Waste2GridS

Waste2GridS 826161

Publishable Summary
Project Results and Exploitation Plan

2021.05.26

Waste2GridS

Converting WASTE to offer flexible GRID balancing Services with highly-integrated, efficient solid-oxide plants

Duration: 2019.01-2020.12

Budget: 528750 €

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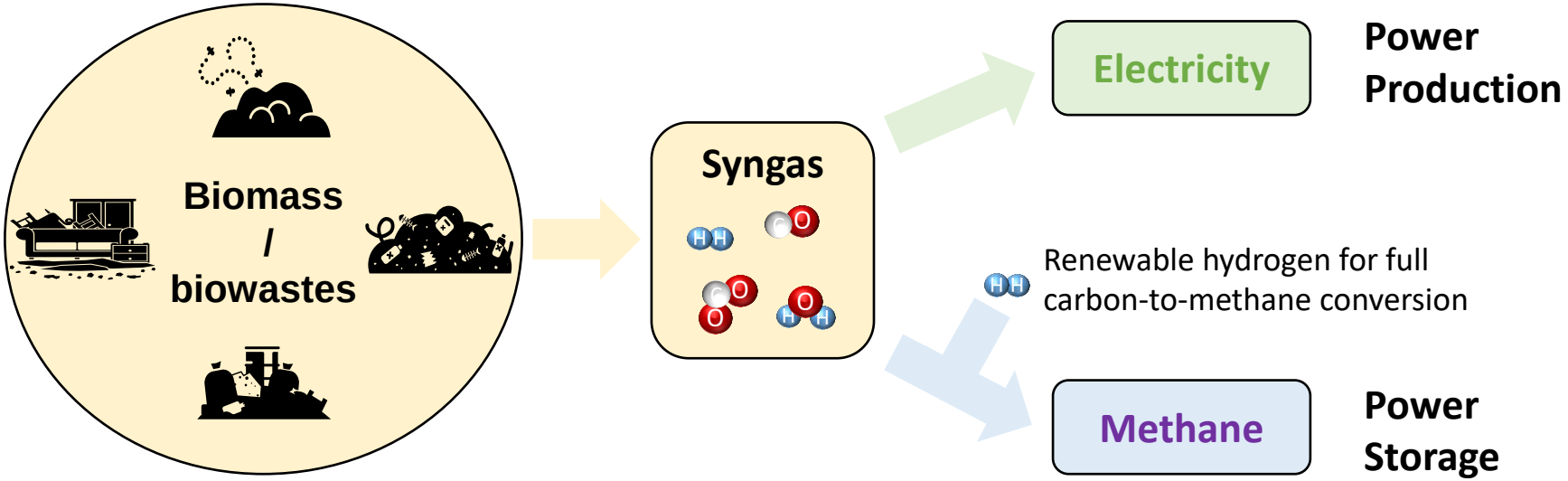
A new potential service from biowastes

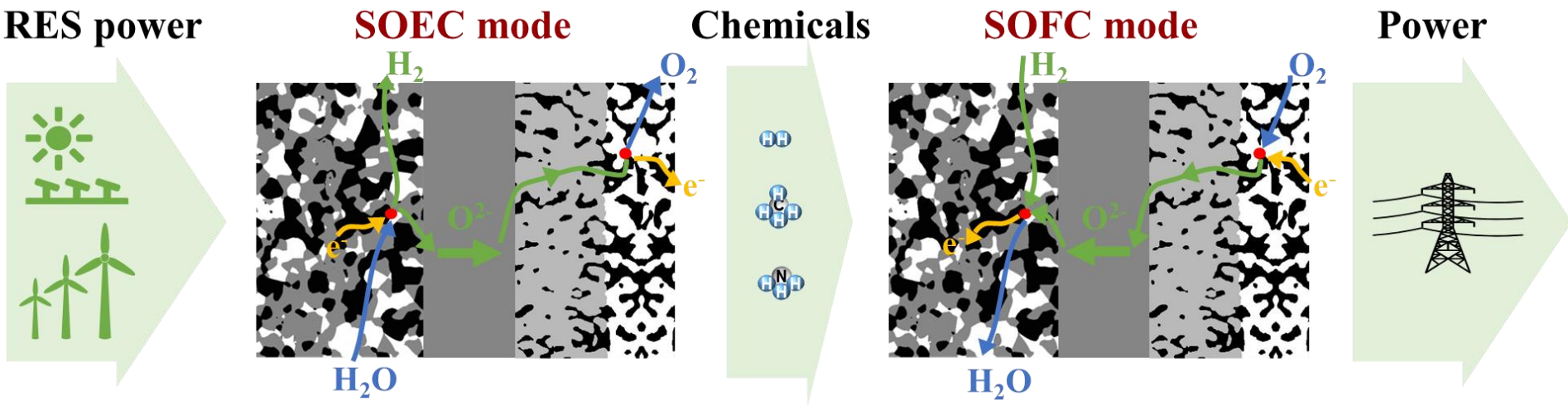


- Biomass/biowaste can potentially participate grid balancing for high penetration of renewable energy sources (RES), given **enhanced efficiency, reduced cost and increased utilization rate**

