Waste2GridS

Waste2GridS (826161) Publishable Summary

Waste-to-Energy for grid balancing services via gasification and RSOC

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Project Info

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

Duration: 2019.01-2020.12

Budget: 528750 €

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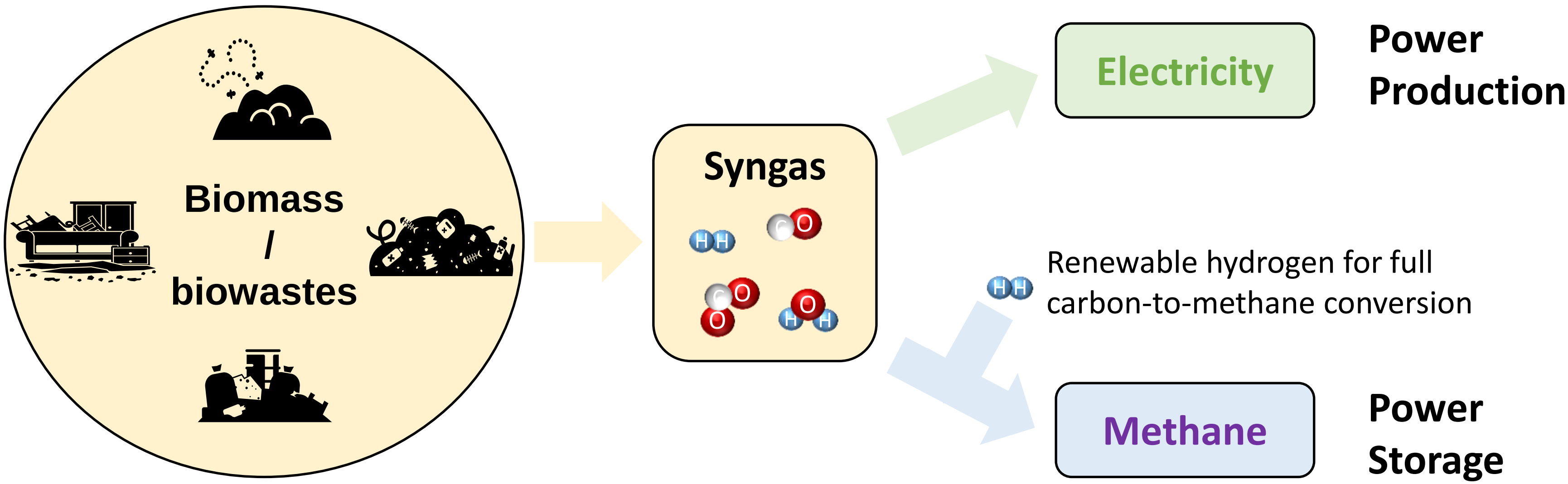
A new potential service from biowastes

