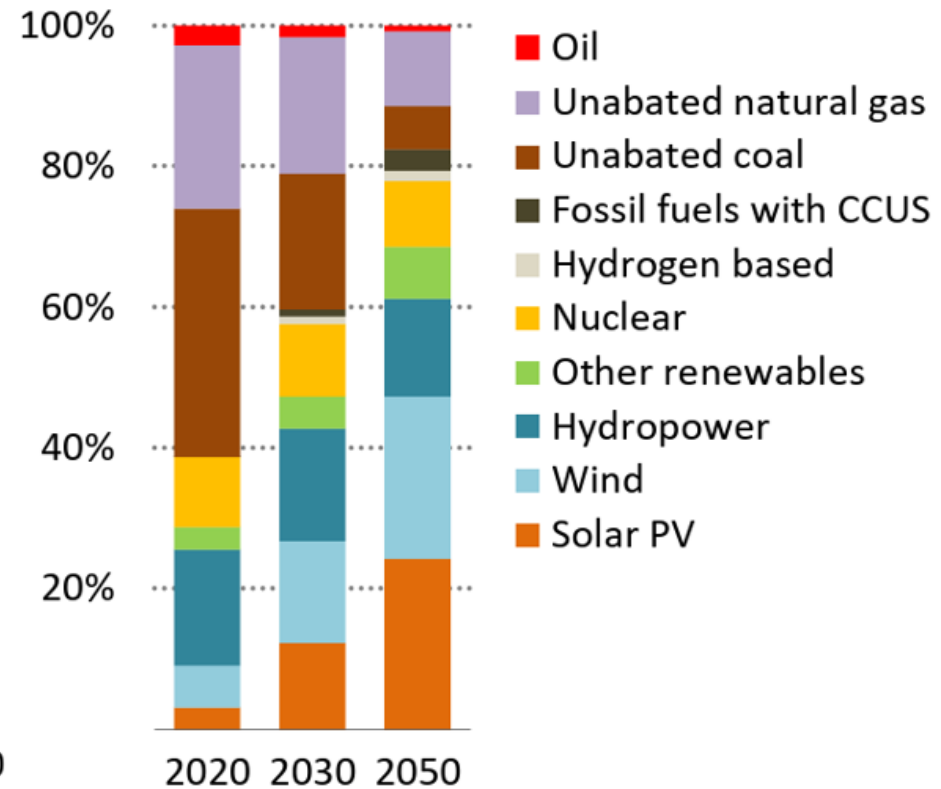
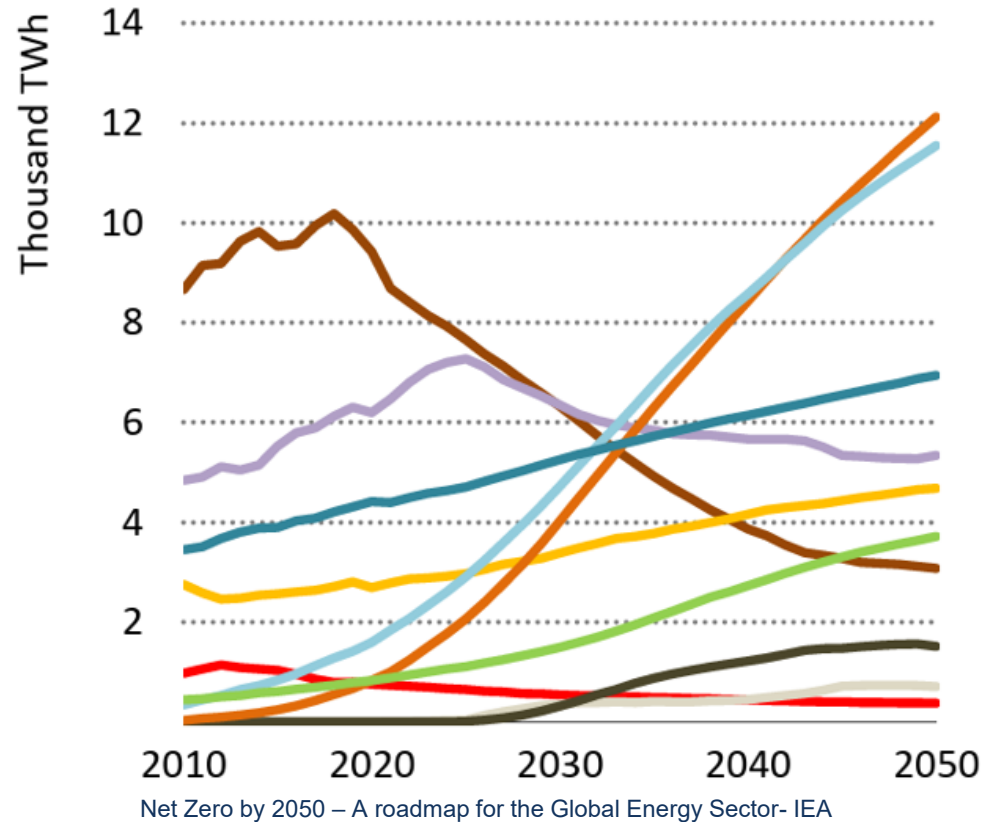


