



Discussions on dynamic characteristics for electrolysis and e-fuel production

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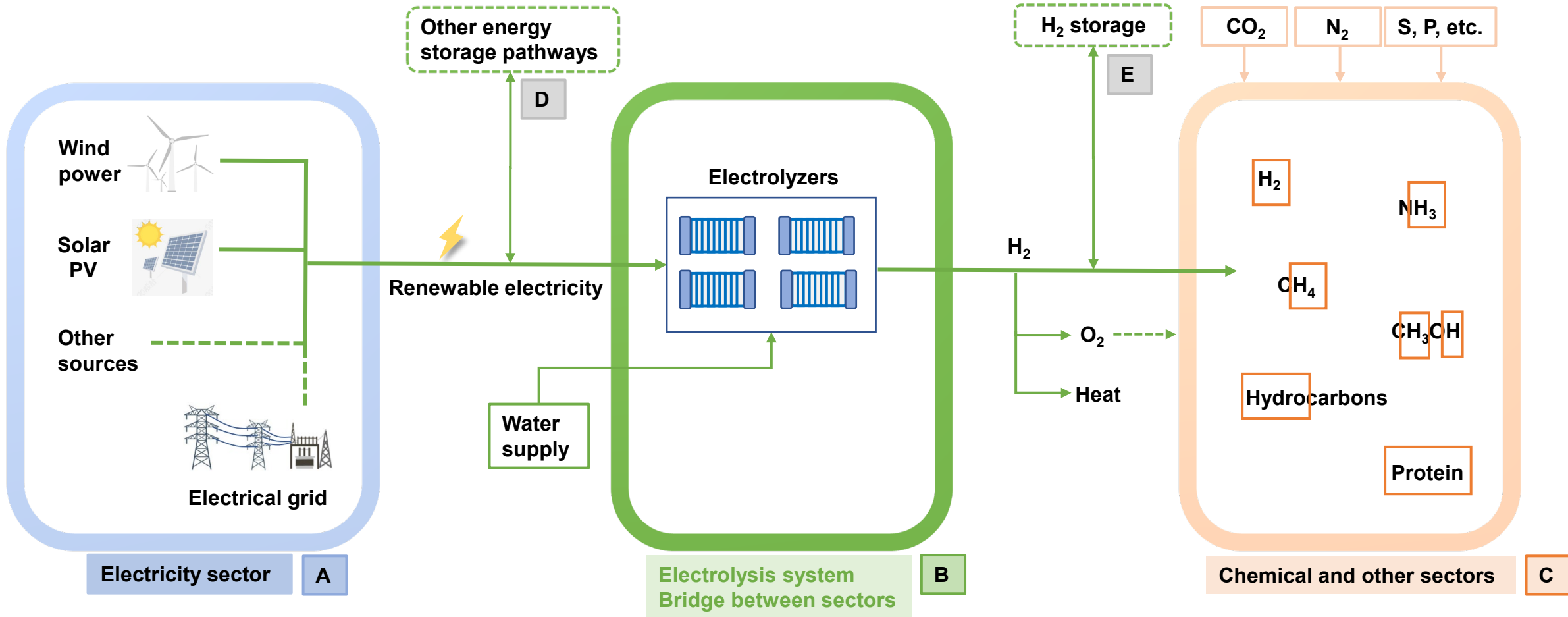
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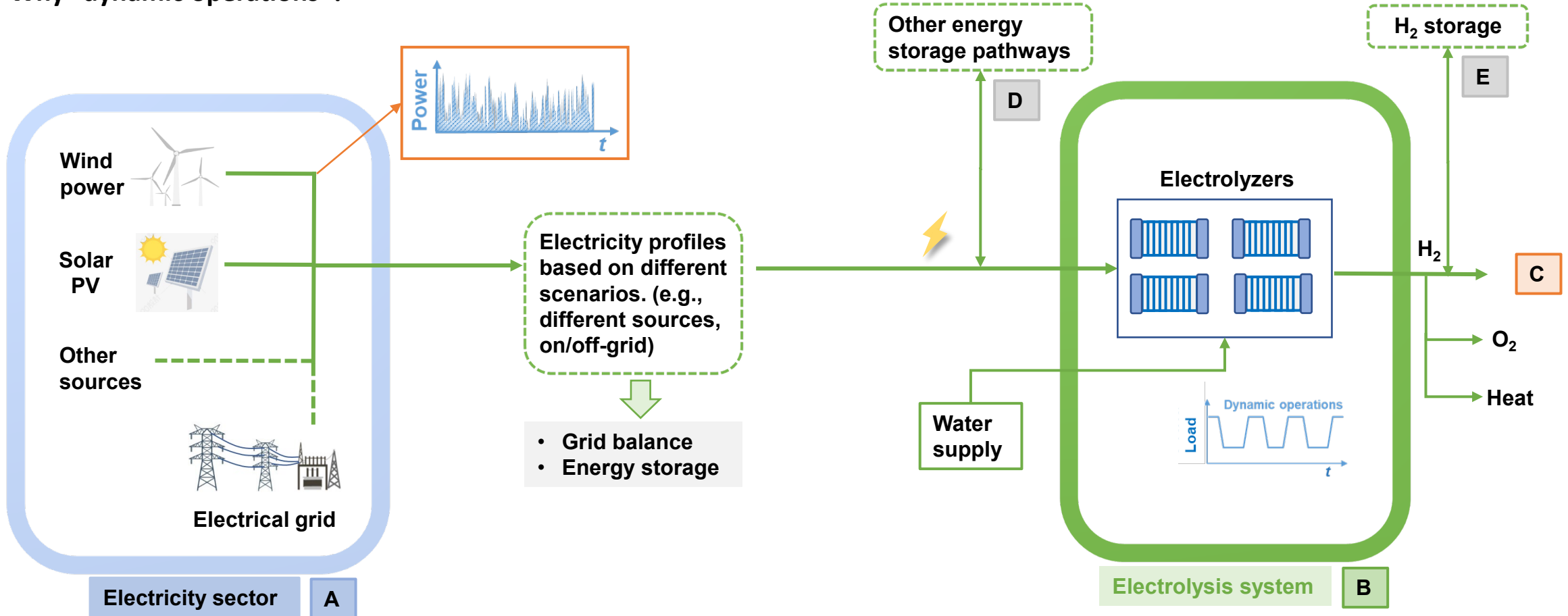
Power-to-X system and dynamic operations

