RNG WORKS

THE COALITION FOR RENEWABLE NATURAL GAS

Best Practices in Nitrogen & Oxygen Rejection Technology

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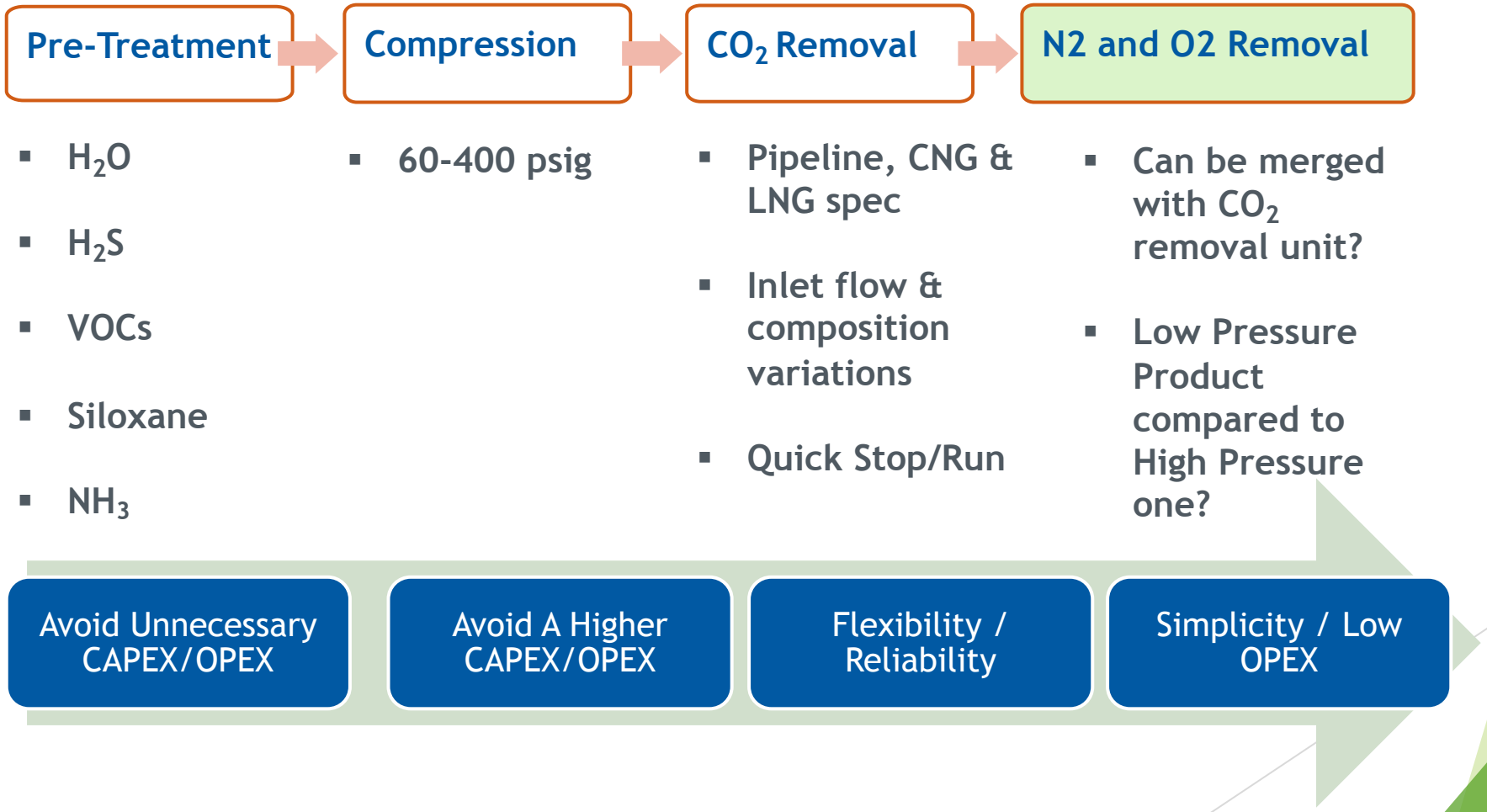
OVERVIEW

