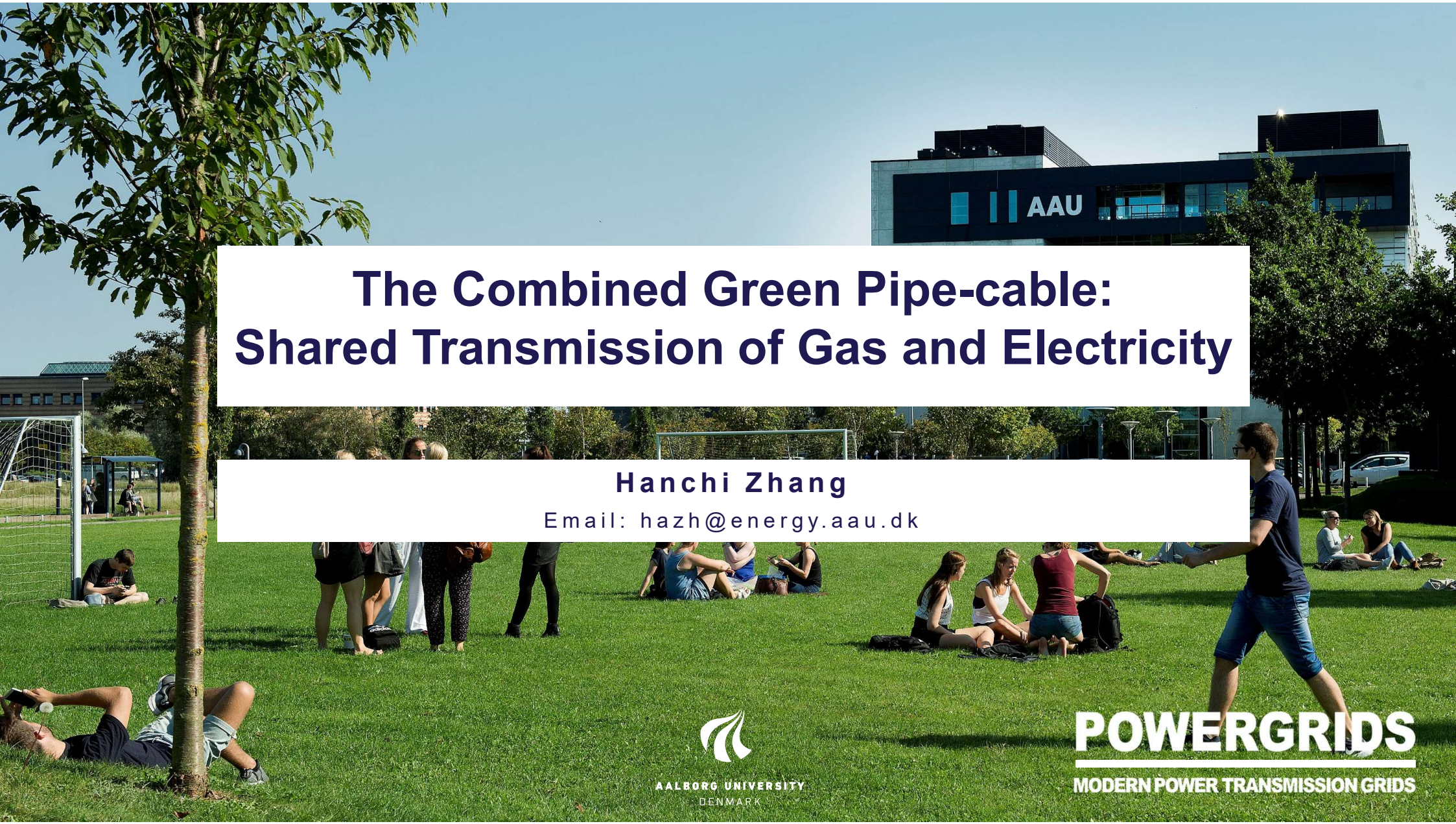

The Combined Green Pipe-cable: Shared Transmission of Gas and Electricity