Typical PtX system



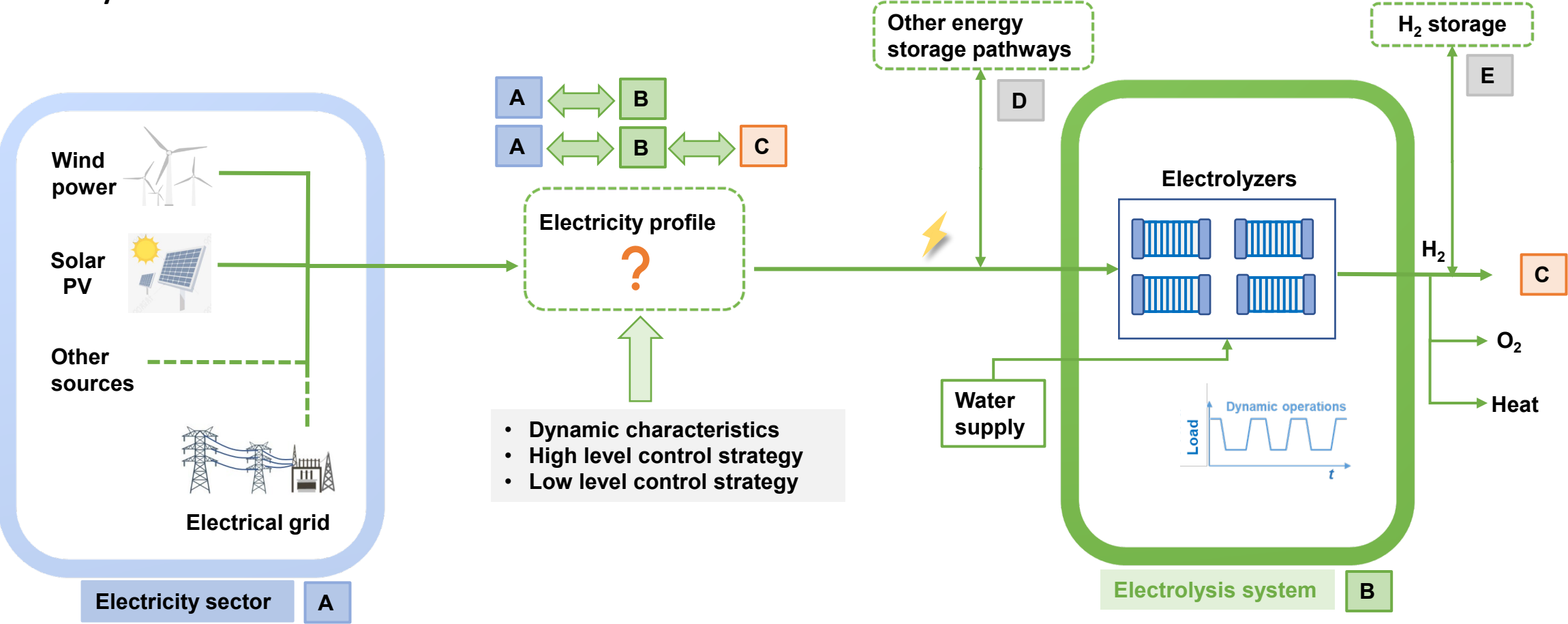
Power-to-X system and dynamic operations

Why “dynamic operations”?



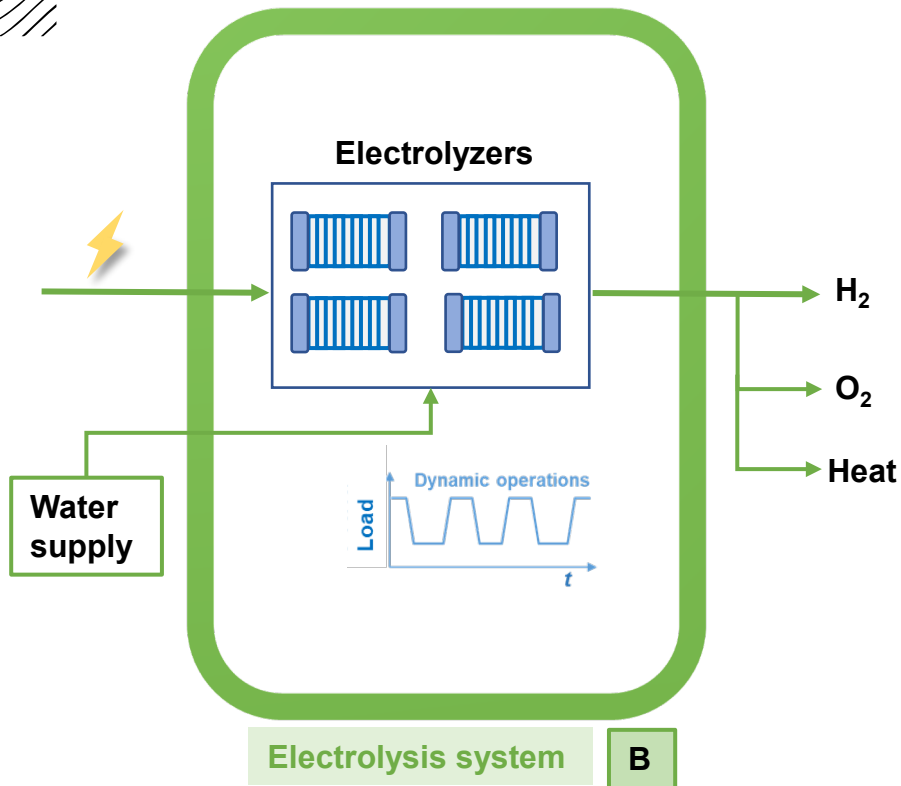
Power-to-X system and dynamic operations

What “dynamic characteristics”?



