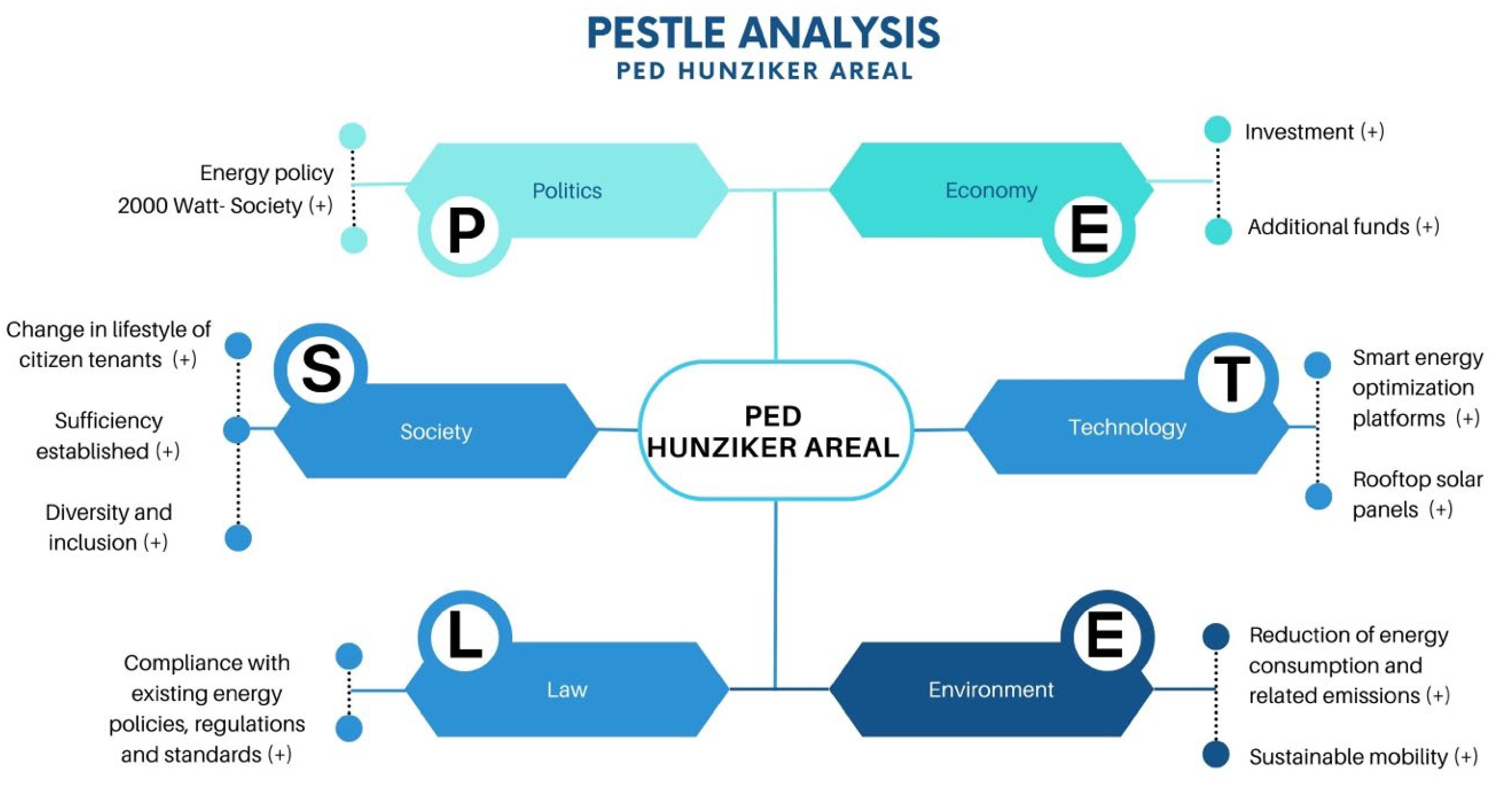


Value Network PED Hunziker Area. Orange node represents the main holder/ co-creator of the PED, all other identified stakeholders in blue (adapted from Speich & Ulli-Beer, 2022, Source Information Derkenbaeva et al., 2020)