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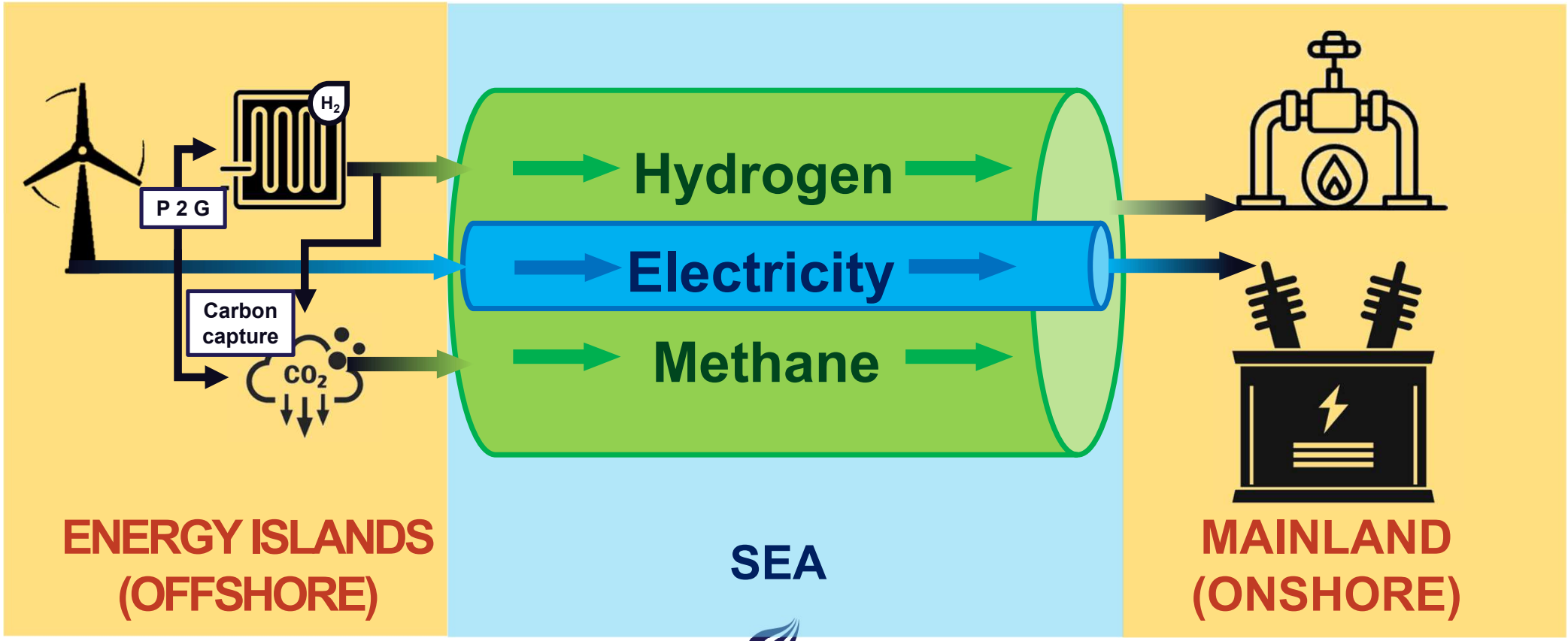
POWERGRIDS
MODERN POWER TRANSMISSION GRIDS