Power-to-X system and dynamic operations

What “dynamic characteristics”?



User Manual

Ramping rate and required time for **dynamic operations**:

- Start up:
- Load change:
- Switch to Standby mode (hot/cold):
- Shut down:

Load range

- Upper limit:
- Lower limit:

Energy efficiencies

Power input

Product output

Degradation rate

...

How fast can we run the electrolysis system?

- Any influence on system lifetime?

Limit

- Unfavorable conditions?

I/O

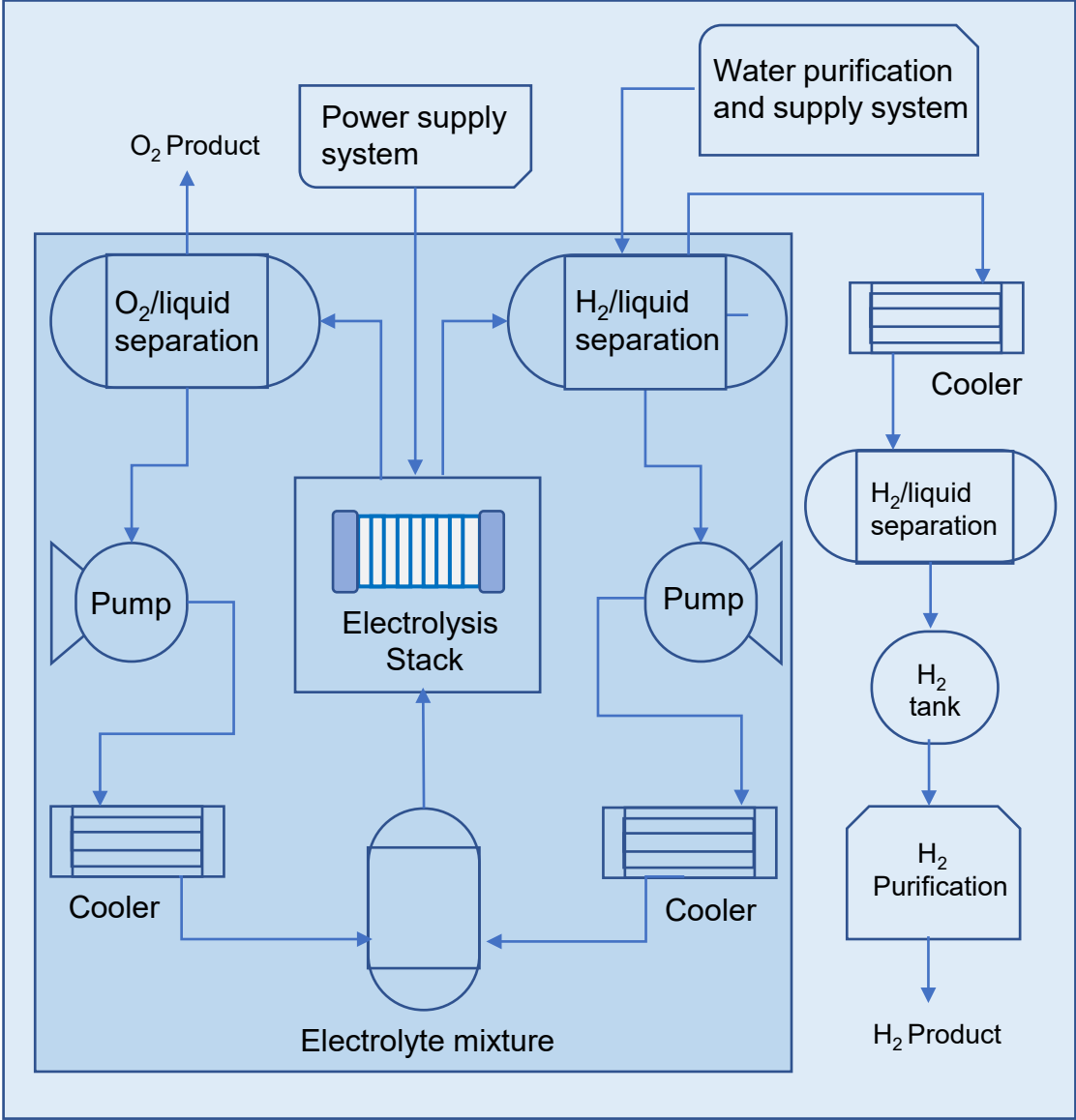
- Upstream/downstream
- Overall strategy



Electrolysis system – dynamic characteristics

User Manual			
Dynamic characteristics	Alkaline Electrolyzer	PEM	SOE
Cold-start time	<60 min ¹ 30-60 min ²	< 20 min ¹ < 1 min ³ 5 min ⁴	hours
Hot-start time	5 seconds ²	1 second ⁴	Seconds ¹
Lower operation load	10-40% ¹	0-10% ¹ > 5% ²	>30% ¹ > 5% ⁶
Upper operation load	105% ⁵	150% ⁵	100% ⁶
Ramping rate	20%/s ⁴	10%/s ³ 100%/s ⁴	10%/min ⁶
Energy efficiency (system)	73-75% (100% load) ²	> 75.5% ³	< 110% ¹
Energy consumption			
Hydrogen production			
Degradation rate	...	...	...
Other operations (e.g., Idle, shutdown)			
...			

What/where “dynamic characteristics” ?