- One plant **capable of switching between electricity and methane production** can enable high annual utilization and cost reduction by sharing major components

Solid-oxide cell (SOC) technology

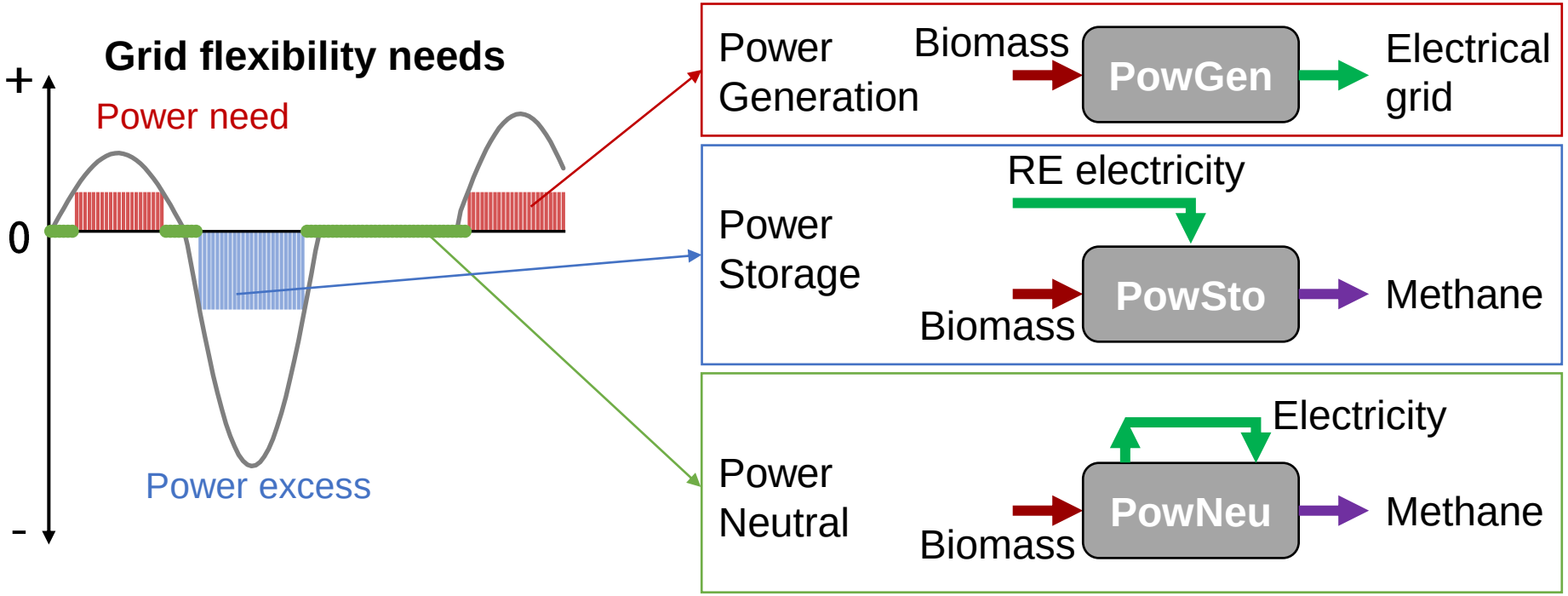
The most suitable syngas conversion technology for biomass utilization



- ❑ High efficiency at a potentially low cost due to no use of noble metal
- ❑ High fuel flexibility with no poisoning impact of CO/CO_2: syngas as fuel for SOFC mode, syngas-to-methane via H2 from SOEC
- ❑ Reversible operation with flexible switch between fuel cell mode (power generation) and electrolysis mode (power storage)