Unpacking Energy Communities

Gonzalo Ott Cruz – PhD Student
ETSAP – Helsinki, 2025



Global Electricity Generation



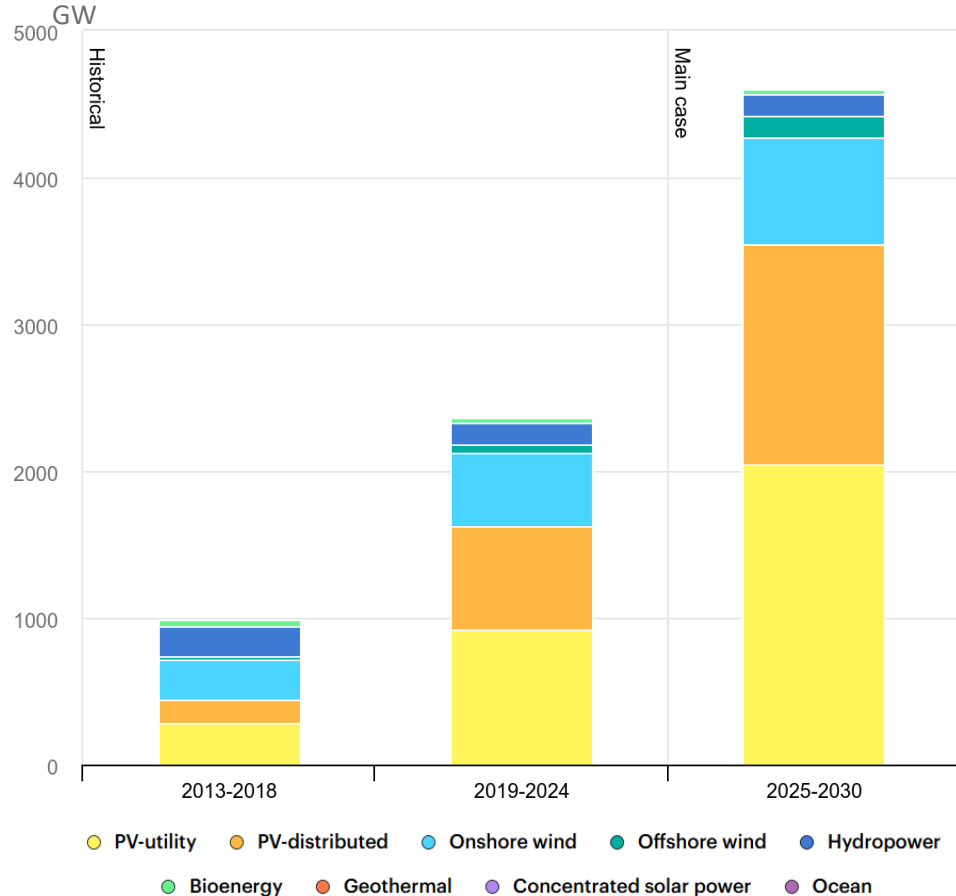
Integration of renewable

Of variable renewable generation (like solar and wind).

01

Distributed PV Expansion

Renewable electricity capacity growth by technology segment, main case, 2013-2030



Renewable electricity report – IEA

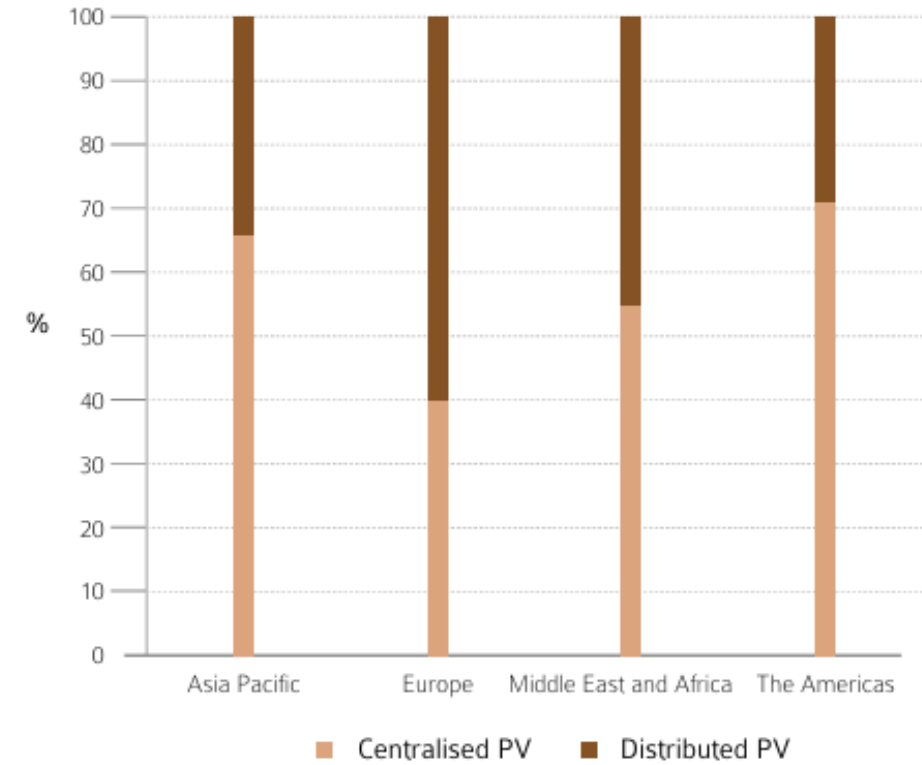
<https://www.iea.org/reports/renewables-2025/renewable-electricity>

