ADREM

Adaptable Reactors for Resource- and Energy-Efficient Methane Valorisation

INNOVATIOVE SOLUTIONS FOR A BETTER FUTURE

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under the Grant Agreement No. 680777

OVERVIEW

ADREM
Adaptable Reactors for Resource- and Energy-Efficient Methane Valorisation

- **START DATE**
  1st October 2015
- **DURATION**
  48 months
- **BUDGET**
  6 million €
- **10 PARTNERS**
  in 8 countries

PROJECT WEBSITE:
www.spire2030.eu/adrem

SPIRE
Sustainable Process Industry through Resource and Energy Efficiency

MOTIVATION

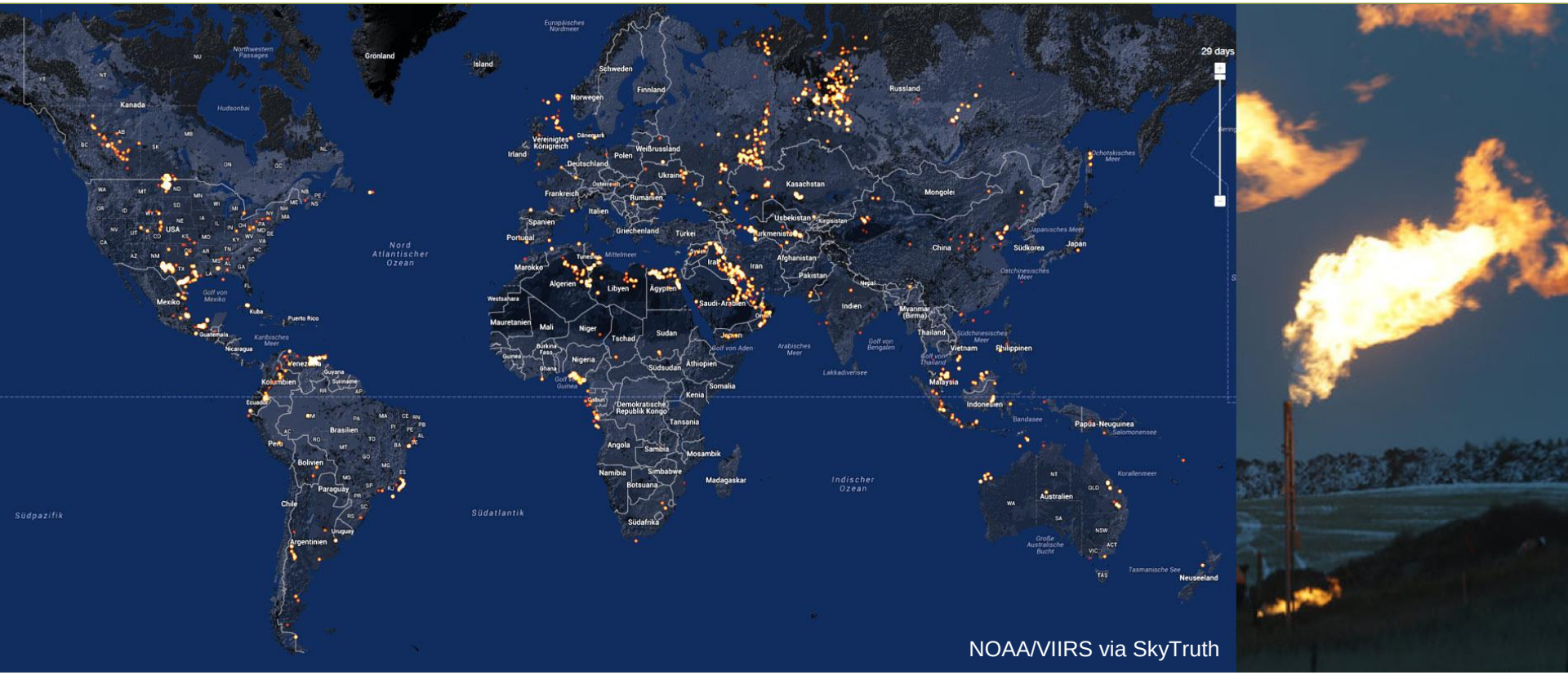




METHANE AS SOURCE OF ENERGY AND CHEMICALS:

- **Enormous reservers**
  - existing gas networks
  - small natural gas reservoirs
  - shale gas
  - coalbed methane
  - agricultural biogas
  - deep-sea methane hydrates
- **Environmental sustainability**
- **Economic advantage**

MOTIVATION



FLARING OF METHANE IN REMOTE LOCATIONS

PROJECT AIM

ADREM
Adaptable Reactors for Resource- and Energy-Efficient Methane Valorisation






BIOMASS *WATER* *SUN* *EARTH* *WIND* *WASTE*

GENERAL AIM:

develop an highly innovative, economically attractive and **resource- & energy efficient** valorisation process of variable methane feedstocks to higher hydrocarbons and liquid fuel

LONG TERM AIM:

valorisation process
based on **green electricity**

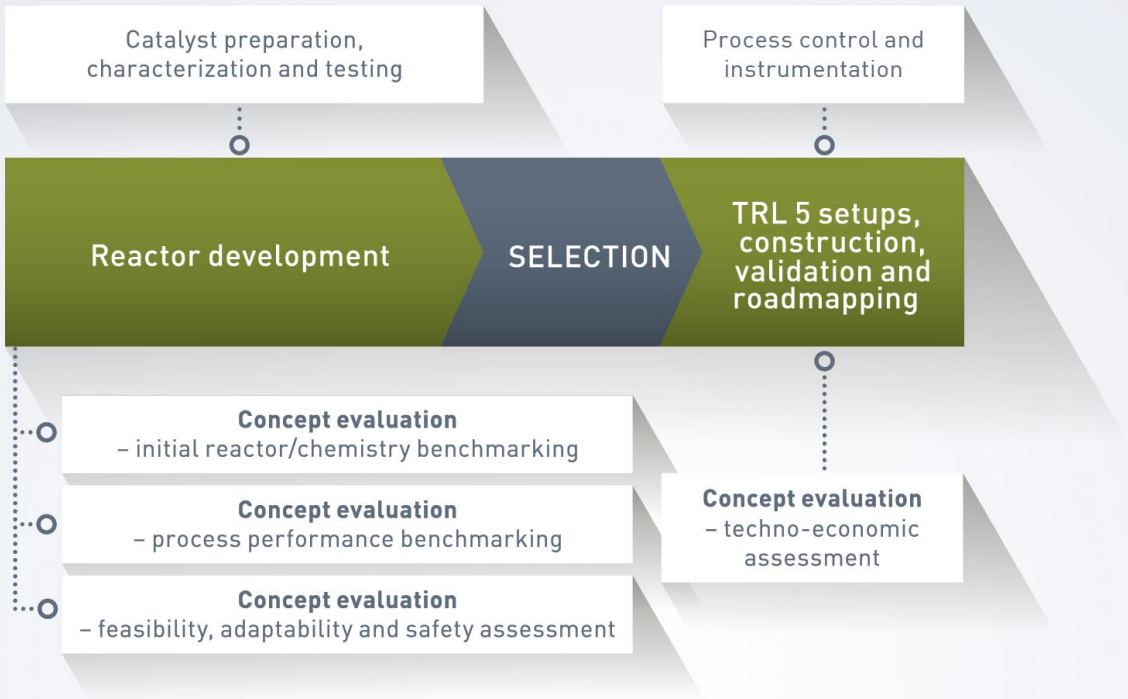
CHALLENGES

ADREM
Adaptable Reactors for Resource- and Energy-Efficient Methane Valorisation

Diversity and distribution of the methane sources	*Adaptibility with respect to feedstock and product distribu*	*Specific catalyst design for single-step conversion*	*Catalyst lifetime and exchangeability*	*High energy efficiency of process*