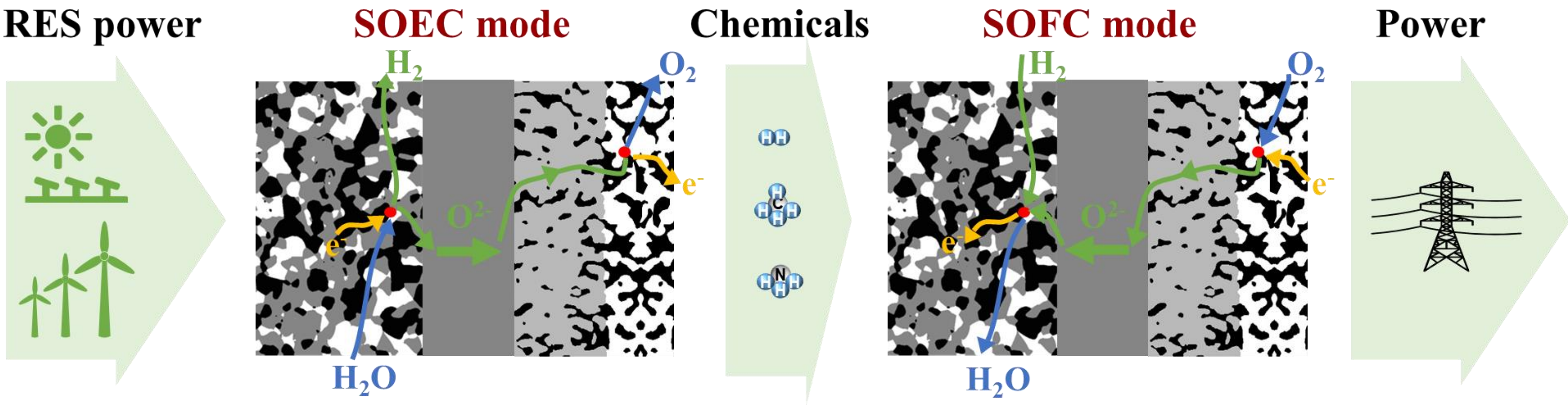


- ❑ Biomass/biowaste can potentially participate grid balancing for high penetration of renewable energy sources (RES), given **enhanced efficiency, reduced cost and increased utilization rate**

- ❑ 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

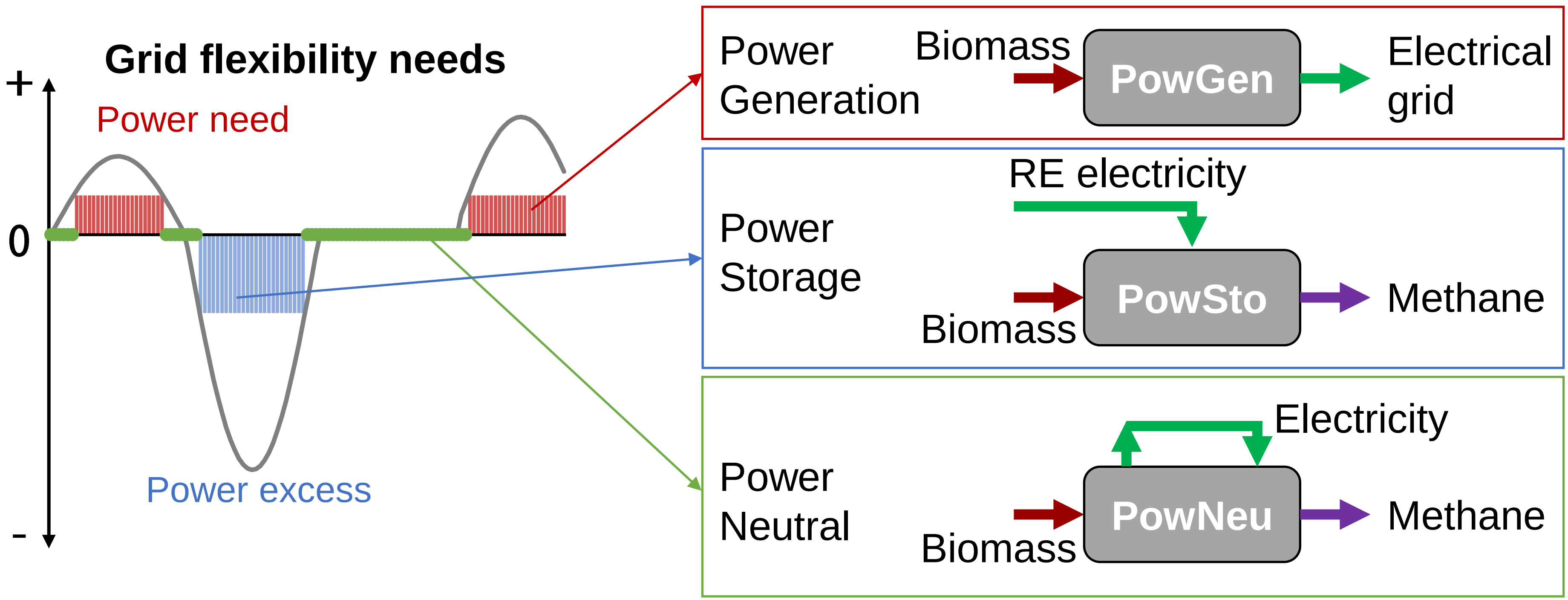
The most suitable syngas conversion technology for biomass utilization



- ❑ High temperature (650-850C), heat integration with gasif. process
- ❑ 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