Waste2GridS concept

Triple-mode grid-balancing plant by integrating biomass gasification & SOC

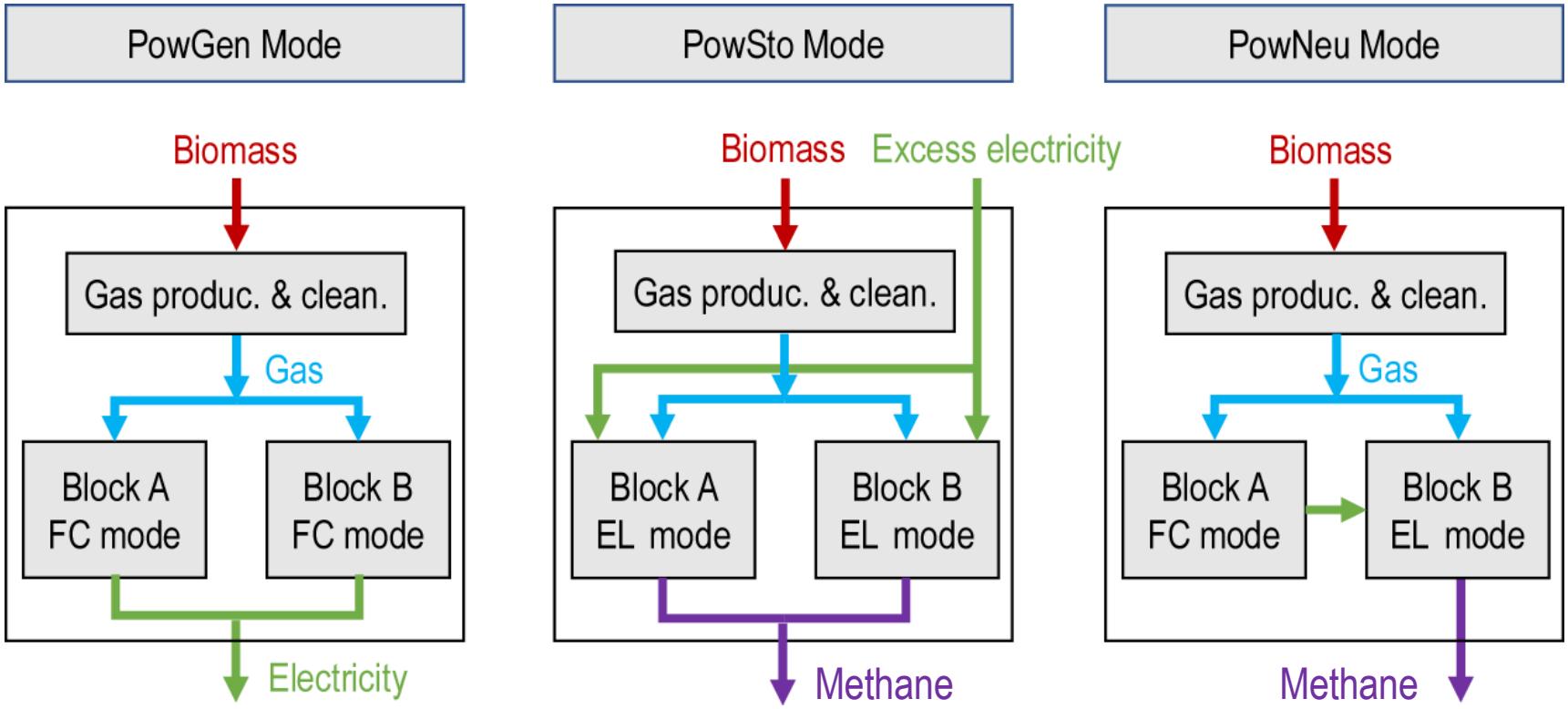


- **Non-stop**, **highly-efficient**, **full-load** operation for high annual operation hours, i.e., theoretically 365 x 24h with no stand-by mode

- Potentially-large **investment reduction** due to key component sharing and syngas-to-methane **with no carbon capture**