Rapid growth of distributed generation

02

Decentralization increases resilience, self-sufficiency, and citizen participation.

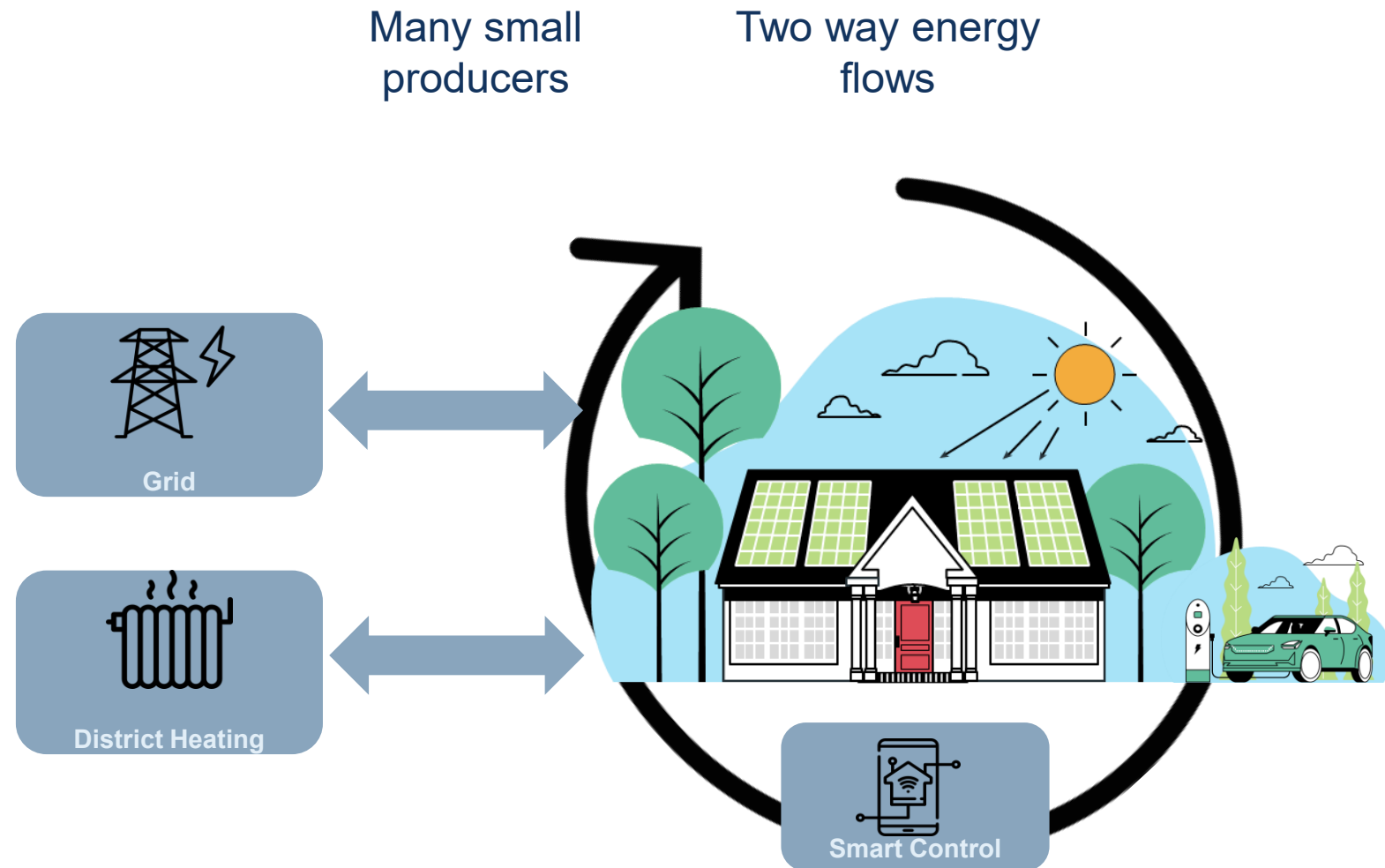
FIGURE 2.12: ANNUAL GRID-CONNECTED CENTRALISED AND DISTRIBUTED PV INSTALLATIONS BY REGION IN 2024