RESEARCH BACKGROUND



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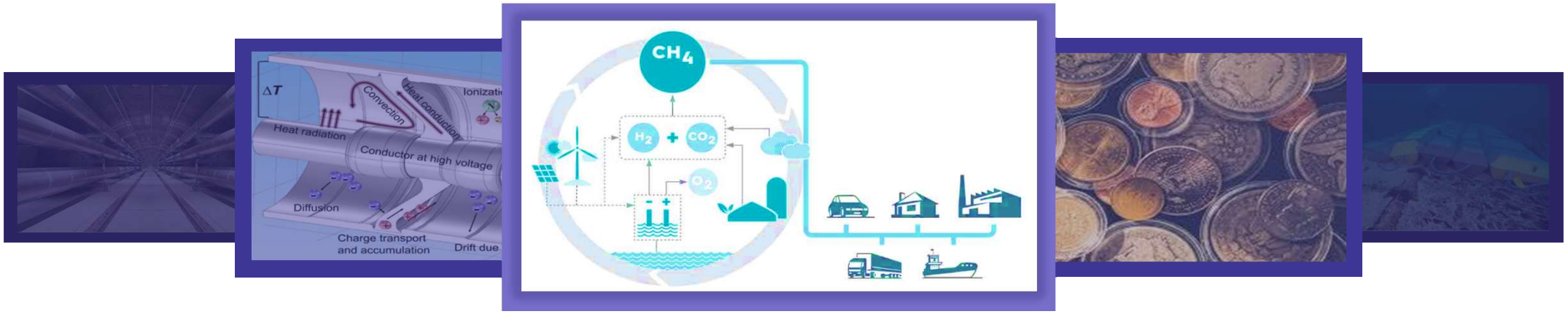
POTENTIAL ADVANTAGES

- **Increasing the flexibility of energy transmission**

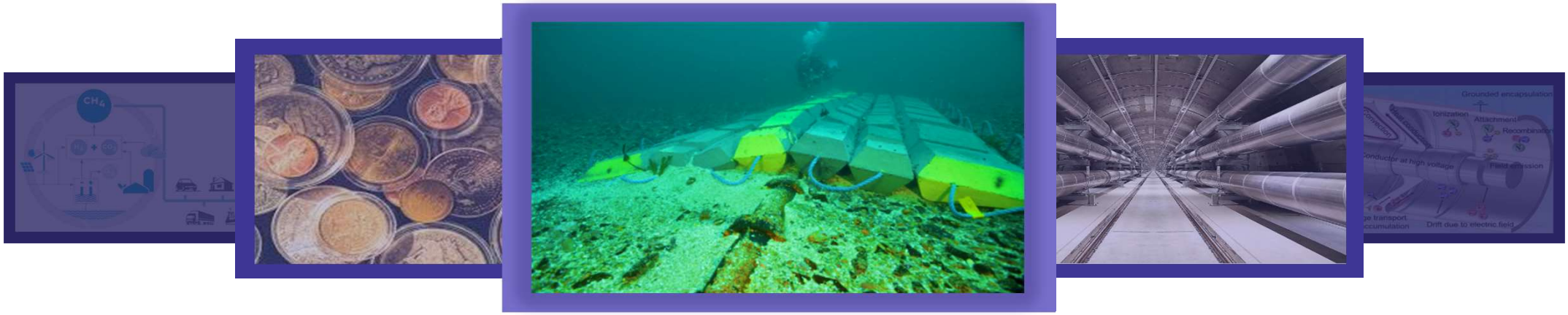


POTENTIAL ADVANTAGES

- **Decreasing the installing cost**

POTENTIAL ADVANTAGES

- **Decreasing the modification of seabed environment**



(Source: B. Taormina et al., "A review of potential impacts of submarine power cables on the marine environment: Knowledge gaps, recommendations and future directions," *Renewable and Sustainable Energy Reviews*, 2018.)

POTENTIAL ADVANTAGES

- **Large theoretical current carrying capacity**

(Source: ABB https://new.abb.com/news/detail/61647/abb-power-grids-commissions-worlds-first-transmission-line-under-the-yangtze-river.)

ADVANTAGES: CURRENT CARRYING CAPACITY

- Comparison of the current capacity of all three transmission lines under the same rated voltage.

Gas insulation convection has good heat dissipation.

Small cross-section area

Solid insulation has poor heat dissipation.

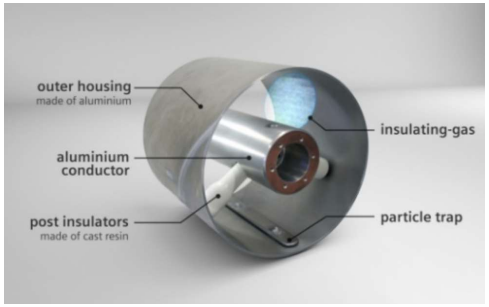
$$I_{c\_GIL} > I_{c\_OHL} > I_{c\_cable}$$

- A factor to limit the I_c of GIL is the poor thermal conductivity of SF_6. Meanwhile, H_2 has the best thermal conductivity among all the gases, and CH_4 is 2.5 times better than SF_6.

