DLHTE

The H2LEC Framework: Optimizing Local Energy Communities with Integrated Hydrogen Systems and Energy Exchange with support of Digital Twin Technologies

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Structure of the talk

(1) What is H2LEC – H2LEC concept and objectives
(2) H2LEC Enabling technologies & its Competitive edge
(3) DLHTE – developmental test environment for H2LEC
(4) Digital twins in development, design and implementation of H2LEC
(5) Conclusion

Based on presentations & papers:





Maturing of the H2LEC Concept & road to implementation

References

1. Energy Communities, https://energy.ec.europa.eu/topics/markets-and-consumers/energy-consumers-and-prosumers/energy-communities
2. Zoran Marinšek, Author, Co-Authors: Aleš Krainer, Boris Orel, Green hydrogen prosumer in smart dispersed electricity and hydrogen supply, Global Conference on Renewable Energy and Sustainable Development (GCRESD2025), London, 19-21st May, 2025)
3. Zoran Marinšek, Sašo Brus & Gerhard Meindl, Local Energy Community as a Small Hydrogen Valley – H2LEC, London Journal of Engineering Research, Volume 24 | Issue 6 | Compilation 1.0, https://journalspress.com/LJER_Volume24/Local-Energy-Community-as-a-Small-Hydrogen-Valley-H2LEC.pdf
4. Zoran Marinšek, Sašo Brus, Gerhard Meindl, Concept of and proposal for international Distributed laboratory for Hydrogen technologies in energy supply (DLHTE), Conference TBMCE 2025, Portorož 3 -9th September 2025
5. Zoran Marinšek, Sašo Brus, Gerhard Meindl. Extension of the HEMRM—Full Harmonization of the Electricity Supply System, Project report, Electricity Journal, electricity-2682386
6. Hydrogen Europe, Hydrogen Europe's position paper to the European Commission's REPowering the EU with Hydrogen Valleys, (roadmap), https://hydrogeneurope.eu/wp-content/uploads/2023/09/HE-Input-to-H2V-Roadmap_final-version-.pdf
7. Zoran Marinšek, H2LEC as subsystem in vertically structured energy system, Stakeholder session: Local energy community as a Small Hydrogen valley – H2LEC, 4th EU Macro-regional Strategies Week, 24-28th April 2023
8. Hydrogen Europe, Hydrogen Europe's position paper to the European Commission's REPowering the EU with Hydrogen Valleys, (roadmap), https://hydrogeneurope.eu/wp-content/uploads/2023/09/HE-Input-to-H2V-Roadmap_final-version-.pdf
9. Z.Marinšek:Hydrogen prosumer in smart harmonized electricity market system, 1st Interregional congress H2greenTECH, 17th June 2021
10. Z.Marinšek: Hydrogen technologies: Hydrogen valleys – Hydrogen prosumer, Panel discussion 2: Green technologies and sustainable energy TBMCE Conference, 15.12.2020
11. Z.Marinšek, L. Karg, GOFLEX View, FLEXIBILITY markets of the future and TSO-DSO cooperation, Session 2: How is the link to other markets organised, Brussels, 13.02.2020
12. Z. Marinšek: Roadmap to future of flexibility: Bottom-up energy systems - The cellular approach, E.DSO, The truth about Flexibility, Brussels, 10.04.2019

(1) What is H2LEC: H2LEC concept and objectives

H2LEC is a **local energy community** of the Renewable Energy Community (REC) type with **integrated hydrogen systems**.

It represents a type of **Small hydrogen valley**.

A small H2 valley of the H2LEC type is an ecosystem in which integrated hydrogen systems play a key role in balancing local energy production and consumption.

H2LEC concept and objectives (2)

LEC: The dual nature of LEC

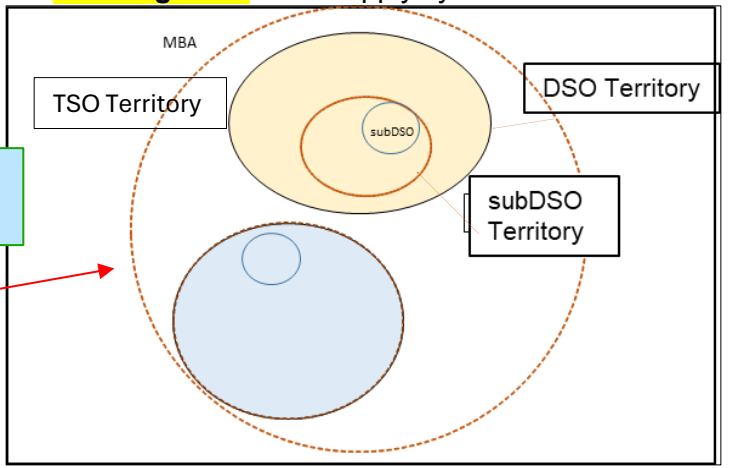
- LEC is **vertically nested system in energy supply**, following the concept of *system of systems*
  - Each subsystem has **similar functions** as its parental system (fractal-like structure)
  - LEC can **optimize its operation** – it includes *production, storage, and consumption*

Vertically nested system!