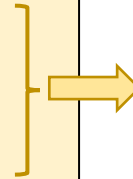


Alkaline Electrolysis system

Electrolysis system – dynamic characteristics

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Energy consumption			
Hydrogen production			
Degradation rate	...	...	...
Other operations (e.g., Idle, shutdown)			
...			



Slow step
Energy consumption step
 E.g., preheating, safety check, gas purging ...

Electrolysis system – dynamic characteristics

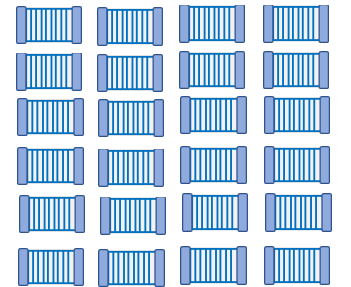
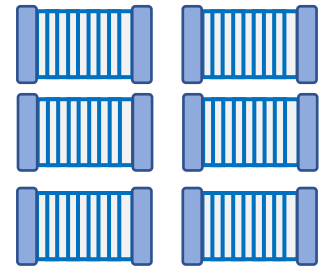
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Hydrogen production			
Degradation rate	...	...	...
Other operations (e.g., Idle, shutdown)			
...			

Also depends on single stack size

E.g.,

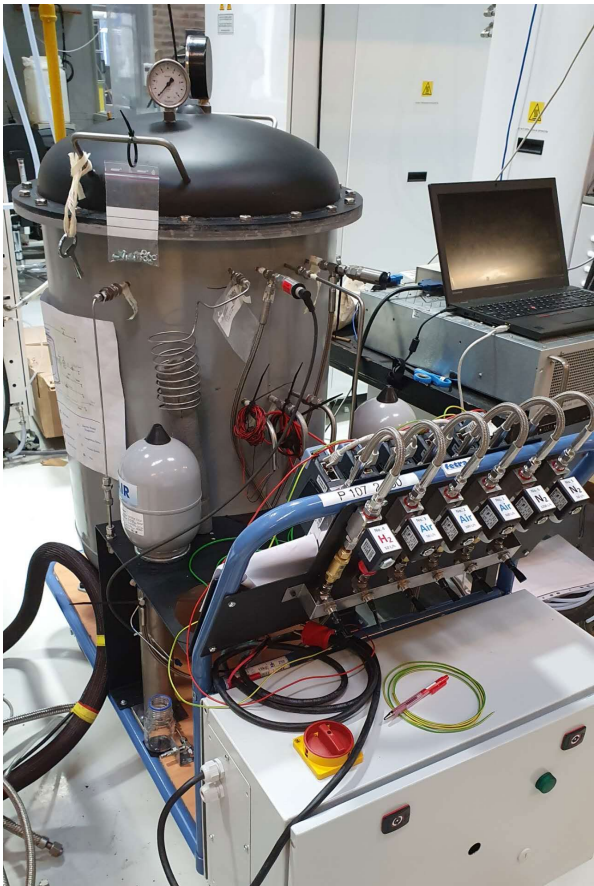
- Alkaline: more than 10 Mw
- PEM: Mw
- SOE: below 100 kW



Electrolysis system – dynamic characteristics

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Energy consumption Hydrogen production Degradation rate Other operations (e.g., Idle, shutdown) ...	...	...	...



High-pressure SOE setup
- MESH project

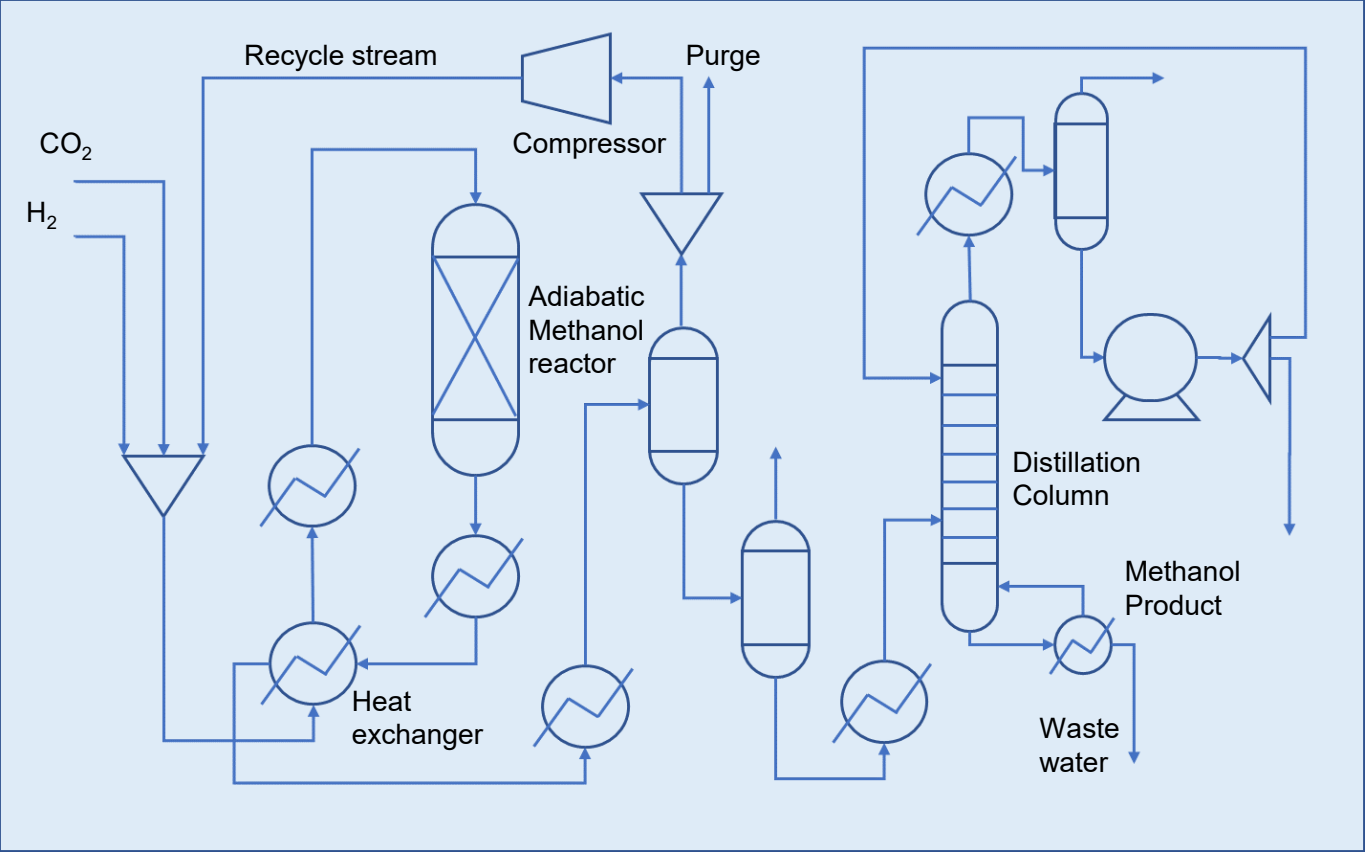
AC:DC operation
Pressure: 0-6 bar
Temperature: up to 750°C
Single cell/short stack testing
(30-100 W)