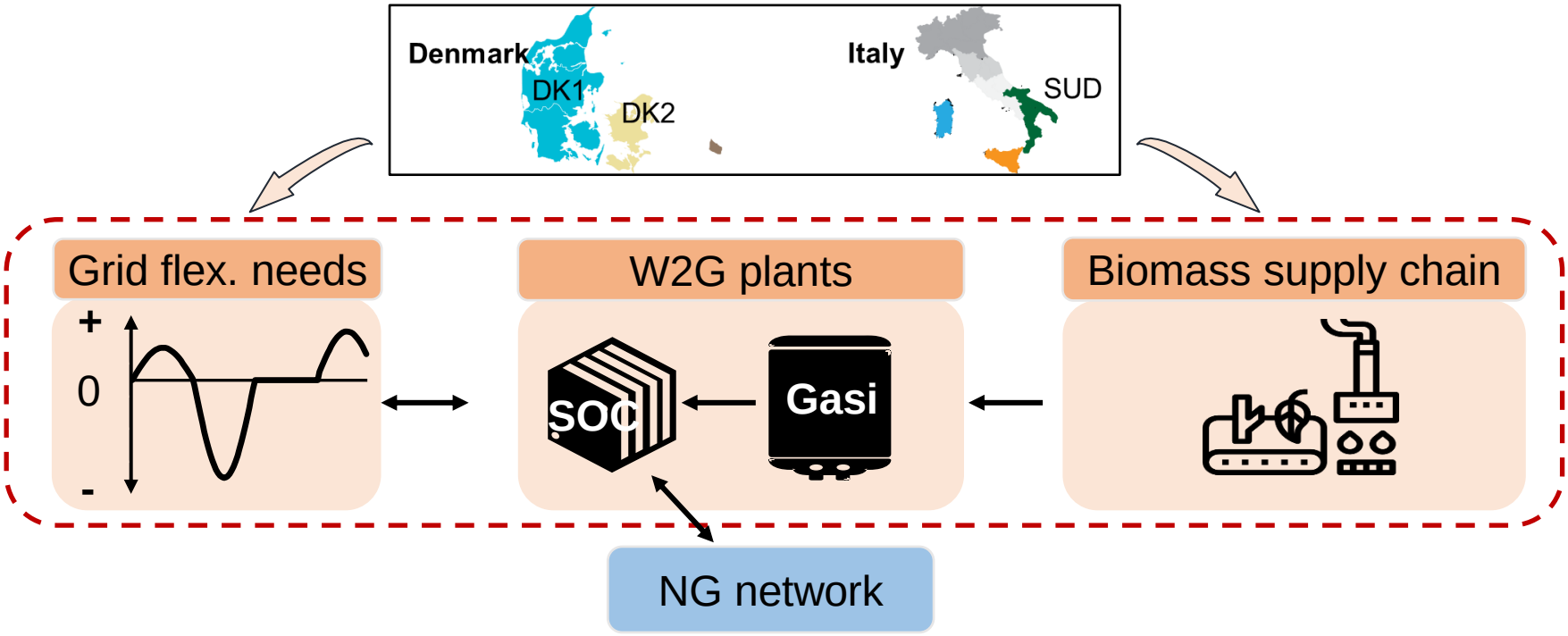
Waste2GridS realization

The coordination of two stack blocks enables the realization of three modes



- **Constant operation** of biomass processing, syngas production/cleaning
- Mode switch by coordinating stack blocks, BoP and methane reactor

Economic evaluation considerations

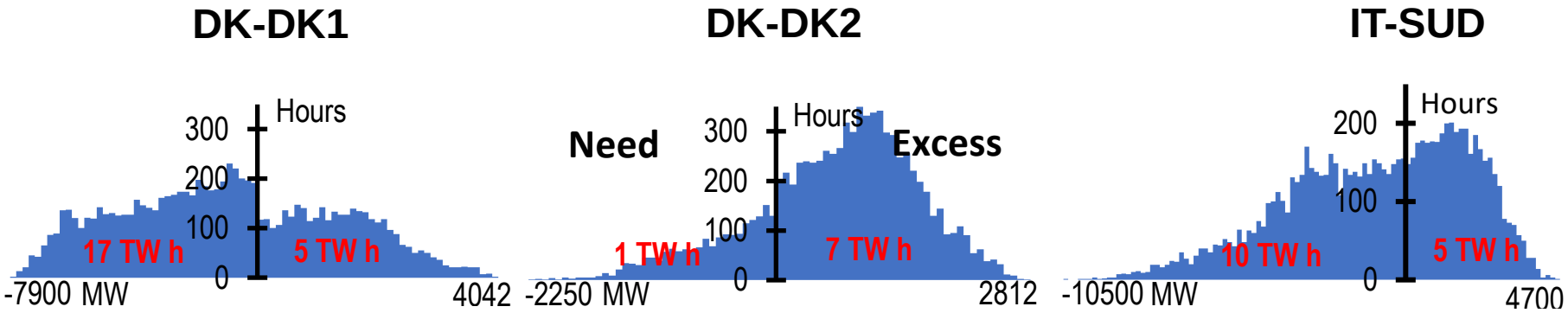


Factors affecting economic feasibility of W2G plants:

- ❑ Grid-balancing service
- ❑ Plant design, performance & operation
- ❑ Chemical onsite storage and trade
- ❑ Biomass supply cost