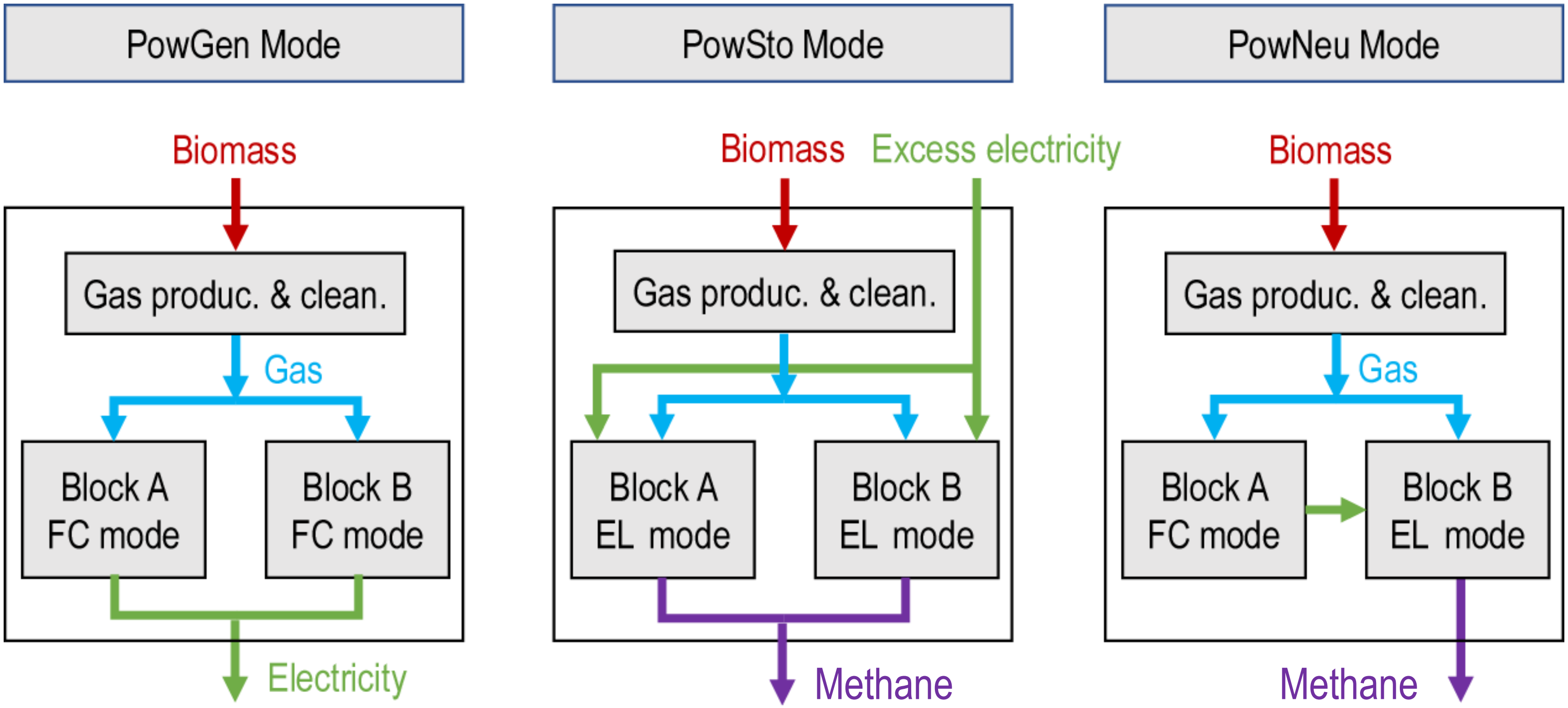
Triple-mode grid-balancing plant by integrating biomass gasification & SOC