TRENDS IN PHOTOVOLTAIC APPLICATIONS - IEA PVPS & Others

https://iea-pvps.org/wp-content/uploads/2025/10/IEA-PVPS_Trends_2025-.pdf

From Consumer to Prosumer



Objectives

- How has the concept “energy community” evolved over time?
- What role do energy communities play in the future energy system?
- What is needed to represent energy communities adequately in comprehensive energy system models to assess its possible contribution to flexibility?

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Two review streams:

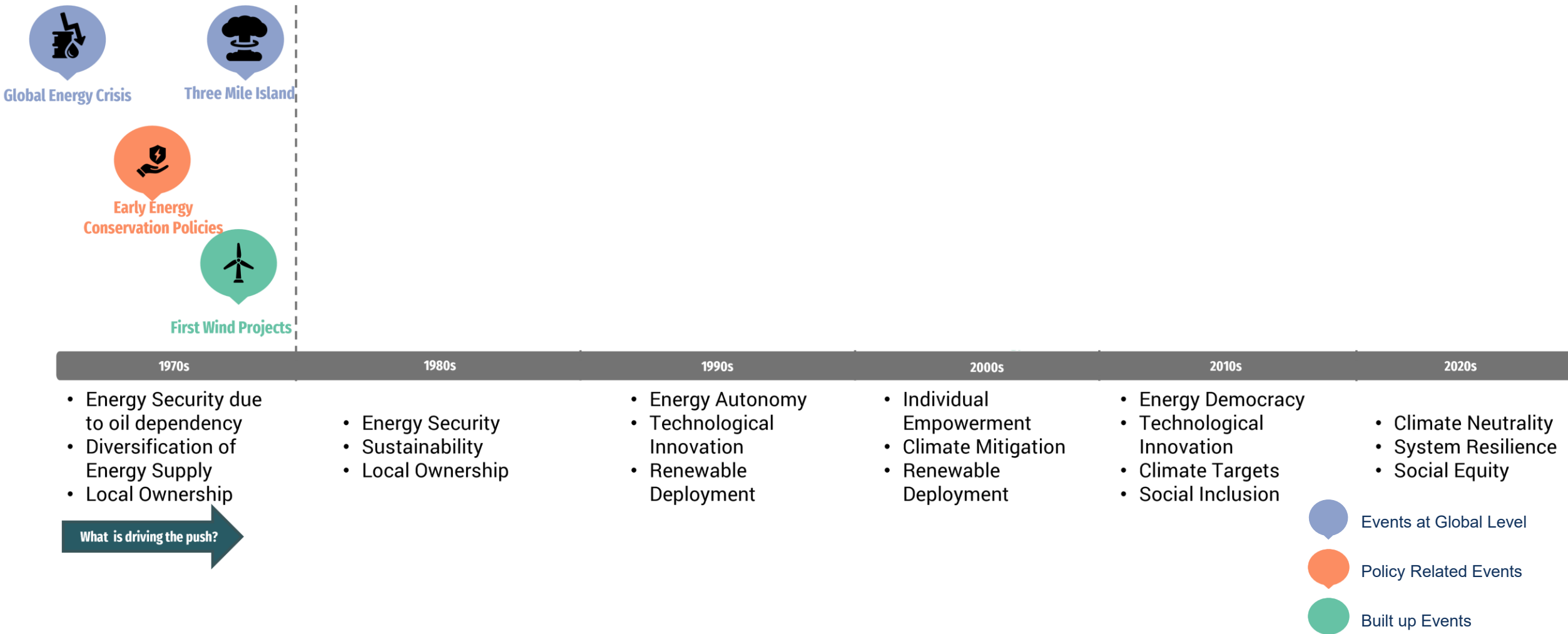
1. Conceptual/policy/historical evolution
2. Modelling treatment in ESOMs