- Biogas Upgrading Process
- Why NRU?
- NRU Technology Review
- Case Studies

Biogas Upgrading Process

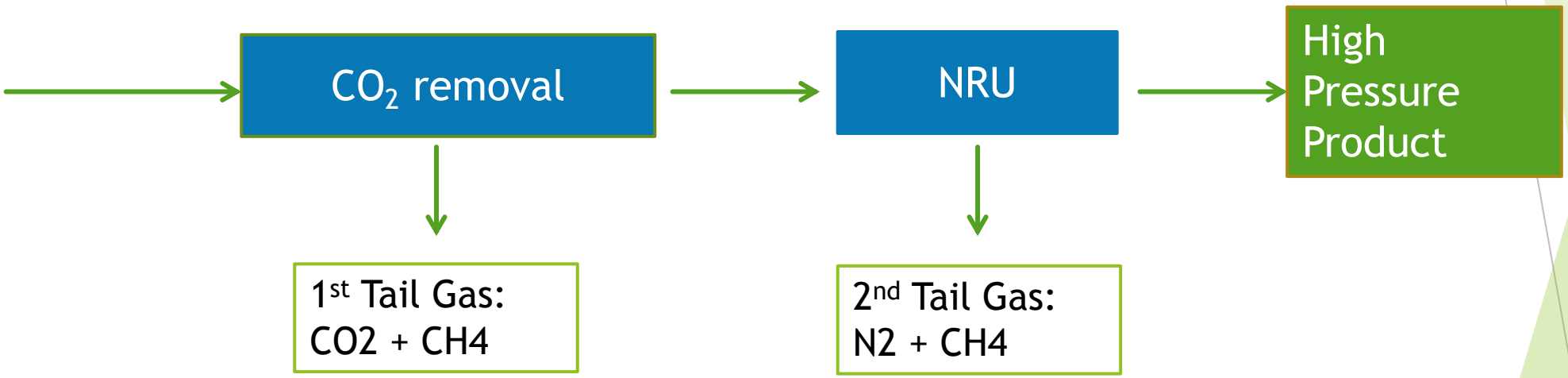


Biogas Upgrading Technology-Review

Comparison	PSA-CO_2 removal	PSA-CO_2, O_2 and N_2 removal	Membrane	Wet Scrubber
O_2 Removal	Yes/No Depends on supplier	Yes	Partially (low)	No
N_2 Removal	No	Yes	No	No
Pros	High recovery	Single Step to remove CO_2-N_2-O_2	High Recovery	High Recovery
Cons	Required to add a NRU	Recovery is a function of inlet N_2	- Required to add a NRU - Sensitive to VOCs - Higher operating pressure than PSA -Safety (O2)	Required to add a NRU Introducing N2 and O2 on top of inlet content

NRU Technology Review

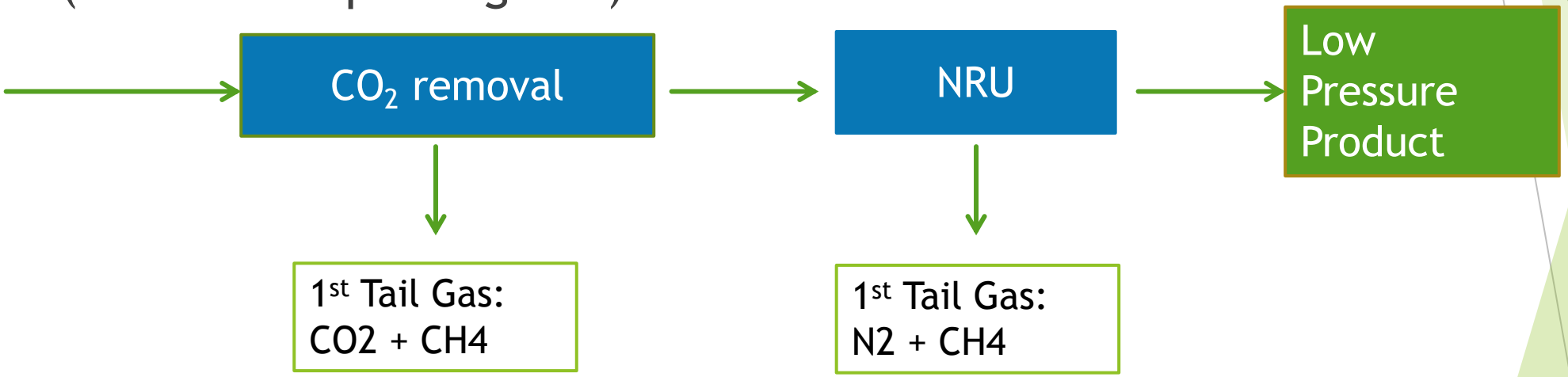
- (1) Conventional Two-step purification: CO_2 Removal + NRU (N2 removal)