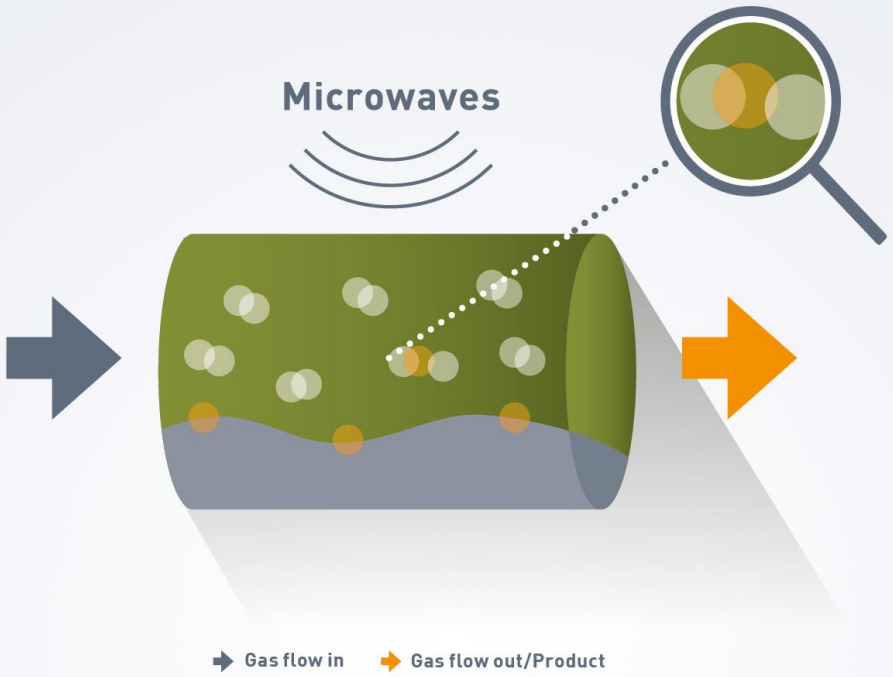
FROM		TO
Transformation of methane via synthesis gas	→	Direct, one-step transformation
Large-scale processing	→	Small to medium scale
Single-type feedstock	→	Multi-type feedstock
Difficult and expensive replacement of catalyst	→	Modular catalyst cartridges for easy switch
One fixed product distribution	→	“On-demand” product distribution
High process temperatures due to natural gas combustion in furnaces causing emissions	→	Low- and high-temperature methane valorisation without furnaces involved
Reactors use fossil fuel-based energy	→	Reactors use renewable electricity as the direct, primary energy source
Classical chemical reactor engineering methodology for reactor design	→	Integral, four-domain process intensification methodology for reactor development

APPROACH



CONSTRUCTION OF REACTOR CONCEPTS AS MOBILE, MODULAR BENCH-SCALE UNITS

MICROWAVE REACTOR



MICROWAVE / RADIOFREQUENCY REACTOR

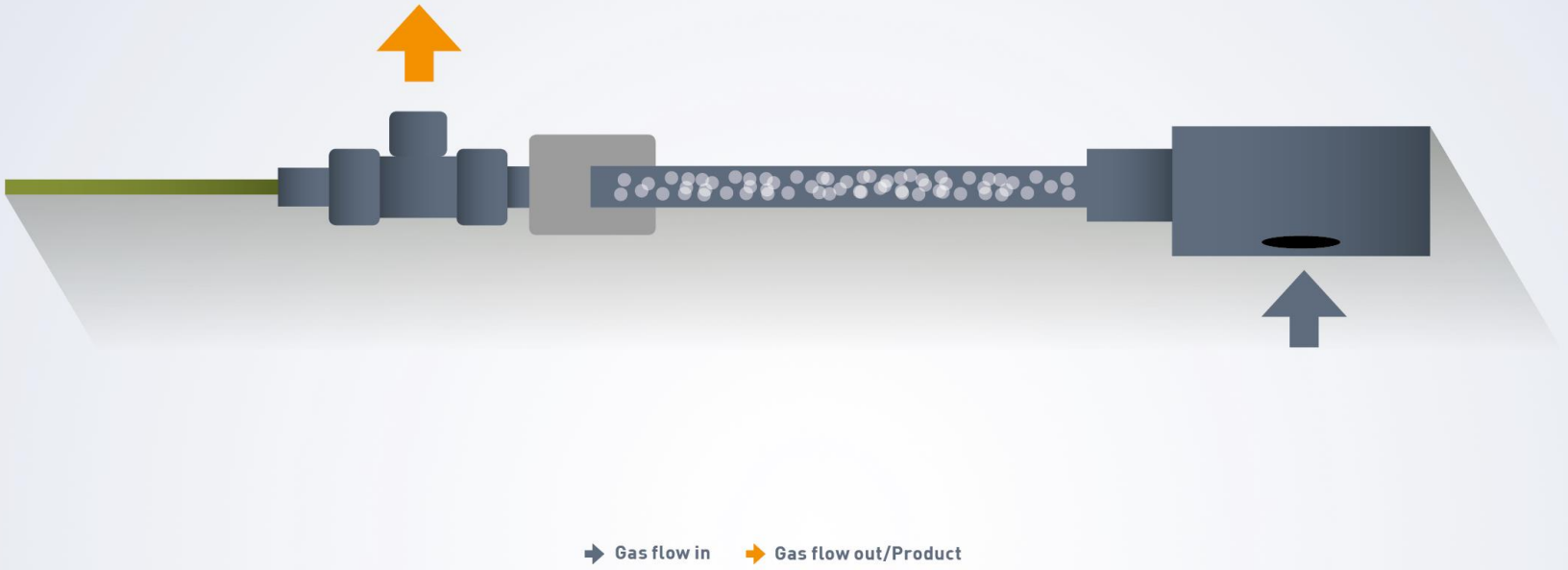
- Selective, energy efficient heating of the catalyst by electromagnetic waves
- Implementing a non-steady state operating cycle
- Reduction of undesired reactions