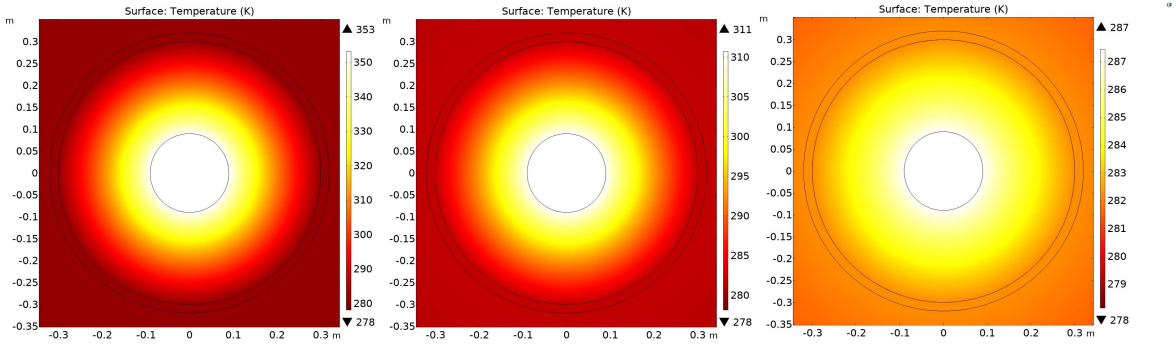
	SF_6	CH_4	H_2
Thermal conductivity [W/(m·K)]	0.0121	0.0300	0.163

ADVANTAGES: CURRENT CARRYING CAPACITY

- A 420 kV GIL from Siemens is shown as an example. The GIL is surrounded by sea water at 5 ° C (278 K).