Theoretical grid flexibility needs 2030

Flexibility-need prediction via historical data and energy development plans



Generation - Demand

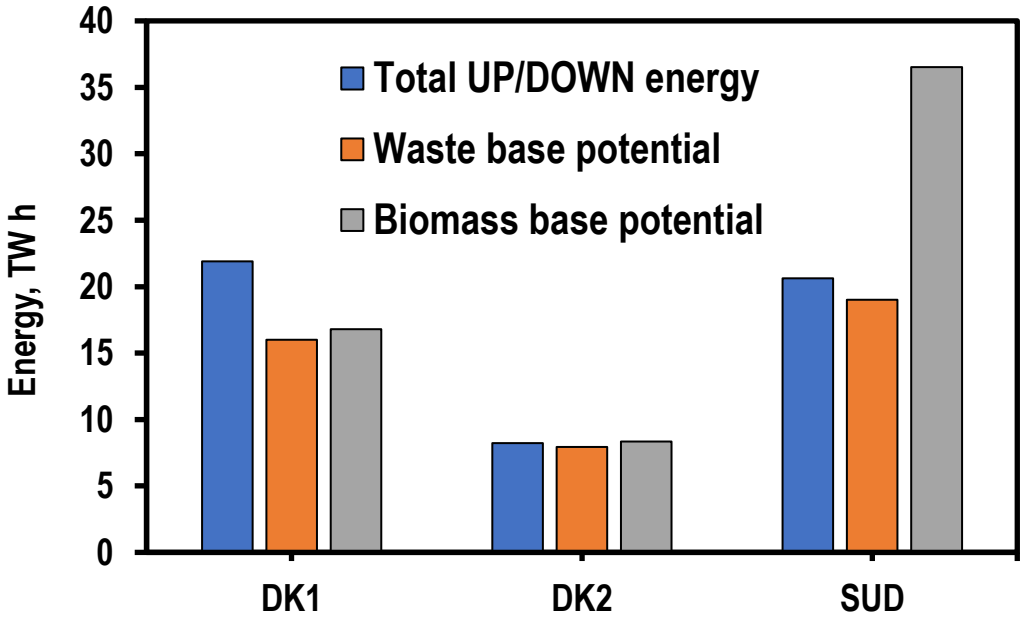
- Capacity wise, three RES dominated zones has significant UP and DOWN regulation needs, reaching **several to even tens of GW level**

- Energy wise, three zones present **annual excess electricity of 5-7 TWh**, to be addressed by multiple flexibility means, e.g., cross-country transmission, traditional fossil plants and **new flexibility capacities**

Applied Energy 264, 2020, 114702.

Waste availability 2030

Waste availability predicted via biomass databases, GIS & EU directives



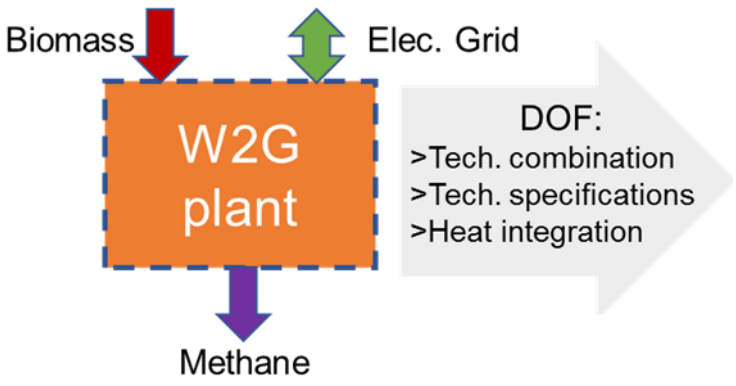
- Total energy of **theoretical** grid flexibility needs is at the same magnitude of the energy of local available waste and biomass

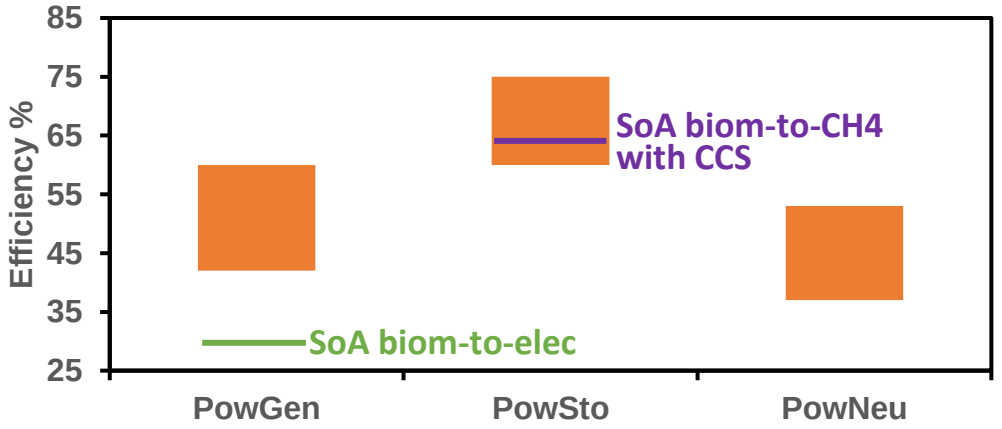
- Since actual W2G contribution will be much less than the theoretical value, local waste & biomass is sufficient to drive W2G for grid services