e-fuel production – dynamic characteristics

User Manual

Dynamic characteristics	Methanol	Ammonia/Methane
Cold-start time	Hours to Days	...
Hot-start time	Minutes	...
Lower operation load	10%	10%/...
Upper operation load	120%	100%/...
Ramping rate	Minutes	...
Energy efficiency (system)	70-80%	...
Energy consumption		
Fuel production		
Degradation rate	...	...
Other operations (e.g., Idle, shutdown)		
...		

What/where “dynamic characteristics” ?

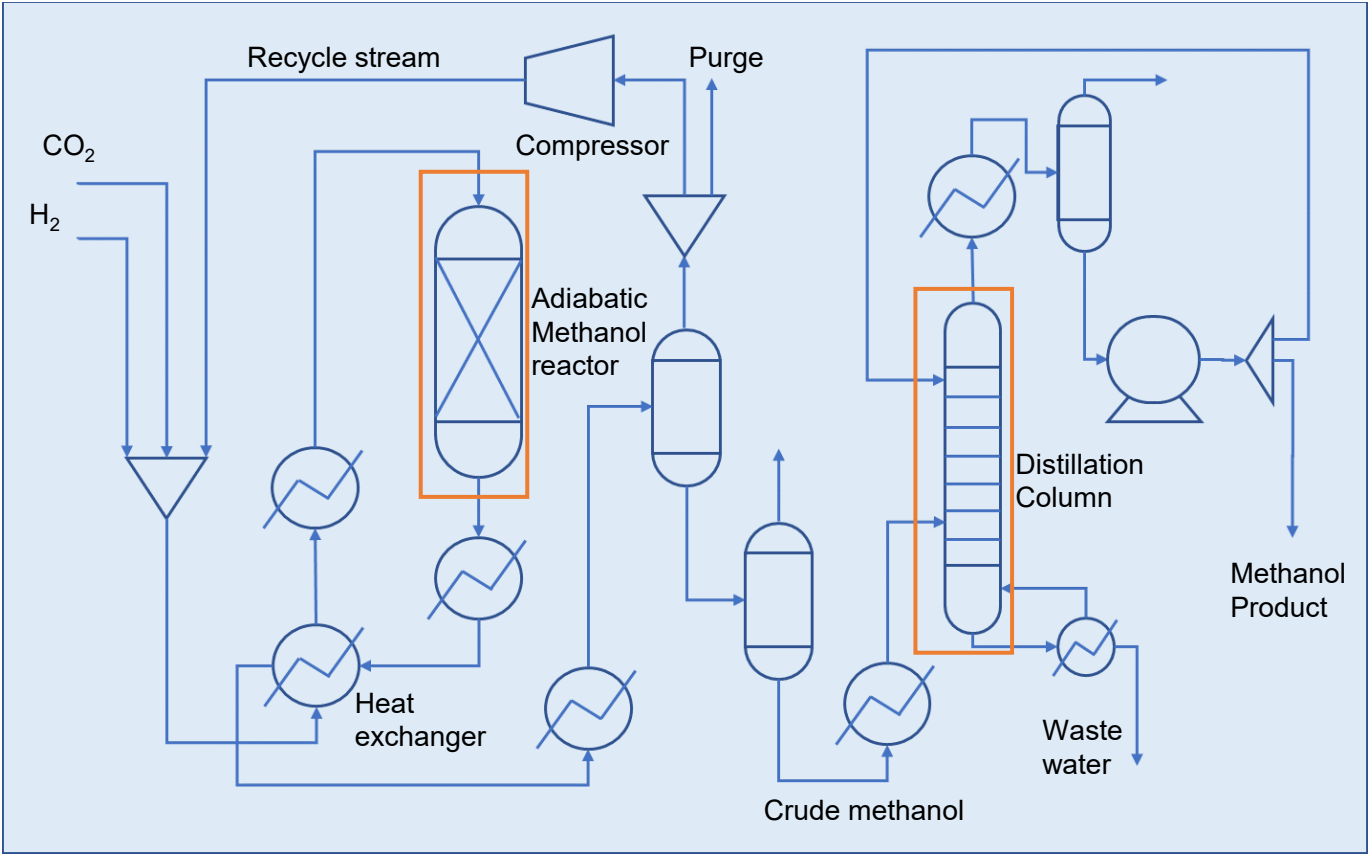


Methanol plant

e-fuel production – dynamic characteristics

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What/where “dynamic characteristics” ?