- High Methane Loss For High N2
- Sensitivity of NRU unit to CO_2
- Operating Two Different Technologies independently (Increasing probability of system downtime)

NRU Technology Review

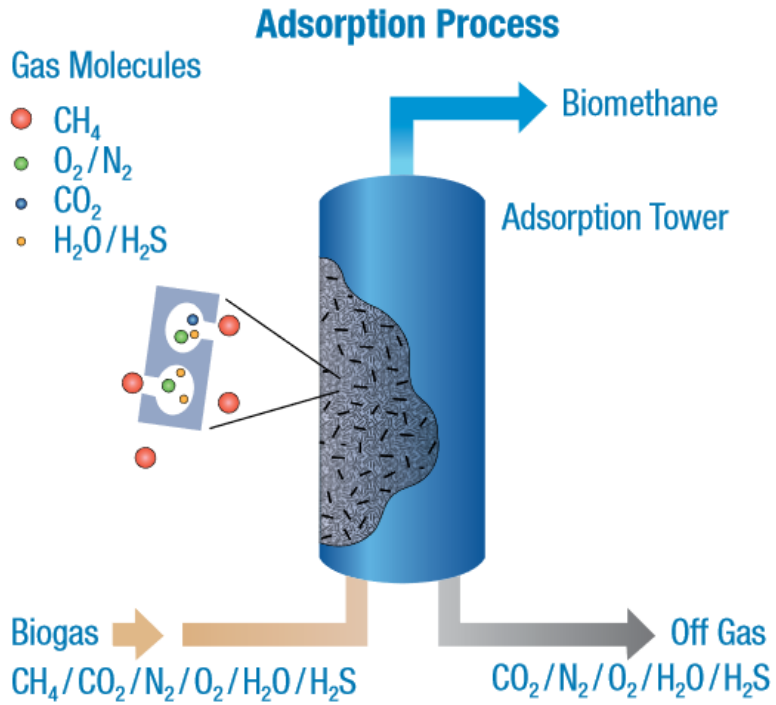
- (2) New Two-step purification: CO_2 Removal + NRU (methane capturing PSA)



- High Energy Consumption (require product compressor and high recycle ratio)
- Operating Two Different Technologies (Increasing probability of system downtime and not meeting the product spec)

NRU Technology Review

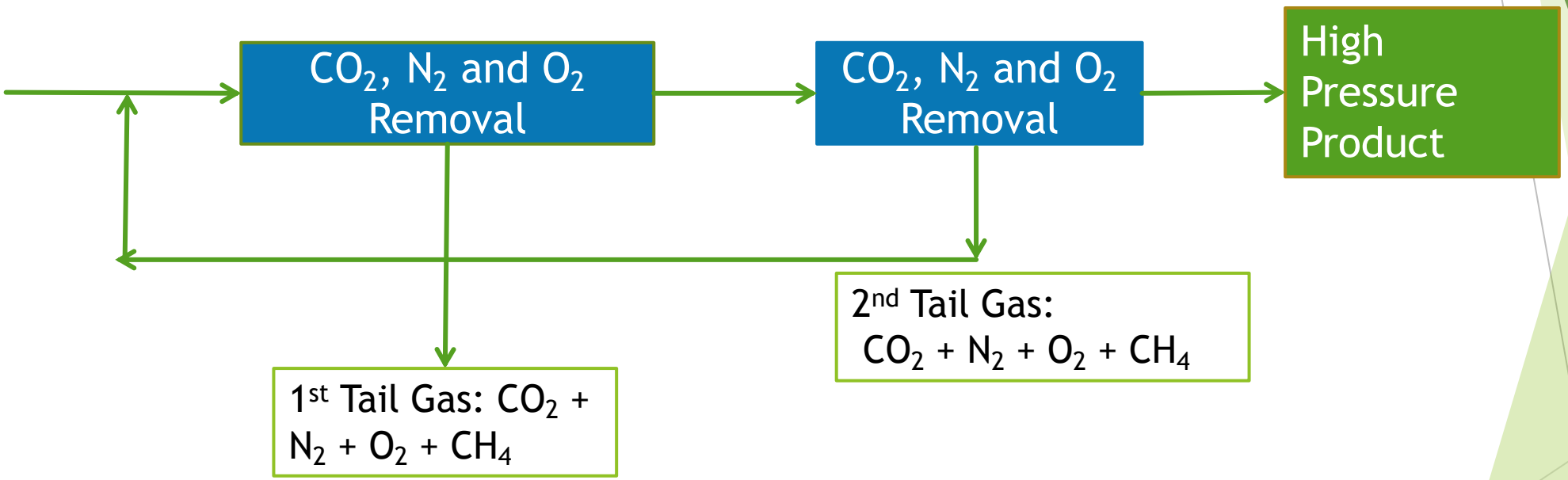
- (3) One Step PSA:



- Methane recovery and size of the PSA are a function of inlet N_2

NRU Technology Review

- (4) New Two-step purification: CO_2, N_2, O_2 Removal Unit



NRU Technology Review

- (4) New Two-step purification: CO_2, N_2, O_2 Removal Unit

Advantages:

- Lower power consumption due to:
  - Lower operating pressure (80-120 psig)
  - Lower internal recycle flow
  - High pressure produce compared to atmospheric pressure from new NRU solution

NRU Technology Review

- (4) New Two-step purification: CO_2, N_2, O_2 Removal Unit

Advantages (Cont.):

- Higher system reliability:
  - Both PSA units can remove CO2, N2 and O2, in case of higher and unexpected N2 to the system, product quality is guaranteed by scarifying the recovery
  - Less sensitive to impurities such as VOSs, H2S, etc, No need to remove VOCs

NRU Technology-Summary

Comparison	Conventional Two Step Purification: CO_2+NRU (HP)	New Two Step Purification: CO_2 + NRU (LP)	Single Step PSA	Two Step PSA
Recovery	Medium (Function of N_2)	High	Medium (Function of N_2)	High
Power Consumption	Medium (Function of N_2)	High	Low (Function of N_2)	Medium (Function of inlet N2)
CAPEX	High (Function of N_2)	Medium	Low (Function of N_2)	High (Function of N2)

Case Study – Single Stage PSA – Low N_2

Project: Gaz Team

Location: France

Technology: PSA

Feed: Biogas from dry anaerobic digestion

RNG use: GRDF Pipeline

Raw gas: 60% CH4; 38% CO2; 2% N2/O2;

Recovery 97.5%

Power Consumption: 0.2 kWh/NCM (105

MMBTU/MWh)

Product gas: 985 Btu/scf

Case Study – Single Stage PSA – Low N_2

Project: Escondido WWTP

Location: California

Technology: PSA

Feed: Biogas from WWTP

RNG use: Rule 30

Raw gas: 60% CH4; 38% CO2; 2% N2/O2;

Power Consumption: 0.25 kWh/NCM (80 MMBTU/MWh)

Product gas: 980-990 Btu/scf

Case Study – Single Stage PSA after CO2 removal unit

Project: Salmon Arm LFG

Location: British Colombia

Technology: PSA

Feed: Biogas from LFG

RNG use: Pipeline

Raw gas: 52% CH4; 36% CO2; 4-12% N2/O2;

Power Consumption: 0.25 kWh/NCM (60 MMBTU/MWh)

Product gas: 990 Btu/scf

Case Study – Two-Stage PSA CO_2, N_2 and O_2 removal unit

Project: Genova Landfill

Location: Italy

Technology: Two-Stage PSA for CO2, N2 and O2

Feed: Biogas from LFG, 16% N_2 + O_2

RNG use: Pipeline

Raw gas to PSA: 46% % CH4; 36% CO2; 18% N2/O2;

Product gas: 970 Btu/scf

Xebec Rotary Valve PSA

- **ROTARY VALVE**

  Reduces significantly the plant's design complexity, footprint and overall capital investment

- **FAST CYCLE ROTARY VALVE**

  Adjusts real time to biogas flow and composition changes while maintaining purity and maximum sales gas recovery

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