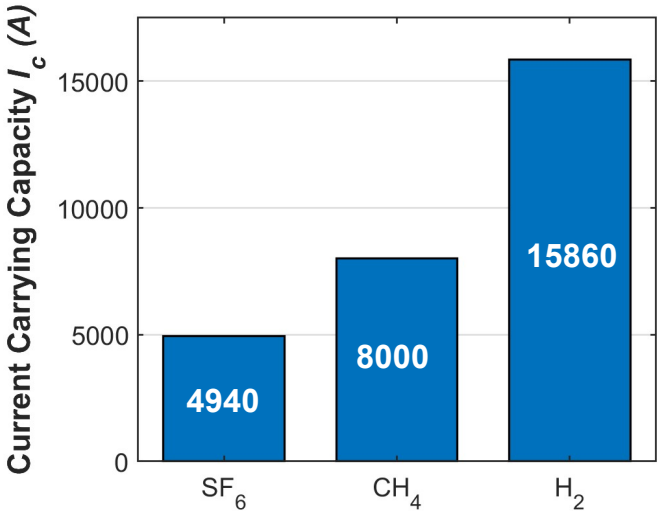


- The same I_c = 4940 A



SF_6, T_c=80°C CH_4, T_c=38°C H_2, T_c=9°C

- The same T_c = 80°C



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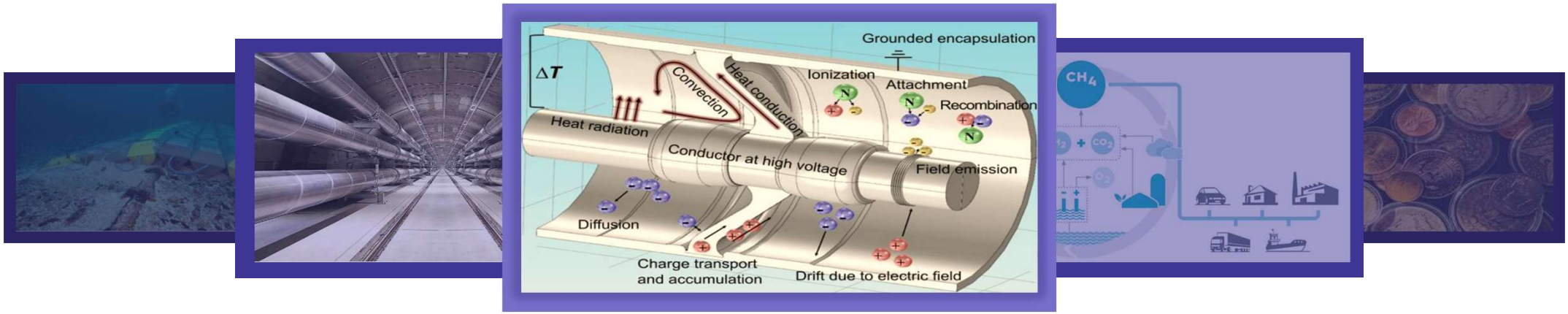
POTENTIAL ADVANTAGES

- **Possible superior or equally good insulation performance**



(Source: N. Zebouchi and M. A. Haddad, "A Review on Real-Size Epoxy Cast Resin Insulators for Compact High Voltage Direct Current Gas Insulated Switchgears (GIS) and Gas Insulated Transmission Lines (GIL)—Current Achievements and Envisaged Research and Development," *Energies*, vol. 13, no. 23, p. 6416, 2020.)

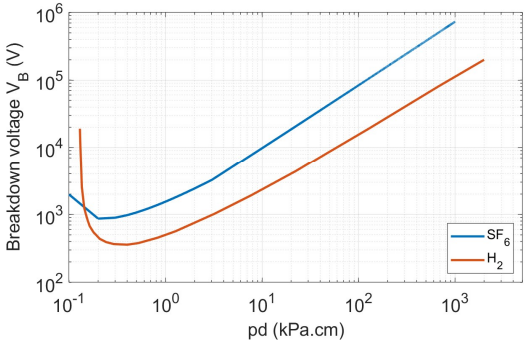
ADVANTAGES: INSULATION PERFORMANCE

- All of the gases are good insulation.

	$E_{breakdown}$ at 1 atm
SF_6	230 kV/cm
Air	27 kV/cm
CH_4	NA
H_2	15 kV/cm

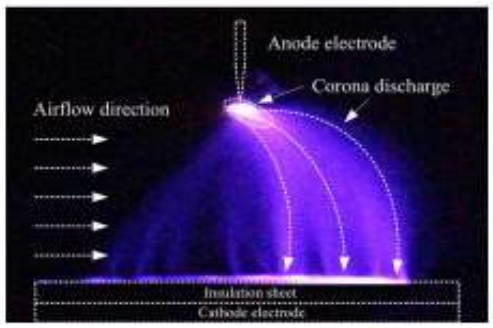
- **Extra high pressure**
- Paschen's law: the insulation performance of the gas increases with increasing gas pressure.

SF_6 in GIS/GIL: 4 atm
Natural gas (CH_4) in pipelines: 20-100 atm
H_2 in transmission pipelines: 30-80 atm



- **Extra fast flowing speed**
- High-speed-flowing gas can change electron path and increase the breakdown voltage.

SF_6 in GIS/GIL: static
Natural gas (CH_4) in pipelines: 12-20 m/s



(Source: [1])