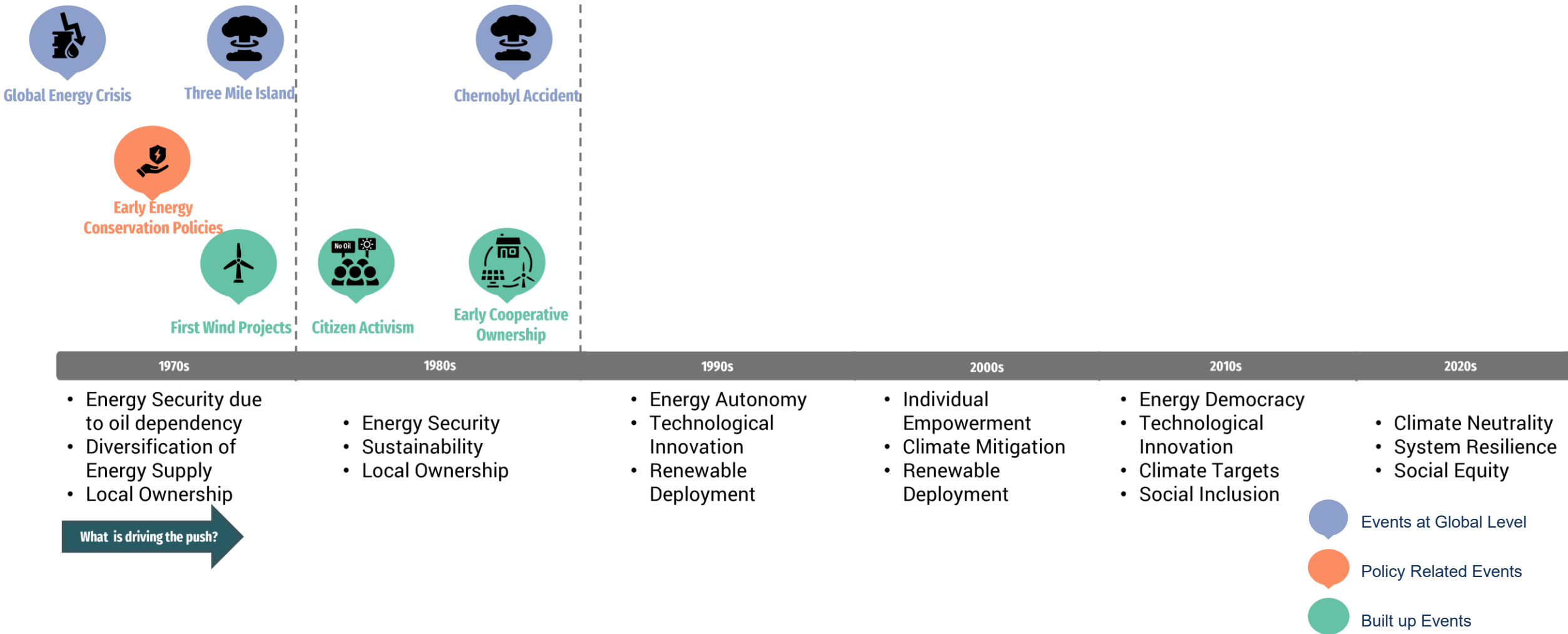
Conceptual Evolution of Energy Communities

Based on a literature review of academic articles and grey literature

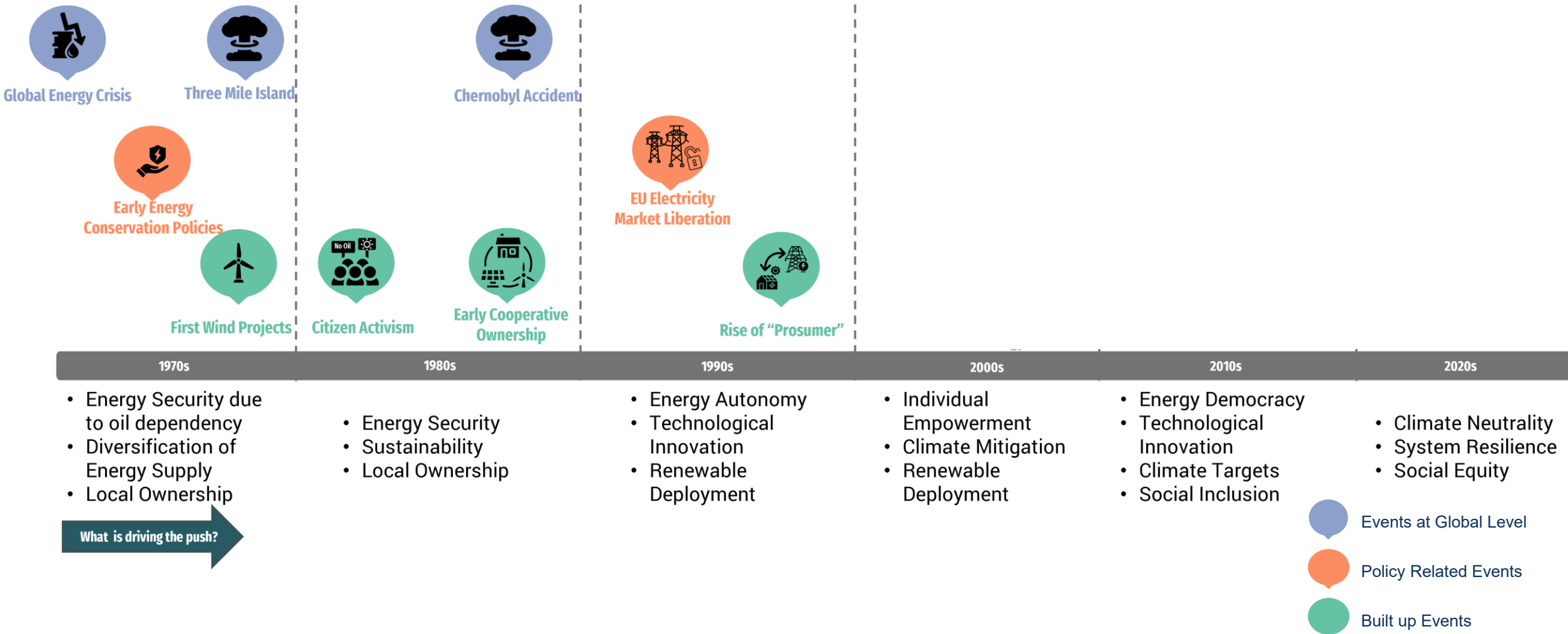
Energy communities – Historical Overview