Methanol plant

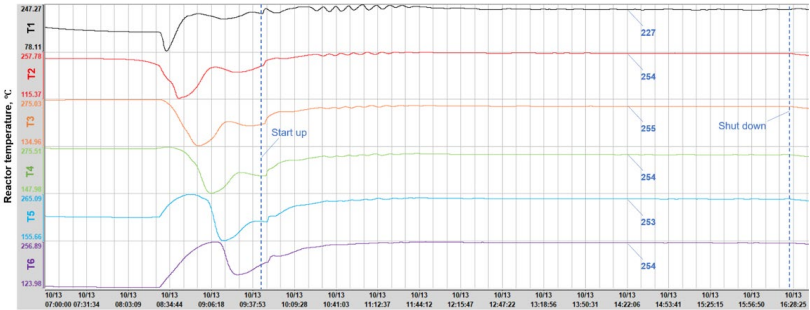
e-fuel production – dynamic characteristics

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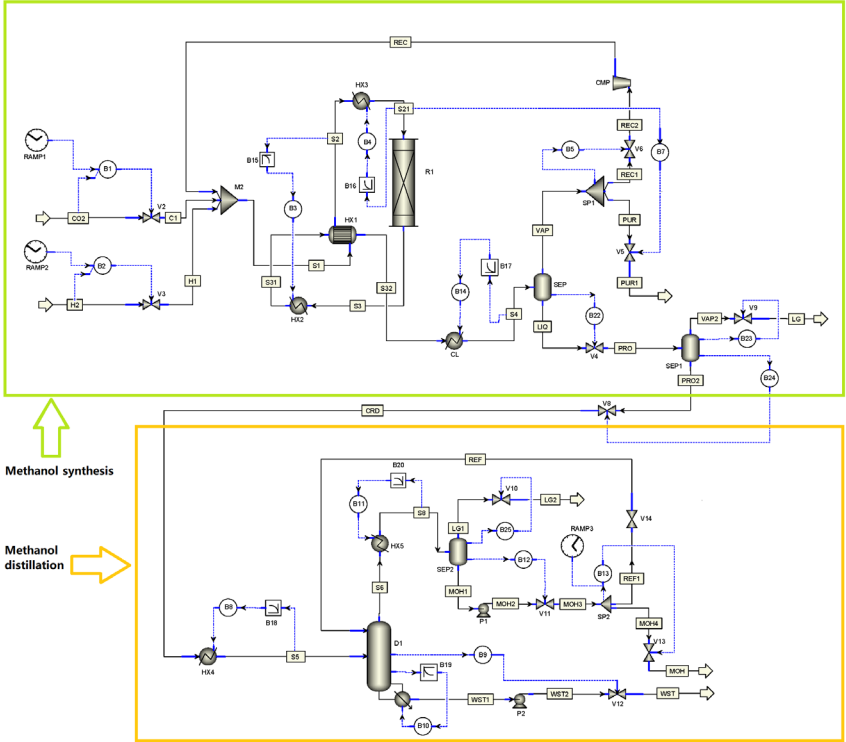


Pilot-scale methanol plant
- Power2Met project

- 220 tons / year e-methanol
- o 60 Nm3/h H2 (250 kW Alkaline electrolyzer)
 - o 20 Nm3/h CO2 (Gas bottle)
 - o Operating pressure: 30 bar
 - o Operating temperature: 200-300°C