- **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

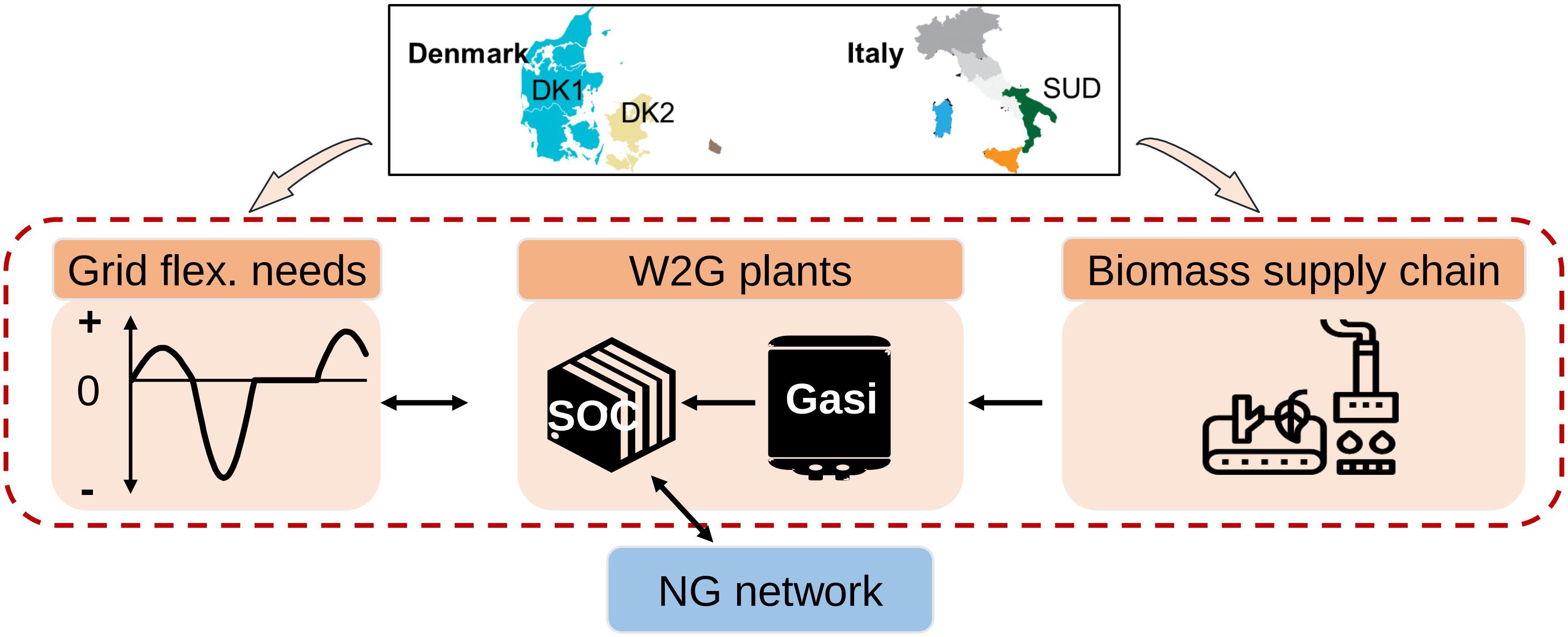
The coordination of two stack blocks enables the realization of three modes



- ❑ **Constant operation** of biomass processing, syngas production/cleaning

- ❑ Mode switch by coordinating stack blocks, BoP and methanation reactor

Economic evaluation for 2030

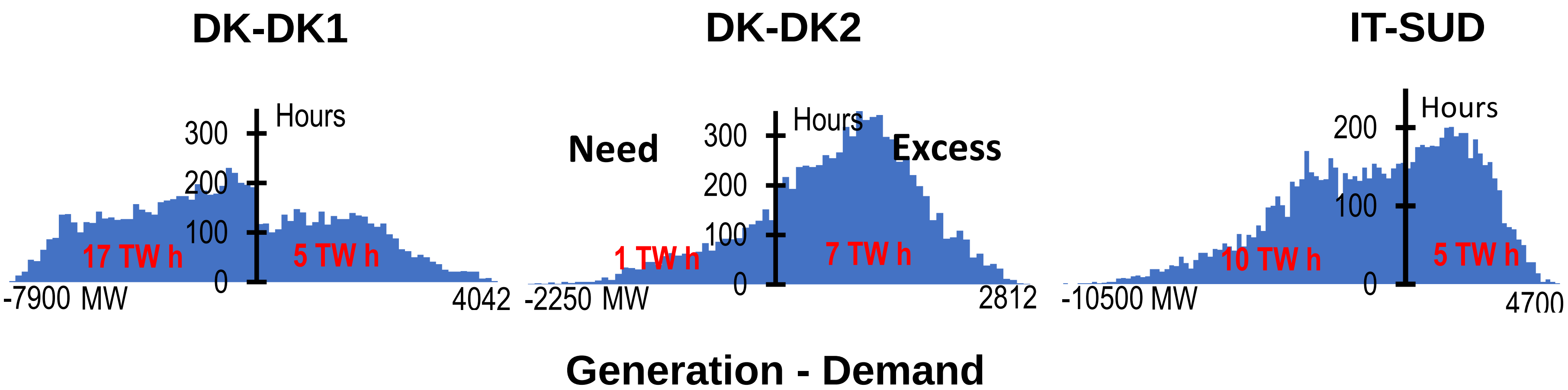


Main factors affecting economic feasibility of W2G plants:

- ❑ Grid-balancing service (energy balancing & capacity reserves)
- ❑ 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



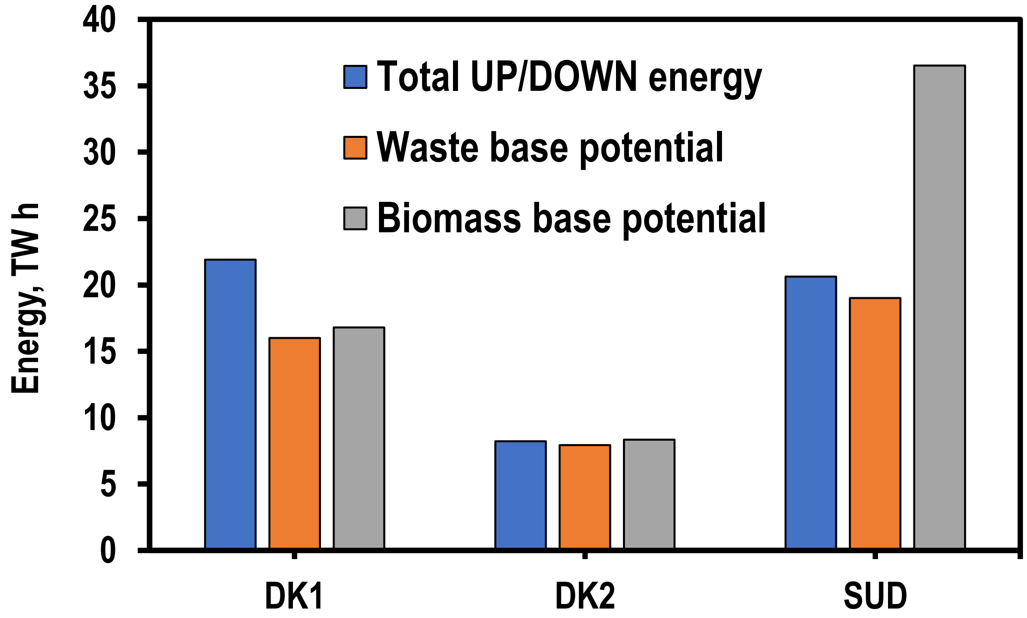
- ❑ Capacity wise, three RES dominated zones has significant UP and DOWN regulation needs, reaching **several to even tens of GW level**

- ❑ Energy wise, three zones present **annual excess electricity of 5-17 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



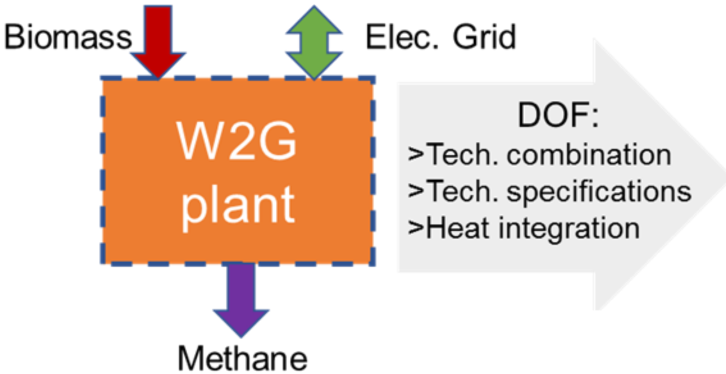
- ❑ Total energy of **theoretical** grid flexibility needs is at the same magnitude of the energy of local available waste and biomass