Front. Energy Res. 2021(9):618229

Plant design

Multi-objective optimal plant design considering multiple degrees of freedom: technology combination, key component specifications and heat integration





$$\eta_{PowGen} = \frac{\text{Net power produced}}{\text{biom energy in}} \qquad \eta_{PowSto} = \frac{\text{LHV energy of CH4}}{\text{Biom energy in} + \text{net elec. in}} \qquad \eta_{PowNeu} = \frac{\text{LHV energy of CH4}}{\text{Biom energy in}}$$

- ❑ **A set of optimal designs** with trade-off performances obtained

- ❑ **High efficiency** enabled for all modes: PowGen &PowSto efficiencies much higher than state-of-the-art single-mode systems, PowNeu mode as an efficient productive alternative of non-productive stand-by

Appl. Energy. 2020, 115987

Plant CAPEX threshold/real

Plant CAPEX levelized to reference stack enabling one indicator for three modes

$$\textbf{Plant CAPEX threshold} = \frac{\textbf{Maximum possible profit of all plant installed}}{\text{number of } \textbf{reference stacks} \text{ of all plants installed}}$$

$$\textbf{Plant CAPEX real} = \frac{\textbf{Evaluated plant CAPEX of all plant installed}}{\text{number of } \textbf{reference stacks} \text{ of all plants installed}}$$

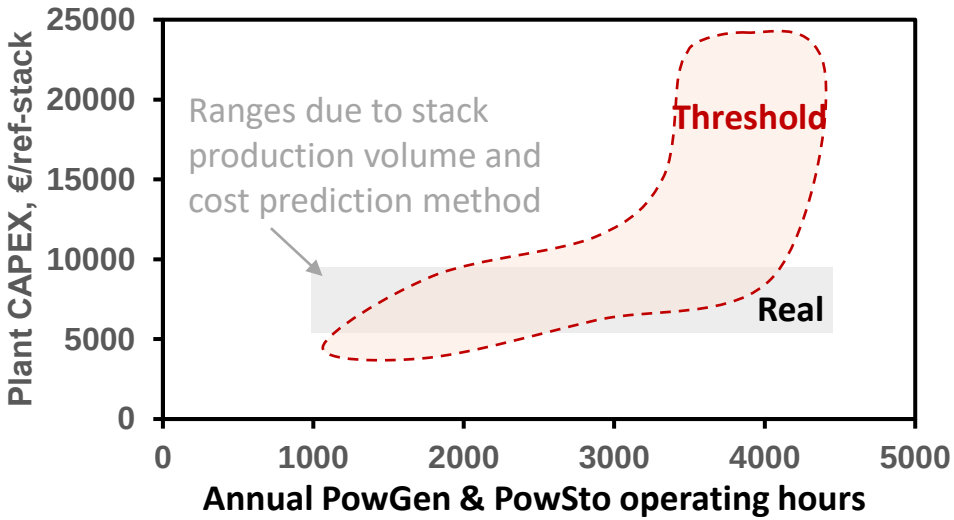
***reference stack*: a stack with 5120 cm^2 active area**

- ❑ Plant CAPEX real < threshold, likely economically feasible
- ❑ Plant CAPEX real > threshold, likely economically infeasible

Front. Energy Res. 2021(9): 659154

Economic feasibility identification

Plant CAPEX threshold and real evaluated for 40 case studies in DK and IT



Key economic assumptions

- Reference energy balancing price 40 €/MWh
- Reference payback time 5 years
- Stack lifetime: 5-year continuous operation
- Synthesis natural-gas price: 0.8 €/kg
- Annual cell production volume > 50,000 m^2

- ❑ Economic feasibility enhanced by increased annual PowGen&PowSto hours. Feasible business cases when **annual PowGen&PowSto operation for over 3500 hours**.