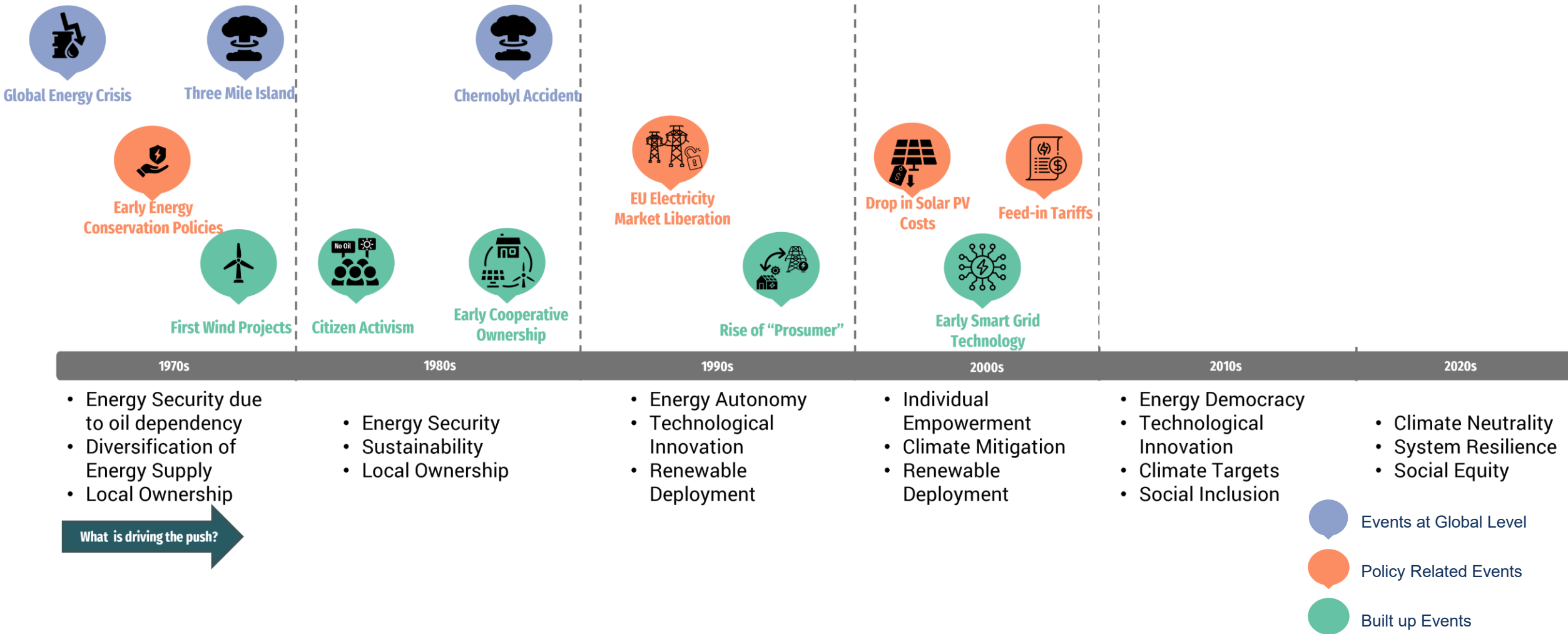
Energy communities – Historical Overview