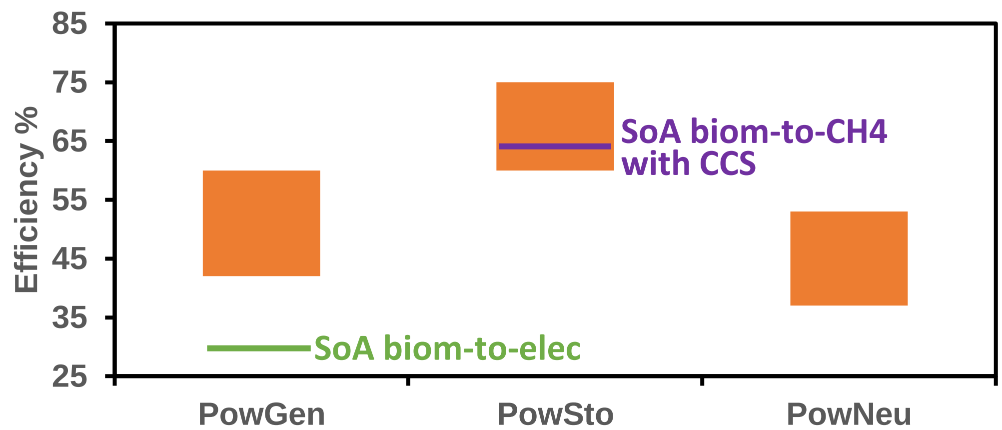
- ❑ Since actual W2G contribution will be much less than the theoretical value, local waste & biomass is sufficient to drive W2G for grid services

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





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

❑ **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 mode

Appl. Energy. 2020, 115987

Plant CAPEX threshold/real

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

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

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

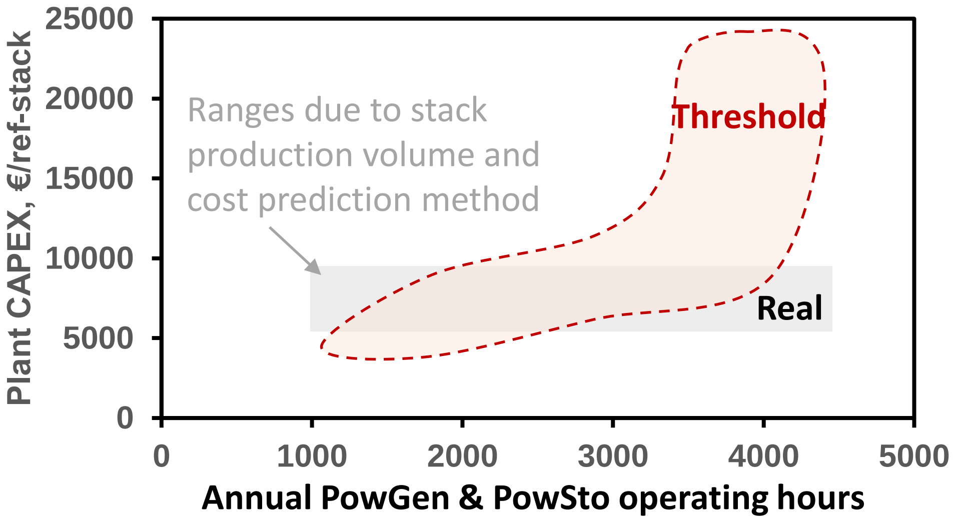
reference stack**: a stack with 5120 cm^2 active area**