- ❑ Economic feasibility mainly affected by grid-service gain and biomass supply cost. Plants below 100 $MW_{th\_biomass}$ are feasible, while 100–1000 MW_{th} plants become not feasible due to biomass supply.

Front. Energy Res. 2021(9): 659154

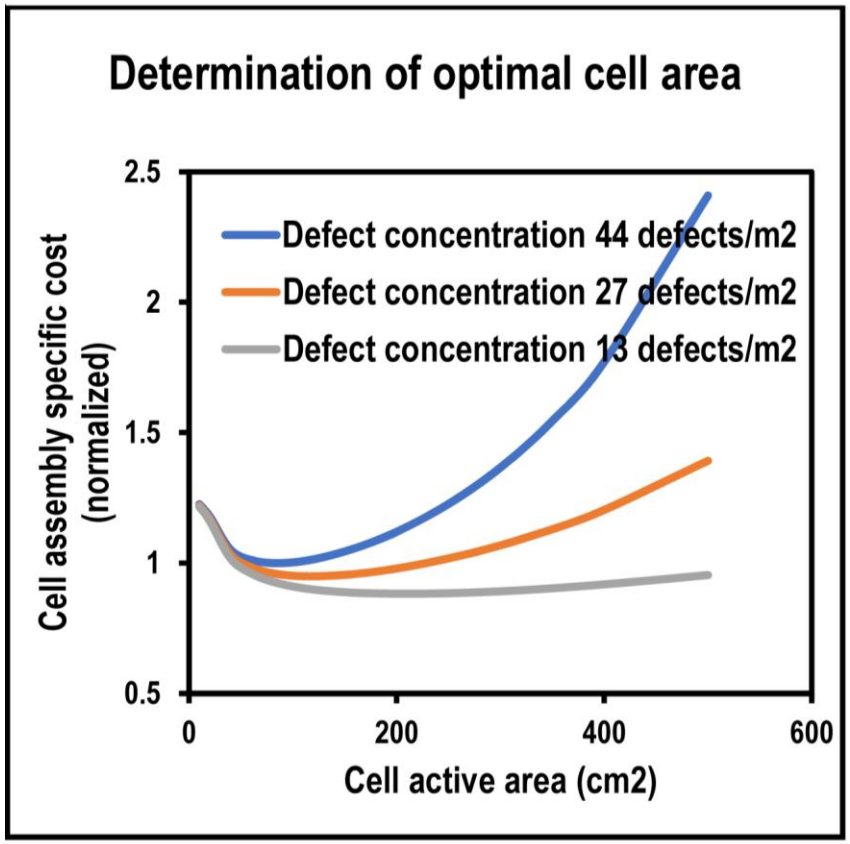
Key conditions for economic feasibility

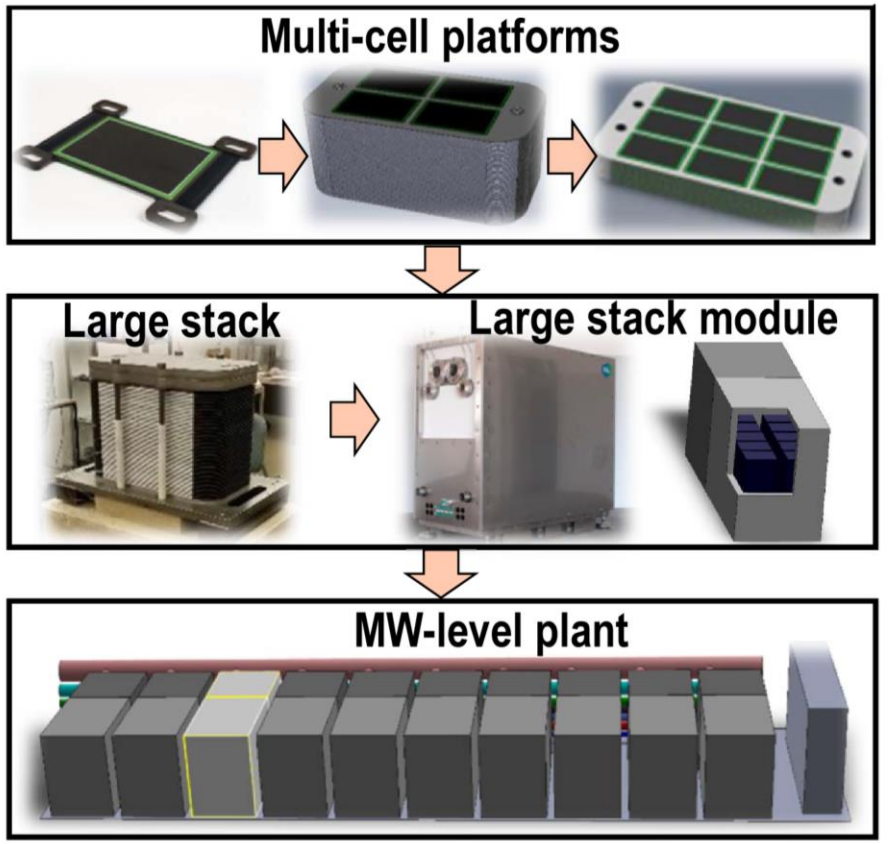
Given current market circumstances, W2G concept could be feasible if stack costs have significant cost reduction