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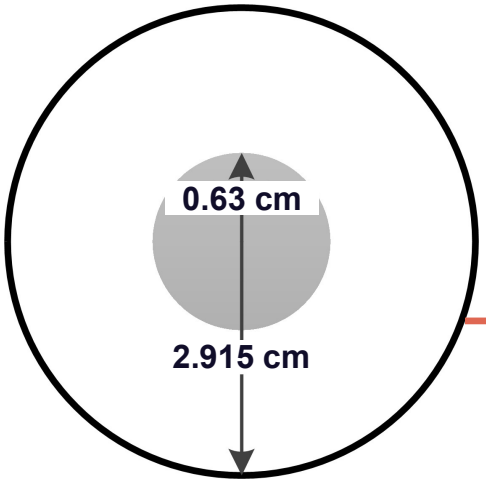
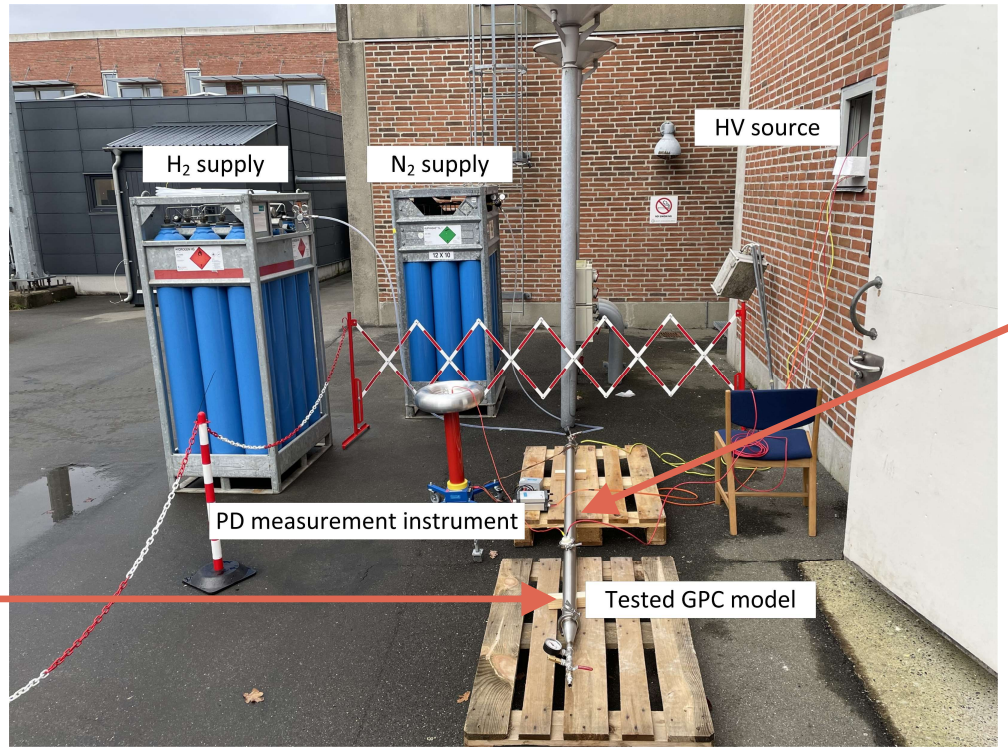
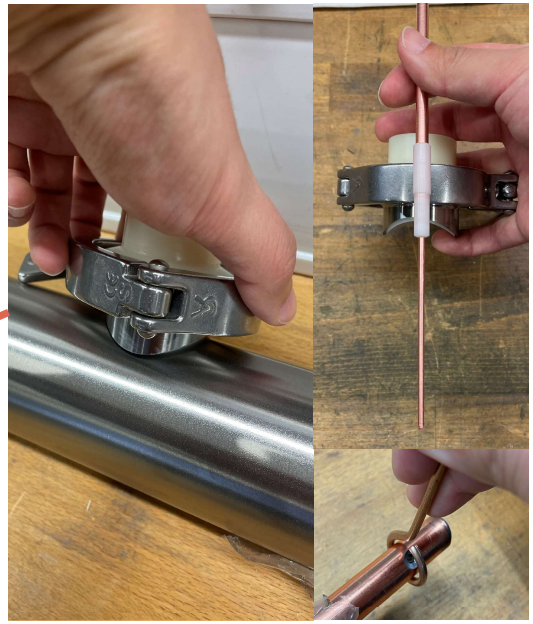
[1] Y. Kang et al., "Breakdown Characteristics and Mechanisms of Short Needle–Plate Air Gap in High-Speed Airflow," IEEE Transactions on Plasma Science, vol. 45, no. 9, pp. 2406-2415, 2017.)