- ❑ 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

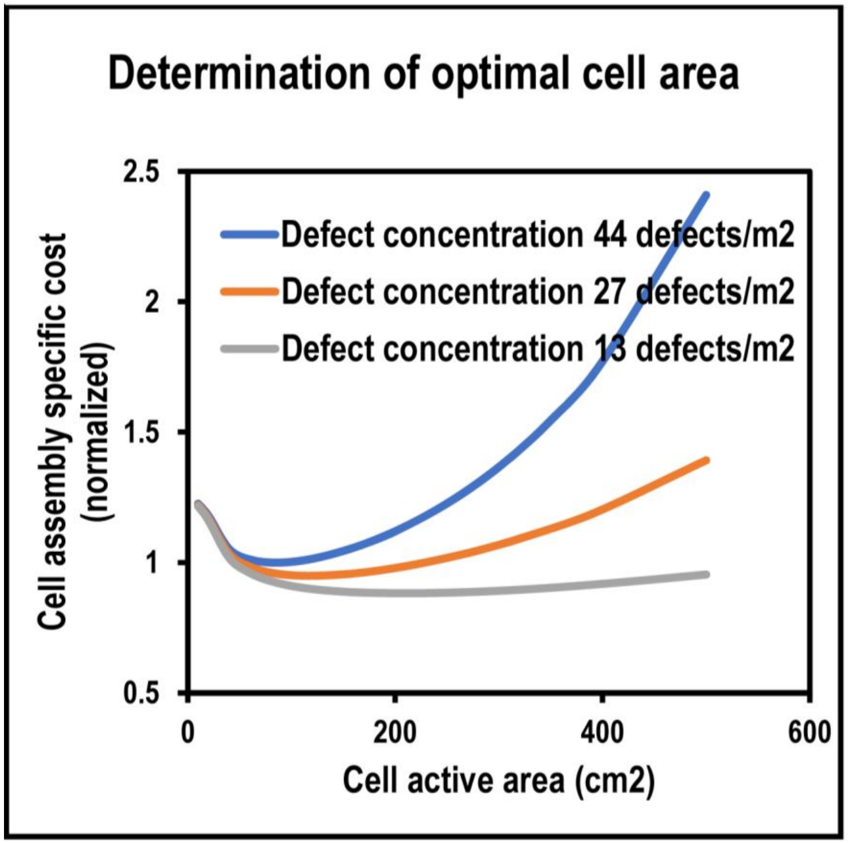
Key conditions for economic feasibility

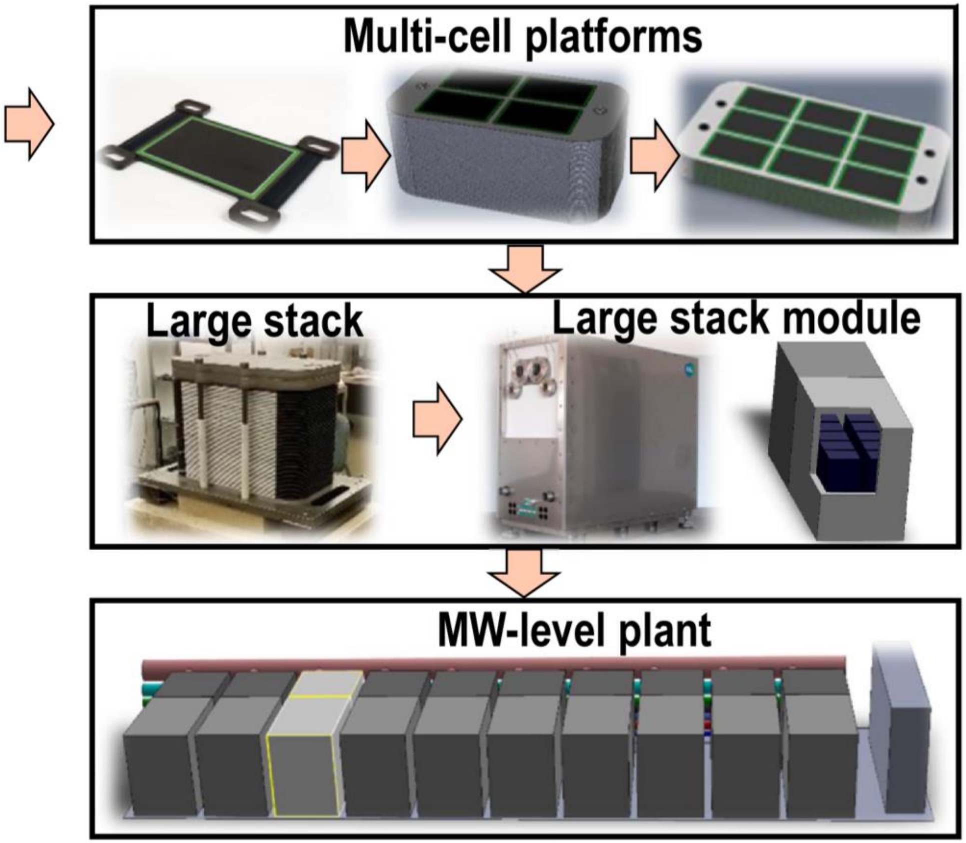
Given current market circumstances, W2G concept could be feasible if stack costs have significant cost reduction

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**

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