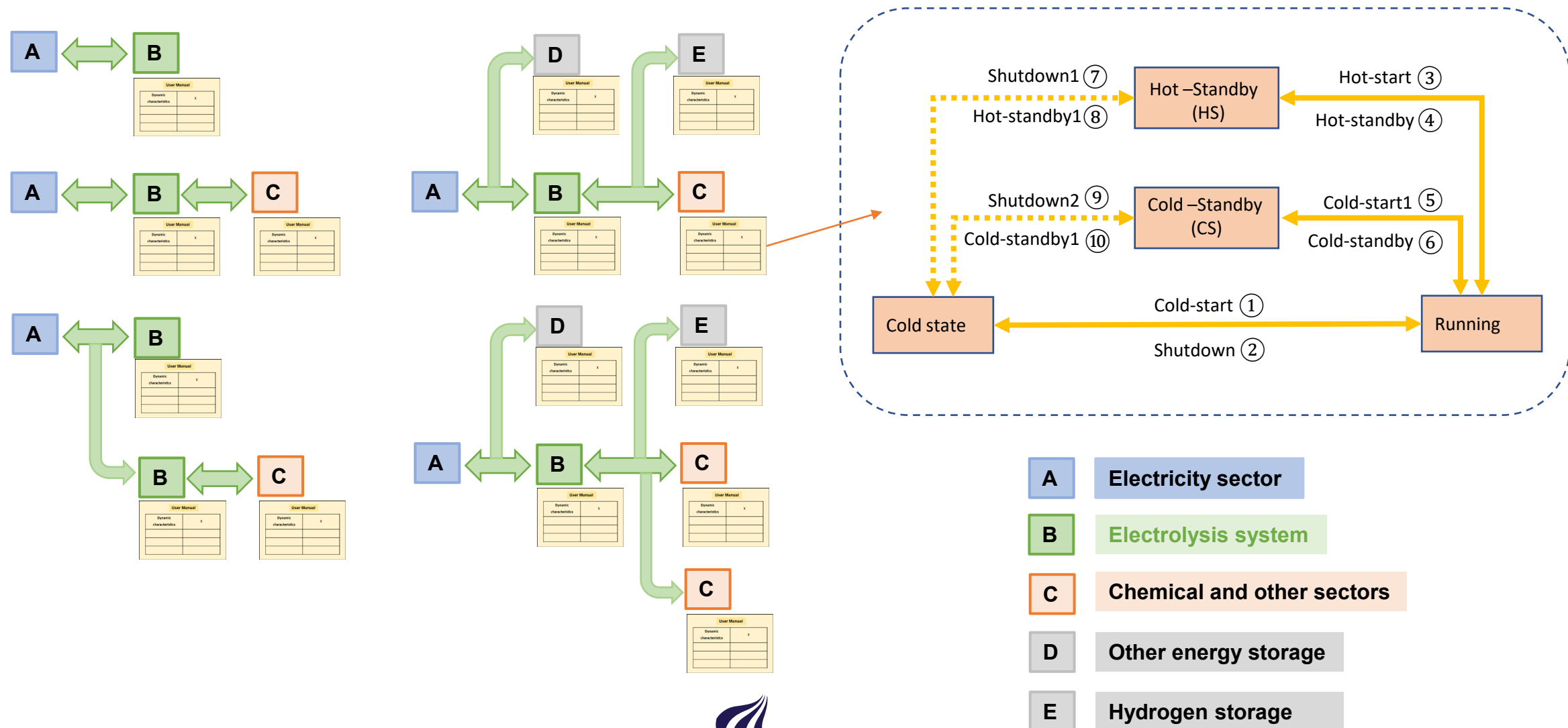


Preliminary plant operation

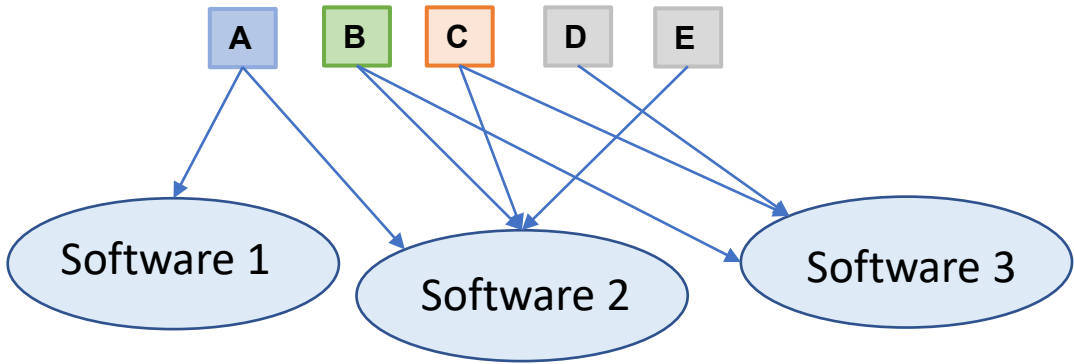
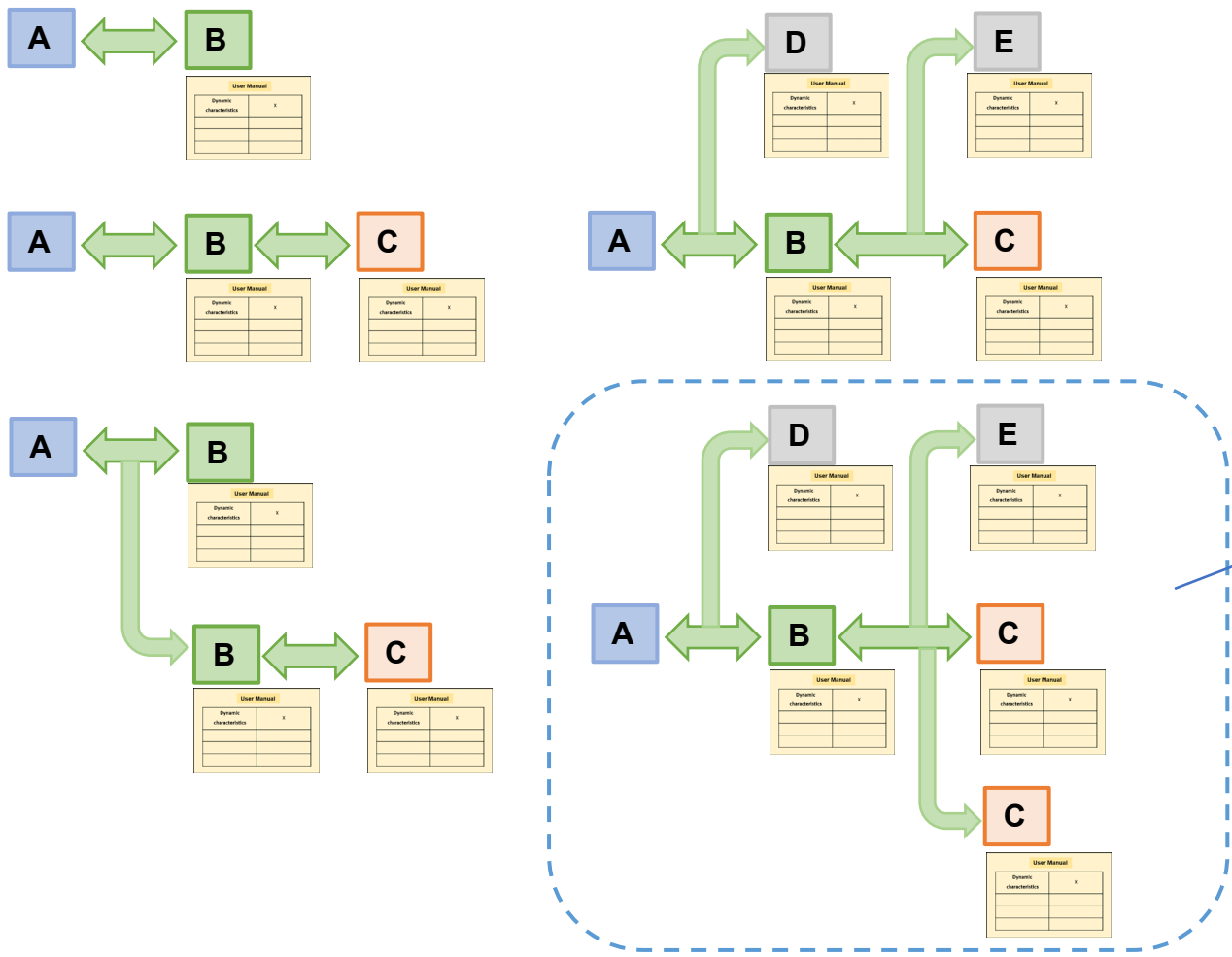