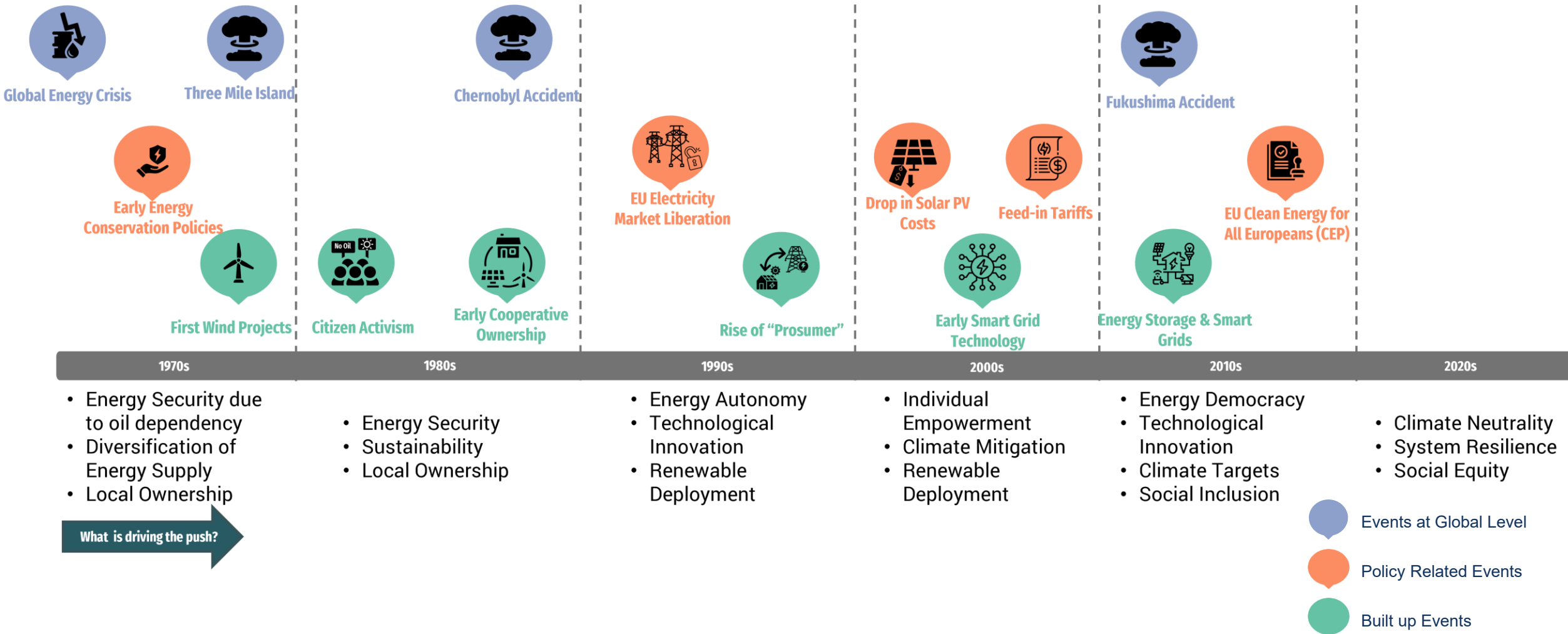
Energy communities – Historical Overview



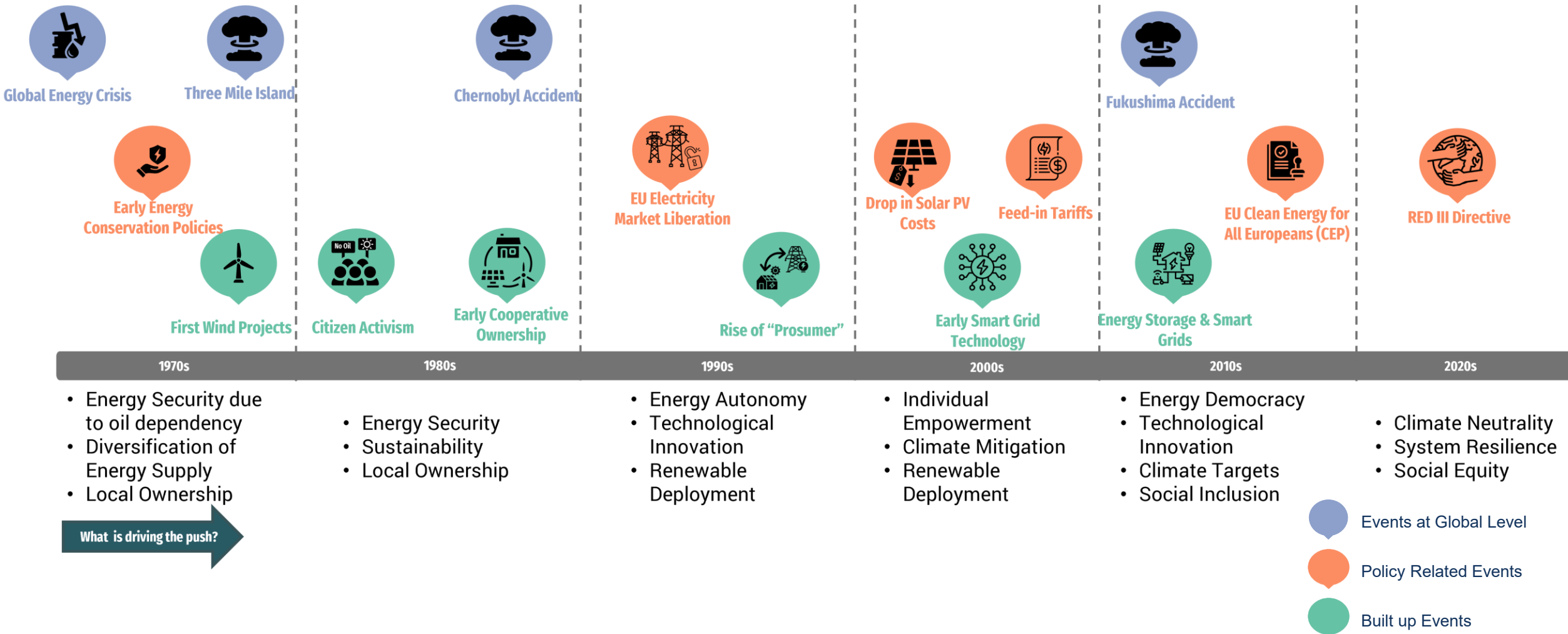
Energy communities – Historical Overview