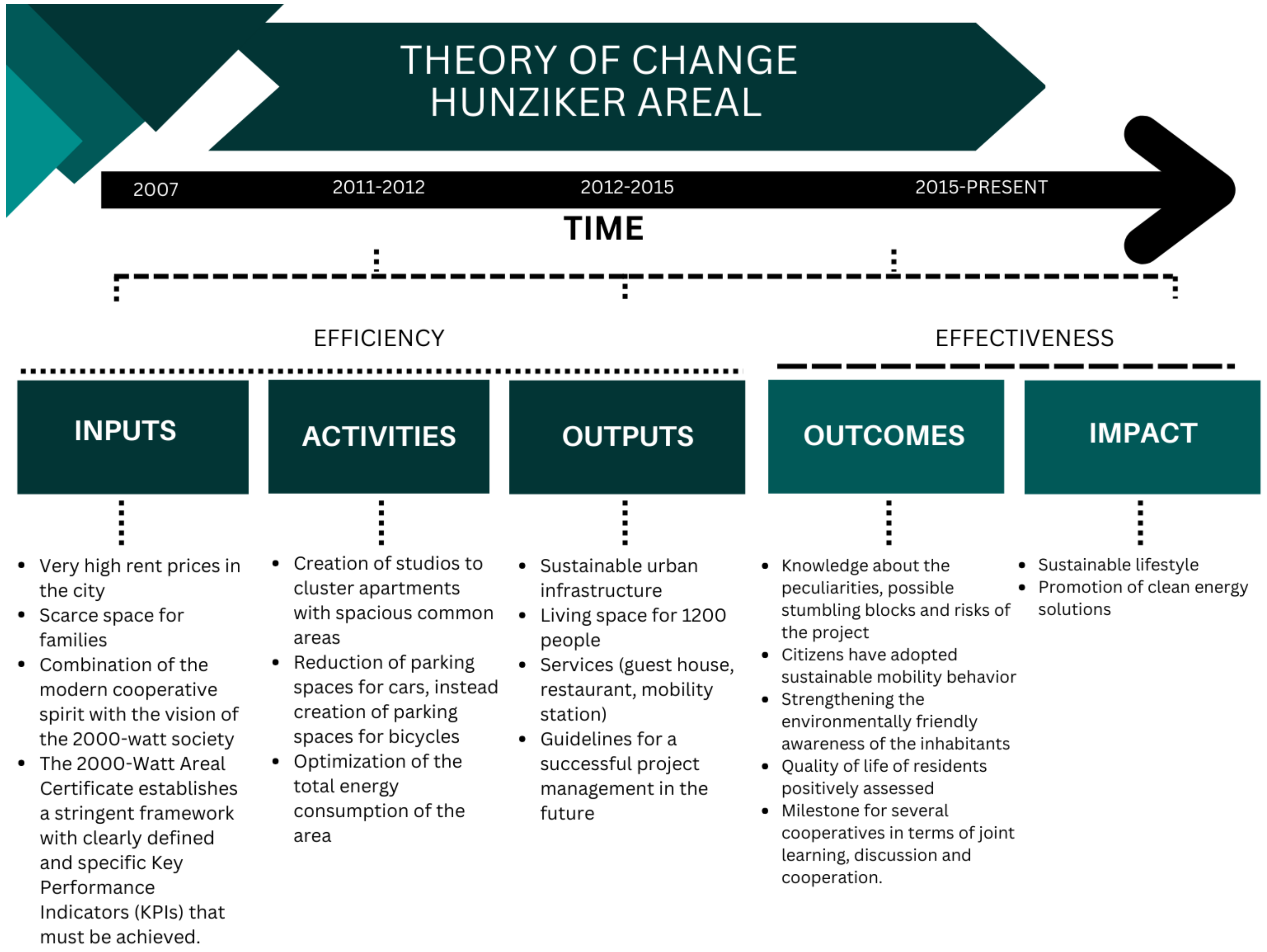


Resource Pool Hunziker Areal (adapted from Speich & Ulli-Beer, 2022; Source Information: (Haller et al., 2018))