EXPERIMENT SETUP







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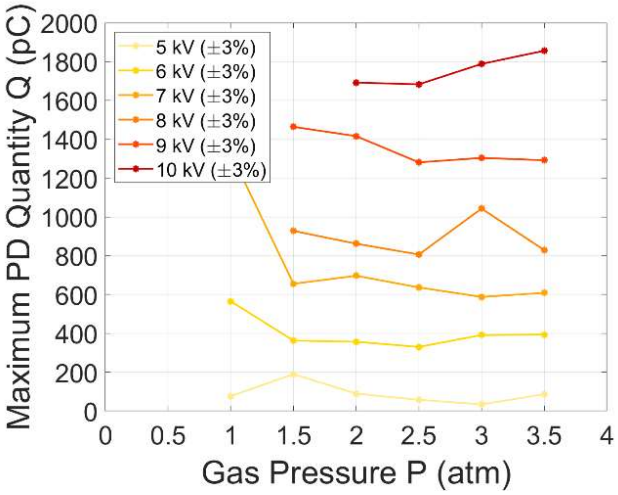
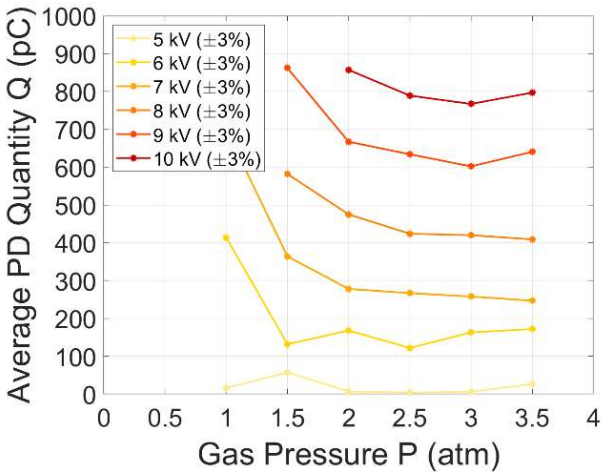
RESULTS

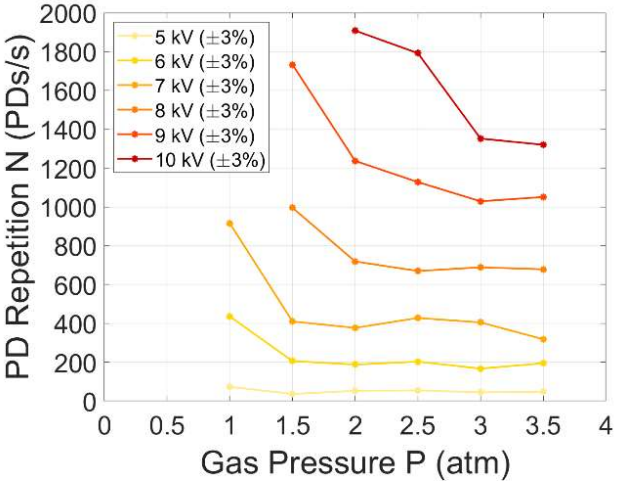
Influence of the hydrogen pressure on the partial discharge



a.The maximum PD quantity



b.The average PD quantity



c.The PD repetition

As expected, the partial discharge is less intense in high-pressure hydrogen than in low-pressure hydrogen.

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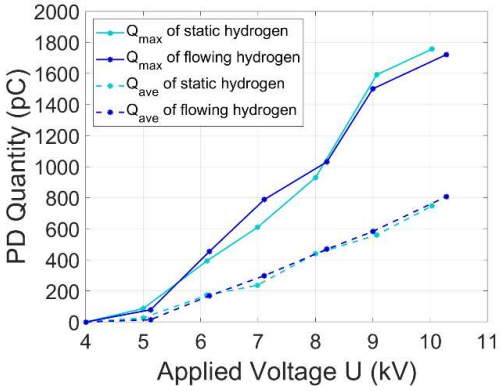
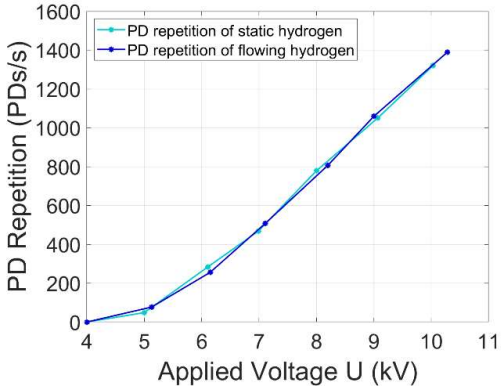
RESULTS