Plant scales	100 MWth biomass feed ≈60 MWe PowGen power ≈160 MWe PowSto power
Payback time	5 years
Balancing price	40 €/MWh
Stack lifetime	5 years
SNG selling price	0.8 €/kg
PowGen&PowSto hours	> 3500
Stack costs	< 1600 €/kWe-SOFC

Scaling up strategy

The method of plant scale-up from kW-level to MW-level plant?





Key conclusions

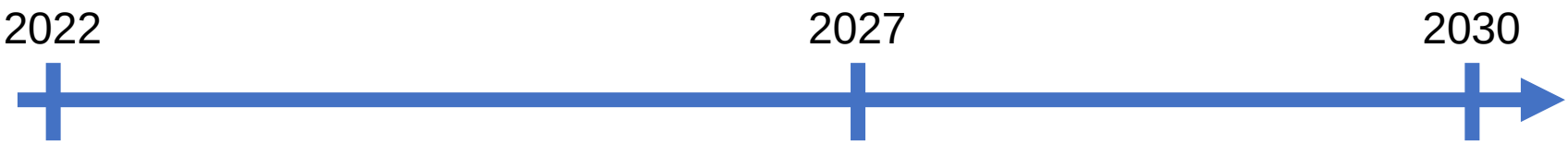
- Large grid flexibility needs in DK and IT-SUD in 2030
- Local biomass sufficient to contribute significantly to grid balancing
- W2G concept enables **highly-efficient grid-balancing service**
- Given current grid-balancing prices, methane price and stack lifetime, economical feasible case studies exist with the conditions:
  - Single plant scale: biomass feed of up to a few hundreds of MW_{th}, PowGen power up to 100 MWe, PowSto power up to a few hundreds of MWe
  - **PowGen&PowSto hours: > 3500 hours**
  - **Stack costs: < 1600 €/kWe-SOFC**

Exploitation plan

Project results	Partner	Exploitation activities
1) Plant conceptual design (D2.1) 2) Technical bottleneck (D3.2) 3) Economic feasibility and prerequisites (D3.3)	**EPFL** **SP**	**DG Ener, FCHJU and biomass community:** Promote stage-wise component and system development towards modular system design approach enabling smooth mode switch for flexible plant operation and sufficient characterization of system dynamic responses
1) Qualification requirement of solid-oxide technology for grid-balancing service (D1.1/D3.2) 2) Prerequisites of economic-feasible case studies (D2.2/D3.3)	**DTU** **ENEA**	**Major EU TSOs and EU electrical grid community:** - Promote pioneer evaluation of technical feasibility of using separate SOFC and SOEC systems for grid-balancing service - Determine the types of grid-balancing services and the priority of using biomass for grid-balancing service.
1) New way of biomass or biowastes utilization (D2.1/D3.2)	**ENEA**	**Biomass community and policy maker:** - whether W2G concept could be a better option of biomass utilization among various ways of using them. - Potential subsidy for W2G concept.
1) Scale-up strategy (D3.1) 2) Economic feasibility (D3.3)	**SP**	**Solid-oxide technology community:** - Promote the awareness of the need of several tens of MW SOFC system as an important scenario of technology development - Increase the interest in technology scale-up for MW level above, and to enhance more robust stacks.

Recommendation on FCHJU program

Two-phase funding plan



Demonstration:
(1) 25kWe biogas-fed RSOC plant,
(2) 75-100kWe biomass gasification-SOEC for producing SNG

Focus:
(1) Comp. development, e.g., low-cost gas cleaning & robust large stack
(2) System demo. and modular operation
(3) Characterization of the capability of stack and systems for grid service
(4) Stack & system scaleup

Demonstration:
(1) MW-level demo. of biomass-SOC integrated plants or W2G plant
(2) Characterization of the W2G plants for grid services

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