GAS-SOLID VORTEX REACTOR

GAS-SOLID VORTEX IN A STATIC GEOMETRY

- Static, cylindrical geometry with a solid catalyst
- Tangential injection of gas-phase causes the solid catalyst to rotate in the reactor – centrifugal force
- The two opposing forces – centrifugal an drag force – for high heat and mass transfer rates on both particle and reactor scale

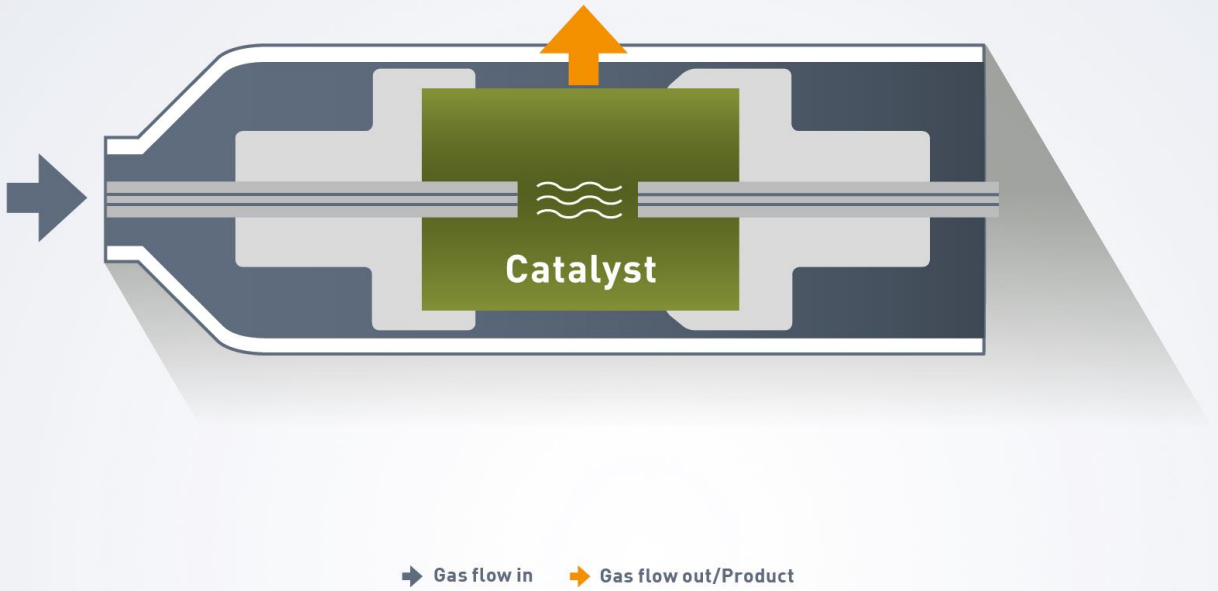
NON-THERMAL PLASMA REACTOR



NON-THERMAL PLASMA

- Far from equilibrium plasma processing, using nanosecond pulsed discharges, favours conversion of electrical energy to heat and reduce the heating effect