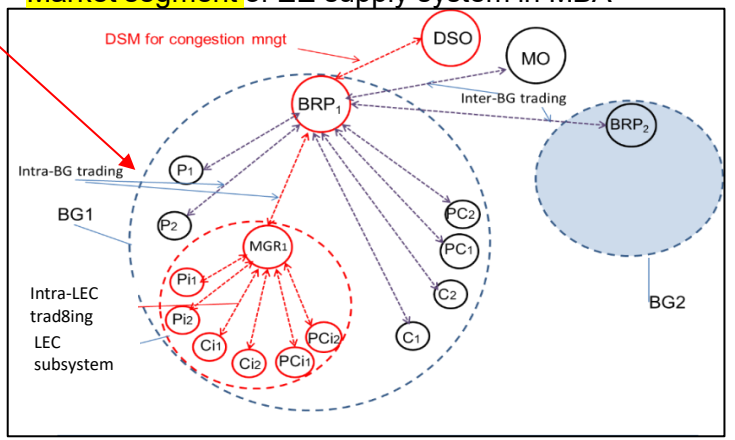
- **LEC is a techno-socio-economic ecosystem** and a **virtual business system** with **joint values and joint objectives:**
  - **It consists of all categories of prosumers:** industrial companies, public and tertiary buildings, residential buildings
  - **it engages competence, initiative and capital of local actors** – local businesses, new technology start-ups and inhabitants.

Ecosystem!

Grid segment of EE supply system in **MBA**



Market segment of EE supply system in MBA



For legend c.f. slide 10

H2LEC concept and objectives (3)

LEC ➡ H2LEC

With **integrated hydrogen systems** to provide balancing between consumption and local production of renewables, **LEC becomes H2LEC**.

H2LEC potential:

H2LEC can optimize its operation **on a sustainable basis at a high level of self-supply**.

(2) H2LEC Technology enablers - H2LEC Competitive edge

H2LEC Technology enablers

generate

H2LEC Competitive edge

Enabling technologies → Enabling building blocks

To realize H2LEC potential, several **technologies** are important **enablers**

- On-site **Integrated hydrogen** production, storage and consumption
- **Automated trading** of energy flexibilities of **the prosumers**
- **Coupling** of electrical energy production with the production of thermal energy.
- **Business model** of ecosystem based on **techno-socio-economic symbiosis** between:
  - integrated hydrogen production, storage and consumption, and
  - *intra-H2LEC* renewables production

- **Substantially reduced (or no) transport of H_2 or EE** from a central production location - produce it & use it on site
- **Medium and long-term storing of electricity:** enables sustainable optimized operation
- **Cross-sector coupling** with other energy vectors and sectors: thermal energy in particular, but also biomass, transport - increases total system efficiency
- **Techno-socio-economic synergy** with local RES production and local needs and capabilities – engages local initiatives and capital

H2LEC Enabling technologies – H2LEC competitive edge (2)

(Clean) Integrated hydrogen system - Hydrogen prosumer

H2LEC Enabling building block

Main building blocks of hydrogen prosumer (HyPro): **Clean**/not Clean?

1. **Electrolyser**
2. **H_2 storage** system
3. **HFC** system with (or w/o) CHP
4. **EMS** with Intelligent trading interface for purchasing and selling flexible energy on the grid

Clean hydrogen prosumer in the smart grid:

- **consumes clean** electrical energy from the grid for producing H_2 in electrolyser
- **provides storage** in H_2 until needed
- **produces** in HFC **clean** electricity and thermal energy
- **purchases and sells** flexible energy through automated trading

H2LEC Enabling technologies – H2LEC Competitive edge (3)

Automated trading of energy flexibilities -> H2LEC in Smart electricity market system

H2LEC Enabling building block

~~No Curtailment:~~

Prosumers – members of the H2LEC - offer their energy flexibilities:

- **Intra-H2LEC**: between themselves, peer-to-peer trading
- **On external markets**: to energy traders or system operators

Main functionalities, advanced automated trading platform:

- **Trading intervals close to real time**, depending on the need
- **Implicit trading of energy transfer capacity** between the location of production (generation) and the location of need
- **Dynamic pricing** established by **forecasting the needs** of the system operators for congestion avoidance and for balancing the grid

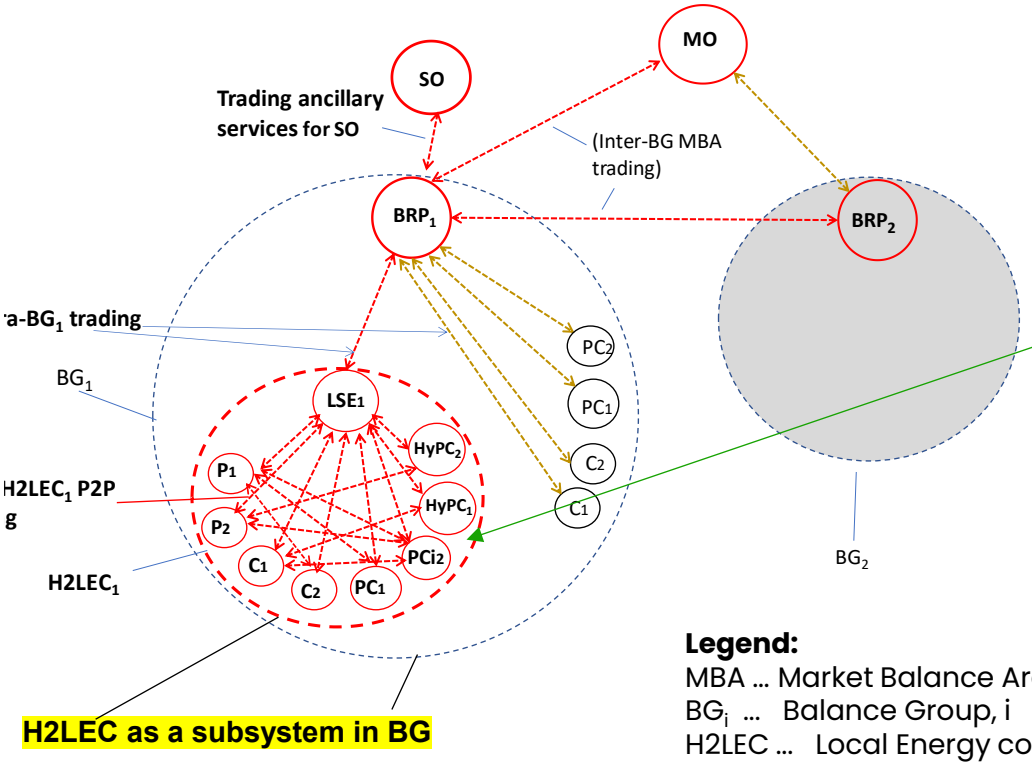
Intra-H2LEC:

- **Multi-dimensional trading** (sector-coupled energy system)
- **Multi-category trading**, based on formulated community objectives

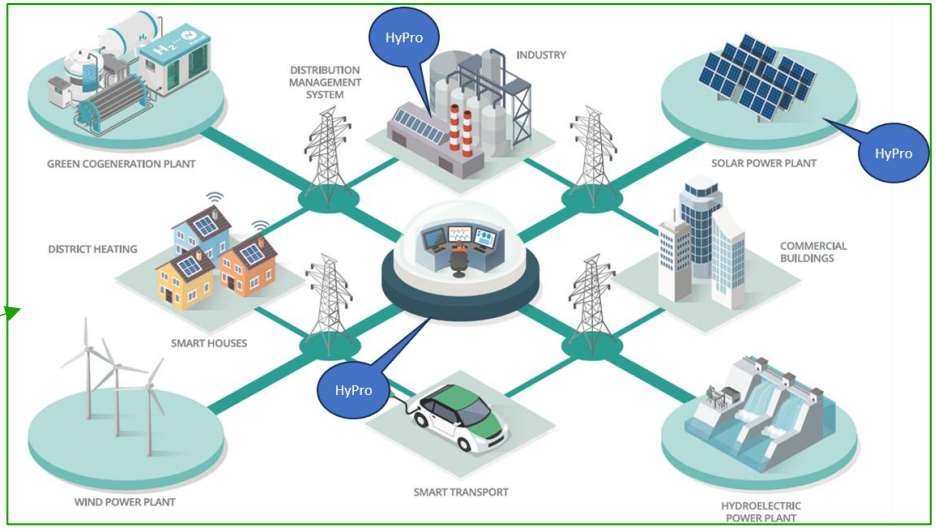
H2LEC Enabling technologies – H2LEC competitive edge (4)