Comparison of partial discharge in flowing H_2 or N_2 with static H_2 or N_2



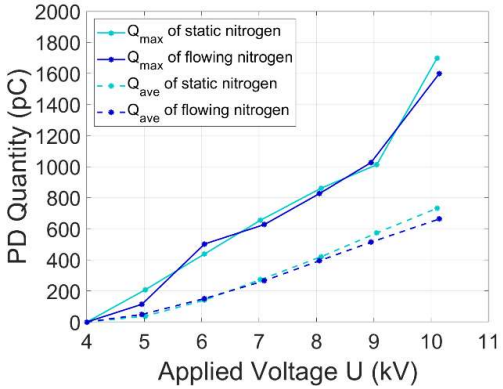
a. The maximum & average PD quantity



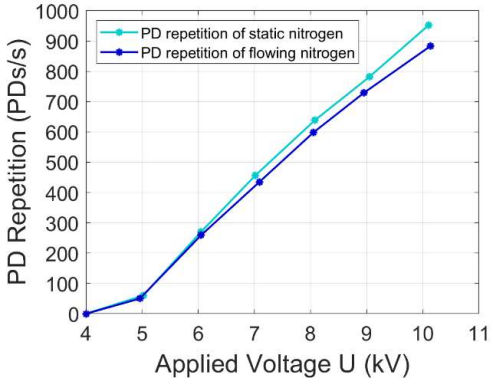
b. The PD repetition

Static hydrogen and flowing hydrogen (0.4 m/s)

Low-speed-flowing hydrogen does not have an obvious effect on partial discharge activities.



a. The maximum & average PD quantity



b. The PD repetition

Static nitrogen and flowing nitrogen (2.4 m/s)

High-speed-flowing nitrogen can impair partial discharge activities to some extent.

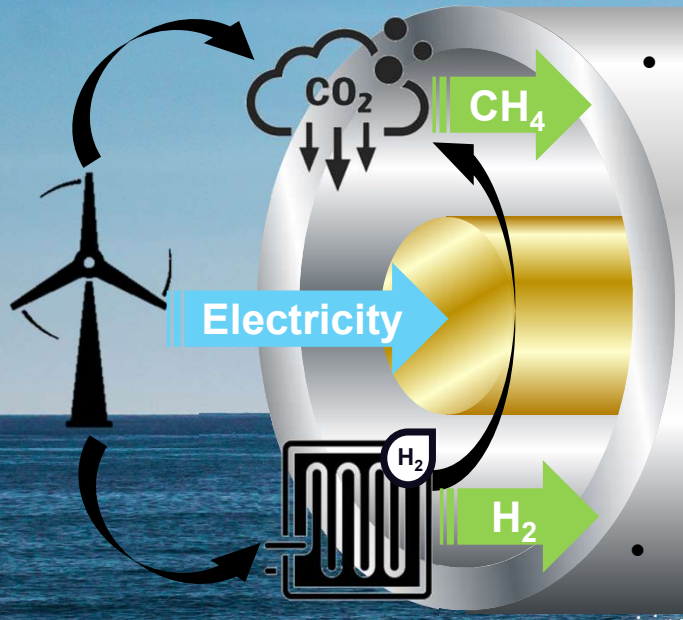
DISCUSSION

Limits at present & works in the future.

- Optimization of the coaxial system to avoid strong electric field points;
- Experiments on higher-pressure and higher-flow-rate hydrogen;
- Experiments on other P2X gases, such as natural gas or the mixture of natural gas and hydrogen.

SUMMARY

PROSPECT



ADVANTAGES

- Flexibility energy transmission
- Low installation cost
- Good insulation performance?
- Large current carrying capacity
- Less modification on seabed

VERIFICATION

High gas pressure

High flowing speed

THANK YOU !

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