HTG-PLASMA REACTOR



TEMPERATURE GRADIENT PLASMA REACTOR
WITH STRUCTURED CATALYST PACKED BED

- Merger of two unit operations (intensification): reactor and separator (separation of gas feedstock and liquid product) in outer reactor jacket
- Central reactor axis: plasma source

REACTOR TYPES

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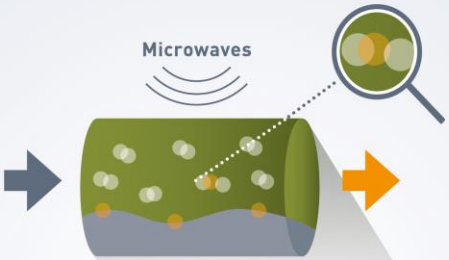
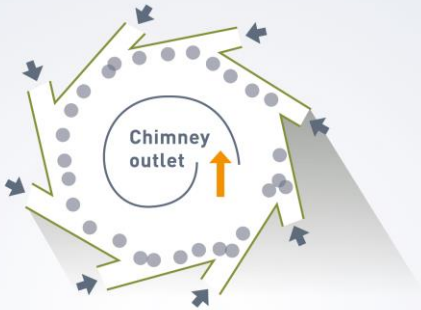
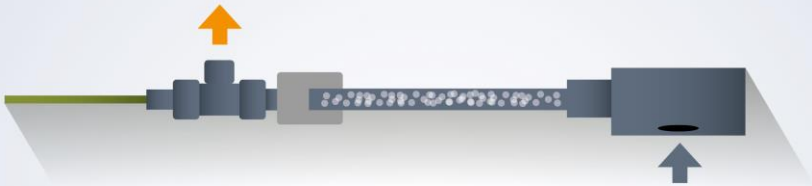


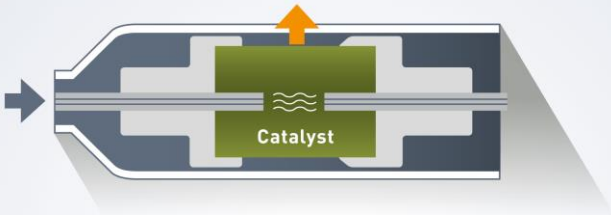
MICROWAVE / RADIOFREQUENCY REACTOR



GAS-SOLID VORTEX IN A STATIC GEOMETRY



NON-THERMAL PLASMA



TEMPERATURE GRADIENT PLASMA REACTOR

Gas flow in Gas flow out/Product

CONCEPT OF APPROACH

THERMODYNAMIC DOMAIN
(Energy)

FUNCTIONAL DOMAIN
(Synergy)

SPATIAL DOMAIN
(Structure)

TEMPORAL DOMAIN
(Time)

INTEGRAL, FOUR-DOMAIN PROCESS INTESIFICATION METHODOLOGY (PI)

- **spatial** (internal arrangement/configuration)
- **thermodynamic** (forms and transfer mechanisms of energy used)
- **functional** (combining functions/steps for synergistic effects; modularity)
- **temporal** (manipulating time variables)

INNOVATION

TECHNOLOGICAL INNOVATIONS

- Flexible, adaptable equipment design
- Process development including electricity as primary energy source
- Tailored, energy-responsive catalysts
- Process control

EXPECTED IMPACTS

ADREM IMPACTS

- On-site valorisation of methane from diverse sources
- Filling the processing gap of methane to avoid flaring
- Descreased carbon footprint
- Increased resource and energy efficiency

SAVINGS

20% less emissions

20% less energy intensity

10% better overall resource effiviency

EXPECTED OUTCOMES

Novel class of intensified adaptable modular catalytic reactor systems able to operate with changing feedstock composition and to deliver “on-demand” the required product distribution

New technology that will, in the long term, be based on renewable (green) electricity as the direct, primary energy source

Increased process flexibility and safety due to modular production

- more efficient equipment
- integration of green electricity
- more efficient process control

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FOR A BETTER FUTURE

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