Connected H2LEC as a subsystem in Smart electricity market system

Automated trading of energy flexibilities – intra H2LEC and on external markets



Generic composition of H2LEC



Legend:
MBA … Market Balance Area
BG_i … Balance Group, i
H2LEC … Local Energy community H2LEC
MO … Market Operator MBA
SO … System Operator (TSO + n.DSO)
BRP … Balance Responsible Party

Legend:
LSE … Local Supplier of Energy
P … Producer
C … Consumer
PC … Prosumer
HyPC, HyPro …Hydrogen Prosumer
P2P … Peer-to-Peer
<--> … Trading relationship

(3) DLHTE – developmental test environment for H2LEC

DLHTE - Distributed **L**aboratory for **H**ydrogen **T**echnologies in **E**nergy Supply

The aim of DLHTE: to provide a distributed **developmental test environment for building blocks that constitute selected Use cases of H2LEC:** primarily:

- **integrated hydrogen systems**,
- **RES producers and prosumers,** e.g. photovoltaics and wind turbines, biomass etc., depending on the specifics of the H2LEC to be tested.

The other building blocks, in particular the buyers of flexibility outside H2LEC, **are simulated**.

DLHTE – developmental testing environment for H2LEC (2)

Composition of the DLHTE

DLHTE emulates the ecosystem of the H2LEC:

1. **Centre DLHTE**: monitoring of the functional integration testing within the simulated H2LEC Use case (emulation of the business operator of the H2LEC)
2. **Hydrogen systems**
   - Integrated hydrogen system = Hydrogen prosumer (HyPro) (and/or its functional parts: electrolyser, storage system, fuel cell system)
   - (CHP coupling with thermal system)
3. **RES producers and prosumers**, depending on available/planned assets in H2LEC: Solar plant (with battery), Battery, Wind plant, Biomass plant
4. **Platform for Automated Trading with Energy Flexibilities**
5. **Integrated System** – Virtual Lab/Developmental H2LEC Use case Test Environment



(4) Digital twins in development, design and implemention of H2LEC

Digital twins in H2LEC:

i) **DTs of essential building blocks**

- **DTs of Hydrogen Prosumer** or its functional parts:
  - **DT of Electrolyzer**
  - **DT of H_2 Storage System**
  - **DT of HFC** (with CHP coupling)
- **DTs of participating RES** (PV, wind turbine, ..)

ii) **DT of H2LEC Use case**: integration of building blocks into the H2LEC ecosystem for selected Use case (and business model)

Digital twins in H2LEC (2)

The roles of Digital Twins

The Digital Twins are implemented in DLHTE. **Basic roles of DTs:**

A. In development and implementation of selected H2LEC pilot Use case:

- **For solution providers**: Focused - optimized design and development of building blocks, with **recursive cycling on specifications**.
  - (The building blocks are previously developed to TRL4).
- **For H2LEC business operator** (**Local supplier of energy**): Pre-deployment testing of
  i) Building block prototypes (at TRL 5/6 or higher)
  ii) Pilot Use case system
  for optimized start-up in real pilot environment (**FAT**).
  - (The building blocks are first prototypes to be further developed in pilot demonstration projects)

B. In replication of H2LEC Use case and solutions to other pilot cases in other industrial sectors and European regions/environments

Digital twins in H2LEC (3)

Digital twin of H2LEC Use case & target Use cases

➔ **H2LEC DTs are Use case DTs –› DTs of tested Systemic Use cases**

= Systemic Use cases represent **segments of the market**, based on extended *Harmonized electricity market roles model* [5].

➔ **Systemic Use cases include nesting of H2LEC into energy supply system**

The **targeted systemic Use cases** bottom-up are:

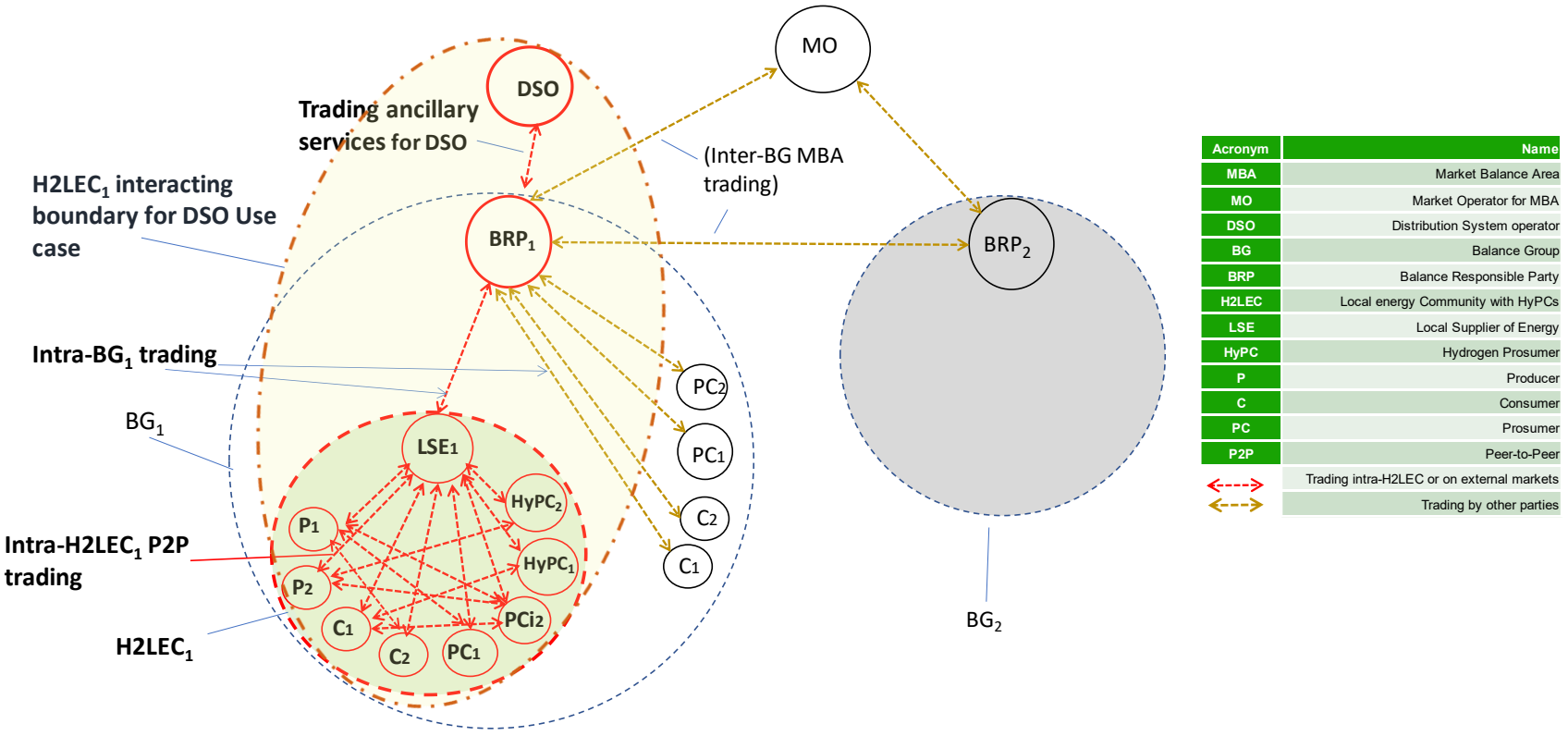
- **Local Flexibility market of DSO** (SubDSO) (*ancillary services of DSO/subDSO*)
- **Regional Balancing market for energy flexibilities for DSOs**/subDSOs
- **Regional Balancing market for energy flexibilities for BRPs**
- **Balancing market of TSO** (*ancillary services for TSO*)
- **Intraday market of MBA system**

Digital Twins in H2LEC (4)

Use case: Local flexibility market for DSO

Use case involves trading with DSO – providing it flexibility for congestion avoidance and grid balancing

Local Flexibility Market for DSO



Acronym	Name
MBA	Market Balance Area
MO	Market Operator for MBA
DSO	Distribution System operator
BG	Balance Group
BRP	Balance Responsible Party
H2LEC	Local energy Community with HyPCs
LSE	Local Supplier of Energy
HyPC	Hydrogen Prosumer
P	Producer
C	Consumer
PC	Prosumer
P2P	Peer-to-Peer
<-->	Trading intra-H2LEC or on external markets
<-->	Trading by other parties

Conclusion – H2LEC Potential

H2LECs have the potential to become ***the carrier of localized energy production*** **and usage**– an **emerging pillar** that complements the **concentrated energy production**.

- It is estimated that **the H2LECs** can achieve at least **75% level of sustained self-supply**.

H2LECs will create

- the need for **focused technology development of smaller size systems** and create **a new segment of the market**, in particular suitable for technology developing **SME's and mid-caps.**
- synergies and engage **local competences, initiatives** and **capital**.

Thank you for your attention!

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Additional back-up slides

DLHTE – developmental testing environment for H2LEC (3)

Diagramme of the Distributed Laboratory (vision)