Energy communities – Historical Overview



Energy communities – Historical Overview



Stakeholders views

- ECs evolved from grassroots social movements to digitally enabled, legally recognized socio-technical actors.

Stakeholder	Views	Concern
Policymakers	Decarbonization, citizen participation	Market complexity
Energy Sector / DSOs	Flexibility, local balancing	Grid impacts, revenue loss
Communities	Empowerment, lower costs, autonomy	Equity barriers, admin burden, upfront costs
Researchers	Socio-technical innovation	Governance issues, data gaps

Energy Communities and Their Definition

- **Energy communities now have a solid legal foundation within EU law**
 - RECs under the *Renewable Energy Directive (RED II)*
 - CECs under the *Electricity Market Directive (EMD)*
- **ECs are conceptually diverse:**
 - **REC – RED II/RED III**
 - Must use renewables
 - Local proximity requirement
 - Controlled by local citizens/SMEs/municipalities
 - Purpose: social, environmental, economic benefits
 - Activities: generate, consume, store, share, sell renewable energy
 - **(CEC) – Electricity Directive**
 - Broader: any electricity, not only renewables
 - No strict geographical limits (except for energy sharing)
 - Can act as suppliers, aggregators, storage operators, demand-response providers
 - Purpose: community benefits, not profit
 - **Broader Concepts (IRENA, IEA, REScoop)**
 - Community-driven
 - Citizen/collective ownership
 - Emphasis on local empowerment, energy democracy
 - No strict legal boundaries

Conclusions from the literature review

- ECs have evolved from grassroots groups to institutionalized, digitally enabled socio-technical actors.
- Legal definitions (REC, CEC) now provide structure but differ in scope and requirements.
 - RECs → local + renewable
 - CECs → broader roles + electricity system services



Role in the Energy System

Based on a literature review of academic articles and grey literature

Conclusions from the literature review

- Energy Communities have the potential to support decarbonization by:
 - deploying renewables
 - enabling flexibility
 - supporting local balancing
 - enhancing resilience
 - generating local social/economic value

- EC participation remains limited by:
 - regulatory complexity
 - limited access to markets
 - administrative burdens



Energy Communities in Energy System Optimization Models Based on a literature review of academic articles

Energy Communities in ESOMs – Historical Overview

Early ESOMs

- National focus.
- Centralized generation and transmission.
- Consumers passive; ECs invisible.

80s - 2000s



Technical Inclusion

- Solar PV and wind enter ESOMs.
- Households aggregated, no social agency.
- Prosumer concept introduced.

2000s - 2015



Legal Momentum

- EU Clean Energy Package and RED II.
- Segmentation of demand-side users.
- First attempts at collective modeling.

2016 - 2019



Active ECs

- ECs modeled stand-alone or part of modelling framework.
- Active role in markets (P2P, EVs).

2020 - Today



Concluding remarks – Aspects of Energy Communities to include in ESOMs to be able to investigate how they potential could contribute to the future energy system

- ECs are rarely integrated within large system-level ESOMs
- Interactions between ECs and the wider energy system could be explored to understand potential system-level impacts rather than assessing communities in isolation.
- Different forms of flexibility (storage coordination, demand response, EV charging) could be tested to assess their potential contribution to system balancing and peak reduction.
- Social and behavioral factors (e.g., participation willingness, trust, equity concerns) could be investigated by soft-linking ESOMs with social science studies or behavioral models, enabling exploration of how human and organizational dynamics affect EC performance.

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