Best Practice: Case Study Hunziker Areal



Pestle Analysis Hunziker Areal. The plus sign stands for a positive factor for the system, the minus sign for a negative factor (adapted from Lewrick, 2021; Source Information: Knüsel & Sidler, 2013)



Theory of Change PED Hunziker Areal adapted from (Mattos et al., 2022; Source Information: (Jakovac, 2019) , (Knüsel & Sidler, 2013)

Lessons Learned: Case Study Hunziker Areal

Urban Development & Architecture

- Integrating urban planning with architecture was crucial. Open spaces were designed first, followed by the buildings, ensuring a cohesive and diverse district rather than a fragmented settlement.
- A mix of architectural teams led to a more dynamic yet cohesive design.

Sustainability & Innovation

- The project aimed to create a **2000-watt society**, balancing ecological, economic, and social sustainability.
- Sustainability labels (Minergie-P-Eco) were used to ensure environmental responsibility across the entire complex, rather than just individual buildings.

Community & Participation

- The project actively involved residents in decision-making through local groups, workshops, and participatory structures.
- Facilitating participation required professional support and clear communication to avoid confusion or frustration.

Housing Diversity & Social Mix

- The project experimented with new housing models such as **satellite flats** and multi-generational housing, though the effectiveness of these formats remains to be fully evaluated.
- Smaller apartments (two- and three-room flats) were in high demand and should have been incorporated in greater numbers.

Research & Learning Hub

- Research was integrated into the project from the beginning, but too many studies made some residents feel like “guinea pigs”.
- A balance must be maintained between gathering valuable insights and avoiding research fatigue among residents.

Financial & Organizational Management

- A small but agile management team was key to the project's success.
- Heritable building rights agreements with the City of Zurich provided financial stability while ensuring affordable housing.

Commercial & Cultural Integration

- Ground-floor spaces were reserved for businesses, cultural initiatives, and community uses, ensuring a vibrant and functional neighborhood.
- A strong artistic and cultural presence contributed to the project‘s attractiveness and long-term success.

Scalability & Influence on Housing Cooperatives

- The project has become a model for cooperative housing, inspiring similar initiatives in Switzerland and beyond.
- Its innovative approach has helped redefine cooperative housing, demonstrating the benefits of mixed-use developments and participatory planning.

(Haller et al., 2018)

Annexes and Resources

Glossary

Carbon dioxide	CO_2
Energy Efficiency as a Service	EEaaS
Energy Service Company	ESCO
Electric Vehicle	EV
Heat Pump	HP
Key Performance Indicator	KPI
Positive Energy Districts	PEDs
Positve Energy Ratio	PER
Photovoltaic	PV
Business Model	BM
Positve Energy District	PED
Peer to Peer	P2P
Political, Economic, Social, Technical, Legal and Environmental	PESTLE
Public-Private Partnership	PPP
System Dynamics	SD
Theory of Change	ToC

Tools and Templates for PED Planing

Stakeholder Analysis Matrix
Resource Pool
PESTLE Analysis
Theory of Change Framework