Dynamic modeling by Aspen Plus

Power-to-X system and dynamic modeling



Power-to-X system and dynamic modeling



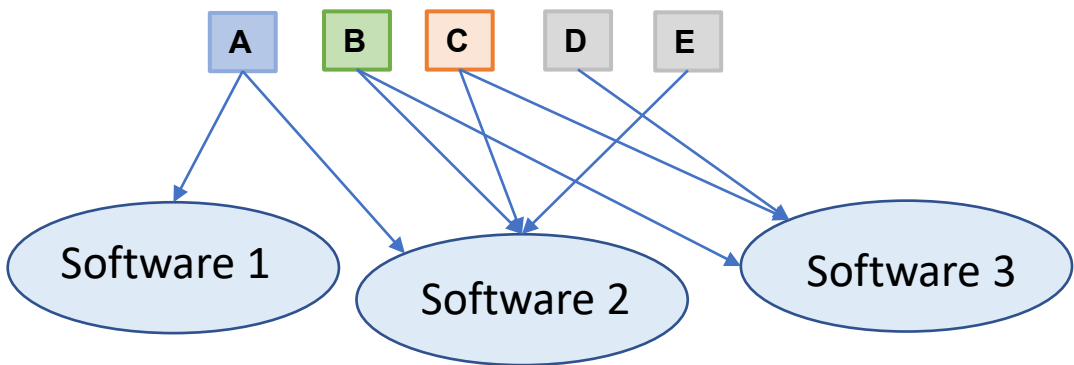
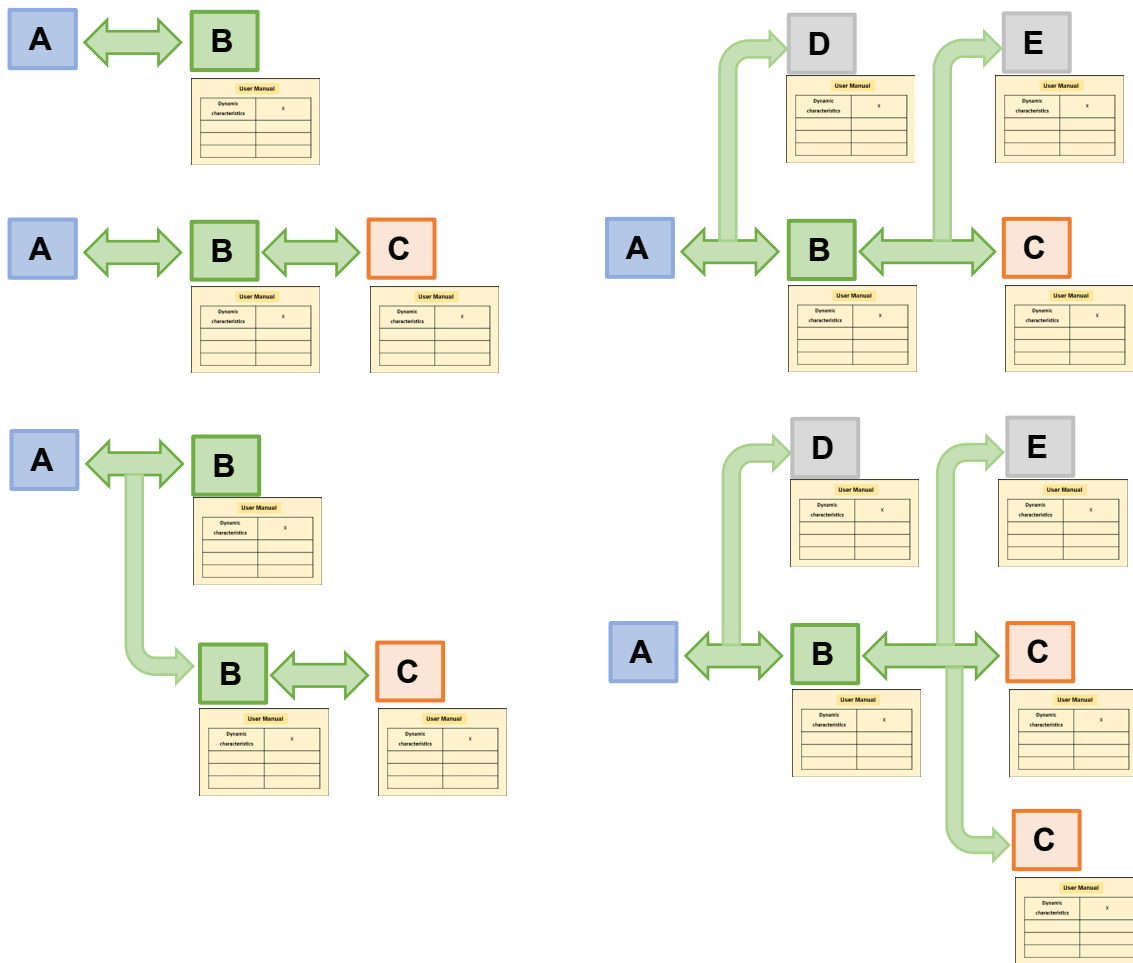
- Co-simulation ?
- Surrogate model?
- One software ?
- Other software ?

Aspen Plus
MATLAB
Python
...

A	Electricity sector
B	Electrolysis system
C	Chemical and other sectors
D	Other energy storage
E	Hydrogen storage



Power-to-X system and dynamic modeling



- Co-simulation ?
- Surrogate model?
- One software ?
- Other software ?

Aspen Plus
MATLAB
Python
...

Aspen Plus Dynamic
(methanol plant)

Surrogate model in Matlab
(ML)





Thank you!



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