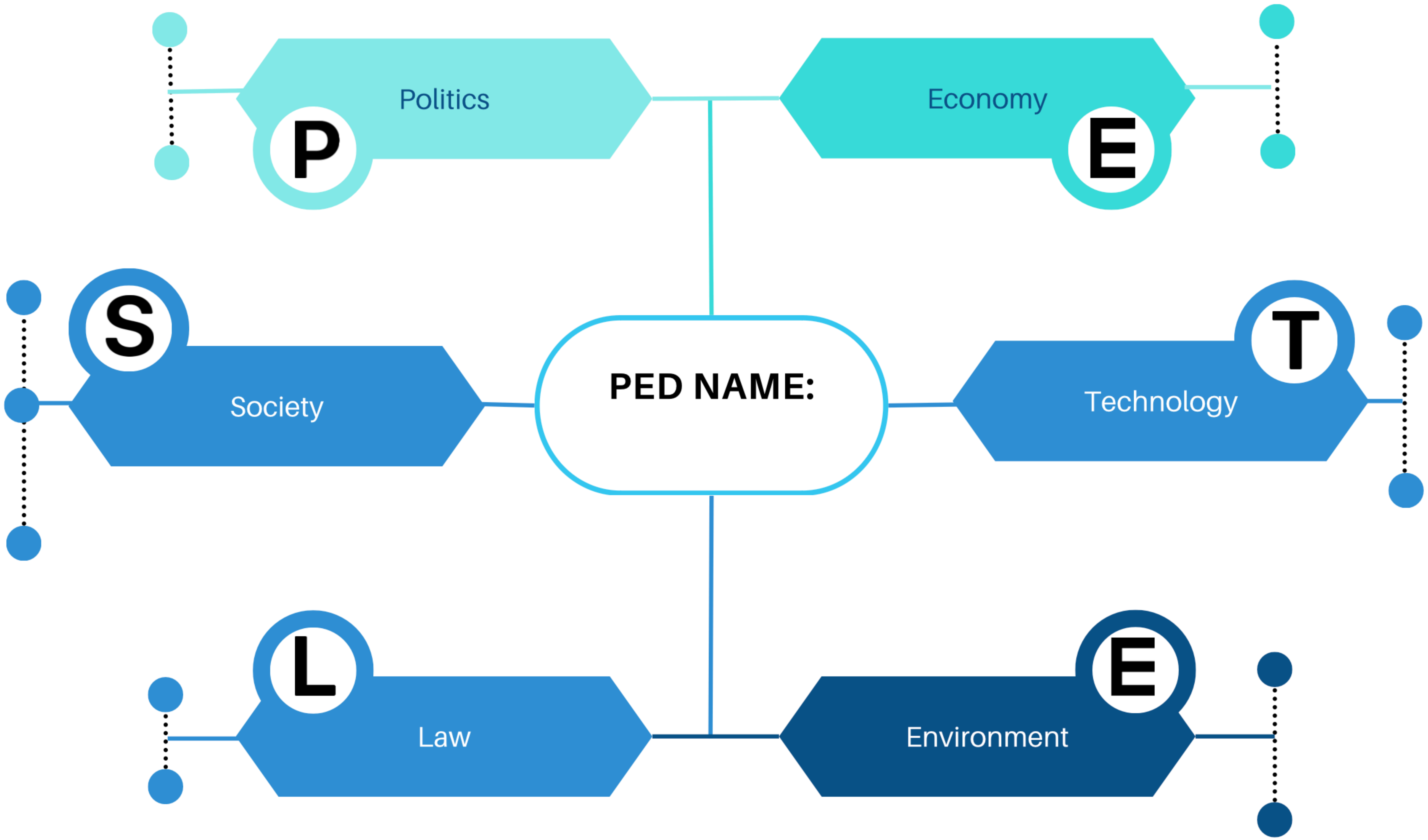
Stakeholder Analysis Matrix

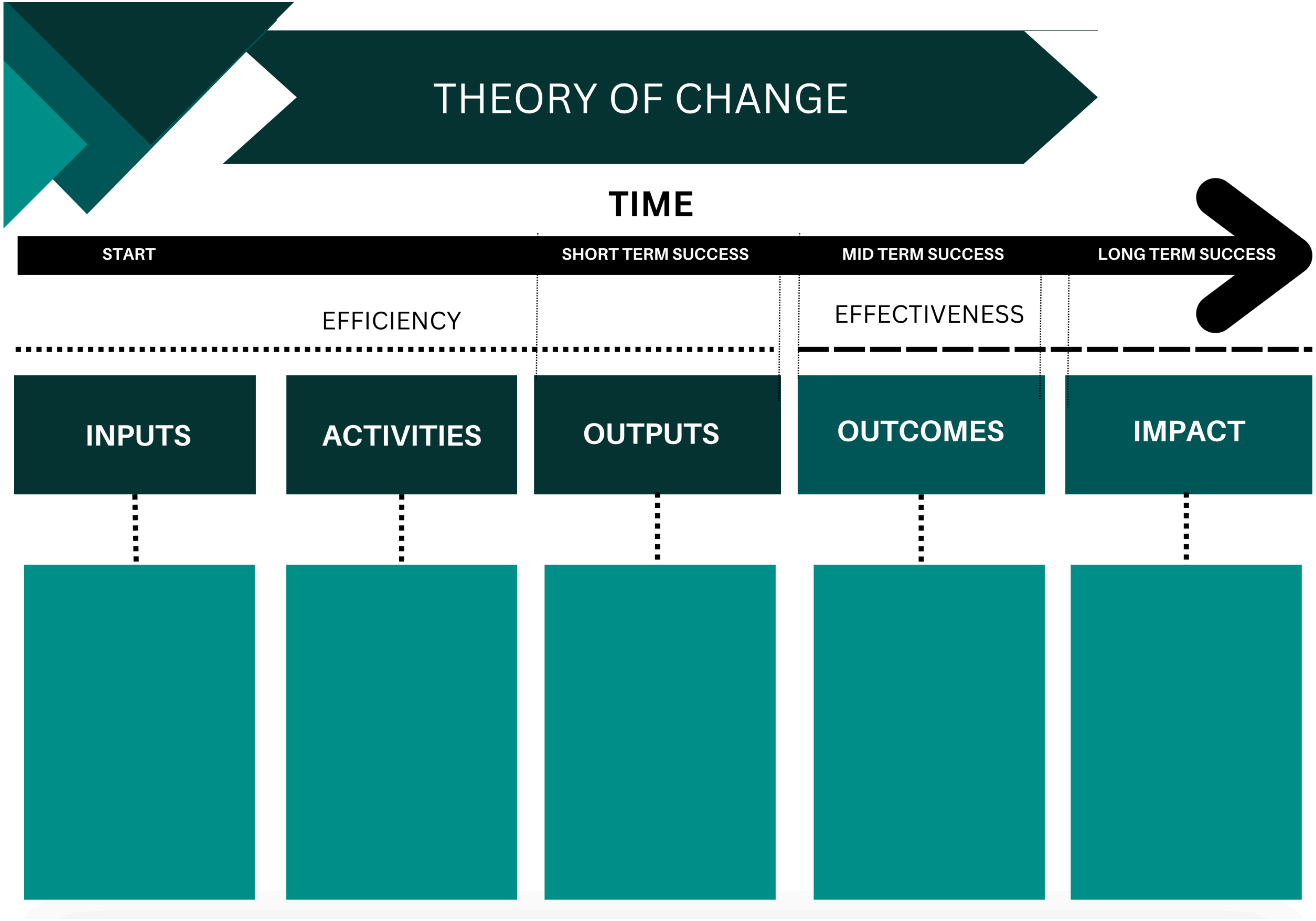
Name Stakeholder	**Impact:** How much does the project impact the stakeholder? (Low, medium, high)	**Influence:** How much influence does the stakeholder has? (Low, medium, high)	**Relevance:** What is important to the stakeholder?	**Involvement:** How could the stakeholder contribute to the project?	**Barriers:** How might the stakeholder potentially obstruct or delay the project? (Pains or concerns)	**Alignment:** Strategy to engage the stakeholder

Resource Pool

Physical Resources	Financial Resources	Data information and digital assets	Human Resources and know-how	Social Capital	Intangible Resources

PESTLE ANALYSIS





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Recommended further reading

The **PED-EU-NET** is dedicated to advancing the development and deployment of **Positive Energy Districts (PEDs)** across Europe. It serves as a platform for researchers, practitioners, and stakeholders to share knowledge, collaborate on innovative solutions, and support the implementation of energy-efficient, sustainable urban environments.

For more information, visit https://pedeu.net

Energy Cities is a network of local authorities working towards sustainable energy transitions in cities.

For more information, visit https://energy-cities.eu

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